Mubamba, Chrisborn (2018) ***An exploration of novel approaches to improve surveillance for infectious diseases in rural poultry of Zambia using Newcastle Disease as a case study.*** **PhD Thesis, James Cook University.**

https://doi.org/10.25903/5cd4e43a0b4d6

An exploration of novel approaches to improve surveillance for infectious diseases in rural poultry of Zambia using Newcastle Disease as a case study.

Thesis submitted by

Chrisborn Mubamba

MTrVSc, BVM

in May 2018

for the Degree of Doctor of Philosophy

in the Discipline of Veterinary Sciences
College of Public Health, Medical and Veterinary Sciences
James Cook University

STATEMENT OF ACCESS

I, the undersigned, author of this work, understand that James Cook University will make this thesis available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere.

Chrisborn Mubamba

20th May 2018

STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Chrisborn Mubamba,

Signature Date

STATEMENT ON CONTRIBUTIONS OF OTHERS TO THE PHD STUDY

Title of PhD thesis:

A study of Newcastle Disease and the utilisation of trade hotspots to enhance community driven syndromic surveillance of poultry diseases in Zambia

Name of candidate:

Chrisborn Mubamba

Nature of Assistance	**Contribution**	**Names, Titles (if relevant) and Affiliations of Co-contributors**
Intellectual support	Study design and academic supervision	Prof. Bruce Gummow (Principal supervisor, JCU) Prof. Celia Abolnik (co supervisor, UP) Prof. Gavin Ramsay (co supervisor, CSU)
	Co implementation of field and laboratory work	Dr George Dautu (co researcher, Department of Veterinary Services, Zambia)
Financial support	Stipend, tuition fees and part of research costs	Australia Awards, Department of Foreign Affairs and Trade (DFAT)
	Research costs	James Cook University, Australia National Research Fund (South Africa), University of Pretoria Department of Veterinary Services, Zambia
Material support	Vehicles, Offices and computers, access to data bases, laboratory and other research facilities	James Cook University, Australia University of Pretoria, South Africa Department of Veterinary Services, Zambia
Field support	Sample collection, questionnaire surveys, data entry and sample processing	Veterinary officers, veterinary assistants and laboratory technicians from the Department of Veterinary Services in Zambia Laboratory technicians from Deltamune poultry laboratory and University of Pretoria in South Africa
	Volunteer participation in research	Rural poultry farmers of Eastern Zambia

STATEMENT ON CONTRIBUTIONS OF OTHERS TO THE PUBLICATIONS

Title of PhD thesis:

A study of Newcastle Disease and the utilisation of trade hotspots to enhance community driven syndromic surveillance of poultry diseases in Zambia

Name of candidate:

Chrisborn Mubamba

Chapter	Details of publication(s) on which chapter is based	Nature and extent of the intellectual input of each author	I confirm the candidate's contribution to this paper and consent to the inclusion of the paper in this thesis
1	N/A	N/A	N/A
2	Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2016. A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia. Preventive veterinary medicine 133, 97-107.	**Chrisborn Mubamba:** Project design, data collection, data analysis, write up of the paper. **Bruce Gummow:** Project design, supervision and guidance during data collection, detailed editing of the paper including methodology, and discussion. **Celia Abolnik:** Detailed editing of the paper including inputs on methodology and discussion. **Gavin Ramsay:** Detailed editing of the paper and final review George Dautu: Final review of the paper	Name (please print) Chrisborn Mubamba Sign: Date:20th May 2018 Name (please print) Bruce Gummow Sign: Date: Name (please print) Celia Abolnik Sign: Date: Name (please print) Gavin Ramsay Sign: Date: Name (please print) George Dautu Sign: Date:
3	Mubamba, C., Abolnik, C., Dautu, G., and Gummow, B.	**Chrisborn Mubamba:**	Name (please print)

	Seroprevalence and molecular characterization of circulating Newcastle Disease Viruses in Eastern Zambia. To be submitted.	Project design, sample collection and processing, write up of the paper. **Celia Abolnik:** Project design, supervision and guidance during research, data analysis and review of paper. **Bruce Gummow:** Project design and final review. **George Dautu:** Sample collection, input on results and final review	Chrisborn Mubamba Sign: Date: 20th May, 2018 Name (please print) Celia Abolnik Sign: Date: Name (please print) Bruce Gummow Sign: Date: Name (please print) George Dautu Sign: Date:
4	Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B., 2017. Analysing production and financial data from farmers can serve as a tool for identifying opportunities for enhancing extension delivery among the rural poultry sub-sector in Zambia. Preventive veterinary medicine 158, 152-159.	**Chrisborn Mubamba:** Project design, data collection, data analysis, write up of the paper. **Bruce Gummow:** Project design, supervision and guidance during data collection, detailed editing of the paper including methodology, and discussion. **Celia Abolnik:** Detailed editing of the paper including inputs on methodology and discussion. **Gavin Ramsay:**	Name (please print) Chrisborn Mubamba Sign: Date: 20th May, 2018 Name (please print) Bruce Gummow Sign: Date: Name (please print) Celia Abolnik Sign: Date: Name (please print) Gavin Ramsay

		Project design, supervision and guidance during data collection, detailed editing of the paper including methodology, and discussion. **George Dautu:** Data collection and final review	Sign: Date: Name (please print) George Dautu Sign: Date:
5	Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B. Combining value chain and social network analysis as a viable tool for informing targeted disease surveillance in the rural poultry sector of Zambia. Transboundary & Emerging Diseases, 1-11.	**Chrisborn Mubamba:** Project design, data collection, data analysis, write up of the paper. **Bruce Gummow:** Project design, supervision and guidance during data collection, detailed editing of the paper including methodology, and discussion. **Celia Abolnik:** Detailed editing of the paper including inputs on methodology and discussion. **Gavin Ramsay:** Detailed editing of the paper and final review George Dautu: Final review of the paper **George Dautu:** Data collection and final review	Name (please print) Chrisborn Mubamba Sign: Date: 20th May, 2018 Name (please print) Bruce Gummow Sign: Date: Name (please print) Celia Abolnik Sign: Date: Name (please print) Gavin Ramsay Sign: Date: Name (please print) George Dautu Sign: Date:
6	Mubamba, C., Ramsay, G., Dautu, G., Abonlik, C., Gummow, B. Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018. Is syndromic data from rural poultry farmers a viable poultry disease reporting tool and means of identifying likely farmer responses to poultry	**Chrisborn Mubamba:** Project design, data collection, data analysis, write up of the paper. **Bruce Gummow:** Project design, supervision and guidance during data collection, detailed editing of the paper	Name (please print) Chrisborn Mubamba Sign: Date:20th May, 2018 Name (please print)

	disease incursion? Preventive veterinary medicine 153, 84-93.	including methodology, and discussion. **Celia Abolnik:** Detailed editing of the paper including inputs on methodology and discussion. **Gavin Ramsay:** Detailed editing of the paper and final review **George Dautu:** Data collection and final review	Bruce Gummow Sign: Date: Name (please print) Celia Abolnik Sign: Date: Name (please print) Gavin Ramsay Sign: Date: Name (please print) George Dautu Sign: Date:
7	Mubamba, C., Ramsay, G., Dautu, G., Abonlik, C., Gummow, B., 2017. Using community-based poultry clubs to effectively and sustainably drive disease surveillance in the rural poultry sector. Submitted to the Journal of Agriculture and Rural Development in the Tropics and Subtropics (Manuscript ID 3545).	**Chrisborn Mubamba:** Project design, data collection, data analysis, write up of the paper. **Bruce Gummow:** Project design, supervision and guidance during data collection, detailed editing of the paper including methodology, and discussion. **Celia Abolnik:** Detailed editing of the paper including inputs on methodology and discussion. **Gavin Ramsay:** Detailed editing of the paper and final review George Dautu: Final review of the paper **George Dautu:** Data collection and final review	Name (please print) Chrisborn Mubamba Sign: Date:20th May, 2018 Name (please print) Bruce Gummow Sign: Date: Name (please print) Celia Abolnik Sign: Date: Name (please print) Gavin Ramsay Sign: Date: Name (please print) George Dautu Sign:

			Date:

DECLARATION OF ETHICS

The research reported in this thesis was approved by the human and animal ethics Committees of James Cook University with ethics approval numbers of H5830 and A2095 respectively. Authority to conduct the research in Zambia was granted by the Zambian Department of Veterinary Services through its Director of Veterinary Services.

Chrisborn Mubamba

20th May 2018

ACKNOWLEDGEMENTS

I would like to thank my primary advisor, professor Bruce Gummow for his dedication and commitment to this work. Without his extra effort, completing this work would have been a bigger challenge. I would also like to acknowledge the intellectual input, academic guidance and support provided by Professors Celia Abolnik and Gavin Ramsay, my co advisors. Dr George Dautu from the Central Veterinary Institute in Lusaka, Zambia is also appreciated for the excellent support he provided in coordination and quality control of the project as a co researcher who was based in Zambia during the full length of the research.

I would also like to acknowledge the massive assistance and support given to this project by Drs Yona Sinkala (Director of Veterinary Services), Joseph Mubanga (late Director of Veterinary Services), Arthur Mumbolomena, Anna Songolo and Swithurn. Kabilika my supervisors from the Department of Veterinary Services (DVS) in Zambia. Drs Martha Sinzala, David Mweemba, Kelvin Kampamba, Carol Mulipukwa and Jordan Samuwika, professional colleagues from DVS are also acknowledged for the different roles they played during this research.

Additionally, I would also like to acknowledge the excellent technical and field support provided during the project by James Sikazindu, Danny Chilembo, Casiano Hapoma, Christian Moono, Esther Kafundanga, Peter Mwango, Naomi Mulombwaluse, Nawa Alibandila, Jonas Ngambi, Chiyasa Mainza, Judith Kabucha, Wycliff Sinyangwe, and Kalaluka Mbumwae from DVS in Eastern Zambia. Nyangu Bilima, Dulani Phiri and Esther Sinzala are also thanked for assisting with data entry and provision of some data from the local district councils in Eastern Zambia.

Lastly, I would like to thank Telana Rapp and Thandeka Phiri from South Africa for their excellent technical assistance rendered during virus isolation and PCR work.

ABSTRACT

Poultry provides an important protein and revenue source for communities in tropical regions. Unfortunately, mechanisms for early detection of diseases in the rural poultry sector of developing countries like Zambia remain a challenge. Early detection of Newcastle Disease (ND) and other poultry diseases in domestic birds can reduce their spread. Understanding the status of priority poultry diseases like ND and movement of birds through trade will allow identification of disease and trade hotspots where frequent contact between birds can be expected and disease can be transmitted.

Consequently, ensemble modelling was used to identify disease and trade hotspots with the aim of utilising them for rapid poultry disease detection. The approach involved a hazard and risk assessment which identified priority diseases and high disease risk hotspots for the rural poultry sector within Eastern Zambia respectively. This was followed by implementation and assessment of community based syndromic surveillance using poultry clubs (PCs).

Newcastle Disease was identified as a priority disease. A retrospective study found that the disease followed a seasonal and cyclic pattern, with peaks in the hot dry season (Overall Seasonal Index 1.1) and had an estimated provincial incidence range of 0.16 to 1.7% per year, in eastern Zambia. Additionally, there were apparent spatial shifts in districts with outbreaks over time which could be because of veterinary interventions chasing outbreaks rather than implementing uniform control. When retrospective ND data was fitted to a predictive time series model, it showed an increasing trend in ND annual incidence over 25 years if existing interventions continue.

The seroprevalence of ND among indigenous chickens that were not vaccinated against ND in Eastern Zambia was 73% (95% confidence interval 59-94%). Group specific reverse transcription assays and full genome sequencing identified NDV sub-genotypes VIIh and XIII, which were first identified in Asia, to be among the circulating ND viruses in Eastern Zambia. These findings revealed how vulnerable countries like Zambia are to exotic poultry disease infections.

Descriptive and financial analysis of the rural poultry sector at the farm gate revealed that Poultry ranked highest in terms of popularity and numbers when compared with other animals kept by respondents (median=20). Gross margin analysis conducted using costing data from poultry farmers and expert opinion of extension workers revealed that indigenous chickens had the highest gross margin percentage (72%) compared to commercial broilers and layers which had gross margin percentages of 53% and 56% respectively. Breakeven analysis revealed that indigenous chickens required the lowest

number of products to be sold (27) to realise profit compared to broilers (1011) and layers (873). The study further discusses how extension workers could utilise the weaknesses and strengths identified to initiate information sharing sessions with farmers that can arouse interest and ensure sustainable participation and implementation by farmers in sustainable disease extension programmes.

A study that conducted social network analysis and analysed poultry trading practices revealed that some farmers and traders sourced their poultry from neighbouring countries thus justifying the need for regional collaboration when conducting poultry disease surveillance. Trade of poultry and its products was at its peak in December and January and was associated with Christmas and New Year celebrations respectively, thus providing information when surveillance should be taking place. This was the first study that formally described poultry movement networks within Zambia and the surrounding region. Its findings provided data required for implementing targeted surveillance in regions where resources are either inadequate or non-existent.

A study that assessed the viability of syndromic data as a possible source for disease surveillance data found that farmers reported an overall annual disease incidence in rural poultry for eastern Zambia of 31% (90% CI 29-32%). On farm disease in poultry was associated with use of middlemen to purchase poultry products ($p=0.05$, $OR=7.87$), poultry products sold or given away from the farm ($p=0.01$, $OR=1.92$), farmers experiencing a period with more trade of poultry and its products ($p=0.04$, $OR=1.70$), presence of wild birds near the farm or village ($p<0.01$, $OR=2.47$) and poultry diseases being reported from neighbouring farms or villages ($p<0.01$, $OR=3.12$). The study also tentatively identified three poultry diseases (Newcastle Disease, Gumboro Disease and Fowl Pox) from the thirty-four disease syndromes provided by farmers. Farmers reported an incidence of 27% for Newcastle Disease in 2014. When compared with the state veterinary services data which reported Newcastle Disease incidence at 9% in 2014, it seems syndromic data obtained from farmers may be more sensitive in identifying disease incursion.

The efficiency of PCs was assessed by computing the proportion of meetings conducted by PCs compared to the actual meetings planned. Sustainability was assessed by comparing the mean ranks of report submission of farmers over the 24 months post PC inception using the Friedman test. The effectiveness of disease surveillance using PCs was evaluated by determining the minimum number of reports required from club members to detect at least one household with poultry disease in the population. This was modelled further using a geometric distribution function to establish the sensitivity of the reporting system. Additionally, PCs were evaluated using focussed group discussions and structured questionnaire interviews. The syndrome reporting efficiency of PCs was 0.8. The PC approach was sustainable because there were no significant differences in report submission between the 24 months post inception (Friedman test, $\chi2(23) = 32.93$, $p = 0.08$). The probability of detecting outbreaks in disease hotspots of Eastern Zambia was estimated at 98% (51-100). Most respondents were either very satisfied or extremely satisfied with the approach. The study concluded that PCs can be used as a community-based platform for low cost syndromic surveillance that is sustainable.

Using ensemble modelling, the project managed to set up a viable system for rapid detection of poultry diseases which utilised disease and trade hotspots among the rural poultry sector in Eastern Zambia. Through its studies this research revealed key disease control issues which could be extrapolated to other regions and its model may be applied to enhance disease surveillance for other livestock such as pigs, goats, cattle and aquaculture.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATTIONS AND ACRONYMS

Acquired Immune Deficiency Syndrome (AIDS)

African Development Bank (ADB)

Akaike Information Criterion (AIC)

Annual Expenditure (AE)

Annual Income (AI)

Apparent incidence (AI)

Auto Regressive Moving Average (ARMA)

Avian Influenza (AI)

avian paramyxovirus 1 (APMV-1)

Base pairs (bp)

Community livestock auxiliaries (CLAs)

Confidence intervals (CI)

Department of Veterinary Services (DVS)

Enzyme Linked Immune Sorbent Assay (ELISA)

Ethno Veterinary Medicine (EVM)

Fifth National Development Plan (FNDP)

Food and Agriculture Organisation (FAO)

Food Animals Biosecurity Network (FABN)

Fourth National Development Plan (4thNDP)

Government of the Republic of Zambia (GRZ)

Gross Domestic Product (GDP)

Haemaglutination Inhibition

Highest probability density (HPD)

Human Immune Virus (HIV)

Infectious Bursal Disease (IBD)

International Monetary Fund (IMF)

Intra cerebral pathogenicity index (ICPI)

Livestock Development and Animal Health Project (LDAHP)

Lower Confidence Level (LCL)

Moving Average (MA)

National Livestock Epidemiology and Economic Information Centre of Zambia (NALEEIC)

Net income (NI)

Newcastle Disease (ND)

Newcastle Disease Virus (NDV)

Overall seasonal index (OSI)

Percent inhibition (PI %)

Positive predictive value (PPV)

Poultry clubs (PCs)

Poverty Reduction Programme (PRP)

Seasonal index (SI)

Sensitivity (Se)

Seventh National Development Plan (7thNDP)

Sixth National Development Plan (SNDP)

Social Network Analysis (SNA)

Specific pathogen free (SPF)

Specificity (Sp)

Structural Adjustment Programme (SAP)

Time to the most recent common ancestor (tMRCA)

Upper Confidence Levels (UCL)

Veterinary Assistants (Vas)

World Animal Health Information System (WAHIS)

World Bank (WB)

World Organisation for Animal Health- OIE

Zambian Kwacha (ZMW)

Chapter 1

GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 Literature Review

1.1.1 Introduction

Poultry

Poultry production is an agricultural activity that involves rearing of birds for domestic consumption and/or sale. When practiced on a large scale with birds (fed on commercial feed) bred for high and quality meat or egg production, it is termed commercial poultry. On the other hand, when birds are kept at a low scale mainly meant for domestic consumption (usually with less than 100 birds) or when birds are meant for sale but reared with minimal resources (even if they are improved breeds), could be termed as rural poultry (Sonaiya E.B., 2007; Akinola and Essien, 2011).

Birds have been domesticated for approximately 8000 years (Alders R.G., 2004). Birds were first domesticated in China (Alders R.G., 2004; Alders R.G. et al., 2009). This trend of domesticating chickens is then known to have moved westwards to Europe (Alders R.G., 2004). In Africa, poultry is known to have been reared for several centuries. Poultry provides the greater population of Africa with most of their protein needs and has a potential for increasing the living standards of most rural households through income generation (Mapiye et al., 2008; Msoffe et al., 2010; Akinola and Essien, 2011; Mtileni et al., 2012).

Rural Poultry

Village chickens, which are mostly reared as rural poultry, have demonstrated a lot of advantages over commercial breeds. These advantages as summarised by Alders et al., 2009 are that they can adapt to different ecological zones, require low inputs, tend to be robust and agile, are mostly preferred by women (Guèye, 2000) and form the first step in the ladder of livestock ownership of rural farmers. Above all, they provide protein of the highest quality that is produced in a sustainable manner with little or no impact on the environment (Alders R.G. et al., 2009).

In Zambia (Figure 1-1), village chickens are mostly left to scavenge for food around villages and townships (Songolo and Katongo, 2000). Though it is difficult to classify village chickens into breeds, village chickens have generally been identified as small dwarf breeds with naked necks and larger breeds (Songolo and Katongo, 2000). Due to growing demand for poultry meat within and outside the same townships and villages, commercial birds meant for sale are also kept in housed structures with minor restrictions on their access in most cases. This situation creates a complex mixture of birds reared in a rural environment.

Figure 1-1: Map of Africa showing the position of Zambia.

Despite its potential to contribute significantly to sub-Saharan economic growth, the rural poultry industry is faced with numerous challenges such as disease, predation, and lack of proper housing (Songolo and Katongo, 2000; Msoffe et al., 2010). Disease seems to be the biggest challenge faced by this sector. This review therefore briefly attempts to outline the status of poultry diseases affecting rural poultry in sub-Saharan Africa and specifically in Zambia. Attention will be given to Newcastle Disease (ND) - a major disease affecting rural poultry in Zambia.

Poultry Diseases in Zambia

Newcastle Disease has been identified as a leading disease among rural poultry in Zambia. For example, in 2013, 5293 suspected cases of ND were reported in the Eastern province of Zambia compared to very low numbers of other poultry diseases reported in the province during the same year (GRZ, 2013). Other diseases like mycoplasmosis, helminthiasis, ectoparasite infestations and coccidiosis are also quite common in rural poultry (Songolo and Katongo, 2000). In rural poultry kept as backyard commercial breeds, Infectious Bursal Disease (Gumboro Disease) has also been reported (GRZ, 2013).

Since ND is the most common poultry disease affecting rural poultry in Zambia, this review will focus on ND as a model poultry disease. It will identify gaps in the control of the disease and highlight the status of the disease as well as explore possible means of mitigating negative impacts of poultry diseases using latest modelling approaches. Reference will be made to strategies that have been used for surveillance and control of ND and other related poultry diseases in other countries.

1.1.1 Newcastle Disease

Description of the Disease

Newcastle Disease (ND) is a highly contagious disease of birds that is characterized by weak limbs, cyanosis of the wattle and comb, nasal and eye discharges, greenish diarrhoea, weight loss, loss of egg production and high mortality (Alexander D. J., 1997; Rakibul Hasan A. K. M. et al., 2010). At post-mortem, the characteristic lesions that have been described are 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 (Pazhanivel N. et al., 2002).

Distribution

Newcastle Disease has been reported from all regions of the world (Alexander, 2000; Bwala et al., 2012). It has been reported to affect more than 250 bird species around the world (Sa'idu et al., 2004). It is also known to affect all age groups of birds although younger birds are more prone to the disease (Alexander, 2000).

In Zambia, the first report of the disease was in 1952 when 15 outbreaks were reported (Sharma R. N. et al., 1985; Songolo and Katongo, 2000) in the Southern Province of Zambia. The disease eventually spread making the disease enzootic in the country. As a result of good disease control measures existing in the commercial poultry sectors of the Copperbelt, Central, Lusaka and Southern Provinces of Zambia, the disease has very low incidence in this sector (Songolo and Katongo, 2000). However, incidence remains high in the rural poultry sector of the country with outbreaks being reported frequently.

Aetiologic Agent

Newcastle Disease is caused by Newcastle Disease Virus (NDV). The virus is a linear, single stranded, non-segmented, enveloped, negative RNA virus (Barbezange C. and Jestin V., 2005). It belongs to the order Mononegavirales, family Paramyxoviridae. NDV belongs to the genus Avulavirus and species *Newcastle disease Virus*. NDV and pigeon paramyxovirus are reffered to as avian paramyxovirus 1 (APMV-1) (Afonso et al., 2016).

Depending on their virulence, APMV-1 serotypes have been grouped as viscerotropic velogenic, neutrotropic velogenic, mesogenic, lentogenic and asymptomatic enteric pathotypes (Beard C. W.

and Hanson R. P., 1984). In Zambia, most circulating NDV are known to be of velogenic viscerotropic and velogenic neurotropic strains (Hussein N. A. et al., 1984). It has been reported that ND caused by velogenic strains can lead to very high mortality that could be as high as 100% (Rakibul Hasan A. K. M. et al., 2010).

All strains of NDV belong to a single serotype but multiple genotypes and sub-genotypes (Diel et al., 2012). New sub genotypes have emerged over a period probably due to intensive farming and use of new high densities of poultry and the use of vaccines (Abolnik et al., 2017). There are two classes of NDV (I and II) but all virulent strains implicated of ND emerged from Class II (Molini et al., 2017). Class II is further divided into eighteen genotypes (I to XVIII), some containing sub-genotypes, based on genetic distances between viral fusion glycoprotein gene sequences (Diel et al., 2012; Abolnik et al., 2017b). Viruses from Genotype VII have been responsible for the most recent ND panzootic. It originated in Southeast Asia, with the earliest known outbreaks beginning around 1985. Currently, sub-genotypes VIIa to VIIk have been described (Diel et al., 2012; Abolnik et al., 2017; Molini et al., 2017).

Laboratory Diagnosis

Laboratory diagnosis is vital for confirmation of ND and characterisation of NDV strains. Confirmation of the disease usually involves growth and isolation of the NDV in embryonated eggs that is further identified using Haemaglutination Inhibition (HI) test that utilises specific ND sera (Alexander D.J., 2009; Rakibul Hasan A. K. M. et al., 2010). The World Organisation for Animal Health (OIE), recognises two methods for determination of virulence that are inoculation of specific pathogen free (SPF) eggs with an isolate followed by determination of intra cerebral pathogenicity index (ICPI) of isolates and, alternatively, determination of virulence by using a molecular method that involves analysing amino acid sequences of NDV isolates at the cleavage site of the fusion glycoprotein (F protein) (OIE, 2008; Alexander D.J., 2009; Cattoli et al., 2010). In Zambia only HI and ICPI have been previously used to diagnose and characterise ND isolates respectively (Hussein N. A. et al., 1984).

Epidemiology

The faecal-oral route has been described as the main mode of transmission in scavenging rural poultry (Nwanta et al., 2008b). On the other hand, the respiratory route through aerosols seems to be the mode of transmission in intensive poultry production systems where birds are kept in close contact to each other (Nwanta et al., 2008b). Village chickens are known to be more resistant to ND than commercial broilers and layers (Alders R.G. et al., 2009). Young birds are more susceptible than older ones (Alexander, 2000).

Vaccination increases immunity to ND (Nwanta et al., 2008b). However, when immunized birds are infected with virulent NDV, they will be able to transmit the disease to other susceptible birds despite their failure to succumb to clinical ND (Nwanta et al., 2008b). This may complicate the epidemiology of the disease in rural flocks where we could have a mixture of vaccinated and unvaccinated flocks that frequently mix through free movements (Nwanta et al., 2008b). Studies have shown that NDV may survive up to 30 days in environments with temperatures between 20- 30 degrees Celsius (Nwanta et al., 2008b). Consequently, a country with most poultry freely roaming like Zambia needs to develop a system that would rapidly identify any emerging out breaks of ND to control the disease as soon as possible.

Generally, wild birds are known to be carriers of avirulent NDV (Chantal et al., 2013) while village chickens are said to be carriers of virulent NDV (Snoeck et al., 2013). However, it has been demonstrated that water fowl and white storks could carry virulent NDV. Recently, virulent strains of NDV (genotype VI) derived from doves in Nigeria and South Africa have been described (Pfitzer S et al., 2000; Oladele S. B. et al., 2012). Such a situation justifies the need for poultry surveillance systems to monitor any possible interactions of local poultry with birds like waterfowls and doves to react quickly to possible severe outbreaks of ND which may occur due to such interactions.

In Zambia, very few studies that comprehensively study the epidemiology of ND have been conducted. One of the earliest studies conducted by Sharma et al revealed that a total of 525 ND cases were confirmed between 1975 and 1984 and that the disease had two annual peaks, the first between January and March and, the second being between September and November (Sharma R. N. et al., 1985). The other study conducted in 1984 established that most circulating NDV strains in Zambia are viscerotropic velogenic followed by neurotropic velogenic strains (Hussein N. A. et al., 1984). The next study carried out in 1994 established seroprevalence of ND in village chickens of Zambia to be in the range of 29.2% and 51.3% in the Northern and Copper belt provinces of Zambia respectively (Alders R. G. et al., 1994). Recently, a study conducted by Musako and Abolnik in five provinces revealed a ND seroprevalence range of 48.3% (Luapula province) and 82% (Eastern Province) among the provinces of Zambia (Musako and Abolnik, 2012). Unfortunately, most of the data collected on the disease is only based on reports of suspected cases (which are rarely confirmed probably due to inadequate resources at the time of outbreaks) (GRZ, 2013). This situation could lead to under reporting of the actual situation on the ground and at times, could also lead to misdiagnosis.

Control

Several approaches for effective control of ND have been suggested. Maintenance of hygiene, segregation, vaccination, selection for resistance when breeding birds and slaughter of infected flocks (depopulation) followed by proper disposal are some methods suggested for effective control of the disease (Fasina et al., 2012). Despite hygiene being effective in controlling the disease in commercial poultry and some rural poultry kept under the semi intensive system (Nwanta et al., 2008b), it is quite difficult to use it effectively in villages and townships of countries like Zambia where most chickens are left to roam freely.

Vaccination on the other hand has better prospects for effective control of the disease in rural poultry (Alders R.G. et al., 2004). The challenge in achieving a good vaccination response has probably been due to lack of adequate awareness about the disease (GRZ, 2013). Furthermore, maintaining a good cold chain for vaccines has been a problem (Arthur Mumbolomena, Provincial Veterinary Officer, Personal communication). This challenge could, nevertheless, be overcome by the recent availability of thermo stable vaccines that can be stored at room temperatures (Alders R.G. et al., 2009).

Hygiene, segregation and depopulation form part of a set of measures broadly termed as biosecurity. Segregation can be implemented at farm or village, veterinary camp, district, province and national levels (Fasina et al., 2012). In Zambia, this is implemented through poultry movement controls which involve provision of sanitary certificates at veterinary camp, district, provincial and national levels (GRZ, 2013). Adherence to such a policy is vital for Newcastle Disease control because it would prevent movement of birds infected flocks to those not infected.

People need to adopt a set of attitudes and behaviours to achieve biosecurity for ND (Fasina et al., 2012). This change of mindset is very important in reduction of risk for ND transmission in activities involving domestic, captive, exotic and wild birds and their products (Fasina et al., 2012). In other words, control of ND would be very difficult if socioeconomic aspects of affected communities that concern the trade of poultry and its products are not understood. Unfortunately, studies that describe social networks of the poultry trade in Zambia have not been conducted.

1.1.2 Syndromic surveillance

Current animal disease surveillance efforts conducted by Veterinary Services in Africa are limited, with paper reports of notifiable diseases taking a long time to reach a central database (Walker et al., 2011). This is due to inadequate road networks and electricity infrastructure (Walker et al., 2011). The essential objective of syndromic surveillance is to find disease clusters early; before diagnosis is confirmed and reported to disease control agencies (Dorea and Vial, 2016). Thus, it assists in mobilising a rapid response to an outbreak which leads to reduced morbidity and mortality (Henning, 2004). Syndromic surveillance has been implemented in some developed countries and has been trialled in some developing countries like Kenya and the Pacific Island Countries (PICs) (Yombo, 2010; Walker et al., 2011; Brioudes and Gummow, 2015), but has not been trialled in Zambia. Developing it in Zambia would help reduce losses due to morbidity and mortality in the livestock sector particularly in the rural poultry sector. For syndromic surveillance to be implemented in the rural poultry sector of Zambia, there is need to assess the farmers' ability in recording reporting syndromes and how they respond to outbreaks as a basis for evaluating the feasibility of establishing the surveillance system.

1.1.3 Participatory approaches

The aim of extension is to raise the standard of living of farmers and their families in rural areas (Duman, 2018). Several extension models have been used in agriculture extension. Among these are; a farmer first, technology transfer, and participatory extension approach (Ozcatalbas et al., 2011). The first model is a top-down approach, that involves taking the thoughts, plans and schemes from researchers down to the farmers' community (Duman, 2018). Conversely, a bottom top model takes the opinion, problems and suggestions of the farming community up to the researchers to aid them in making hands-on and result-oriented research programs (Queenan et al., 2017; Duman, 2018). The participatory approach involves mixing and intensifying of the first two models. The participatory approach model involves both farmers and the researchers and brings other stakeholders on board (Ozcatalbas et al., 2011). The use of groups has been proved to enhance information dissemination through participatory extension approaches (Agwaru et al., 2004; Jost et al., 2007). With this background in mind, veterinary services can use participatory epidemiology to conduct livestock disease awareness to farmers (Hoinville et al., 2013; Jost et al. 2007), while at the same time collecting syndromic data from farmers that are organised in groups. This can lead to reduced reaction time between a poultry disease outbreak and response from veterinary services in resource constrained communities.

1.1.4 Financial viability of rural poultry enterprises

To be used sustainably as sentinels were syndromic surveillance could be placed, targeted rural poultry enterprises should be financially sustainable. Many studies have mentioned the nutritional and income generation potential of rural poultry (Mack et al., 2005; Copland J.W. and Alders R.G., 2009; Mtileni et al., 2012). However, very few studies have ascertained which production system is more financially viable between broiler, layer and indigenous chicken production within the rural sub-Saharan context like rural Zambia. Such studies can help farmers and veterinary services make informed choices on which production system to prioritise when selecting an enterprise and conducting disease control activities respectively. More importantly, it can assist participatory epidemiologists to select a group of farmers with sustainable enterprises that they can work with over a longer period.

1.1.5 Modelling approaches

In the past, the veterinarians' perceptions on livestock disease were mostly based on their knowledge of veterinary science. However, recent studies have proved that there is need to account for socioeconomic factors that may influence the spread of disease in affected areas. That is because there seems to be a significant association between disease spread and socioeconomic activities related to an animal or animals that are affected by a respective disease (Firestone et al., 2011; Paul et al., 2013). NDV can spread through movement of people, live birds, poultry products and its associated equipment (Alexander D.J. et al., 2004). Studies have demonstrated the association between increased chicken sales and increased socio-cultural activities in relation to incidence of ND (Alexander D.J. et al., 2004; Otim M.O. et al., 2007; Chaka et al., 2013). In addition, poultry exhibits in Australia were recently assessed to pose a biosecurity risk in the poultry industry due to high frequencies in bird movements coupled with close contacts between birds, people and equipment from different farms and regions during these functions (Hernández-Jover et al., 2013). Other studies conducted on the spread of ND and or Avian Influenza (AI) in several regions of the world further substantiate the fact that it is important to understand the socioeconomic networks involved in poultry trade of a region to effectively survey and control these poultry diseases (Nickbakhsh et al., 2011; Chaka et al., 2013).

To take into consideration the epidemiological and socio-economic factors that leads to spread of diseases, there is need for a holistic approach that incorporates all studies using a multi-display approach. Within this model, a step by step framework which included hazard analysis and risk analysis that will identify disease outbreak hotspots within the poultry value chain (Stärk et al., 2006). This will lead to placement of syndromic surveillance in the identified hotspots thus achieving cost effective risk-based surveillance. Risk based surveillance is defined by Stärk et al. (2006) as a surveillance programme in the design of which exposure and risk assessment methods have been applied together with traditional design approaches to assure appropriate and cost-effective data collection. To achieve reduction in poultry losses due to poultry mortality in the resource constrained rural poultry sector of Zambia, there is need to conduct a research which involves

Ensemble modelling. Ensemble modelling is the process of running two or more related but different analytical models and then synthesizing the results into a single outcome (Brioudes and Gummow, 2017).

1.1.6 Conclusion

In Zambia, few studies have comprehensively studied trends of ND since 1995. Therefore, there is need for a retrospective study that would examine reported cases of the disease in the past 25 years. Such a study would create better understanding of the temporal, spatial and population trends of the disease in the country.

Socioeconomic factors play a role in propagation of ND. As a result, there is need for a study that comprehensively examines the social behaviours of the rural Zambian communities where poultry movements and trade is concerned. Furthermore, the study should also examine the level of knowledge for identification and control of ND among rural Zambian communities. It would also be vital to assess the socioeconomic impacts of the disease.

Molecular characterization of circulating NDV has not been done in Zambia. Bearing in mind that NDV is constantly evolving, and new genotypes that cause disease in waterfowl, there traditional asymptomatic hosts are emerging; there is need for a comprehensive study that would characterize molecular strains in the country. The information derived from such a study would provide baseline information that would be critical should emergence of strains that could cause more severe disease in other species take place.

There is need for a system that would rapidly identify ND outbreaks in Zambia. By the time most outbreaks are reported, high mortalities may have already occurred. To avoid huge losses, the rural poultry farmers could be incorporated in a sustainable ND rapid identification program that involves training them in key symptoms of the disease. Such an approach, termed syndromic surveillance, would be part of the risk management system for ND and other poultry diseases that would be developed after following a step by step framework that would lead to reduction of poultry losses as a single combined outcome (FAO, 2011).

1.2 Problem statement and hypothesis

1.2.1 Problem

Currently, existing knowledge on the status of ND (the priority poultry disease in Zambia) and the role that social networks and market value chains play in propagating the disease in the rural poultry of Zambia is low. Consequently, this has led to a weak poultry surveillance system that allows for major poultry losses by the time outbreaks are identified and controlled.

1.2.2 Hypothesis

Updating the knowledge of poultry diseases and studying the role of social networks and market value chains in their propagation would facilitate establishment of a syndromic surveillance platform that would reduce losses in the rural poultry sector of Zambia.

1.3 Benefits arising from the research

The questionnaire surveys would identify gaps in knowledge of avian diseases amongst poultry farmers interviewed. This would provide an opportunity for targeted training of poultry farmers that focuses on their weaknesses and needs. These focussed trainings would lead to more knowledge on control of poultry diseases among rural poultry farmers. Furthermore, poultry farmers would be trained on the importance of disease reporting. This increased awareness will result in early detection of diseases.

The studies would lead to placement of syndromic surveillance platforms in poultry hubs that are identified through social network and market chain analysis. These hubs would then provide a basis for effective surveillance and research of poultry diseases in the future.

The syndromic surveillance platforms introduce a novel approach to monitoring and surveillance of poultry diseases through promotion of an economic poultry data template that could indirectly gather real time disease data from poultry farmers.

The project would also study the molecular epidemiology of ND in identified hubs (social and commercial hubs). It would characterize the molecular strains of ND in the region providing baseline information that is critical should future emergence of strains that cause more severe disease in humans take place.

The results and conclusions of these studies would lead to increased knowledge of ND amongst Zambian Government Veterinary officials involved in disease control and other stakeholders interested in poultry thereby leading to a more holistic way of controlling the disease. Furthermore, results of the study could contribute to the broad knowledge bank of science and stimulate more research into poultry diseases of this region.

Lastly, the long-term effects of the study can lead to reduced incidence of the disease thereby increasing resilience of rural communities to food shortages (food security). Reduced prevalence of the disease would also lead to more income gained through increased poultry and poultry bi products sales. This would eventually contribute to increasing the GDP of Zambia.

1.4 Objectives of the research

The overall objective of the project was to establish the scientific basis for a system for early detection of priority diseases like ND, which utilises social networks and value chains within the rural poultry sector of Zambia, using ensemble modelling. Ensemble modelling is the process of running two or more related but different analytical models and then synthesizing the results into a single outcome (Brioudes and Gummow, 2017). The model for this research involved a step by step framework which included hazard analysis, risk analysis and placement of community based syndromic surveillance among the rural poultry sector of Zambia. Specific objectives for the project were;

1.4.1 To carry out a retrospective study on the trends of Newcastle Disease from 1989 to 2014 (25 years) through a retrospective study that examines disease reports on Newcastle Disease within Zambia. This will be done with a view of determining the current spatial and temporal trends of the disease.

1.4.2 To assess the level of knowledge of Newcastle Disease (ND) and its control among rural poultry farmers of eastern Zambia through questionnaire surveys.

1.4.3 Through questionnaire surveys, assess the financial sustainability of rural poultry enterprises, assess social networks and map out trade of birds within informal markets and identify hubs (Hot Spots) where most interaction of poultry breeds and species takes place. This was done with a view of making ND surveillance in the informal poultry sector more efficient by using such hubs.

1.4.4 To assess the serological prevalence of Newcastle Disease in social and trade poultry hubs with a view of obtaining baseline knowledge on prevalence of the disease in these hubs that would assist in future disease monitoring.

1.4.5 To carry out molecular characterization of the circulating ND viruses in Zambia as a baseline for identifying new strains of the viruses that would be introduced or that would emerge because of mutations, antigenic drift and shift of the virus.

1.4.6 To place and assess a syndromic surveillance platform of ND and other poultry diseases in some poultry social and commercial hubs of eastern Zambia to improve cost effectiveness of disease surveillance in the rural poultry sector.

1.5 Building of the Ensemble Model

Based on gaps identified from the literature review and reports from veterinary services, an ensemble model whose main aim was to establish a targeted, low cost and sustainable poultry disease reporting system within the rural poultry sector of Zambia was assembled. The model was composed of hazard analysis, risk analysis and placement of and intervention (syndromic surveillance platform) in identified disease outbreak hotspots. The model was modified based on recommendations by Stärk et al. (2006) and FAO (2011)

Hazard analysis was in two parts. The first part involved conducting serological survey and molecular characterisation of NDV, which was identified as a priority disease by the literature review. The second part involved identifying a socio-economically viable poultry production enterprise that could be sustainably be used as sentinel for placement of a targeted surveillance platform.

Risk analysis had two parts. The first part involved identifying elevated risk disease transmission hotspots within the rural poultry market chain of Eastern Zambia. Part two involved studying the poultry socionetworks to identify trade hotspots where disease transmission could most likely occur.

The last component of the model was the placement of an intervention, which was placement of syndromic surveillance platforms among viable rural poultry farmers in identified disease outbreak hotspots thus ending up with a low cost, targeted and sustainable early warning reporting system for poultry disease outbreaks that uses selected poultry farming communities as sentinels. The ensemble model is further illustrated in Figure 1-2 below.

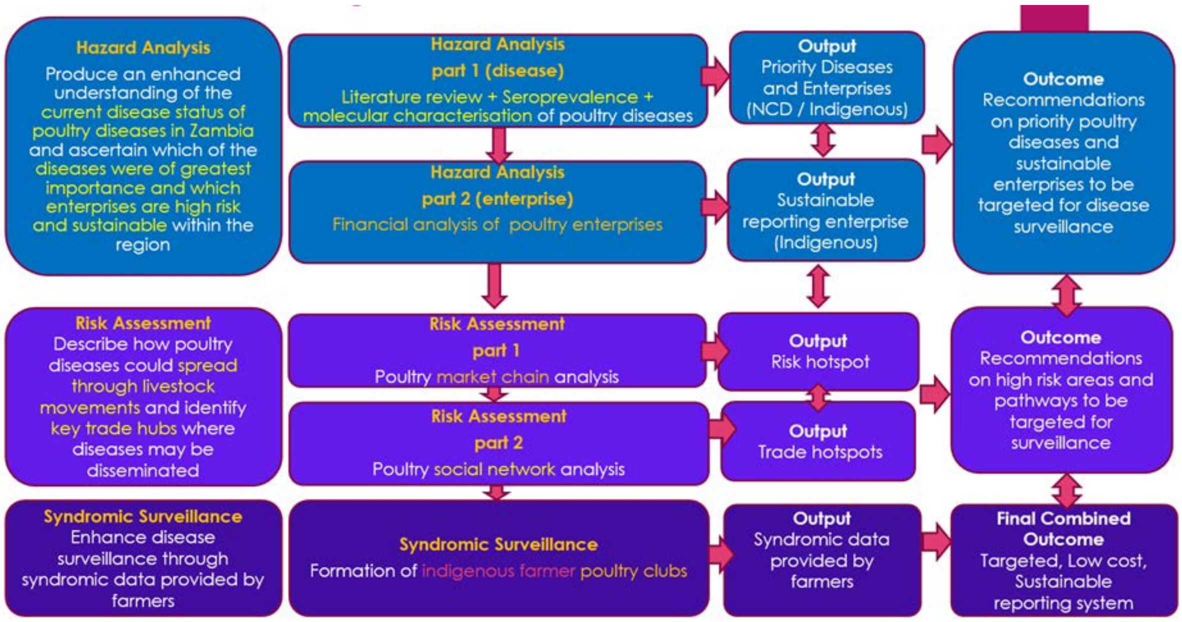


Figure 1-2: Ensemble model for improving poultry disease reporting among the rural poultry sector of Zambia. The model involved hazard analysis, risk analysis and syndromic surveillance with a final combined outcome of developing a targeted, low cost sustainable disease reporting system for the rural poultry sector of Eastern Zambia. Modified from work done by Brioudes and Gummow (2017).

1.6 Scope of the thesis

The following chapters cover the studies conducted, which were approached and aligned to the ensemble model (Table 1-1). Chapter 2 is a retrospective study and predictive modelling of ND trends among rural poultry of Eastern Zambia. Chapter 3 involves assessment of seroprevalence and molecular characterisation of circulating NDV in eastern Zambia. Chapter 4 is a descriptive and financial analysis of rural poultry enterprises in eastern Zambia. Chapter 5 then contains an assessment of poultry movement and trading practices in Eastern Zambia. This is followed by an assessment of syndromic data obtained directly from poultry farmers as a viable disease reporting tool in Chapter 6. Chapter 7 is a trial and assessment of poultry clubs as drivers of disease surveillance risk communication and capacity building among the rural poultry sector of Eastern Zambia. Lastly, a general discussion, conclusion and recommendations are presented in Chapter 8.

Table 1-1: Studies conducted to improve poultry disease surveillance in Eastern Zambia from 2014 to 2016 and how they relate to the components of the ensemble model.

Step of the ensemble model	**Component of the step**	**Study conducted**
I. Hazard analysis	a. Retrospective studies, sero survey, virus isolation and molecular characterisation	1. Retrospective study and predictive modelling of ND trends among rural poultry of Eastern Zambia 2. Assessment of seroprevalence, molecular characterisation and tracing origin of circulating NDV in eastern Zambia
	b. Financial analysis	3. Descriptive and financial analysis of rural poultry enterprises in eastern Zambia
II. Risk Assessment	a. Value chain and social network analysis	4. Assessment of poultry movement and trading practices in Eastern Zambia
III. Syndromic Surveillance	a. Assessment of syndromic data b. Implementation and assessment of community based syndromic surveillance	5. Assessment of syndromic data obtained directly from poultry farmers as a viable disease reporting tool and means of evaluating remedies and measures farmers use to mitigate poultry diseases in Eastern Zambia 6. Trial and assessment of poultry clubs as drivers of disease surveillance risk communication and capacity building among the rural poultry sector of Eastern Zambia

1.7 References

Abolnik, C., Mubamba, C., Wandrag, D.B.R., Horner, R., Gummow, B., Dautu, G., Bisschop, S.P.R., 2017. Tracing the origins of genotype VIIh Newcastle disease in Southern Africa. Submitted to Journal of Transboundary and Emerging Diseases. In press.

Afonso, C.L., Amarasinghe, G.K., Bányai, K., Bào, Y., Basler, C.F., Bavari, S., Bejerman, N., Blasdell, K.R., Briand, F.-X., Briese, T., 2016. Taxonomy of the order Mononegavirales: update 2016. Archives of virology 161, 2351-2360.

Agwaru, G., Matsiko, F., Delve, R., 2004. Assessing approaches for dissemination of research information to the farmers within their livelihood situations in Tororo district, Uganda. Uganda Journal of Agricultural Sciences 9, 265-270.

Akinola, L. A. F., & Essien, A. (2011). Relevance of rural poultry production in developing countries with special reference to Africa. *World's Poultry Science Journal, 67*(04), 697-705. doi: doi:10.1017/S0043933911000778

Alders R. G., Inoune S., & Katongo J. C. (1994). Prevelence and evaluation of Hitchner B1 and vaccine for the control of Newcastle disease in village chickens in Zambia. *Preventive Veterinary Medicine, 21*(125-132).

Alders R.G. (2004). Poultry for profit and pleasure. FAO Diversification Booklet 3. Food and Agriculture Organization of the United Nations: Rome.

Alders R.G., Spradbrow P.B., & Young M.P. (Eds.). (2009). Village chickens, poverty alleviation and the sustainable control of Newcastle disease. *Proceedings of an international conference held in Dar es Salaam, Tanzania, 5–7 October 2005. ACIAR Proceedings No. 131, 235 pp* .

Alexander D. J. (Ed.). (1997). Newcastle disease and other avian Paramyxoviridae infections (Vol. 10). Ames Iowa: Iowa State University Press.

Alexander D.J. (2009). Ecology and epidemiology of Newcastle disease. In: Capua, I., Alexander, D.J. (Eds.), Avian Influenza and Newcastle Disease, a Field and Laboratory Manual. Springer-Verlag, Italy, pp. 19–26.

Alexander D.J., Bell J.G., & Alders R.G. (2004). Technology review: Newcastle disease with special emphasis on its effect on village chickens. FAO Animal Production and Health Paper No. 161, 63 pp. Food and Agriculture Organization of the United Nations: Rome.

Alexander, D. J. (2000). Newcastle disease and other avian paramyxoviruses. *Rev Sci Tech, 19*(2), 443-462.

Barbezange C., & Jestin V. (2005). Molecular study of the quasispecies evolution of a typical pigeonparamyxovirus type 1 after serial passages in pigeons by contact. *Avian pathology, 34*, 111-122.

Beard C. W., & Hanson R. P. (Eds.). (1984). *Newcastle Disease* (8 ed.). Iowa State University Press, Ames, Iowa.

Brioudes, A., Gummow, B., 2017. A framework for targeted allocation of resources for livestock disease surveillance in selected pacific island countries. In, 9th Veterinary, Paraveterinary & SASVEPM Congress 2017 Proceedings, Johansburg, South africa.

Bwala, D. G., Clift, S., Duncan, N. M., Bisschop, S. P. R., & Oludayo, F. F. (2012). Determination of the distribution of lentogenic vaccine and virulent Newcastle disease virus antigen in the oviduct of SPF and commercial hen using immunohistochemistry. *Research in Veterinary Science, 93*(1), 520-528. doi: http://dx.doi.org/10.1016/j.rvsc.2011.06.023

Cameron, A. R. (1999). Survey Toolbox- A Practical Manual and Software Package for Active Surveillance of Livestock Diseases in Developing Countries. *ACIAR Monograph, 54*(330).

Cattoli, G., Fusaro, A., Monne, I., Molia, S., Le Menach, A., Maregeya, B., . . . Capua, I. (2010). Emergence of a new genetic lineage of Newcastle disease virus in West and Central Africa--implications for diagnosis and control. *Vet Microbiol, 142*(3-4), 168-176. doi: 10.1016/j.vetmic.2009.09.063

Chaka, H., Goutard, F., Roger, F., Bisschop, S. P. R., & Thompson, P. N. (2013). Household-level risk factors for Newcastle disease seropositivity and incidence of Newcastle disease virus exposure in backyard chicken flocks in Eastern Shewa zone, Ethiopia. *Preventive Veterinary Medicine, 109*(3–4), 312-320. doi: http://dx.doi.org/10.1016/j.prevetmed.2012.10.003

Chantal, J., Snoeck, A., Adeniyi, T., Adeyanju, B. C., Ademola, A., Owoade, d., . . . Ulf Ottosson, b., g.,. (2013). Genetic Diversity of Newcastle Disease Virus in Wild Birds and Pigeons in West Africa. *Applied and Envirolmental Microbiology, 79*(24), 7867. doi: 10.1128/AEM.02716-13.

Copland J.W., Alders R.G., 2009. The comparative advantages of village or smallholder poultry in rural development.Village chickens, poverty alleviation and the sustainable control of Newcastle disease Proceedings of an international conference held in Dar es Salaam Tanzania, 5–7 October 2005.ACIAR Proceedings No. 131, 235 pp.

Diel, D. G., Susta, L., Cardenas Garcia, S., Killian, M. L., Brown, C. C., Miller, P. J., & Afonso, C. L. (2012). Complete genome and clinicopathological characterization of a virulent Newcastle disease virus isolate from South America. *J Clin Microbiol, 50*(2), 378-387. doi: 10.1128/jcm.06018-11

Dorea, F.C., Vial, F., 2016. Animal health syndromic surveillance: a systematic literature review of the progress in the last 5 years (2011–2016). Vet Med Res Rep 7, 157-169.

Duman, M.B., 2018. Participatory Aproaches And Developments. Proceedings of the 2nd International Conference on Food and Agricultural Economics 27-28th April 2018 Alanya, Turkey, 229.

FAO. (2011). A value chain approach to animal diseases risk management- Technical framework for field application. *Animal Production and Health Guidelines Rome, 4*.

Fasina, F. O., Ali, A. M., Yilma, J. M., Thieme, O., & Ankers, P. (2012). The cost-benefit of biosecurity measures on infectious diseases in the Egyptian household poultry. *Prev Vet Med, 103*(2-3), 178-191. doi: 10.1016/j.prevetmed.2011.09.016

Firestone, S. M., Ward, M. P., Christley, R. M., & Dhand, N. K. (2011). The importance of location in contact networks: Describing early epidemic spread using spatial social network analysis. *Preventive Veterinary Medicine, 102*(3), 185-195. doi: http://dx.doi.org/10.1016/j.prevetmed.2011.07.006

GRZ. (2013). Annual report for the Departments of Veterinary Services and Livestock Development-Eastern province of Zambia. 1-49.

Guèye, E. H. F. (2000). Women and Family Poultry Production in Rural Africa. *Development in Practice, 10*(1), 98-102. doi: 10.2307/4029778

Hall, T. A. (1999). BioEdit: a user friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nuc Acid Sym Ser, 41*, 95-98.

Henning, K.J., 2004. What is syndromic surveillance? Morbidity and mortality weekly report, 7-11.

Hernández-Jover, M., Schemann, K., & Toribio, J.-A. L. M. L. (2013). A cross-sectional study on biosecurity practices and communication networks of poultry exhibition in Australia. *Preventive Veterinary Medicine, 110*(3–4), 497-509. doi: http://dx.doi.org/10.1016/j.prevetmed.2012.12.012

Hoinville, L.J., Alban, L., Drewe, J.A., Gibbens, J.C., Gustafson, L., Häsler, B., Saegerman, C., Salman, M., Stärk, K.D.C., 2013. Proposed terms and concepts for describing and evaluating animal-health surveillance systems. Preventive veterinary medicine 112, 1-12.

Hussein N. A., Sharma R. N., Ando R., & Chizyuka H. G. B. (1984). A study on Newcastle disease virus pathotypes in Zambia *Rev. sci. tech. Off. int. Epiz, 3*(2), 383-389.

Jost, C., Mariner, J., Roeder, P., Sawitri, E., Macgregor-Skinner, G., 2007. Participatory epidemiology in disease surveillance and research. Revue Scientifique Et Technique-Office International Des Epizooties 26, 537.

Mack, S., Hoffmann, D., Otte, J., 2005. The contribution of poultry to rural development. World's Poultry Science Journal 61, 7-14.

Mapiye, C., Mwale, M., Mupangwa, J. F., Chimonyo, M., Foti, R., & Mutenje, M. J. (2008). A Research Review of Village chicken production constraints and Opportunities in Zimbabwe. *Asian-Australasian Journal of Animal Science, 21*(11), 1680-1688.

Molini, U., Aikukutu, G., Khaiseb, S., Cattoli, G., Dundon, W.G., 2017. First genetic characterization of Newcastle disease viruses from Namibia: identification of novel VIIk subgenotype. Arch Virol 162, 2427-2431.

Msoffe, P. L., Bunn, D., Muhairwa, A. P., Mtambo, M. M., Mwamhehe, H., Msago, A., . . . Cardona, C. J. (2010). Implementing poultry vaccination and biosecurity at the village level in Tanzania: a social strategy to promote health in free-range poultry populations. *Trop Anim Health Prod, 42*(2), 253-263. doi: 10.1007/s11250-009-9414-8

Mtileni, B. J., Muchadeyi, F. C., Maiwashe, A., Chimonyo, M., Mapiye, C., & Dzama, K. (2012). Influence of socioeconomic factors on production constraints faced by indigenous chicken producers in South Africa. *Trop Anim Health Prod, 45*(1), 67-74. doi: 10.1007/s11250-012-0175-4

Musako, C., & Abolnik, C. (2012). Determination of the seroprevalence of Newcastle disease virus (avian paramyxovirus type 1) in Zambian backyard chicken flocks. *Onderstepoort J Vet Res, 79*(1), E1-4. doi: 10.4102/ojvr.v79i1.502

Nickbakhsh, S., Matthews, L., Bessell, P. R., Reid, S. W., & Kao, R. R. (2011). Generating social network data using partially described networks: an example informing avian influenza control in the British poultry industry. *BMC Vet Res, 7*, 66. doi: 10.1186/1746-6148-7-66

Nwanta, J. A., Abdu, P. A., & Ezema, W. S. (2008). Epidemiology, challenges and prospects for control of Newcastle disease in village poultry in Nigeria. *World's Poultry Science Journal, 64*(01), 119-127. doi: doi:10.1017/S0043933907001766

OIE. (2008). Manual of Diagnostic Tests and Vaccines for Terrestrial Animals 2008. Available on the website: http://www.oie.int/eng/normes/mmanual/A_summry.htm.

Oladele S. B., Enam S J., & Okubanjo O. O. (2012). Pathogenic haemoparasites and antibody to Newcastle disease virus from apparently healthy wild birds in Zaria, Nigeria. *Vet. World, 5*, 13-18.

Ozcatalbas, O., Boz, I., Demiryurek, K., Budak, D.B., Karaturhan, B., 2011. Developing participatory extension applications in Turkey. African Journal of Agricultural Research 6, 407-415.

Otim M.O., Kabagambe E.K., & Mukiibi G.M. (2007). A study of risk factors associated with Newcastle disease epidemic in village free-range chickens in Uganda. *Trop. Anim. Health Prod, 39*, 27-35.

Paul, M., Baritaux, V., Wongnarkpet, S., Poolkhet, C., Thanapongtharm, W., Roger, F., . . . Ducrot, C. (2013). Practices associated with Highly Pathogenic Avian Influenza spread in traditional poultry marketing chains: Social and economic perspectives. *Acta Tropica, 126*(1), 43-53. doi: http://dx.doi.org/10.1016/j.actatropica.2013.01.008

Pazhanivel N., Balsubramaniam G. A., George V. T., & Mohan B. (2002). Study of natural outbreak of Newcastle disease in and around Namakkal. *Indian Veterinary Journal, 79*(3), 293-294.

Pfitzer S, Verwoerd D. J., Gerdes G. H., Labuschagne AE., Erasmus A., & Manvell R. J. (2000). Newcastle disease and avian influenza A virus in wild waterfowl in South Africa. *Avian Dis, 44*, 655-660.

Poolkhet, C., Chairatanayuth, P., Thongratsakul, S., Yatbantoong, N., Kasemsuwan, S., Damchoey, D., & Rukkwamsuk, T. (2013). Social network analysis for assessment of avian influenza spread and trading patterns of backyard chickens in Nakhon Pathom, Suphan Buri and Ratchaburi, Thailand. *Zoonoses Public Health, 60*(6), 448-455. doi: 10.1111/zph.12022

Queenan, K., Mangesho, P., Ole-Neselle, M., Karimuribo, E., Rweyemamu, M., Kock, R., Häsler, B., 2017. Using local language syndromic terminology in participatory epidemiology: Lessons for One Health practitioners among the Maasai of Ngorongoro, Tanzania. Preventive veterinary medicine 139, 42-49.

Rakibul Hasan A. K. M., Ali M. H., Siddique M. P., Rahman M. M., & Islam M. A. (2010). Clinical and Laboratory Diagnoses of Newcastle and Infectious Bursal Diseases of Chickens. *Bangl. J. Vet. Med., 8*(2), 131-140.

Sa'idu, L., Tekdek, L. B., & Abdu, P. A. (2004). Prevalence of Newcastle disease antibodies in domestic and semi-domestic birds in Zaria, Nigeria. *VETERINARSKI ARHIV, 74*(4), 309-317.

Sharma, R.N., Hussein, N.A., Pandey, O.S., Shandomo, M.N., 1985. A study on Newcastle disease outbreaks in Zambia,1975-1984. Rev. sci. lech. Off. int. Epiz, 5(1) 5-14.

Snoeck, C.J., Adeyanju, A.T., Owoade, A.A., Couacy-Hymann, E., Alkali, B.R., Ottosson, U., Muller, C.P., 2013. Genetic diversity of Newcastle disease virus in wild birds and pigeons in West Africa. Applied and environmental microbiology 79, 7867-7874.

Sonaiya E.B. (2007). Family poultry, food security and the impact of HPAI. *World's Poultry Science Journal 63*(1), 132-138.

Songolo, A., & Katongo, J. C. (2000). 'Country report: Zambia'. In R. G. Alders & P. B. Spradbrow (Eds.), *SADC planning workshop on Newcastle disease control in village chickens: Proceedings of an international workshop, ACIAR Proceedings 103, Maputo, Mozambique* (pp. 43-45).

Stärk, K.D., Regula, G., Hernandez, J., Knopf, L., Fuchs, K., Morris, R.S., Davies, P., 2006. Concepts for risk-based surveillance in the field of veterinary medicine and veterinary public health: Review of current approaches. BMC Health Services Research 6.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M., & Kumar, S. (2011). MEGA5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Mol. Bio. Evol., 28*, 2731-2739.

Thrusfield, M. (Ed.). (2005). *Veterinary Epidemiology* (3 ed.). Oxford UK: Blackwell Publishing.

Walker, J.G., Ogola, E., Knobel, D., 2011. Piloting mobile phone-based syndromic surveillance of livestock diseases in Kenya. Epidémiologie et Santé Animale 59, 19-21.

Yombo, A., 2010. Syndromic animal health surveillance in Papua New Guinea. Is it working? . Veterinary Sciences. MTVSc, James Cook University, Australia.

Chapter 2

RETROSPECTIVE STUDY AND PREDICTIVE MODELLING OF NEWCASTLE DISEASE TRENDS AMONG RURAL POULTRY OF EASTERN ZAMBIA

Publications

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2016. A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia. Preventive Veterinary Medicine 133, 97-107.

2.1 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 because 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 because of more awareness of the disease.

2.2 Key Words

Rural Poultry, Newcastle Disease, Trends, Modelling

2.3 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).

Newcastle Disease 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 the strain of virus and is generally 4 to 5 days (range 2 to 15 days). The disease is characterized 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 infection 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 (Nwanta et al. 2008a), 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 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.

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. This study formed part of part 1 of the hazard analysis in the ensemble model (Figure 1-2).

2.4 Materials and Methods

2.4.1 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 because 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, 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 to highlight the aspect of missing data as a weakness that might exist in institutions with passive disease surveillance systems.

2.4.2 Study Procedures

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 Equation 1.

Equation 1; PGR=$(X_t\ /X_0)$^$\frac{1}{t}$ - 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, B, C, D) was considered because of gaps in available census data (Table 2-1 and Figure 2-1). Population growth in the four blocks were modelled as follows:

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 Petauke and Chipata populations. The provincial growth rates were used for Petauke and Chipata districts to normalise values in the model since these two districts recorded negative growth rates that were giving extreme values when based on the 2002-2006 data. Provincial population growth rate was calculated by using Equation 1 where X_t was the total population of village chickens for the province in the 2006 census and X_0 was the total population of chickens for the province in 2006.

Period B 2002 - 2006

In this period population growth rates were extrapolated from the 2002 and 2006 census.

Period C 2007 - 2011

Mambwe, Chama and Nyimba districts were created by the Zambian government by re-demarcating Chipata, Lundazi and Petauke districts respectively thus ending up with eight districts during this period. Population size in this period was extrapolated by using respective calculated growth rates for the population growth between the 2006 census and population data obtained from stock registers in 2014.

Period D 2012 - 2014

In 2012, the Zambian government realigned Chama district to another province (Muchinga Province) and Chadiza was re-defined thus creating Vubwi district. Secondly, Petauke and Katete districts were also re-demarcated to create Sinda district thus ending up with 9 districts within the province. Within this period, population growths were extrapolated from the 2006 census and 2014 stock registers.

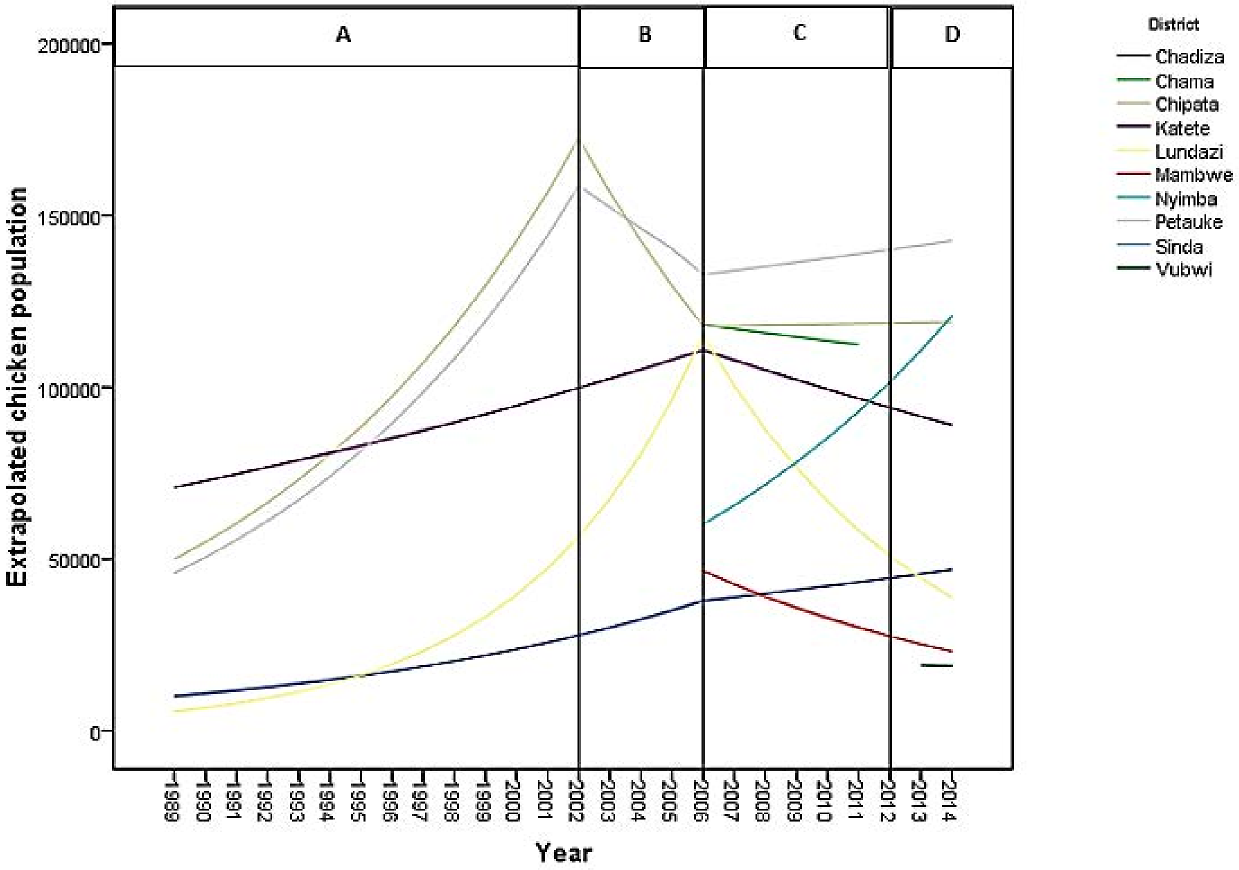


Figure 2-1: Modelled indigenous chicken population for districts in Eastern Zambia from 1989 to 2014 divided into four time blocks (A, B, C, and D).

Table 2-1: Village chicken population in eastern province of Zambia and calculated exponential population growth rates for 2002-2006 and 2006-2014 periods.

District	Population 2002	Population 2006	Population 2014	PGR 2002-2006	PGR 2006-2014
Chadiza	28,361.00	37,918	46,843	0.075	0.027
Chipata	172,552.00	117,848	119,031	-0.091	0.001
Katete	100,150.00	110,904	89,222	0.026	-0.027
Lundazi	62,855.00	115,080	38,961	0.163	-0.127
Petauke	158,702.00	132,825	142,885	-0.044	0.009
Mambwe		46,568	23,145		-0.084
Nyimba		60,185	121,395		0.092
Chama		118,231			
Sinda			76,982		
Vubwi			18,992		
Provincial	**522,620**	**739,559**	**677,456**	**0.091**	**-0.011**

The extrapolated population was required for calculating district apparent incidence of ND at yearly intervals using Equation 1 (Thrusfield, 2005b).

Equation 2; $AI = \frac{D}{N}$

Where *AI* was the apparent incidence of ND per year, D was the total number of new ND cases per year and N was the total population of chickens in the district.

Since district ND incidence values were calculated from clustered chicken populations, weighted analysis was used to calculate adjusted provincial annual ND incidence (Thrusfield, 2005). This was done by initially adding district chicken populations for each year to obtain provincial chicken populations. Respective district populations were then divided by provincial populations to weight the district chicken populations proportionally within the province. This was multiplied by the district apparent incidence calculated using Equation 2 and the subsequent proportional district incidences were then summed to compute the annual provincial ND incidence for that year.

To account for an incomplete sample of the population due to under reporting and misdiagnosis of ND by field Veterinary Assistants, the 95% confidence interval for the estimated incidence of the disease was calculated using Equations 3 and 4 derived from Cameron, 1999:

Equation 3; Var (*AI*)= $AI(1 - AI)/N(Se + Sp)^2$

Where Var (*AI*) was the sampling variance for the apparent incidence per year, N was the chicken population in the district, Se and Sp were the sensitivity and specificity respectively. The sampling variance was then used to calculate the Lower Confidence Level (LCL) and Upper Confidence Levels (UCL) using Equation 4 (Cameron, 1999):

Equation 4; *AI*–$\left(Z * \sqrt{var(AI)}\right) and\ I + \left(Z * \sqrt{var(AI)}\right)$

Were Z, was α/2 at 95% confidence level which is 1.96. Estimates of variance for incidence estimates, LCL and UCL were then presented in tables.

Sensitivity (Se) was the ability of field veterinary assistants to detect the ND positive birds in the population concerned and the specificity (Sp) was their ability to identify ND negative cases correctly (Mubamba et al., 2011).

Selected experts were sent a small questionnaire (Appendix 1) that asked the respondents questions on their experience, qualifications and specific questions on ND. From these experts, estimates for sensitivity and positive predictive value (PPV) were obtained. Positive predictive value, the ability to diagnose ND cases correctly instead of Sp was obtained from respondents because of the way the question for the expert was framed. Values for Se, PPV and AI were used to populate the two by two contingency Table to calculate for the corresponding Sp using. All experts were veterinarians who were serving in the Zambian Government and particularly, the eastern province for a minimum of nine years during the study period. The Sp was then calculated based on the expert opinion of Se and PPV and a ND incidence of 0.48%. This incidence rate was based on the results of this study, which found a median apparent annual ND incidence rate of 0.48% for the study period 1989-2014.

The average Se obtained from expert opinion and calculated Sp were then used to calculate sampling variance (var (*AI*)) for the estimated incidence (Mubamba et al., 2011).

Seasonal trends were analysed by grouping provincial monthly ND incidence data from 1999 to 2005 into the rainy season (January, February, March, April and December), the cool dry season (May, June, July and August) and the hot dry season (September, October and November) aligned with the Zambian climate (Our-Africa, 2015). Seasonal incidence rates for each season in each respective year were calculated and followed by computing of ND mean seasonal incidence for each year, seasonal index (SI) and overall seasonal index (OSI) (Barnett and Dobson, 2010) using Equations 5, 6 and 7 respectively.

Equation 5; $ND\ mean\ seasonal\ incidence = \frac{Sum\ of\ ND\ seasonal\ incidences}{Number\ of\ seasons\ per\ year}$

Equation 6; $SI = \frac{Incidence\ for\ a\ season\ in\ each\ respective\ year}{ND\ mean\ seasonal\ incidence}$

Equation 7; $OSI = \frac{sum\ of\ all\ seasonal\ indices\ for\ a\ respective\ season}{Number\ of\ indices\ for\ the\ season}$

Overall seasonal indices were then used to compare ND apparent incidence for the three seasons where seasons with OSI values greater than one were considered to have incidence higher than an average season and *vice versa.*

For annual trends, confidence intervals of annual ND incidence were plotted and compared with main government policies implemented during the period 1989-2014.

2.4.3 Government plans for controlling livestock diseases 1989 - 2016

In Zambia, attempts to control ND disease among rural poultry have been part of the greater plans implemented by the Government of Zambia with the help of funding agencies like the International Monetary Fund (IMF), the World Bank and other cooperating partners (Government-of-Zambia, 1989). This has been implemented through the Fourth National Development Plan (4thNDP) (1989 to 1993), the Structural Adjustment Programme (SAP), the Fifth National Development Plan (FNDP) from 2006 to 2010 (Government-of-Zambia, 2006), the Sixth National Development Plan (SNDP) from 2011 to 2016 (Government-of-Zambia, 2011, 2014b) and the Seventh National Development Plan (7thNDP) which started running in 2017.

Fourth National Development Plan (1989-1993)

During this period control of ND in rural poultry was mainly based on restriction of poultry movement from outbreak areas with limited control and awareness campaigns due to lack of funding specifically meant for ND control. Newcastle Disease vaccinations were voluntary and at the farmer’s cost.

Structural Adjustment Programme (1994-2005)

In this period there was less disease control extension than in the previous time block due to a wage and employment freeze. As a result, poultry movement control during outbreaks was also reduced. Newcastle Disease vaccination control was voluntary and at a farmer’s cost.

Fifth National Development Plan (2006-2010)

There was recruitment of additional extension workers during this period and subsequently more disease control and prevention awareness was carried out. Consequently, movement restrictions for poultry from outbreak areas was increased. Free ND vaccinations were conducted in 2006 and 2007 using a Poverty Reduction Programme (PRP) and African Development Bank (ADB) funds. However, there were no funds specifically allocated to ND control during this period.

Sixth National Development Plan (2011-2016)

More funding was allocated to the control of ND in the province through the Livestock Development and Animal Health Project (LDAHP) funded by the World Bank (WB). Free vaccination campaigns were conducted in 2015 where over 700 000 birds were vaccinated against ND within the eastern province of Zambia.

Efficiency of Reporting

The efficiency of reporting was computed by dividing the number of submitted district morbidity reports by the number of reports expected over the 25 years study period.

Spatial analysis

Spatial trends were analysed by first dividing the study period into three time blocks that corresponded to the Zambian government's demarcation of districts and then computing for each district the median incidence for ND for that time (1999 – 2005, 2006 – 2011 and 2012 – 2014). These medians were then exported to Epi Map where choropleth maps that analysed median estimates of ND incidence for districts in each time block were developed.

2.4.4 Statistical Tests

IBM SPSS Statistics® version 24 was used to conduct all statistical analysis.

The Kolmogorov-Smirnov and Shapiro-Wilk tests for normality of estimated incidence values was done to determine whether to use parametric or non-parametric statistical tests.

The Friedman test, a non-parametric alternative to the one-way repeated measures ANOVA test which is used to determine whether there are statistically significant differences between the distributions of three or more related groups (Conover, 1999; Laerd-Statistics, 2015a), was used to determine statistical significance of differences in time blocks for annual incidence of ND as well as differences in ND incidence between districts for spatial patterns. Where differences were significant, *post hoc* tests involving pair wise comparisons between related groups were carried out to pinpoint pairs of groups that significantly differed.

2.4.5 Predictive model for ND prevalence

A model for predicting future ND incidence in the study area was developed based on the modelling of the province's mean annual incidence rates from 1999 to 2014 using the @Risk[1] software package.

Maximum likelihood estimates (MLE) of the parameters was used to achieve the closest match between the time series processes and the input. This was done by using a fit command which fits a Time Series process to data based on the defined input (estimated average ND incidence values from 1999 to 2014). As stationarity could not be assumed when examining the historical data, input data

[1] @Risk, 2014. Risk Analysis Add-In for Microsoft Excel. Palisade Corporation

was de-trended using first order differencing with the last value of the historical data set as a starting point for the forecast (Vose et al., 2004).

Akaike Information Criterion (AIC) was used as the model selection statistic (Vose et al., 2004) to determine the best fitting model. Time Series models fitted were MA1 (Moving Average to the order of 1), MA2 (Moving Average to the order 2), ARMA (Autoregressive, Moving Average) processes, GBM (Geometric Brownian Motion) and its variations, including ARCH (Autoregressive Conditional Heteroskedasticity) and its variations (Vose et al., 2004).

2.5 Results

2.5.1 Expert Opinion

Expert opinion results indicated that the average Se for detecting ND outbreaks was 66% and the average PPV value was 75% (Table 2-2). The median apparent annual ND incidence rate for the study period 1989-2014 was calculated to be 0.48%. Using this information, it was possible to calculate the Sp using the contingency Table. The Sp was computed as 99.9%. Variability between experts with respect to Se and PPV was small with standard deviations of 7 and 13 for Se and PPV respectively.

Table 2-2: Expert opinion results from seven government veterinarians in Eastern Zambia*

Position	**Experience (Years)**	**Sensitivity (%)**	**Positive predictive value (%)**	**Calculated Specificity** (%)**
Veterinary Officer	17	70	90	99.9
Senior Veterinary Officer	24	60	80	99.9
Provincial Veterinary Officer	18	60	55	99.7
Senior Veterinary Officer	24	65	65	99.8
Veterinary Research Officer	9	60	75	99.9
Veterinary Officer	9	78	85	99.9
Mean		66	75	99.9
Median		63	78	99.9
Standard deviation		7	13	0.1

*Experience was the number of years' respective experts served in Eastern Zambia, sensitivity (Se) was the experts score for the ability of veterinary assistants to detect birds affected by ND within their respective catchment, positive predictive value (PPV) was expert's scores on their ability to identify ND positive cases correctly. ** Specificity, their ability to classify negative ND cases correctly, was calculated using an assumed annual incidence of 0.48% and the expert's estimate of Se and PPV.

2.5.2 Efficiency of reporting

From a total of 158 expected annual reports from districts at the provincial veterinary office, only 113 reports were received thus bringing the reporting efficiency during the study period to 72%. Most of the missing reports were from 1994 to 1998 (18) where reports from all the five districts were missing. Except for Mambwe and Chama in 2006, Petauke and Chama in 2009 as well as Mambwe and Nyimba in 2011, all the reports from the period 2006 to 2014 were missing. For monthly reports, only the period 1999-2005 had a 100% reporting efficiency thus only reports from this period were analysed for seasonal trends. Most monthly reports for the periods 1989-1998 and 2006-2014 were missing. Missing data was excluded during statistical analysis and was recorded as a blank cell. Records with a recording of zero meant a report was submitted but there were no cases for a respective district during a period.

2.5.3 Tests for normality of estimated incidence values

Provincial ND incidence data was not independent (reported from same districts within the province at different time points) as well as not normally distributed (Kolmogorov-Simonov test; $p<0.01$ and the Shapiro-Wilk test; $p<0.01$) hence the Friedman test, a non-parametric test for repeated measures was used to test for statistical significance.

2.5.4 Temporal Patterns

Seasonal Trends

Newcastle Disease presented a seasonal trend with highest overall seasonal index of 1.10 recorded in the hot dry season and low incidence recorded in the rainy season (0.96) as well as the cool dry season (OSI=0.95) (Table 2-3).

Table 2-3: Seasonal patterns of ND apparent incidence in Eastern Zambia from 1999 to 2005

Year	Rainy season		Cool & Dry season		Hot & Dry season		Mean
	ND AI	S Index	ND AI	S Index	ND AI	S Index	
1999	0.15	1.42	0.14	1.39	0.02	0.20	0.10
2000	0.15	1.43	0.15	1.46	0.01	0.11	0.10
2001	0.02	0.29	0.04	0.81	0.10	1.90	0.05
2002	0.16	1.19	0.12	0.91	0.12	0.90	0.13
2003	0.04	0.71	0.06	1.02	0.07	1.28	0.05
2004	0.01	0.07	0.02	0.21	0.21	2.73	0.08
2005	0.54	1.59	0.28	0.83	0.20	0.57	0.34
Overall		**0.96**		**0.95**		**1.10**	

Annual Trends

An increasing trend of ND annual incidence with peaks that occurred in cycles of roughly three years was observed during the study period (Figures 2-2 and 2-3). The average provincial estimated incidence ranged from 0.16 to 1.71% (Fig. 3). However, there were no statistically significant differences in annual ND incidence between the four time blocks (Friedman test; , $\chi2(3) = 4.5$, $p = 0.212$).

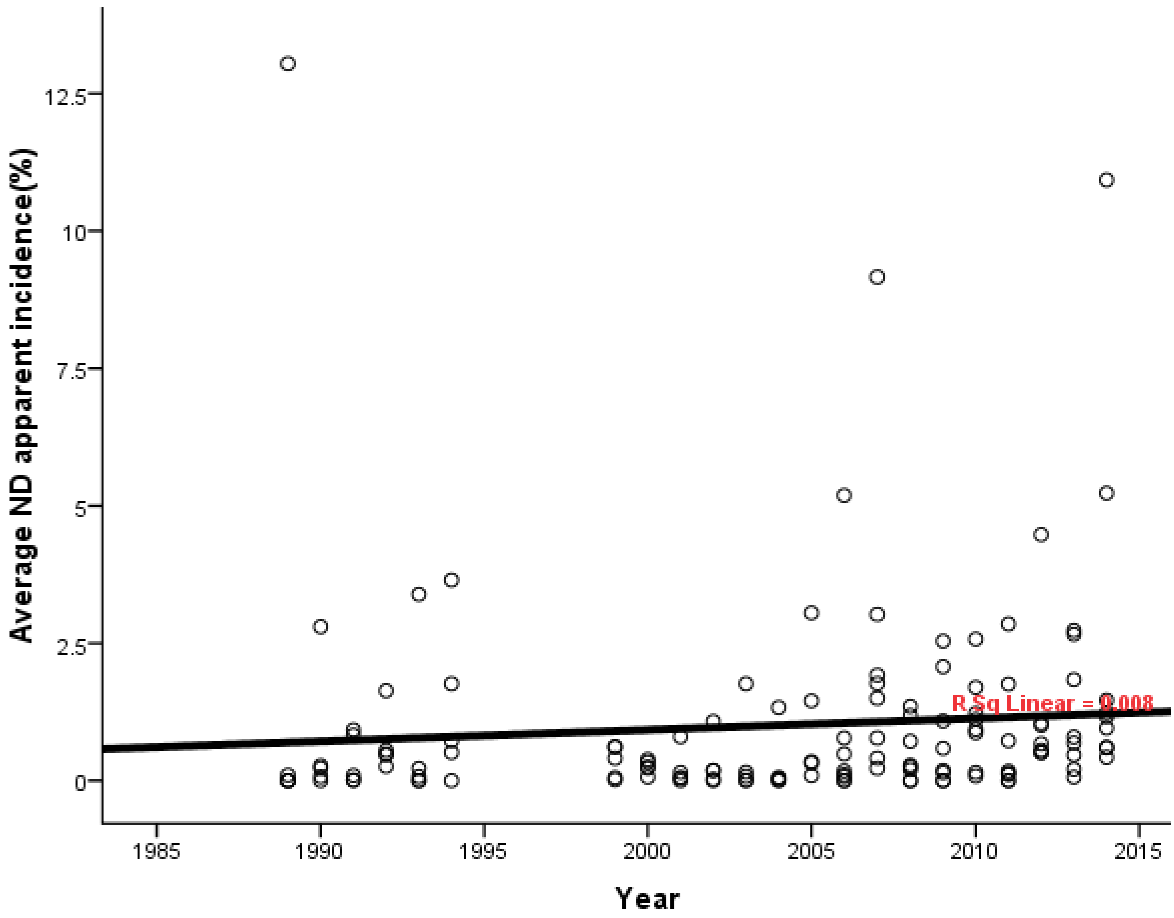


Figure 2-2: Increasing trend of estimated ND incidence per year in Eastern Zambia from 1989 to 2014. Each dot represents a district's annual ND incidence for a respective year.

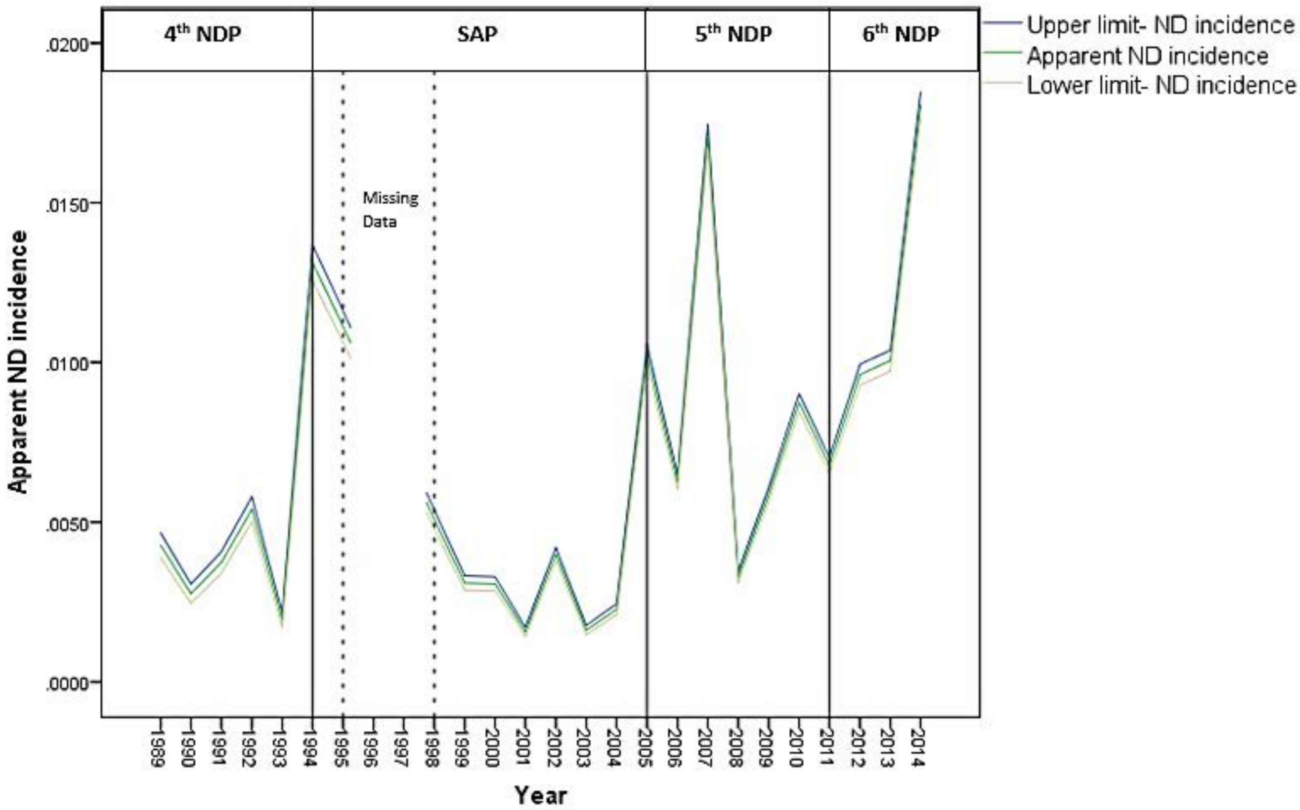


Figure 2-3: Apparent annual incidence and confidence limits per year aligned with main government economic policies implemented in Eastern Zambia during the period 1989 to 2014.

Spatial Patterns

There were spatial shifts of ND incidence between time blocks that were accompanied by an increasing trend. Overall, median ND incidence was significantly different between the three time blocks (Friedman test; $\chi^2(2) = 7$, $p = 0.03$). *Post hoc* pairwise comparisons with a Bonferroni adjustment revealed a significant difference between time block 1999-2005 (median ND incidence 0.002) and 2012-2014 (median incidence 0.09) (adjusted p= 0.028).

1999 to 2005

Petauke had the highest estimated median AI of 0.32% in the period from 1999 to 2005. This was followed by Katete and Lundazi. Chipata, which had the lowest median incidence (0.03%) (Figure 2-4). However, differences in median annual incidence between the five districts in time block 1999 - 2005 were not statistically significant (Friedman test; χ^2 (4) 2.171, p= 0.704).

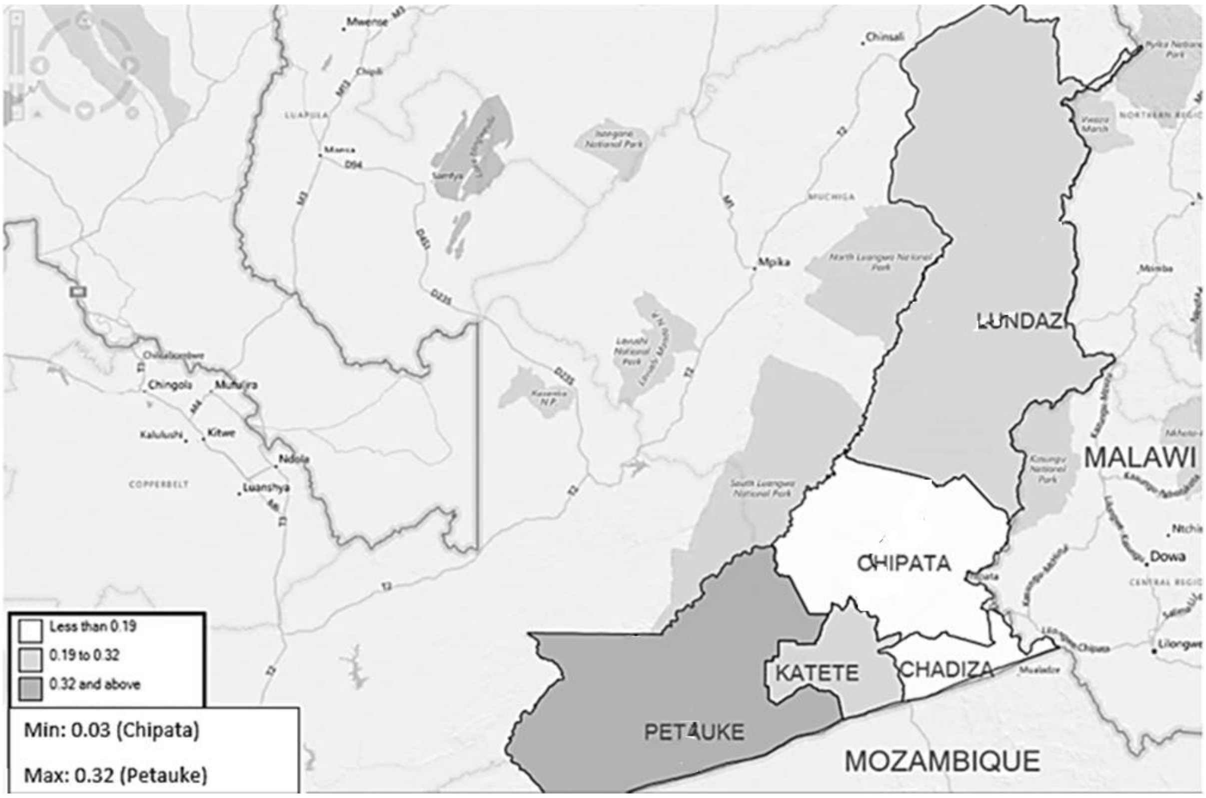


Figure 2-4: Median apparent incidence of ND per year in five veterinary districts of Eastern Zambia from 1999 to 2005.

2006 to 2011

There were statistically significant differences in median incidence of ND between districts in time block 2006 – 2011 (Friedman test; χ^2 (7)17.47, p= 0.015). The highest median AI was recorded in Mambwe district (median AI = 1.6%) (Figure 2-5). However, pairwise comparisons with a Bonferroni adjustment (Laerd-Statistics, 2015a) only revealed a significant difference of estimated apparent incidence between Chadiza and Chama (adjusted p=0.03).

Figure 2-5: Median apparent incidence of ND per year in eight districts of Eastern Zambia from 2006 to 2011.

2012 to 2014

When compared with time block 2006 – 2011 (Figure 2-5), the number of high AI districts were similar to the period 2012 to 2014 but Chadiza was replaced by Sinda thus having Mambwe, Lundazi and Sinda as high ND districts. Additionally, the median AI was generally higher with high incidence districts being more widely distributed across the province in 2012 – 2014 (Figure 2-6) than 2006 – 2011time blocks (Figure 6). However, differences in median AI of ND between districts in 2012-2014 were not statistically significant (Friedman test χ^2 (8)8, p=0.433)

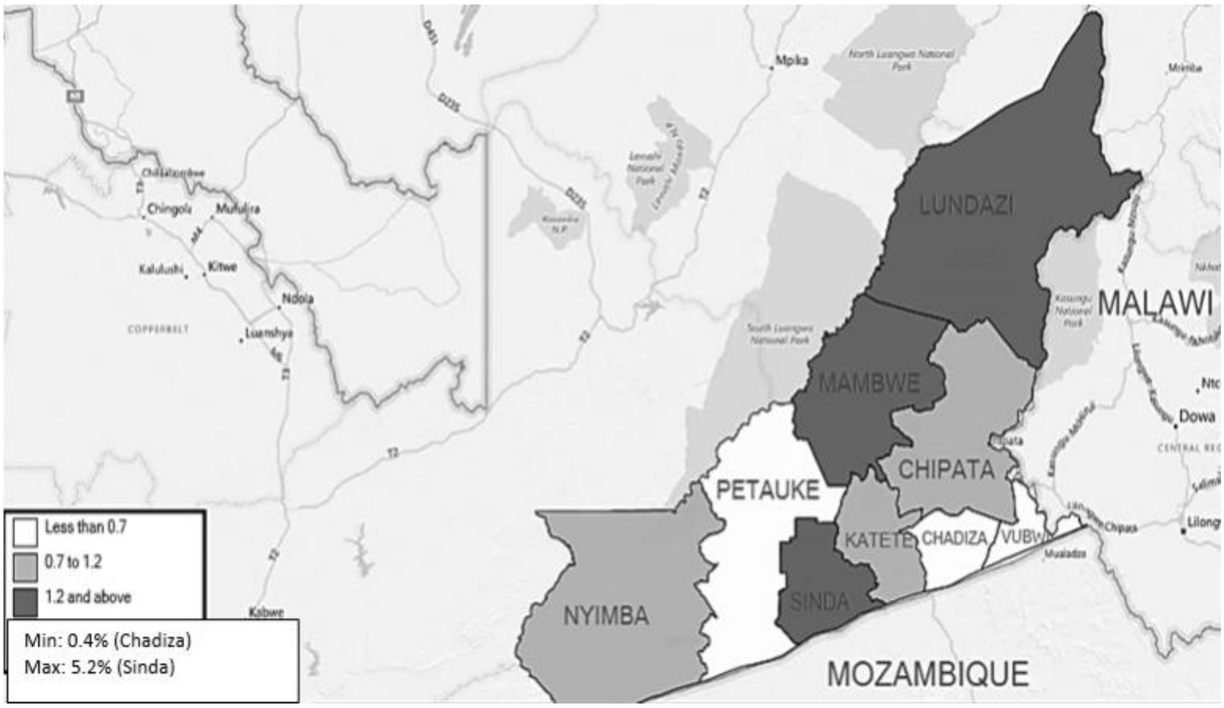


Figure 2-6: Median apparent incidence of ND per year from 2012 to 2014 in nine districts of Eastern Zambia.

2.5.5 Predictive Model (@Risk Time Series Model) for forecasting future ND incidence

The first order Moving Average (MA1) (μ= 0.1, ó= 0.4, b_1= -0.830 and Σ_0= 0.5) model fitted the historical ND incidence data best with an AIC of 16.94 (Figure 2-7). This was followed by the Auto Regressive Moving Average (ARMA 1, 1) and the second order Moving Average (MA2) time series models with AIC of 24.46 and 26.00 respectively (Table 2-4). After considering these other two top ranked models, the MA1 model was finally selected as the model of choice because it presented a prediction that was in line with the past and current ND trends. The predicted positive trends show a likely slight increase of mean estimated ND incidence in the next 25 years from 1.7 to 3.8% (Figure 2-7) if the current trend is not halted. Predictions of this model would only be valid if there is no major change in human and consequently poultry population in the region within the predicted time frame.

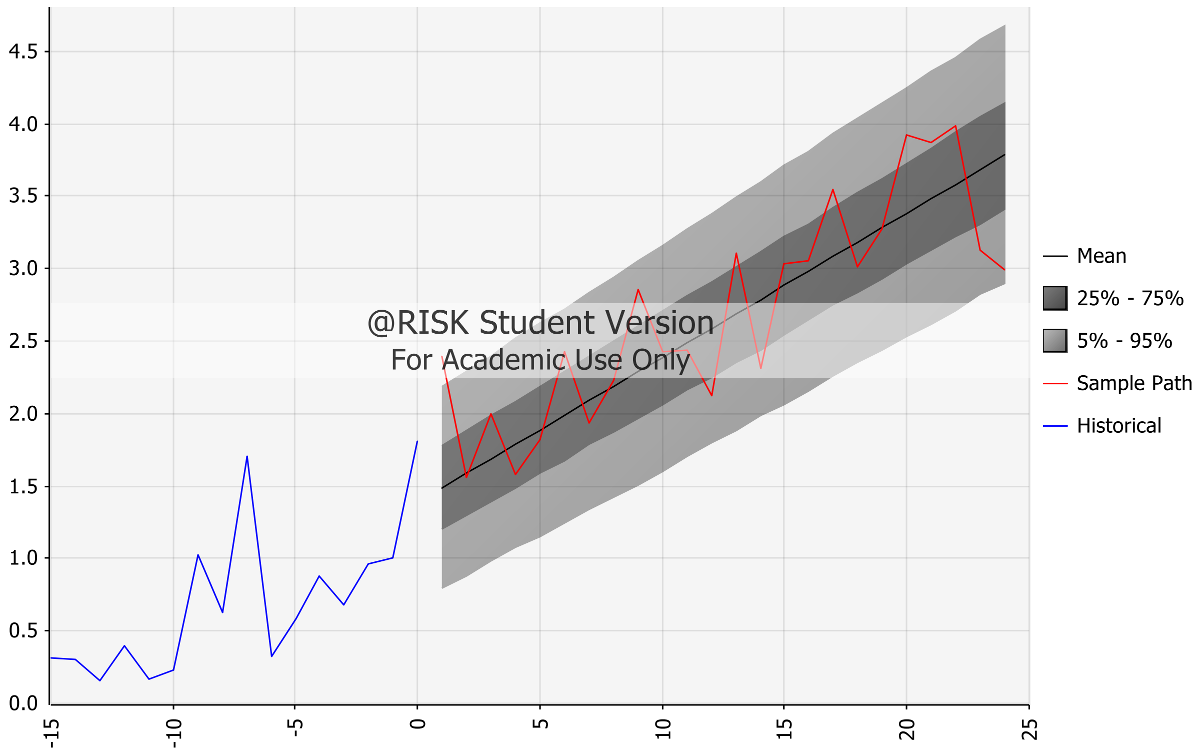


Figure 2-7: Twenty-five year (X axis) prediction of mean apparent ND incidence (Y axis) per year in Eastern Zambia (from 2015 to 20140) if currently existing control strategies for the disease continue.

Table 2-4: Summary of model fit results from the first to the seventh ranked time series model for ND annual apparent incidence

Type	AR1	AR2	ARCH	ARMA	GARCH	MA1	MA2
Data Transform	Manual	Manual	Manual	Manual	Manual	Manual	Manual
Function	None	None	None	None	None	None	None
Shift	0	0	0	0	0	0	0
Detrending	First Order	First Order	First Order	First Order	First Order	First Order	First Order
Depersonalizing	None	None	None	None	None	None	None
Seasonal Period	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Akaike (AIC) Rank	#4	#5	#6	#3	#7	#1	#2
Akaike (AIC) Fit	27.25	29.80	32.60	26.01	33.71	16.94	24.46
Parameters	3	4	3	4	4	3	4
Parameter #1	Mu	Mu	Mu	Mu	Mu	Mu	Mu
Value	0.097	0.097	0.097	0.097	0.097	0.097	0.097
Parameter #2	Sigma	Sigma	Omega	Sigma	Omega	Sigma	Sigma
Value	0.46	0.46	0.33	0.39	0.15	0.42	0.37
Parameter #3	A1	A1	A	A1	A	B1	B1
Value	-0.61	-0.67	0.02	-0.21	0.61	-0.83	-0.95
Parameter #4		A2		B1	B		B2
Value		-0.10		-0.93	0.11		-0.35

2.6 Discussion

Absence of poultry census data necessitated the development of an exponential population growth model that estimated poultry populations in each year of the study period. The model was developed with an assumption of a normal population growth in an open environment that is not severely affected by factors like poultry disease and natural disasters (Bernstein, 2003). That is, it assumed normal death and reproduction (Bernstein, 2003) of poultry in the study area. The model can be affected by high poultry mortality due to disease outbreaks. It can also be affected by interventions such as increased slaughter (due to increased trade of poultry) and improved poultry production technologies, like use of housing and hatcheries. Consequently, this would either lead to underestimation or overestimation of populations depending on the circumstances thus affecting the accuracy of the calculated ND incidence. Nevertheless, the model was used after because most rural poultry is left to scavenge in villages with little or no disease control and poultry husbandry interventions.

Monthly trends were consistent with previous research findings where the ND cases increase in the hot dry season (Sharma et al., 1985; Musako and Abolnik, 2012) which recorded an OSI of 1.10 (Table 2-3). This was probably due to an increase in the movement of birds due to trade and different ceremonial occasions that precede the outbreaks. The economy for the eastern province is mainly dependant on agriculture (IMF, 2007). In the period of July to September, there is increased trade in agricultural products including chickens. This increases the movement of chickens within the province thus increasing the likelihood for ND outbreaks. The situation is probably worsened by different traditional ceremonies such as the Kulamba ceremony of the Chewa people conducted during the hot dry season (Phiri, 2014). Exchange of gifts in the form of live chickens is not uncommon during this event (Pym et al., 2006).

Annual trends of ND in the province revealed an interesting pattern in that the average annual incidence had been increasing over the study period with notable peaks in 1994, 1999, 2003, 2005, 2007, 2010, 2012 and 2014 (Figures 2-2 and 2-3). Highest provincial AI of 1.7% was recorded in the study period 1989 to 2014 (Figure 2-3). Other than the studies that show that there are 2 outbreaks of ND in free range chickens every year (Awan et al., 1994; Njagi et al., 2010), there are no studies that demonstrate evidence of the three-year cyclic pattern of the disease. The 3-year cyclic peaks in ND incidence could indicate a growth of susceptible village chicken populations (Otim et al., 2007), every 2-3 years. It may also indicate increase in immunity to ND due to increased immunisation as a reaction to ND outbreaks (Alexander, 2001). Furthermore, the results revealed an increasing trend of ND incidence (Figure 2-2). This was probably due to poor vaccination coverage and poor vaccine quality because of a weak ND control strategy. On the other hand, the increase in the ND trend may have been influenced by improved awareness of the disease by farmers over time but as very little has changed in terms of the surveillance and disease reporting during this time (Government-0f-Zambia, 2013), this is less likely.

Spatial patterns revealed a possible failure to control spread of ND in the province from 1999 to 2014. This is because there was an apparent increase in trend of median AI that was accompanied by a spatial shift of high ND incidence districts from the northern and southern regions to some districts flanking the central region of the eastern province (Mambwe, Chadiza and Lundazi) from time block 1999 – 2005 to time block 2006 – 2011 (Figures 2-4 and 2-5). The increasing trend in median AI continued in the time block that followed (2012 – 2014) but there was a wider spatial distribution of high ND incidence districts with only Katete, Chadiza and Vubwi districts recording low median AI

(Figure 2-6). This apparent spread of ND from high incidence districts to low incidence districts of the eastern province during the past 16 years (Figures 2-4, 2-5 and 2-6) could indicate some failure in controlling ND spread within the province due to possible movement of poultry from vaccinated to non-vaccinated areas as a consequence of inadequate capacity of the veterinary department to monitor all poultry movement between districts coupled with socioeconomic pressure such as need to find markets for poultry and its products by farmers. On the other hand, conversion of formerly high incidence districts (Petauke and Chadiza in 1999 – 2005 and 2006 – 2011 time blocks respectively) to low incidence districts in time block 2012 – 2014 (Figure 2-6) could indicate some success in containing the disease through ND vaccinations. Additionally, the spatial shifts in districts with outbreaks over time could also be because of veterinary interventions chasing outbreaks rather than implementing uniform control within the province.

Despite significant allocation of resources to livestock diseases during implementation of the policies highlighted above, most attention had been given to diseases affecting cattle - the livestock species perceived to be the most important in the country by many stakeholders (Mubamba et al., 2011; Government-of-Zambia, 2013, 2014a). The Zambian livestock development policy classifies ND as a management disease (Government-of-Zambia, 2015), which implies that control of this disease is entirely the responsibility of the rural poultry farmer. On the other hand, control of most diseases affecting other livestock, like cattle, receive significant funding because they are classified as diseases of national importance (DNEI) (Government-of-Zambia, 2015). Consequently, less resources and attention have been given to poultry diseases like ND. This is probably the reason why there was no impact of major economic policies on reducing the trend of ND AI in the last 25 years (Figure 2-2) which is substantiated by the fact that there was no statistically significant difference in median ND incidence between the 4th NDP, SAP, 5th NDP and 6th NDP. This lack of statistically significant differences in the median AI between economic time blocks implies that ND incidence has remained constant despite control measures implemented by different economic plans (Figure 2-3). The 25 -year forecast predicts an increasing trend of ND and hence higher poultry losses if the existing lack of effective control strategies continue (Figure 2-7). It may also be a function of improved disease reporting due to increased awareness and training. This is however less likely due to the devastating nature of the disease to poultry farmers who are unlikely to let the disease go unnoticed.

Confidence intervals that considered the Se and Sp of the surveillance system were used to report annual ND incidence. However, for the time series model historical AI values were used as an input because only a single value of incidence was required for each year to produce the forecast in @Risk software (Figure 2-7). This has the weakness that the Se and Sp of the surveillance system are not accounted for in the model. Cannon's (Thrusfield, 2005) formula to calculate true prevalence could be applied but generates unrealistic incidence values when used with low incidence estimates and poor Se and was therefore not applied in this case. Due to the lower Se and PPV of the reporting system the model is probably underreporting the True Incidence. The purpose of the model was not however, to obtain precise estimates of future incidence but rather to examine future trends and therefore despite this weakness serves its purpose.

There is no standard guide for identifying ND among veterinarians and their assistants who depend on their individual clinical skills to identify the disease. As a result, veterinarians may be overestimating the incidence of ND when visiting outbreaks. This is mitigated however by the fact that the surveillance system depends on the number of clinical cases reported to state veterinary services by farmers implying that in circumstances where cases exist but have not been reported, veterinary offices may not record them. By developing a standard case definition for a ND case, the PPV of the surveillance system could be improved, while improving disease reporting by farmers is needed to improve the sensitivity of the surveillance system.

Newcastle Disease has no pathognomy clinical and post mortem signs (Alexander et al., 2004). Thus, it is likely that Sp and PPV estimates provided by nine experts may affect the estimated ND incidence computed in this study in both extremes if the experts underestimate or overestimate the disease the ND diagnosing capabilities of their field veterinary assistants. There are currently no studies that compare the clinical ND diagnostic capabilities of field veterinary technicians with confirmed conventional laboratory diagnosis of ND in Zambia. Thus, expert opinion was the only available method for computing Se and PPV for ND diagnosis in eastern Zambia. Much effort was however put into getting experienced experts to provide estimates of Se and PPV to minimise bias in this regard. Table 2-2 shows that there is good agreement between experts with relatively small standard deviations, which allows some confidence in their estimates of Se and PPV. In retrospect, an estimate of Sp by experts should have been asked for at the same time.

Quality of reporting by veterinarians and their assistants may also have had some impact on the incidence rates, since reports from 1994 to 1998 were not traced (Figure 2-3). This may, however, reflect a weakness in storage of data at both district and provincial veterinary offices rather than quality of reporting. There has been better record storage since 1999 but whether that reflects a better evolution in quality of disease reporting over time is hard to say. Because the Friedman test analyses differences between three or more related groups with related measures that are matched (Laerd-Statistics, 2015a), missing data in respective time blocks would have significant effects on results of the analysis. This could be the reason why differences between time blocks were not statistically significant.

Despite the acknowledged weaknesses of this study, it provides an insight to the spatial and temporal trends of ND in the region and forms part of the hazard analysis in the ensemble model (Figure 1-2). Additionally, the study demonstrates how historical livestock disease data obtained from livestock disease control agencies of low-income countries could be used to analyse and predict future trends of ND and other diseases considering the bias that might arise due to misdiagnosis and under-reporting of the disease.

2.7 Conclusion and Recommendations

This study forms part of the hazard analysis in the ensemble model (Figure 1-2) by showing that there is increasing annual trend for estimated ND incidence in eastern Zambia and that this trend will most likely continue in the next 25 years. It also shows that livestock disease control programmes implemented in this region through major economic policies that existed from 1989 to 2014 probably had little impact on ND trends. Furthermore, the ND control strategies implemented during this period seem to have failed to halt the spread of the disease from affected districts to those that were previously ND free.

The study also demonstrates how incidence can be estimated with scanty poultry population data and re-emphasises the need to account for uncertainty when analysing poultry disease data obtained mostly through clinical diagnosis by field staff where misdiagnosis and under reporting can easily occur. This can be partially achieved by accounting for Se and Sp of the surveillance system.

2.8 Acknowledgements

Permission to do this study was acquired from the Departments of Veterinary and Livestock Development, Ministry of Agriculture and Livestock in Zambia. This study was funded by Australian Awards (OASIS ID: STOOOK8) and James Cook University, Australia, with contributions from the National Research Foundation in Pretoria, South Africa.

Authors would like to acknowledge the following people for their involvement in this study: Dr K Kampamba, Dr J Lubinga, Dr A. Mumbolomena, Dr M. Sinzala, Dr V. Kangwa and Dr O. Kabinda. They would also like to thank Dr G. Chaka, for providing shape files for maps and finally thank Mr J.

Sikazindu, Mr D. Phiri and Ms M. Mwanza for their numerous contributions towards the success of this study.

2.9 References

Adene, D.F., 1997. Diseases of Poultry in Nigeria. An overview of the problems and solution Trop. Vet. 15, 103-110.

Alders, R.G., Spradbrow, P.B., Young, M.P. (Eds.), 2009. Village chickens, poverty alleviation and the sustainable control of Newcastle disease. Proceedings of an international conference held in Dar es Salaam, Tanzania, 5–7 October 2005. ACIAR Proceedings No. 131, 235 pp

Alexander, D.J., 2000. Newcastle disease and other avian paramyxoviruses. Revue scientifique et technique (International Office of Epizootics) 19, 443-462.

Alexander, D.J., 2001. Newcastle disease. British poultry science 42, 5-22.

Alexander, D.J., Bell, J.G., Alders, R.G., 2004. A technology review: Newcastle disease, with special emphasis on its effect on village chickens. Food & Agriculture Org.

Alexander, D.J., Senne, D.A. (Eds.), 2008. Newcastle disease, other avian paramyxoviruses, and pneumovirus infections. Blackwell Publishing Ames, IA.

Awan, M.A., Otte, M., James, A., 1994. The epidemiology of Newcastle disease in rural poultry: a review. Avian pathology 23, 405-423.

Barnett, A.G., Dobson, A.J., 2010. Analysing Seasonal Health Data. Springer ISBN 978-3-642-10747-4.

Bernstein, R. (Ed.), 2003. Population Ecology: An Introduction to Computer Simulations. John Wiley and Sons, Ltd

Cameron, A.R., 1999. Survey Toolbox- A Practical Manual and Software Package for Active Surveillance of Livestock Diseases in Developing Countries. ACIAR Monograph 54, 330.

Cattoli, G., Fusaro, A., Monne, I., Molia, S., Le Menach, A., Maregeya, B., Nchare, A., Bangana, I., Maina, A.G., Koffi, J.N., Thiam, H., Bezeid, O.E., Salviato, A., Nisi, R., Terregino, C., Capua, I., 2010. Emergence of a new genetic lineage of Newcastle disease virus in West and Central Africa--implications for diagnosis and control. Veterinary microbiology 142, 168-176.

Conover, W.J., 1999. Practical nonparametric statistics (3rd ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Copland, J.W., Alders, R.G., 2009. The comparative advantages of village or smallholder poultry in rural development.Village chickens, poverty alleviation and the sustainable control of Newcastle disease Proceedings of an international conference held in Dar es Salaam

Tanzania, 5–7 October 2005.ACIAR Proceedings No. 131, 235 pp. In: Alders, R.G., Spradbrow, P.B., Young, M.P. (Eds.),

Diel, D.G., da Silva, L.H.A., Hualei, L., Wang, Z., Miller, P.J., Afonso, C.L., 2012. Genetic diversity of avian paramyxovirus type 1: Proposal for a unified nomenclature and classification system of Newcastle disease virus genotypes. Infection, Genetics and Evolution 12, 1770–1779.

Dortmans, J.C.F.M., Peeters, B.P.H., Guus, K., 2012. Newcastle disease virus outbreaks: Vaccine mismatch or inadequate application? Veterinary microbiology.

Government-of-Zambia, 1989. Fourth National Development Plan, 1989-1993. Office of the President, National Commission for Development Planning.

Government-of-Zambia, 2006. Zambia's Fifth National Development Plan 2006 - 2010.

Government-of-Zambia, 2011. Zambia's Sixth National Development Plan 2011 - 2015.

Government-of-Zambia, 2013. Ministry of Agriculture and Livestock; National Agriculture Policy.

Government-of-Zambia, 2014a. Department of Veterinary Services and Livestock Development; 2013 Eastern Province Annual Report.

Government-of-Zambia, 2014b. Revised Sixth National Development Plan 2013 - 2016.

Government-of-Zambia, 2015. Draft Livestock Policy. 2-20.

Harrison, J.L., Alders, R.G., 2010. An assessment of chicken husbandry including Newcastle disease control in rural areas of Chibuto, Mozambique. Tropical animal health and production 42, 729-736.

IMF, 2007. Zambia: Poverty Reduction Strategy Paper. IMF Country Report

Kahn, C.M. (Ed.), 2005. Merck Veterinary Manual. Merck & Co. Inc. and Merial Ltd.

Laerd-Statistics, 2015. Friedman test using SPSS Statistics. Statistical tutorials and software guides. Retrieved from https://statistics.laerd.com/.

Miller, P.J., Estevez, C., Yu, Q., Suarez, D.L., King, D.J., 2009. Comparison of viral shedding following vaccination with inactivated and live Newcastle disease vaccines formulated with wild-type and recombinant viruses. Avian Dis. 53, 39–49.

Mubamba, C., Sitali, J., Gummow, B., 2011. Trends of selected cattle diseases in eastern Zambia between 1988 and 2008. Preventive veterinary medicine 101, 163-172.

Musako, C., Abolnik, C., 2012. Determination of the seroprevalence of Newcastle disease virus (avian paramyxovirus type 1) in Zambian backyard chicken flocks. The Onderstepoort journal of veterinary research 79, E1-4.

Njagi, L., Nyaga, P., Mbuthia, P., Bebora, L., Michieka, J., Kibe, J., Minga, U., 2010. Prevalence of Newcastle disease virus in village indigenous chickens in varied agro-ecological zones in Kenya. Livestock Research for Rural Development 22.

Nwanta, J., Umoh, J., Abdu, P.A., Ajogi, I., Egege, S., Adeiza, A., 2008a. Field trial of Malaysian thermostable Newcastle disease vaccine in village chickens in Kaduna State, Nigeria. Sokoto Journal of Veterinary Sciences 7, 42-45.

Nwanta, J.A., Abdu, P.A., Ezema, W.S., 2008b. Epidemiology, challenges and prospects for control of Newcastle disease in village poultry in Nigeria. World's Poultry Science Journal 64, 119-127.

OIE, 2012. World Organisation for Animal Health - Terrestrial Animal Health Code. OIE, Paris

Otim, M.O., Kabagambe, E.K., Mukiibi, G.M., 2007. A study of risk factors associated with Newcastle disease epidemic in village free-range chickens in Uganda. Trop. Anim. Health Prod 39, 27-35.

Our-Africa, 2015. Zambia: Climate and Agriculture/http://www.our-africa.org/zambia/climate-agriculture.

Phiri, J., 2014. Zambia: Kulamba Ceremony Strengthening, Inspiring. In: Africa, A. (Ed.) Times of Zambia.

Pym, R., Guerne Bleich, E., Hoffmann, I., 2006. The relative contribution of indigenous chicken breeds to poultry meat and egg production and consumption in the developing countries of Africa and Asia. In, Proceedings of the XII European Poultry Conference.

Rakibul Hasan, Ali M. H., Siddique M. P., Rahman M. M., Islam M. A., 2010. Clinical and Laboratory Diagnoses of Newcastle and Infectious Bursal Diseases of Chickens. Bangl. J. Vet. Med. 8, 131-140.

Sharma, R.N., Hussein, N.A., Pandey, O.S., Shandomo, M.N., 1985. A study on Newcastle disease outbreaks in Zambia,1975-1984. Rev. sci. lech. Off. int. Epiz, 5(1) 5-14

Songolo, A., Katongo, J.C., 2000. 'Country report: Zambia'. In: Alders, R.G., Spradbrow, P.B. (Eds.), SADC planning workshop on Newcastle disease control in village chickens: Proceedings of an international workshop, ACIAR Proceedings 103, Maputo, Mozambique. 43-45.

Thrusfield, M. (Ed.), 2005. Veterinary Epidemiology. Blackwell Publishing Oxford UK.

Vose, D., Koupeev, T., Groenendaal, T., 2004. ModelAssist. Project managed by Risk Thinking Ltd, SB Premium, Vladikavkaz, Russia.

Chapter 3

SEROLOGICAL SURVEY AND MOLECULAR CHARACTERIZATION OF NEWCASTLE DISEASE VIRUSES CIRCULATING IN EASTERN ZAMBIA

Publications

Mubamba, C., Abolnik, C., Dautu, G., and Gummow, B. Seroprevalence and molecular characterization of circulating Newcastle Disease Viruses in Eastern Zambia. To be submitted.

3.1 Abstract

Newcastle Disease continues to cause major losses among rural poultry of Zambia. After outbreaks of the disease caused by genotype VIIh of the Newcastle Disease virus (NDV) were recently reported in Mozambique, South Africa and Zimbabwe, we determined the risk to NDV infection among unvaccinated indigenous chickens of Eastern Zambia by conducting a serosurvey. Molecular characterisation of circulating NDV was also conducted to determine whether genotype VIIh had reached this region. The seroprevalence of Newcastle Disease among unvaccinated indigenous chickens in Eastern Zambia was 76% (95% CI 59-94%). Presence of sub-genotype VIIh and genotype XIII of NDV in Eastern Zambia was confirmed. We then finally discuss implications of identifying these exotic strains in Eastern Zambia regarding strengthening restrictions on poultry entry into the country and how this study fits into the the hazard analysis component of the ensemble model for improving disease reporting in Eastern Zambia.

3.2 Key Words

Zambia, Newcastle Disease Virus, seroprevalence, molecular characterization

3.3 Introduction

Part of the hazard analysis component of the ensemble model (Figure 1-2) requires identification of a priority poultry disease in Zambia. Newcastle Disease (ND) was identified as a disease most responsible for poultry mortalities in Zambia through reports from the Zambian Veterinary Services and OIE (GRZ, 2013a, 2016; OIE, 2017; GRZ, 2018). For instance, at least 20 ND outbreaks are recorded in the Eastern Province of Zambia in each year (OIE 2017). The Eastern province of Zambia shares a long border with the Tete province of Mozambique (Figure 3-1) on its south and Malawi on its east. Because of its proximity to Mozambique and Malawi, illegal movement of poultry and poultry products between these regions is likely hence increasing the probability of spread of ND across borders.

Newcastle Disease is a highly contagious disease in birds that is characterized by weak limbs, cyanosis of the wattle and comb, nasal and eye discharges, greenish diarhoea, weight loss, loss of egg production and high mortality (Alexander et al., 2004). At postmortem, the characteristic lesions that have been described are haemorhages in the trachea, brain and spleen. Petechial haemorhages coupled with ulcers that have raised borders on the mucosa of the proventriculus, caecal tonsils and inflamed lungs are also consistent with the disease (Pazhanivel et al., 2002). Newcastle disease (ND) is caused by Newcastle Disease Virus (NDV), an Avulavirus in the Paramyxoviridae family. The enveloped virus contains a negative sense, single-stranded RNA genome and primarily replicates in the respiratory and gastrointestinal tract. Therefore, NDV spreads between infected and susceptible birds through oral/nasal secretions and faeces (Nwanta et al., 2008). Clinical symptoms and the severity ND depend on a range of factors including host species, age, immune status and viral characteristics, although respiratory and neurological symptoms are typical (Alexander, 2000).

All strains of NDV belong to a single serotype but multiple genotypes and sub-genotypes. New sub genotypes have emerged over a period probably due to intensive farming and use of new high densities of poultry and the use of vaccines to prevent ND (Abolnik et al., 2017). There are two classes of NDV (I and II) but all virulent strains implicated of ND emerged from Class II. Class II is further divided into eighteen genotypes (I to XVIII), some containing sub-genotypes, based on genetic distances between viral fusion glycoprotein gene sequences (Diel et al., 2012; Abolnik et al., 2017b). Viruses from Genotype VII have been responsible for the most recent ND panzootic. It originated in Southeast Asia, with the earliest known outbreaks beginning around 1985. Sub-genotypes VIIa to VIIk are presently described (Diel et al., 2012; Abolnik et al., 2017b; Molini et al., 2017).

Thus, to form part of the hazard analysis component of the ensemble model (Figure 1-2), a study to determine serological prevalence and molecular characterization of circulating NDV among unvaccinated village chickens in Eastern Zambia was conducted. The other objective of the study was to determine whether the region was also affected by the recent sub-genotype VIIh NDV detected in Southern Africa (Mapaco et al., 2016).

3.4 Materials and Methods

3.4.1 Serological prevalence of ND among village chickens

A sero survey was conducted to assess the level of NDV contact among the unvaccinated indigenous chickens of eastern Zambia to indirectly assess the risk to ND incursion for the chicken population in this region. Thus, 521 unvaccinated chickens from 163 households sampled from 25 villages using a sampling protocol described below, were tested for presence of NDV antibodies in their serum. Sampling was conducted from 20th of October to 3rd of December in 2015.

Sampling procedure

At the time of the study, approximately 75% of the villages in Eastern Zambia had had their indigenous chickens vaccinated against ND through the LDAHP program supported by World Bank. Therefore, only villages from areas that were not yet vaccinated were purposively targeted from all the 8 districts of the province. After consulting with the provincial and district veterinary offices, the total number of villages with unvaccinated poultry was estimated at 1600, thus a sample size of 25 villages was computed using Aus vet's Epi Tools Epidemiological calculator (http://epitools.ausvet.com.au) using the village as a sampling unit with the following estimations and assumptions;

- estimated proportion of seropositive villages= 0.1
- required precision= 0.1
- confidence level of= 0.95
- estimated number of unvaccinated villages in the province= 1600

The sample of 25 villages (Table 3-1) was then proportionally assigned to the eight districts depending on the number of unvaccinated villages per district. Because of the assumed low within village variation in poultry husbandry practices and high mixing of poultry among households, a range of 2 to 10 households, which represented 20% of the households with chickens in the village was sampled per village using lists of poultry keeping households provided by village headmen as sampling units. Village headmen are responsible for administering, a village which is the smallest administrative unit under the local government system in Zambia. A maximum of 6 apparently healthy chickens from each sampled household were then bled through the wing vein and 2ml of serum was collected for laboratory tests.

Table 3-1: Number of villages, poultry farming households and unvaccinated chickens sampled in each district of Eastern Zambia during a seroprevalence survey for ND conducted from October to December in 2015.

District	**villages**	**households**	**unvaccinated chickens**
Chadiza	4	18	78
Chipata	2	19	68
Katete	2	9	24
Lundazi	1	11	35
Mambwe	5	18	59
Nyimba	1	21	74
Petauke	4	42	97
Sinda	4	14	47
Vubwi	2	11	39
Total	**25**	**163**	**521**

Laboratory procedure

Serum samples were tested with a competitive Enzyme Linked Immune Sorbent Assay (ELISA) kit using the recommended protocol from the commercial kit suppliers (ID Screen®). The laboratory work was done at the Central Veterinary Research Institute in Lusaka Zambia. A microplate reader (Multiskan, Labsystems) was used to read results with absorbance values measured at 450 nm. Results were interpreted by computing percent inhibition (PI %) using Equation 1 below;

Equation 1 $PI\% = \frac{OD_{NC-}OD_{sample}}{OD_{NC}}$

Where OD_{NC} was the optic density of the negative control and $OD_{\cdot sample}$ was the optic density for the sample.

Samples presenting a PI greater than 40% where considered positive and those with PI% between 30 and 40% were considered doubtful while those with PI less than 30% were considered negative.

A household was considered ND seropositive if at least one of its sampled chickens was seropositive. Similarly, if at least one of the households in the village was ND seropositive, that entire village was considered ND seropositive.

Data analysis

Apparent ND seroprevalence in unvaccinated chickens of Eastern Zambia was then computed by dividing the number of seropositive villages by the total number of villages sampled. Published values for Specificity and Sensitivity of the test of 98.4% and 98.9% respectively (Phan et al., 2013), were used to calculate true prevalence and the 95% confidence interval using the Epi Tools Epidemiolocal calculators (http://epitools.ausvet.com.au).

Spatial analysis

A spot map was created in Epi Info 7.2 to indicate location and ND status of sampled villages. This was done by adding the data layer containing GPS coordinates of the sampled villages to existing shape files for Eastern Zambia obtained from the provincial local government office.

3.4.2 Molecular characterization of circulating NDV

Sampling

Tracheal and cloacal swabs were collected from dead and clinically sick indigenous chickens with signs of ND such as paralysis, green diarrhea, nasal and oral lacrimation. Samples were collected during active ND outbreaks that occurred in 2015 in Chipata, Katete and Chadiza districts.

Virus isolation

Tracheal and cloacal swabs were shipped to Deltamune Laboratory Pretoria, South Africa where virus isolations in specific pathogen free embryonated chicken eggs were performed according to the OIE recommended procedure (OIE, 2015). Total RNA was extracted from egg alantoic fluids with TRIzol® reagent (Life Technologies, Carlsbad, CA).

Reverse transcription PCR

Group specific reverse transcription PCR assays were run for the NDV positive samples using the procedures described by Abolnik et al. (2017b) and (Abolnik et al., 2017a). The genotypes of NDV were then identified using agarose gel electrophoresis. The full genome sequence analysis of the isolated viruses is described elsewhere (Abolnik 2017a; 2017b).

3.5 Results

3.5.1 Newcastle Disease seroprevalence survey of unvaccinated indigenous chickens

Nineteen out of the 25 sampled ND-unvaccinated villages had at least one bird infected with ND (Figure 3-1). Thus, the ND prevalence amongst unvaccinated indigenous chickens was computed at 76.0%. The computed true prevalence was 76% (CI=59-94%).

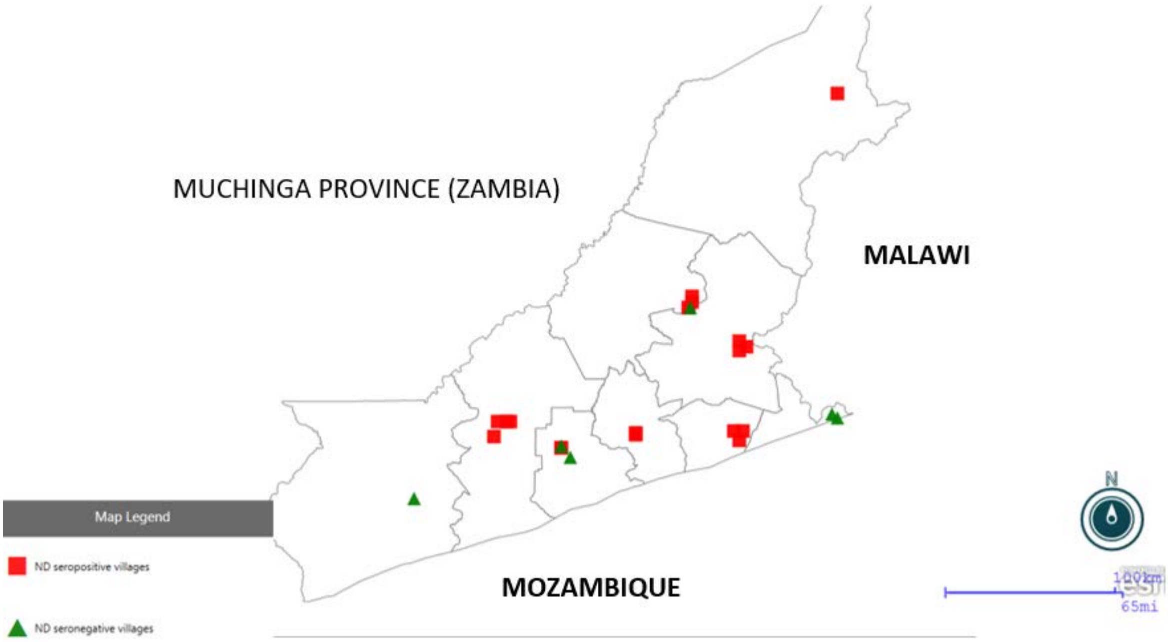


Figure 3-1: Location of ND seropositive (red squares) and seronegative (green triangles) villages in Eastern Zambia according to results of a seroprevalence survey conducted from October to December in 2015.

3.5.2 Molecular characterization of circulating NDV

3.5.3 A total of 17 birds were sampled. Genotypes VIIh (Figure 3-2) and XIII were confirmed from the samples Chicken/Zambia/Chidiza/2-015, Chicken/Zambia/Katete/2015 and Chicken/Zambia/Mbeweka/2015 while genotype XIII was confirmed from the sample chicken/Zambia/Chiwoko/2015. A genome announcement for genotype XIII was published (Abolnik et al., 2017a).

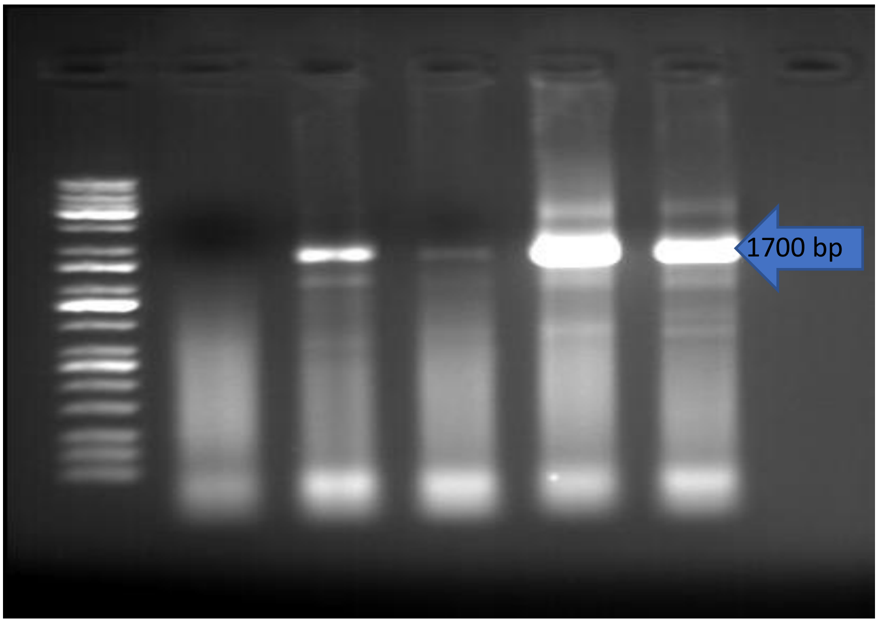


Figure 3-2: Agarose Gel results for a sub-genotype VIIh specific assay conducted on NDV strains isolated from indigenous chickens of Eastern Zambia in 2015. Lane 1: 100bp molecular weight marker. Amplicons at the molecular weight of 1700 base pairs in lane 2 (Chicken/Zambia Chidiza/2015), Lane 5 (chicken/Zambia/Katete/2015) and lane 6 (Chicken/Zambia/Mbeweka/2015) were identified as sub-genotype VIIh.

3.6 Discussion

High ND seroprevalence reported among unvaccinated villages in Eastern Zambia by this study was consistent with reports from a study conducted previously (Musako and Abolnik, 2012). High ND seroprevalence indicate high infection of indigenous chickens to pathogenic NDV infections in this region. Thus, veterinary services must ensure that chickens in all villages are adequately vaccinated against ND. Although there has been a ND vaccination programme supported by WB within the region where vaccinations are done with a thermostable I2 ND vaccine (Alders et al., 1994), three times a year, vaccination coverage has been low and erratic (GRZ, 2018). On the other hand, the high ND seroprevalence reported may partly be attributed to the non-pathogenic NDV infections from vaccinated chickens because of possible movement of birds between ND vaccinated-villages and unvaccinated villages, which may lead to spread of the viruses because vaccinated poultry are known to transmit the nonpathogenic NDV viruses to unvaccinated poultry (Alexander D.J. et al., 2004; Nwanta et al., 2008). This is however very unlikely because severe ND outbreaks were reported from most of the unvaccinated villages at the time of the study (GRZ, 2016).

The port of Maputo was recently determined as the port of entry for sub-genotype VIIh NDV infection in Southern Africa using time scaled phylogenic analysis that determined the time to most common recent ancestor to determine when the virus entered (Abolnik et al., 2017b). Infection is suspected to have come through ships which carried illegal poultry or dumped swill from Asia at the port (Abolnik et al., 2017b). The spread of infection was determined to have been in the northern direction until it entered Zambia either through Tete province of Mozambique or through Malawi (Abolnik et al., 2017b). Presence of exotic sub-genotype VIIh NDV in Eastern Zambia underpins the importance of regional collaboration in the control and prevention of exotic livestock diseases. It would also be vital to carry out molecular characterization of other strains obtained from other regions as well as other Zambian neighbouring countries like Congo, Tanzania and Angola to further ascertain the spread of the sub-genotype VIIh strain. The point of entry for the genotype XIII Chiwoko strain (Abolnik et al., 2017a) identified in Eastern Zambia is not yet determined. It is however likely that it came from Asia through a similar pattern or through another route which also involved illegal poultry movement into Africa (Abolnik et al., 2017).

By determining seroprevalence and molecular characterization of ND, this study fulfills part of the hazard analysis component of the ensemble model (Figure 1-2). The findings of this study can be used to justify more funding towards poultry disease control activities such as intensifying poultry movement controls which can lead to zoning of ND-infected and non-infected villages. Since there is a high prevalence of ND in Eastern Zambia (Figure 3-1), more resources are needed to increase the ND vaccination coverage in the region. Presence of the new strains of NDV in the region (Figure 3-2) may also require revaluating the efficacy of the ND vaccines currently being used in this region to determine whether they can still protect the birds against the genotype VIIh and XIII NDV infections. Currently the thermostable I2 ND vaccine is being promoted among indigenous chickens in Zambia (Alders et al., 1994).

3.7 Conclusion

This study was able to determine the seroprevalence and molecular characterization of circulating NDV in Eastern Zambia. It was also able to establish that the exotic sub-genotype VIIh NDV is present in Zambia. Thus, by providing this information, the study fulfills part of the hazard analysis component of the ensemble model (Figure 1-2).

3.8 Acknowledgements

The authors thank Casiano Hapoma, Telana Rapp and Thandeka Phiri for the excellent technical assistance. The study was funded by James Cook University, Australia Awards and the South African National Research Foundation grant #CPRR 93461.

3.9 References

Abolnik, C., Mubamba, C., Dautu, G., Gummow, B., 2017a. Complete Genome Sequence of a Newcastle Disease Genotype XIII Virus Isolated from Indigenous Chickens in Zambia. Genome announcements 5, e00841-00817.

Abolnik, C., Mubamba, C., Wandrag, D.B.R., Horner, R., Gummow, B., Dautu, G., Bisschop, S.P.R., 2017b. Tracing the origins of genotype VIIh Newcastle disease in Southern Africa. Submitted to Journal of Transboundary and Emerging Diseases. 65(2):e393-403..

Alders, R., Inoue, S., Katongo, J., 1994. Prevalence and evaluation of Hitchner B1 and V4 vaccines for the control of Newcastle disease in village chickens in Zambia. Preventive veterinary medicine 21, 125-132.

Alexander, D.J., 2000. Newcastle disease and other avian paramyxoviruses. Scientific and Technical review (International Office of Epizootics) 19, 443-462.

Alexander, D.J., Bell, J.G., Alders, R.G., 2004. Technology review: Newcastle disease with special emphasis on its effect on village chickens. FAO Animal Production and Health Paper No. 161, 63 pp. Food and Agriculture Organization of the United Nations: Rome.

Diel, D.G., da Silva, L.H.A., Hualei, L., Wang, Z., Miller, P.J., Afonso, C.L., 2012. Genetic diversity of avian paramyxovirus type 1: Proposal for a unified nomenclature and classification system of Newcastle disease virus genotypes. Infection, Genetics and Evolution 12, 1770–1779.

GRZ, 2013. Annual report for the Departments of Veterinary Services and Livestock Development-Eastern province of Zambia. 1-49.

GRZ, 2016. Twenty fifteen annual report for the Departments of Veterinary Services- Eastern province of Zambia. 1-19.

GRZ, 2018. Twenty seventeen annual report for the Departments of Veterinary Services- Eastern province of Zambia. 1-49.

Mapaco, L.P., Monjane, I.V., Nhamusso, A.E., Viljoen, G.J., Dundon, W.G., Achá, S.J., 2016. Phylogenetic analysis of Newcastle disease viruses isolated from commercial poultry in Mozambique (2011–2016). Virus genes 52, 748-753.

Molini, U., Aikukutu, G., Khaiseb, S., Cattoli, G., Dundon, W.G., 2017. First genetic characterization of Newcastle disease viruses from Namibia: identification of novel VIIk subgenotype. Arch Virol 162, 2427-2431.

Musako, C., Abolnik, C., 2012. Determination of the seroprevalence of Newcastle disease virus (avian paramyxovirus type 1) in Zambian backyard chicken flocks. The Onderstepoort journal of veterinary research 79, E1-4.

Nwanta, J.A., Abdu, P.A., Ezema, W.S., 2008. Epidemiology, challenges and prospects for control of Newcastle disease in village poultry in Nigeria. World's Poultry Science Journal 64, 119-127.

OIE, 2015. OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals (2015). Chapter 2.3.1.4. Newcastle disease (Infection with Newcastle disease virus). Accessed at:http://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/2.03.14_NEWCASTLE_DIS.pdf.

OIE, 2017. World Animal Health Information System (WAHIS) database.

Pazhanivel, N., Balsubramaniam, G.A., George, V.T., Mohan, B., 2002. Study of natural outbreak of Newcastle disease in and around Namakkal. Indian Veterinary Journal 79, 293-294.

Phan, L., Park, M.-J., Kye, S.-J., Kim, J.-Y., Lee, H.-S., Choi, K.-S., 2013. Development and field application of a competitive enzyme-linked immunosorbent assay for detection of Newcastle disease virus antibodies in chickens and ducks. Poultry science 92, 2034-2043.

Chapter 4

DESCRIPTIVE AND FINANCIAL ANALYSIS OF RURAL POULTRY ENTERPRISES IN EASTERN ZAMBIA

Publications

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018. Analysing production and financial data from farmers can serve as a tool for identifying opportunities for enhancing extension delivery among the rural poultry sub-sector in Zambia. Preventive veterinary medicine 158, 152-159.

Conference Presentations

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B. Are Indigenous chickens among rural communities an economically viable alternative to commercial broilers and layers? Proceedings of the 2017 Scientific conference for the ANZCVS science week Epidemiology Chapter.

Mubamba, C., Ramsay, G., Dautu, G., Abonlik, C., Gummow, B. Analysing Production and financial data from farmers to identify sustainable poultry enterprises in a resource constrained rural poultry Sub-sector of Eastern Zambia. Oral presentation at the 2018 SASVEPM Congress held in June 2018.

4.1 Abstract

There are limited data on production and financial performance of the rural poultry sector in developing countries like Zambia that could be used by extension services as a feedback loop to enhance service delivery in the sector. Thus, a study that used production and financial data obtained from poultry farmers of Eastern Zambia was conducted to describe the rural poultry sub-sector and conduct financial analysis. It compared the financial performance of indigenous chicken production to broiler and layer production. The aim of the study was to identify opportunities and knowledge gaps among poultry farmers that could be used to initiate and enhance a participatory extension approach and build capacity of farmers in the sector. Descriptive, spatial, gross margin and breakeven analysis was used to analyse data obtained from 459 rural poultry farmers and expert opinion from 5 local extension workers. Poultry ranked highest in terms of popularity and numbers when compared with other animals kept by respondents (median=20). Most poultry were kept under free-range and brood an average of 3.1 clutches. Except for annual set up costs, some variable costs and household poultry consumption, the study could obtain data on most production costs and income generated from poultry farmers. Nevertheless, gross margin analysis conducted using costing data from poultry farmers and expert opinion of extension workers revealed that indigenous chicken enterprises had the highest gross margin percentage of 72% compared to commercial broilers and layers which had gross margin percentages of 53% and 56% respectively. Breakeven analysis revealed that indigenous chickens required the lowest number of products to be sold (27) to realise profit compared to broilers (1011) and layers (873). The study justifies investment into the rural poultry sub-sector and discusses the use of gross margin templates as a means of incentivising rural farmers to participate in extension programmes.

4.2 Key Words

Rural poultry, financial analysis, extension programmes, production costs.

4.3 Introduction

Poultry contributes significantly to Asian and African food requirements (Dolberg, 2008; Alders et al., 2009). In sub-Saharan countries of Africa where food production is a challenge, rural poultry farming provides an affordable way of farming. When poultry farming is practised on a large scale and birds (fed on commercial feed) bred for high and quality meat or egg production, it is referred to as commercial poultry. When birds are kept on a small scale (usually with less than 100 birds), and mainly meant for domestic consumption, or when birds are meant for sale but reared with minimal resources (even if they are improved breeds), it is often referred to as rural poultry (Sonaiya E.B., 2007; Akinola and Essien, 2011).

Within the rural poultry sector, there is indigenous poultry that comprises indigenous chickens, ducks and guinea fowl, which mostly scavenge for feed with limited housing provided. Indigenous poultry production is common in rural communities in Zambia (Songolo and Katongo, 2000; Copland and Alders, 2009; Bwalya and Kalinda, 2014). That popularity is largely due to the low initial investment required and the purported resistance of indigenous poultry to some poultry diseases (Copland and Alders, 2009). In addition, indigenous poultry enterprises are more popular among socially disadvantaged groups like widows and orphaned children whose numbers are high in the region due to the Acquired Immune Deficiency Syndrome (AIDS) pandemic (Mutenje et al., 2008; Moreki and Dikeme, 2011; Simainga et al., 2011). On the other hand, indigenous poultry has a low feed to meat conversion ratio as well as low egg production which affects their profitability (Mtileni et al., 2012; Roberts, undated). More expensive commercial broilers and layers have been introduced to rural poultry enterprises, and this change has increased demand for investment in the sector. Despite commercial breeds requiring more investment, they have some advantages over indigenous chicken breeds because they have a higher feed to meat conversion ratio and take less time to reach market weight. Additionally, commercial layers lay more eggs in their productive life than indigenous chickens.

Despite its potential to contribute significantly to sub-Saharan economic growth, indigenous poultry is faced with numerous challenges such as mortality (Songolo and Katongo, 2000; Msoffe et al., 2010) and low productivity. The challenge of mortality may be partly addressed by veterinary services, but the issue of low productivity still poses a challenge for rural poultry farmers (Grace Lungu, Senior Animal Production Officer, Personal Communication). To sustainably improve productivity and ensure that there are healthy flocks among the rural poultry sector, extension services need to innovate new strategies that will increase farmers competences and stimulate them to adopt new production technologies.

Unfortunately, veterinary service's investment into enhancing production in the rural poultry sector of developing countries like Zambia is low. This is partly because governments may believe funding other enterprises such as beef and dairy production provides greater financial gain than poultry (Mwacalimba, 2012). This bias is worsened by a male-dominated African society that traditionally believes funds spent on large livestock (which traditionally belong to men) is a better investment

(Mwacalimba and Green, 2014). Thus, little work has been done by extension services in countries like Zambia, to evaluate the extension needs for the sector, which could help enhance and facilitate dialogue between service providers and farmers. As a result, most of the extension conducted in the sector has been a top down approach which has led to low adoption rates of sustainable poultry production strategies by rural poultry farmers (Yona Sinkala, Director of Veterinary Services, Personal Communication). Taking advantage of the fact that over 70% of rural households in this region keep poultry (GRZ, 2010), enhancing extension in the rural poultry sector would tap into the potential it has in increasing household income and food security among resource constrained households.

If disease control programmes such as syndromic surveillance using farmers are to be sustainable, veterinary services need to work with farmers running financially sustainable poultry enterprises. For veterinary services to understand the current gaps in financial performance of rural poultry enterprises (financial hazards), it is important to comprehensively describe production and income generated by the sector. Such information can be used to conduct financial analysis that can be used to demonstrate to poultry farmers on the likely return on investment as well as how many products they need to produce for them to make profits in the poultry production system they choose (Malcolm et al., 2005; McCown, 2005). For example, if farmers are trained to conduct financial analysis, they can decide whether to embark on indigenous, broiler or layer production depending on the availability of labour, material and financial resources. Unfortunately, there is very little data that comprehensively describes financial performance and production in the rural poultry sector of sub-Saharan countries like Zambia.

As a sequel to the background above, a study which used production and financial data obtained from poultry farmers of Eastern Zambia, to describe the rural poultry sector and conduct financial analysis that compared the financial performance of indigenous chicken production to broiler and layer production was conducted. The aim of this study was to reveal financial hazards in the rural poultry sector that would form part 2 of hazard analysis model (Figure 1-2) and in turn offer a practical tool for livestock extension officers to stimulate and enhance sustainable production among the rural poultry sector.

4.4 Materials and Methods

4.4.1 Study area and description of the study population

The study was conducted in the Eastern Province of Zambia (Fig. 1) from October 2014 to January 2015. For veterinary and livestock purposes, the Eastern Province of Zambia is divided into nine districts namely; Chipata, Chadiza, Katete, Lundazi, Mambwe, Petauke, Nyimba, Sinda and Vubwi (Figure 1B). Districts are further divided into veterinary camps which are further divided into crush pen zones. Crush pen Zones are further divided into villages.

Figure 4-1: Location of Zambia and its Eastern Province within Africa (A). Nine districts of the Eastern Province of Zambia (B) and veterinary camp zones where farmers (each farmer represented by a dot) were sampled.

4.4.2 Study design

The study was conducted in two stages. The first stage involved collection of data on rural poultry production and raising systems, production and marketing costs as well as poultry mortality from rural poultry farmers using a structured questionnaire modified from those used by Brioudes and Gummow (2015). The questionnaire was administered by local veterinary assistants who received prior training in administering it. Some data obtained from the survey was then used as inputs in the financial analysis of broiler, layer and indigenous chicken enterprises in the next stage of the study.

Sample size justification

Four hundred and sixty five poultry farming households were targeted as a representative sample using a three-stage cluster sampling strategy (Thrusfield, 2005) of veterinary camps (stage 1), villages (stage 2) and poultry farming households (stage 3) from each of the nine districts of the Eastern Province of Zambia (Figure 4-1).

4.4.3 Study procedures and data analysis

Interviews

An information sheet and consent form were provided to respondents before the commencement of interviews. After reading and understanding these documents, they were requested to sign the consent form. Interviews lasted approximately 80 minutes per respondent. GPS coordinates for all respondents were digitally and manually captured by the enumerators at the time of the interviews.

Information used for the study was derived from three sections of the questionnaire (General information, farm structure and poultry diseases) which gathered information on farmers' bio data and GPS coordinates, farm demographics, poultry reproduction, poultry mortality, poultry raising systems, poultry ranking versus other animals kept on the farms as well as monthly production and farm gate marketing costs including income derived from sales of poultry and its products.

Where farmers failed to provide some information, expert opinion was sought from 5 extension workers who had worked closely with rural poultry farmers in the region for at least 3 years. The detailed questionnaire is available in Appendix 2.

Data storage

Questionnaires with their associated tables were recreated and stored in Epi Info 7.2® (CDC). All data obtained from interviews was then entered and stored in this software as data base files. When needed for analysis, tables required were exported to Excel where they were merged, sorted and edited after which they were exported to required software packages for analysis.

Data analysis

Questionnaire and expert opinion data

All the questionnaire data was de identified to maintain confidentiality.

Descriptive and statistical analysis

IBM SPSS® version 24 was used to analyse quantitative and qualitative data. The median was used as the measure of central tendency because data was not normally distributed (Kolmogorov-Simonov test; $p<0.001$ and the Shapiro-Wilk test; $p<0.001$). When required, Kruskal Wallis H test, a rank-based nonparametric test that can be used to determine if there are statistically significant differences of median income obtained from poultry enterprises between districts of Eastern Zambia. The pairwise comparisons using Dunn's (1964) procedure with a Bonferroni adjustment

(Laerd-Statistics, 2015b) was then used to pinpoint differences between respective districts. Qualitative data from the general information, farm demographics, farm raising systems, production costs and farm income sections of the questionnaire was analysed as frequencies for specific responses.

Spatial Analysis

Choropleth maps were used to indicate the median contribution of poultry income to households per district in eastern Zambia using Epi Map version 7.2. The data layer with median income obtained from poultry per district was added to shape files of Eastern Zambia and its districts that were obtained from the provincial veterinary office.

Financial analysis

Financial analysis was conducted using gross margin analysis (GMA) that compared gross margin percentage (GMP) for the indigenous, broiler and layer chickens using production and costing information provided by poultry farmers in the survey and expert opinion from extension officers. The GMA was selected based on guidelines provided by Malcolm et al. (2005) and Rushton (2009).

Inputs for the Analysis

The following inputs obtained from the poultry farmer survey or expert opinion of extension workers were used for the financial analysis. Number of products sold per year was computed by multiplying the median monthly sales for each enterprise by 12 (1 unit= 1chicken or 1 tray of 30 eggs). Products Consumed by the household per year was calculated by multiplying the number of units sold per year by the proportion of products consumed and later dividing the product by the proportion of products that were sold. The proportion of poultry and products consumed annually was derived from the expert opinion and were 0.6 for indigenous chickens and 0.05 for both broilers and layers. Annual mortality rates for each chicken enterprise were obtained from the survey results. Mortality rates were calculated by dividing the number of respective poultry that died by the total stock of respective poultry groups. The unit price per product for each enterprise was the price of a live chicken, 1 kg of chicken meat or offal, 1 tray of 30 eggs and 1 kg of manure.

Setup costs (fixed costs) included costs of poultry equipment like feeders and drinkers and those for infrastructure. Set up costs were obtained from expert opinion of extension workers. To account for depreciation, the residue value of setup costs after 3 years was used in the break-even analysis. It was computed by subtracting annual depreciation from initial set up costs for each poultry enterprise. Depreciation for setup costs was estimated at 20% over 3 years. A period of 3 years was selected because it is assumed to be the time it takes for most rural enterprises to start running sustainably in Eastern Zambia (Grace Lungu, Senior Livestock Production Officer, Personal

Communication). Variable costs included costs that rise proportionally to a rise in production. These included costs for procuring chicken stock, chicken feed, veterinary, labour and farmgate marketing costs obtained from the survey and expert opinion. Farmgate costs included advertising and costs of some packaging materials such as trays for eggs. Monthly variable costs and income derived from questionnaire results were converted to annual values by multiplying them by 12.

Gross Margin Analysis

Broiler and Layer production were compared to indigenous chicken production as a model species for indigenous poultry enterprises within the province using GMP. Gross margin percentage for each enterprise was computed using a process that computed the following parameters. Annual Enterprise Output (AEO) included the total value of poultry and poultry product sales including the value of poultry and products that were consumed by households during the year. The annual poultry sales were computed by multiplying number of products sold per year by the sales price. The value of the poultry consumed was calculated by multiplying the number of poultry consumed per year by the sale price of a respective product unit for each respective enterprise. Annual Variable Costs (AVC) included the total of variable costs incurred per year. The annual Gross Margin (GM) was computed by subtracting AVC from AEO (GM=AEO-AVC). Gross Margin Percentage (GMP) was finally computed by dividing GM by AEO. The enterprise with the highest GMP was then identified as the most financially effective in the first year of inception and vice versa.

Break-even analysis

Breakeven analysis (Malcolm et al., 2005; Cafferky, 2010) was conducted using the following steps and variables. Sale Price Per Product was obtained from the survey results (Table 3). Fixed costs included residual costs of setup costs, labour costs and veterinary costs. In this analysis, labour and veterinary costs were regarded as semi fixed costs. Variable costs per product unit were then computed from total variable costs by dividing annual variable cost by respective number of products sold annually for each respective enterprise. The unit contribution margin represents how much money each unit sold brings in after recovering its own variable costs. It was calculated by subtracting a unit's variable costs from its sales price for each respective enterprise. The contribution margin ratio gives a percentage that can be used to determine the profits that will result from various sales levels. The contribution margin ratio was calculated by dividing the unit contribution margin by sales price per product. The enterprise break-even point, which tells the volume of sales to be achieved to cover all the costs was finally calculated by dividing set up costs by the respective unit contribution margin.

4.5 Results

4.5.1 Sample size

A sample of 459 poultry farmers were sampled within 200 villages and 40 veterinary camps from all the nine districts of Eastern Zambia in a poultry survey conducted from October 2014 to January 2015 (Table 4-1).

Table 4-1: Veterinary camps, villages and poultry farmers sampled in each district of Eastern Zambia during a poultry farmer survey conducted from October 2014 to January 2015.

District	No. of camps (n)	No. of camps sampled	No. of villages sampled (5 per camp)	Median number of poultry farming households per village	No. of poultry farming households sampled per village	Targeted sample of poultry farming households per district	Actual No. of poultry farming households sampled per district
Chipata	18	11	55	63	3	165	172
Petauke	9	5	25	39	2	50	49
Katete	10	5	25	40	2	50	50
Lundazi	9	5	25	45	2	50	56
Sinda	8	4	20	37	2	40	37
Chadiza	6	3	15	33	2	30	25
Vubwi	1	1	5	72	4	20	18
Mambwe	4	4	20	32	2	40	32
Nyimba	3	2	10	40	2	20	20
Totals	**71**	**40**	**200**			**465**	**459**

4.5.2 Survey and expert opinion results

General information

A total of 459 poultry farmers were interviewed across eastern Zambia. Among these, 169 (36.8%) were female and 290 (63.2%) were male. Their average experience of poultry farming was 14 years (SD=11.79, range 0-55). Only fourteen percent of farmers had no education background while 60%, 22%, and 1% attained primary, secondary and tertiary education respectively.

Farm demographics

Overall, the median number of chickens per farmer was 20 (Median=20, range 1-465). For farmers that kept ducks, guinea fowls, pigeons and other poultry species, the median per household was 6 (range 1-61), 6 (range 2-32), 19 (range 1-423) and 8 (range 2-41) respectively.

For flock composition, indigenous chickens were the most common poultry type among all age groups of poultry with compositions of 88.3, 87.4, 83.6 and 79.5% for chicks, pullets, cockerels, and hens within each age group of poultry (not segregated by poultry type) respectively. Overall median flock composition across all poultry types was 8, 5, 2 and 5 chicks, pullets, cockerels and hens per household respectively.

Reproduction in rural poultry

Indigenous chickens brood at a median of 3 clutches (range 1-6) of 7-18 eggs (Songolo and Katongo, 2000)

Mortalities in rural poultry

Mortality rates for indigenous chickens, broilers, and layers were computed at 45%, 15%, 5% per year respectively.

Farm poultry raising systems

The main poultry raising system used by farmers was free range (80.1% of responses) followed by a semi intensive traditional system which involves some limited traditionally constructed shelters and some feeding of kitchen and grain left overs (14.1% of responses). The large-scale system which involves advanced housing and intensive feeding of poultry with commercial feeds only received 5.4% of the responses. Lastly, other systems not described above only received 0.4% of responses.

Poultry ranking *versus* other animals kept on farms

Poultry ranked highest in terms of popularity and numbers when compared with other animals kept by respondents (mean=43 birds per household, SD=101.9, percentage of total livestock=64.5%). Cattle and pigs followed with total livestock percentages of 14.4% and 6.7% respectively. Overall, the average number of livestock units owned by each farming household or farm was 16. A livestock unit represented one domestic animal regardless of species and breed.

Production and marketing costs for rural poultry

About 73.6% of poultry farmers interviewed were not aware of production costs for their poultry while only 22.4% were aware. Approximately 3.9% of respondents did not respond to this question. Results derived from informed farmers revealed that the median monthly cost for purchase of chicken and feed per household was 500 Zambian Kwacha (ZMW), ZMW 60 for treatment costs and ZMW 45 for other costs. At the time of the survey ZMW 1 was equivalent to 0.17 United States dollars (USD). Layer production was the costliest (median cost for chicks feed and housing= ZMW 750, treatment costs= ZMW 225 and other costs= ZMW 63.89) followed by broilers (median cost for chicken feed = ZMW 583, treatment costs= ZMW 63). Production costs for indigenous chickens were at a monthly median of ZMW 20 for chicks and stock feed, and ZMW 30 for treatment costs.

Since farmers were only able to provide a combined amount on what they spent on the purchase of stock (chicks, pullets, hens, etc.) and feed, a short follow-up interview of 5 local extension officers was conducted to estimate what proportion of this amount would specifically consist of feed costs and stock costs. The most frequent response was that 70% of the combined amount consisted of feed costs. Thus, estimated feed costs were computed as ZMW 525, ZMW 408 and ZMW 14 per month for layers, broilers, and indigenous chickens respectively, while estimated costs of stock were ZMW 225, ZMW 175, and ZMW 6 respectively.

Poultry farmers were also unable to estimate set up costs, some variable costs like labour and marketing costs as well as the proportion of poultry they consumed per year for each enterprise. Thus, expert opinion, whose results are summarised in Table 4-2 was sought from 5 local extension officers to estimate these costs.

Table 4-2: Median and range (in brackets) of set up costs and some variable costs for indigenous, broiler and layer chicken production in Eastern Zambia according to the expert opinion provided by extension workers during a survey conducted from October 2014 to January 2015.

Item	Indigenous	Broilers	Layers
Proportion of poultry and products consumed	0.6 (0.5-0.8)	0.05 (0.03-0.10)	0.05 (0.02-10)
Infrastructure costs (ZMW)	85 (50-150)	9000 (5000-27000)	11000 (8500-32000)
Cost of equipment (ZMW)	45 (30-60)	5000 (250-6000)	5000 (650-8000)
Farmgate marketing costs per unit (ZMW)	0.05 (0.01-0.10)	0.40 (0.10-0.50)	0.8 (0.40-2.50)
Labour hours per day	0.25 (0.20-0.50)	6.00 (3.00-8.00)	4 (1.50-8.00)

Income from rural poultry

Among poultry farmers, 56.4% of them said they sold their poultry while 41.6% did not. Two percent of respondents did not give a response to this prompt. Furthermore, 45.8% of farmers were aware of how much monthly income they derived from the sale of poultry while 50.1% were not and 4.1%

did not give a response. Income from poultry enterprises contributes an average of 30% to the total household income (median=20%, minimum=10%, maximum=100%).

High poultry income districts were Katete, Petauke, Chadiza and Vubwi with median poultry income contributions to overall household income of 30% and above (Figure 4-2). On the other hand, Lundazi, Mambwe, Chipata, Sinda and Nyimba districts were medium poultry income districts with median poultry income contribution to overall household income ranging from 10 to 20% (Figure 4-2). There was no low poultry income district (median poultry income contribution less than 10%). Differences in median income between high and medium poultry income districts were statistically significant (Kruskal Wallis test; p=0.001 and all pairwise comparisons with Bonferroni adjustment between high and low poultry income districts p=0.001)

Overall median monthly income derived from poultry sales was ZMW 80 per household. Highest median income was from layers followed by broilers and indigenous chickens with median values of ZMW 2793, ZMW 2500 and ZMW 75 respectively. From this data, number of units sold per month was computed as 93, 100 and 3 for layers, broilers, and indigenous chickens, based on prices of ZMW 25 and ZMW 30 for 1 chicken and 1 tray of eggs, provided by farmers.

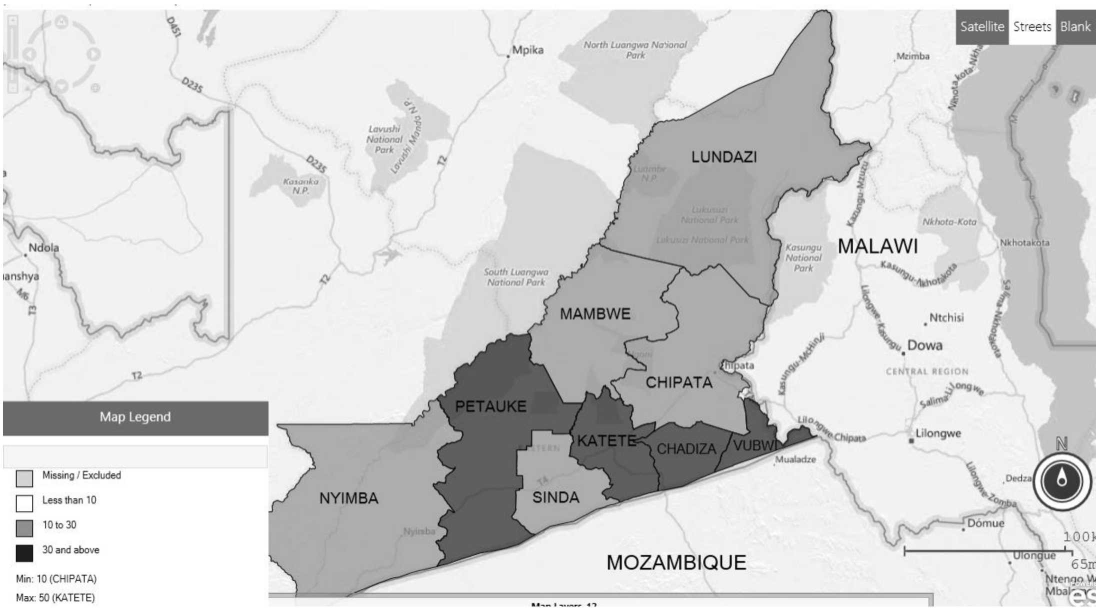


Figure 4-2: Median contribution of poultry income in percentages to household income of rural poultry farmers in Eastern Zambia's districts according to the poultry survey conducted from October 2014 to January in 2015.

4.5.3 Financial analysis of rural poultry enterprises

Inputs for financial analysis

Table 4-3 shows poultry production and income data obtained from the farmer survey and expert opinion that was used to compute inputs for the annual cash flow and break-even analysis.

Table 4-3: Input values used in the financial analysis for indigenous, broiler and layer chickens in Eastern Zambia according to the data provided by rural poultry farmers and expert opinion of extension workers in a survey conducted from October 2014 to January 2015.

Item	Indigenous	Broiler	Layer	Comments/ data source
Production and Health data				
Units produced & sold*	36 (12-54)	1260 (24-2340)	1116 (9-1853)	Obtained from questionnaire results
Proportion of units produced and consumed*	0.6 (0.5-0.8)	0.05 (0.03-0.10)	0.05 (0.02-10)	Expert opinion from extension workers
Mortality	0.45 (0.25-0.55)	0.15 (0.02-0.37)	0.05 (0.01-0.23)	Obtained from questionnaire results
Farm gate sale price per unit (ZMW)	25 (15-30)	25 (20-35)	30 (27-35)	Obtained from questionnaire results
Set up costs (ZMW)				
Infrastructure costs	85 (50-150)	9000 (5000-27000)	11000 (8500-32000)	Expert opinion from extension workers
Feeders and drinkers	45 (30-60)	5000 (250-6000)	5000 (650-8000)	Expert opinion from extension workers
Variable costs (ZMW)				
Stock costs per bird	2.0 (1.2-3.8)	1.7 (1.7-5.9)	2.4 (2.1-4.3)	Obtained from questionnaire results
Feed Costs per bird	4.7 (4.2-5.9)	3.9 (3.5-4.8)	5.6 (4.1-6.4)	Obtained from questionnaire results
Vet costs per 1000 batch of birds**	30 (5-442)	63 (40-3000)	225 (50-9950)	Obtained from questionnaire results
Labour costs per day	1.0 (0.20-0.50)	21.6 (3.00-8.00)	14.4 (1.50-8.00)	Expert opinion from extension workers and Zambian government labour law rate of 3.6 ZMW per hour.
Farmgate marketing costs per unit	0.05 ((0.01-0.10)	0.4 (0.01-0.10)	0.8 (0.40-2.50)	Expert opinion from extension workers

* 1 product unit= 1live chicken, 1kg of chicken carcass or offal, and 1 tray of 30 eggs.

**Since most vet drugs and vaccines are packaged in doses of 1000, vet costs were assumed to be doubling when the products exceed 1000, 2000 etc.

Gross Margin Analysis

When GMA was conducted using production and costing information which was provided by farmers and extension officers, indigenous chicken enterprises had the GMP of 72% compared to commercial broilers and layers which had GMP of 53% and 56% respectively (Table 4-4).

Table 4-4: Gross Margin analysis for the indigenous, broiler and layer chicken enterprises in the first year of inception in Eastern Zambia, according to data obtained from the poultry farmers and extension workers during a survey conducted from October 2014 to January 2015.

	Indigenous Chickens	**Broilers**	**Layers**
A. Enterprise outputs			
Sale of poultry and its products	ZMW 900.00	ZMW 31,500.00	ZMW 33,480.00
Consumed poultry and its products	ZMW 1,350.00	ZMW 1,657.89	ZMW 1,762.11
Total outputs	***ZMW 2,250.00***	***ZMW 33,157.89***	***ZMW 35,242.11***
B. Enterprise inputs			
Annual stock costs	ZMW 72.00	ZMW 2,142.00	ZMW 2,678.40
Annual feed Costs	ZMW 169.20	ZMW 4,914.00	ZMW 6,249.60
Annual vet costs	ZMW 30.00	ZMW 126.00	ZMW 450.00
Annual farmgate marketing costs	ZMW 1.80	ZMW 504.00	ZMW 892.80
Annual labour costs	ZMW 365.00	ZMW 7,884.00	ZMW 5,256.00
Total inputs	***ZMW 638.00***	***ZMW 15,570.00***	***ZMW 15,526.80***
C. Gross Margin	**ZMW 1,612.00**	**ZMW 17,587.89**	**ZMW 19,715.31**
D. Gross Margin Percentage	**71.64**	**53.04**	**55.94**

Break even analysis

Breakeven analysis results revealed that indigenous chickens required the lowest number of products sold to breakeven in the first year of inception (27) followed by layers (873) and broilers (1011) (Table 4-5).

Table 4-5: Breakeven analysis for the indigenous, broiler and layer chicken enterprises in Eastern Zambia according to the data provided by poultry extension workers during a survey conducted from October 2014 to January 2015.

	Indigenous chickens	**Broilers**	**Layers**
Farmgate sale price per unit	ZMW 25.00	ZMW 25.00	ZMW 30.00
Fixed costs	ZMW 499.00	ZMW 19,210.00	ZMW 18,506.00
Variable costs per unit	ZMW 6.75	ZMW 6.00	ZMW 8.80
Unit contribution margin	ZMW 18.25	ZMW 19.00	ZMW 21.20
Contribution margin ratio	0.7	0.8	0.7
Break Even Point	**27**	**1011**	**873**

4.6 Discussion

The sampling strategy used to select farmers could affect the accuracy of results for this study. This is because the exact number of villages per camp could not be obtained and thus it was estimated. More still sampling depended on sampling frames provided by village headmen at the village. Village headmen could possibly miss out some poultry farmers due to selection and memory bias. To counter part of this weakness, interviewers were instructed to conduct interviews on farm for verification of farmers as viable poultry farmers and they were also requested to ask respondents whether they knew any other poultry farmers within their village to ensure that other farmers were not missed.

Accuracy of data provided by farmers could have been affected by misclassification and memory bias among respondents (Schacter, 1999). Misclassification and memory bias were not accounted for in this study. Nevertheless, most poultry farmers (86%) in this study had some form of education, which implies that most of them had the ability to understand the questionnaire and provide accurate responses. Furthermore, to counter possible memory and selection bias, medians were used to compute data obtained from questionnaires and expert opinion. The other reason medians were used was because the data were not normally distributed. Using averages for inputs would have led to more biased computed return on investment values thus leading to exaggerated conclusions as averages are significantly affected by extreme values (Cockroft and Holmes, 2003; Sheskin, 2003). The other weakness with the study was that the interviews targeted the head of the household rather than the actual owner. This is probably the reason why 60% of the respondents where male despite most literature citing women as the gender that keeps most rural poultry (Guèye, 2000; Copland J.W. and Alders R.G., 2009; Akinola and Essien, 2011).

Expert opinion data on poultry and products consumed by households, start-up, labour and marketing costs could also affect the accuracy of financial analysis. This is because it was obtained from extension workers rather than the actual poultry farmers who conduct poultry farming. The possibility of this bias was however minimised by only obtaining expert opinion from extension workers who had extensive experience and worked within the communities with the poultry farmers.

Despite the highlighted weaknesses, this study reveals key poultry production information which could be utilised by government extension services as well as the poultry industry, including farmers, in planning, implementation and monitoring of their programs. Extension officers could use production and financial analysis data to enhance extension services and lobby for increased funding to the rural poultry sector by government. Disease control planners could use this production data to set baseline and targets for implementing disease control activities like mass vaccination and disease awareness campaigns.

Survey results indicate that poultry ranks highly among livestock kept by rural farmers. Secondly, it contributes significantly to the rural households' monthly income with an average of 30% of their income. Despite its popularity, indigenous poultry is not adequately considered for funding by government agricultural extension and livestock disease control agencies because they prioritise cattle and other large livestock perceived to be more economically important (Mwacalimba and Green, 2014). This study, nevertheless, shows how popular poultry farming is among rural farming households and provides justification why veterinary and extension services should enhance the quality of their extension delivery methodologies for this subsector.

The level of poultry income contribution to the overall rural household income may indirectly indicate importance attached to poultry farming in respective regions. These areas need to be prioritised when planning for disease control and rural poultry production enhancement projects because increased funding for rural poultry in such regions may have greater socioeconomic impacts and vice versa. According to the survey results of this study, Petauke, Katete, Chadiza and Vubwi districts are high poultry income districts (Fig. 2), and hence need to be prioritised for rural poultry development.

The current stocking level of poultry in indigenous chickens is adequate for realising a positive return on investment in the first year of inception (Table 4). More still, indigenous chickens are more practically possible to rear for rural farmers who are challenged with resources for setting up a viable poultry enterprise because they require less production costs than broilers and layers (Mack et al., 2005; Akinola and Essien, 2011). Viability of indigenous chickens in this study was further demonstrated by the low breakeven point which implies fewer indigenous chickens need to be produced to realise a positive gain on investment compared to broilers and layers (Table 5). Extension officers can use these results to demonstrate the viability of the indigenous chickens to rural farmers.

Bearing in mind that 74% of poultry farmers in this study were unable to provide costs for their poultry enterprises, extension workers can utilise this weakness to initiate open information sharing sessions with farmers by introducing a simple GM analysis. Since all the farmers were unable to provide set up costs and some variable costs such as marketing and labour costs, attention can be given to these items as an example. To encourage participation and ownership of the budgeting lessons among farmers, extension workers would need to act as moderators rather than teachers. The plausibility of this approach is further supported by the fact that most poultry farmers interviewed in the survey had some form of education and experience (general information), thus implying most of them had sufficient numeracy and literacy skills that are required to fully participate in budgeting discussions.

Gross margin analysis was preferred over other conventional farm management, enterprise and business analysis techniques such as input and output analysis, enterprise budgets and whole-farm budgets because GMA would assist farmers to determine and monitor the performance of their business without accounting for fixed costs (Rushton, 2009). Thus, GMA would indicate the profit farmers would get from each poultry production systems that could be used for paying off loans used to acquire capital assets and other long-term investments (Malcolm et al., 2005). GMP is also used to compare the financial performance of different related enterprises (McCown, 2005; Rushton, 2009). Thus, in this study, GMP provided greater detail for farmers to understand the financial performance of their indigenous, broiler and layer chickens in a more practical and simpler manner (Table 4). On the other hand, breakeven analysis (Malcolm et al., 2005; Cafferky, 2010) was performed to determine how many product units each enterprise needed to sell to recover its costs and start realizing profit. This in turn would help assess which enterprise required the list number of product units to breakeven and thus be more practical to manage by rural poultry farmers whose financial and material resources for investments are usually low or non-existent. Thus, indigenous chickens were the most viable since they required less products to breakeven (Table 5).

Open information sharing sessions on GM budgets with poultry farmers would provide a foundation for leading them into discussing more complex financial analysis. An example of such analysis is the discounted cash flow (Malcolm et al., 2005; McCown, 2005; Rushton, 2009) which would assess the performance of the enterprises over several years in which repayment of capital investments including interests is spread over years and assigned a present value. This would in turn assist in assessing the value for the money that is spent on the three poultry production systems.

One way to increase farmers' consciousness to poultry mortality is by demonstrating its cost implications on their enterprises. Conducting GMA with a scenario where mortality rates for the indigenous, broiler and layer chickens were set at zero, would provide an opportunity to sensitize farmers to the importance of reducing poultry mortality in their flocks. This could then be followed by encouraging poultry farmers to use vaccinations as a mitigation measure for the problem. As a result, this could arouse farmers' interest in developing a vaccination calendar with an extension worker that relates the time of reproductive activity of indigenous chickens with important vaccinations. For instance, results of this study revealed that indigenous chickens had an average of three clutches per year. Thus, to ensure that all generations of chickens are adequately covered with

ND vaccinations should be carried out three times in a year. This is in line with the current strategy where ND vaccinations are recommended three times per year (Alders et al., 2002; Government-of-Republic-Zambia, 2015) as opposed to the current trend where ND vaccination in indigenous chickens are mostly done twice per year (Personal observation). Such an extension strategy could significantly reduce mortality rate in indigenous chickens which currently stands at 0.45.

Demonstration of a GMA scenario with mortality set at 0% may also arouse farmers' interest in analyzing cost implications of other production and health challenges among their flocks. Taking advantage of this opportunity, more open sharing sessions which identify, and analyses costs of possible challenges could be facilitated by the extension provider. Additionally, the extension provider may stimulate more interest by adding some of the documented challenges for rural poultry production to a list of those identified by farmers. Other than diseases, predation, malnutrition and extreme environmental conditions, have been previously identified as challenges leading to mortality (Harrison and Alders, 2010). Other challenges to rural poultry production include weight loss and drop in egg production (Harrison and Alders, 2010; Mtileni et al., 2012).

Farmers are known to make decisions based on their values and priorities and these values may vary between farmers and between members of a family (Gamble et al., 2003). They may make such decisions based on their subjective beliefs with those beliefs heavily dependent on their own experience (McCown, 2005). Thus, financial assessments like GMA and break-even analysis can be promoted by extension providers as tools for providing advice to rural poultry farmers as ultimate decision makers on the farm. This is because GM budgeting and breakeven analysis provide a systematic approach to a decision that includes development of a clear outcome to be achieved by the decision through development of models that build links between the decision and the desired outcome.

4.7 Conclusion and Recommendations

Description and financial analysis of the rural poultry enterprises using information provided by rural farmers can be used to reveal financial hazards that can be used by extension services to enhance service delivery and ensure sustainability of the rural poultry sector. Since the study analyses financial hazards, it forms part two of the hazard analysis component in the ensemble model (Figure 1-2).

4.8 Ethical Consideration and Acknowledgements

Permission to do this study was obtained from the Departments of Veterinary and Livestock Development, Ministry of Agriculture and Livestock in Zambia. The study was approved by the Human Research Ethics Committee of James Cook University (Application ID; H5830). It was funded by Australian Aid and James Cook University, Australia, with contributions from the National Research Foundation in Pretoria, South Africa.

The authors acknowledge D. Chilembo, C. Hapoma, C. Moono, E. Kafundanga, P. Mwango, N. Mulombwaluse, N. Alibandila, J. Ngambi, C. Mainza, J. Kabucha, W. Sinyangwe, N. Bilima, E. Sinzala and K. Mbumwae for their role in data collection and entry. Additionally, Dr A. Mumbolomena, Dr M. Sinzala, Mr J. Sikazindu and Ms M. Mwanza from the veterinary department as well as Mr D. Phiri from Petauke district council in Zambia are also recognised for their numerous contributions towards the success of this study.

4.9 References

Akinola, L.A.F., Essien, A., 2011. Relevance of rural poultry production in developing countries with special reference to Africa. World's Poultry Science Journal 67, 697-705.

Alders, R.G., Spradbrow, P.B., Young, M.P. (Eds.), 2009. Village chickens, poverty alleviation and the sustainable control of Newcastle disease. Proceedings of an international conference held in Dar es Salaam, Tanzania, 5–7 October 2005. ACIAR Proceedings No. 131, 235 pp

Bwalya, R., Kalinda, T., 2014. An analysis of the value chain for indigenous chickens in Zambia's Lusaka and Central provinces. Journal of Agriculture studies 2, 31-52.

Cafferky, M., 2010. Breakeven Analysis: The definitive guide to cost-volume-profit analysis. Business Expert Press. 222 East 46th Street, New York, United States of America.

Cockroft, P.D., Holmes, M.A. (Eds.), 2003. Handbook of Evidence-Based Veterinary Medicine. Blackwell Publishing.

Copland, J.W., Alders, R.G., 2009. The comparative advantages of village or smallholder poultry in rural development.Village chickens, poverty alleviation and the sustainable control of Newcastle disease Proceedings of an international conference held in Dar es Salaam Tanzania, 5–7 October 2005.ACIAR Proceedings No. 131, 235 pp. In: Alders, R.G., Spradbrow, P.B., Young, M.P. (Eds.).

Dolberg, F., 2008. Poultry production for livelihood improvement and poverty alleviation. In Proceedings of the International Conference Poultry in the Twenty-first Century: Avian

Influenza and Beyond. Proceedings of an International Poultry Conference, Bangkok, November 2007. [Online] Available: ftp://ftp.fao.org/docrep/fao/011/i0323e/i0323e.pdf.

FAO, 2003. Egg marketing: A guide for the production and sale of eggs. FAO Agricultural Services Bulletin 150.

Gamble, D., Blunden, S., Ramsay, G., 2003. Sustaining the family farm: an integrated approach linking social, business and environmental aspects. . In First Australian Farming Systems Conference, RIRDC, Toowoomba, Queensland. p 4.

GRZ, 2010. Census of population and housing, agriculture analytical report.https://www.zamstats.gov.zm/index.php/publications/category/11-2010-census?download=812:agriculture-census-analytical-report-2010. In: Office, C.S. (Ed.).

Guèye, E.H.F., 2000. Women and Family Poultry Production in Rural Africa. Development in Practice 10, 98-102.

Harrison, J.L., Alders, R.G., 2010. An assessment of chicken husbandry including Newcastle disease control in rural areas of Chibuto, Mozambique. Tropical animal health and production 42, 729-736.

Laerd-Statistics, 2015. Kruskal-Wallis H test using SPSS Statistics. Statistical tutorials and software guides. Retrieved from https://statistics.laerd.com/.

Mack, S., Hoffmann, D., Otte, J., 2005. The contribution of poultry to rural development. World's Poultry Science Journal 61, 7-14.

Malcolm, B., Makeham, J., Wright, V., 2005. The farming game: agricultural management and marketing. Cambridge University Press.

McCown, R.L., 2005. New Thinking About Farmer Decision Makers. . In The Farmer’s Decision: Balancing Economic Successful Agriculture Production with Environmental Quality (J.L. Hatfield, ed), Soil and Water Conservation Society, Ankeny, Iowa, USA. pp 11–44.

Moreki, J.C., Dikeme, R., 2011. Small livestock, food security, nutrition security and HIV/AIDS mitigation. [Online] Available: http://www.intechopen.com/download/pdf/pdfs_id/22357.

Msoffe, P.L., Bunn, D., Muhairwa, A.P., Mtambo, M.M., Mwamhehe, H., Msago, A., Mlozi, M.R., Cardona, C.J., 2010. Implementing poultry vaccination and biosecurity at the village level in Tanzania: a social strategy to promote health in free-range poultry populations. Tropical animal health and production 42, 253-263.

Mtileni, B.J., Muchadeyi, F.C., Maiwashe, A., Chimonyo, M., Mapiye, C., Dzama, K., 2012. Influence of socioeconomic factors on production constraints faced by indigenous chicken producers in South Africa. Tropical animal health and production 45, 67-74.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2016. A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia. Preventive veterinary medicine 133, 97-107.

Mutenje, M.J., Mapiye, C., Mavunganidze, Z., Mwale, M., Muringai, V., Katsinde, C.S., Gavumende, I., 2008. Livestock as a buffer against HIV and AIDS income shocks in the rural households of Zimbabwe. Development Southern Africa, 25(1), 75-82 http://dx.doi.org/10.1080/03768350701837754.

Mwacalimba, K.K., 2012. Globalised disease control and response distortion: a case study of avian influenza pandemic preparedness in Zambia. Critical Public Health 22, 391-405.

Mwacalimba, K.K., Green, J., 2014. ‘One health’ and development priorities in resource-constrained countries: policy lessons from avian and pandemic influenza preparedness in Zambia. Health Policy and Planning 1.

Roberts, J.A., undated. Utilisation of Poultry Feed Resources by Smallholders in the Villages of Developing Countries (available online)http://www.fao.org/docrep/004/AC154E/AC154E12.htm. FAO Document Repository.

Rushton, J., 2009. The economics of animal health and production. Cabi, Wallingford, UK.

Sheskin, D.J. (Ed.), 2003. Handbook of Parametric and Nonparametric Statistical Procedures: Third Edition. CRC Press.

Simainga, S., Moreki, J.C., Banda, F., Sakuya, N., 2011. Socio-economic study of family poultry in Mongu and Kalabo Districts of Zambia Livestock Research for Rural Development 23.

Sonaiya E.B., 2007. Family poultry, food security and the impact of HPAI. World's Poultry Science Journal 63, 132-138.

Songolo, A., Katongo, J.C., 2000. ‘Country report: Zambia’. In: Alders, R.G., Spradbrow, P.B. (Eds.), SADC planning workshop on Newcastle disease control in village chickens: Proceedings of an international workshop, ACIAR Proceedings 103, Maputo, Mozambique. 43-45.

Thrusfield, M. (Ed.), 2005. Veterinary Epidemiology. Blackwell Publishing Oxford UK.

Chapter 5

ASSESSMENT OF POULTRY MOVEMENT AND TRADING PRACTICES IN EASTERN ZAMBIA

Publications

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018. Combining value chain and social network analysis as a viable tool for informing targeted disease surveillance in the rural poultry sector of Zambia. Transboundary & Emerging Diseases, 1-11.

Conference Presentations

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B., 2017a. Analysis of poultry movement amongst rural poultry farms using social network analysis: an information tool for effecting targeted disease surveillance in eastern Zambia In, Proceedings of the 3rd International Conference on Animal Health Surveillance. www.animalhealthsurveillance.org., Rotorua, New Zealand.

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B., 2016. A study of Newcastle Disease and the utilisation of social networks and market chains to enhance food security in Zambia In, European College of Veterinary Public Health annual conference 2016, Swedish University of Agricultural Sciences, Uppsala, Sweden

5.1 Abstract

Infectious diseases are among the greatest challenges to the rural poultry sector in sub-Saharan Africa. The lack of a sustainable poultry disease surveillance system presents a need for targeted surveillance of poultry diseases in these regions. However, the establishment of such a system requires adequate knowledge of the sector in the targeted area. Zambia is an example of a developing country located in the tropics that faces the challenge of frequent poultry disease outbreaks. Consequently, an interview-based survey to study the poultry sector's market chain and social networks was conducted in Eastern Zambia to derive information required for configuring targeted surveillance. This survey involved a poultry value chain analysis that also included an assessment of trading practices to identify biosecurity hotspots within the chain that could be targeted for disease surveillance. A social network analysis of poultry movement within Eastern Zambia was also conducted using whole-network analysis and ego networks analysis to identify poultry trade hubs that could be targeted for poultry disease surveillance based on their centrality within the network and their size and influence within their ego networks. Rural farmers, middlemen and market traders were identified as biosecurity risk hotspots whose poultry could be targeted for disease surveillance within the value chain. Furthermore, social network analysis identified four districts as poultry trade hubs that could be targeted for disease surveillance. This study is the first to formally describe poultry movement networks within Zambia and the surrounding region. Its findings provide data required to implement targeted surveillance in regions where resources are either inadequate or non-existent, and the results provide a deeper understanding of the cultural and practical constraints that influence trade in developing countries.

5.2 Key Words

Rural poultry, social networks, value chain

5.3 Introduction

The importance of rural poultry production in tropical and subtropical developing countries cannot be overemphasised. Such production serves as the cheapest and most readily available source of protein to resource-poor households (Alders et al., 2009; Mtileni et al., 2013). Poultry production also provides a source of quick income in times when income from cash crops and other larger livestock such as cattle, pigs and goats is not available (Songolo and Katongo, 2000). In addition, rural poultry production is common amongst socially disadvantaged groups such as women and orphaned children who may be infected or otherwise affected by the HIV/AIDS pandemic (Copland and Alders, 2009).

Rural poultry refers to domesticated birds kept in small backyard poultry houses or left to scavenge in villages with some form of night shelter (Songolo and Katongo, 2000). Indigenous chickens are common among rural poultry found in the tropics and subtropics (Harrison and Alders, 2010; Msoffe et al., 2010; Mtileni et al., 2013), and other common species kept include ducks, geese, pigeons and guinea fowl. It is challenging to classify village chickens into breeds in Zambia as they are generally classified only as dwarf breeds with naked necks or as larger breeds (Songolo and Katongo, 2000). There are over 1.1 million small-scale poultry-raising households among the 1.5 million agricultural households in Zambia (GRZ, 2010a). At any given time, the stocking level of poultry in Zambia is composed of approximately 12 million broiler chickens, 11 million indigenous chickens and 3 million layers (Songolo and Katongo, 2000).

In Zambia, infectious diseases are among the greatest threats to rural poultry production (Songolo and Katongo, 2000). Newcastle disease (ND) caused by the Newcastle disease virus (NDV) is the most common disease that affects rural poultry in the country (GRZ, 2013). Other diseases that affect rural poultry in Zambia include avian influenza, mycoplasmosis, Gumboro disease, fowl pox, fowl cholera, helminthiasis and ectoparasite infestations (Songolo and Katongo, 2000; GRZ, 2010b). Due to limited resources, active surveillance of these diseases has been a challenge. Thus, veterinarians depend predominantly on passive surveillance in which farmers report diseases to state veterinary authorities.

The nutritional and socioeconomic importance of rural poultry subjects them to extensive movement within and between communities (Snoeck et al., 2009; Fringe et al., 2012). Rural poultry may be traded live at markets or as meat and other products in butcher shops (Martin et al., 2011; Paul et al., 2013). Movement of poultry and their products may involve the use of middlemen who buy birds from several farms and villages and resell them to larger markets or butcher shops. In Zambia, poultry may also be moved in the form of gifts to guests and other important members of rural communities such as traditional leaders during special occasions (Mwansa, 2004; Mudenda, 2008). Unfortunately, such movements are known to be accompanied by the spread of highly infectious poultry diseases such as ND and avian influenza (Firestone et al., 2011; Martin et al., 2011; Paul et al., 2013; Scharrer et al., 2015). As a result, communities that receive more poultry are at higher risk of exposure to infectious diseases (Poolkhet et al., 2013; Brioudes and Gummow, 2017).

The lack of a sustainable poultry disease surveillance system presents a need for targeted surveillance in resource-poor tropical and subtropical countries (Brioudes and Gummow, 2017).

Targeted surveillance involves placing surveillance systems in areas that are considered high-interaction areas or hotspots for livestock movement (Hoinville et al., 2013; Scharrer et al., 2015; Brioudes and Gummow, 2017). A continuous assessment of the poultry disease situation in these areas would serve to monitor the disease status for the region. Timing this targeted surveillance with occasions associated with increased poultry movement would further increase the effectiveness of early disease detection (Brioudes and Gummow, 2017).

The placement of targeted surveillance requires adequate knowledge of the targeted livestock sector in the targeted region (Stark et al., 2006; Calba et al., 2015). Such understanding includes a poultry value chain analysis that can lead to a deeper understanding of the rural poultry trade and its practices, which can in turn assist in identifying high-risk pathways that could be targeted for surveillance within the chain. Combining this information provides a basis for social network analysis (SNA) that could be used to plot poultry movement.

Poultry movement networks have been studied in some tropical regions, such as the Pacific Island Countries (PICS) (Brioudes and Gummow, 2017) and Asia (Martin et al., 2011; Poolkhet et al., 2013). Targeted disease surveillance systems have been evaluated for their value and efficiency in the developed world (Drewe et al., 2015). Unfortunately, despite serious problems with poultry diseases such as ND, few studies of the rural poultry sector and its movement networks have been conducted in sub-Saharan Africa, including Zambia. Thus, this study forms part 1 and 2 of the risk assessment component of the ensemble model (Figure 1-2) whose aim was to evaluate the feasibility of value chain and SNA in Eastern Zambia, as a tool for informing targeted surveillance within a rural African environment where resources and data to study complete networks are either inadequate or non-existent.

5.4 Materials and Methods

5.4.1 Study design

The study used part of the questionnaires used in chapter 4 as well as the same 459 poultry farmers sampled previously (Table 4-1 and Figure 4-1).

An attempt to capture all poultry and poultry product traders as well as their middlemen was made through follow up from poultry farmers' interviews and existing lists of poultry traders at local markets.

At least 50% of existing service providers who were veterinary officers and their assistants, health inspectors, market managers as well as other extension staff from relevant government and non-government organisations were reached through consultations with respective district veterinary and council offices.

5.4.2 Study procedures and data analysis

Interviews

Consent for the interviews and the actual interviews were conducted using procedures described in Chapter 4.

Interviews for this study were based on three questionnaires that targeted poultry farmers, poultry traders and service providers (Appendix 2-4). The questionnaires included a section that collected general information such as physical address followed by a section that collected data on the movement of poultry and trading practices. Table 5-1 shows details of the main questions that were asked to farmers, traders and service providers within the questionnaire used by this study.

Table 5-1: Main questions included in the questionnaire survey of farmers, poultry traders and service providers in eastern Zambia. * means a respective question was asked for that group of respondents.

Section	Question	Farmers	Traders	Service providers
General Information	Physical address	*	*	*
	GPS coordinates	*	*	*
	Gender	*	*	*
Poultry movement and trading practices	Any new live poultry entering farm or trading premises. If yes provide details	*	*	
	Poultry products entering farm or trading premises. If yes provide details	*	*	
	Use of middlemen for purchasing products into farms or trading premises	*	*	
	Any poultry sold or given out from farm or trading places. If yes provide details	*	*	
	Use of middlemen for selling live poultry from farm or trading premises	*	*	
	Use of middlemen for selling poultry products from farm or trading premises	*	*	
	When traders (or the middlemen) pick birds from their source		*	
	How live poultry is usually transported to the market or butcher shop		*	
	How live poultry is contained within the market or your shop		*	
	Customers for traders		*	
	How live birds are transported from the source to the point of sale		*	
	Are all the live birds sold in one day		*	
	Sell of products at the market or butcher shop		*	
	When traders (or the middleman) usually collect poultry products from their source		*	
	How poultry products are transported to point of sale		*	
Seasonality of trade	Periods over the year when there are more sales of poultry and its products than usual. If yes give details		*	
Operating procedures	Need for authorisation for selling live poultry or poultry products in the market or butcher shop		*	*
	Need for sanitary authorisation for selling poultry and its products in the market or butcher shop		*	*

Data storage

All the data obtained from interviews were then entered and stored in Epi Info® as data base files. When needed for analysis the tables required were exported to Excel where they were merged, sorted and edited, after which they were exported to a required software package for analysis.

Data analysis

To maintain confidentiality, all the data were deidentified.

Poultry value chain analysis

The SPSS 22® statistical package was used for statistical analysis. The data was tested for normality using the Kolmogorov-Siminov and the Shapiro-Wilk tests to decide whether to use the one way analysis of variance (ANOVA) test or its non-parametric equivalent, the Kruskall Wallis test to compare differences between groups (Laerd Statistics, 2015). For poultry products, a unit was equivalent to one poultry carcass, one egg, or 1 kg of dressed poultry meat or offal. Qualitative responses from respondents were analysed as frequencies.

Volumes of poultry passing through the value chain

The amount of live poultry and the associated products that passed through stakeholders within the value chain annually was analysed.

Identification of biosecurity risk hotspots within the value chain

Risk hotspots in the value chain were identified by assessing the seasonality, regulations, arrangement and practices of the poultry trade in Eastern Zambia using information provided by rural poultry farmers and traders in the survey.

Overview of the poultry value chain

A flow diagram showing various levels of the value chain and its key stakeholders in Eastern Zambia was developed to highlight disease risk hotspots in the chain that could be targeted to enhance disease surveillance.

Social network analysis

Conversion of cross-sectional data to social network data

Poultry movement data for live poultry and related products obtained through farmer and trader (combined) interviews were exported from Epi Info to Excel for merging and editing. Each unique destination of poultry and its matching origin were entered under two columns (origin and destination) in the spreadsheet. These data were then imported into Ucinet®, where the districts were assigned as nodes and the movement of poultry and downstream products between these nodes was assigned as ties (Borgatti et al., 2002; Hanneman and Riddle, 2005).

Network visualisation

The live poultry and product network was visualised as one network using Net Draw®, a software program embedded within Ucinet® (Hanneman et al., 2005). The socio graphs created were then edited and saved as jpeg files.

Whole-network analysis

Whole networks were assessed by calculating the centrality of each node in the network using the Freeman centrality measures method to assess the nodes using the normalised undirected degree for each node in Ucinet (Borgatti et al., 2002). The node with the highest value of the normalised degrees was most central and thus a poultry trade hub.

Ego networks analysis

The locations of sampled respondents were not evenly distributed in all districts (nodes), which would affect their ties and thus the accuracy of the whole-network analysis. Consequently, an ego networks analysis was also conducted by assessing the density measures of each ego in its neighbourhood. In this case, "ego" was an individual "focal" node (district). The "neighborhood" was the collection of ego and all nodes (altars) to whom the ego had a connection at some path length (Hanneman and Riddle, 2005). Density measures assessed were size, number of directed ties, brokerage and betweenness of each ego (Hanneman and Riddle, 2005). The following are brief descriptions of these measures as outlined by Hanneman and Riddle (2005):

The size of the ego network is the number of nodes that included one-step out neighbours of the ego, plus the ego itself. The number of directed ties is the number of connections among all nodes in the ego network. The number of ordered pairs is the number of possible directed ties in each ego network. The density is the number of ties divided by the number of pairs, representing the percentage of all possible ties in each ego network that are present. Brokerage is the number of pairs not directly connected. Normalized brokerage (brokerage divided by the number of pairs) assesses the extent to which the ego's role was that of the broker. Betweenness is when the ego is "between" two other actors if it lies on the shortest directed path from one to the other. The ego betweenness measure indexes the percentage of all geodesic paths from neighbour to neighbour that passes through the ego. Normalized betweenness compares the actual betweenness of the ego to the maximum possible betweenness in the neighbourhood of the size and connectivity of egos. The "maximum" value for betweenness is achieved when the ego is the centre of a "star" network, that is, when no neighbours communicate directly with one another and when all directed communications between pairs of neighbours go through the ego. Thus districts (egos) with the largest networks, normalised brokerage and betweenness were identified as being powerful and central where poultry movement and trade was concerned and vice versa.

Identification of poultry trade hubs

Nodes (districts) that were most centrally located in the whole-network analysis (based on the value of normalised degrees) and identified as influential egos in the ego networks analysis were thus identified as important poultry trade hubs that could be targeted for disease surveillance.

5.5 Results

5.5.1 Normality tests

The data were not normally distributed (Kolmogorov-Simonov test; $p<0.001$ and the Shapiro-Wilk test; $p<0.001$). Thus, the median value was used to analyse the quantitative data. Where comparisons between independent groups were required, the Kruskal Wallis test, followed by pairwise comparison with a Bonferroni adjustment, was conducted to test for statistical significance and identify which groups significantly differed from others (Laerd-Statistics, 2015).

5.5.2 General information

A total of 459 poultry farmers, 138 poultry traders and 82 service providers were interviewed across the Eastern Province of Zambia.

Among the farmers that were interviewed, 169 (36.8%) were female, and 290 (63.2%) were male. Their median experience in poultry farming was 12 years (range: 0-55). Only 14% of farmers had no educational background, while 59.5%, 21.8% and 1.1% attained primary, secondary and tertiary education, respectively.

Thirty-two percent of the traders were female, while 68.1% were male. The median poultry and poultry product trading experience among them was 4 years (range: 1-23).

For service providers, 19.5% of the respondents were female, while 80.5% were male; 53.7% of them were employed by the department of veterinary services, while 12.2%, 17.1%, 6.1%, 7.7% and 3.7% represented local councils, other non-government organisations, poultry associations, private para-veterinarians and missing responses, respectively.

5.5.3 Poultry value chain analysis

Volumes of live poultry handled by rural poultry farmers and traders annually

Live poultry

Overall, each farmer had received and gave away or sold a median of 3 (responses=47, range: 1-1800) and 32 (responses=104, range: 1-13,400) live birds in the last twelve months, respectively. Each trader had bought and sold a median of 120 (range: 3-54,750) and 150 (range: 1-5200) during the study period, respectively. Table 5-2 provides more details on the number of live poultry movements, their origins and destinations, and the Kruskal Wallis H test results with their accompanying post hoc test results. The Kruskall Wallis H test tested the statistical significance of the differences in medians between different origins and destinations for poultry and their products that entered and exited poultry farming households and trading premises.

Table 5-2: Movement of live poultry among farming households and trading premises per poultry farmers and poultry traders' responses in eastern Zambia.

Stakeholder	Nature of Movement	Origin/destination	Quantity (Median)	Test statistic (X^2)	Degrees of freedom	Significance (P)	Significant Post hoc test results (Adj. Sig)
Rural farming household	Entry	Hatchery agent	150	8.7	2	0.013	None
		Rural farmer	2				
		Commercial farm	4				
	Exit	Rural farmer	3	9.9	3	0.019	Rural farmer-Village market (0.015)
		Village market	7				
		Commercial farm	5				
		Butcher shop	2				
Trading premises	Entry	Village market	200	21.6	4	<0.001	Rural farmer- Hatchery agent (<0.001)
		Hatchery agent	200				
		Commercial farmer	110				
		Rural farmer	40				
		Own backyard	100				
	Exit	Butcher shop	10	15.4	6	0.029	Restaurant- Village farmer (0.029)
		Consumer	100				
		Commercial farm	50				
		Rural farmer	50				
		Restaurant	50				
		School	520				
		Village market	400				

Among live poultry entering households, day-old chicks from commercial hatcheries were the most common (49% of responses) followed by indigenous chicks, indigenous chickens, commercial layers and mature broilers, representing 19.9%, 7.1%, 7.7% and 2.6% of the responses, respectively. The type of live poultry that left farming households was 87% indigenous chickens, while broilers, commercial layers, pigeons and ducks were recorded at 3.8%, 1.4%, 2.1% and 0.7%, respectively.

Poultry products

An overall median of 60 (range: 1-6912) and 25 (range: 1-712) poultry product units had entered and left poultry farming households in the previous 12 months, respectively. In addition, a median of 8850 (range: 730-730,750) and 4380 (range: 365-146,000) poultry product units had been bought and sold by poultry farmers and traders during the study period, respectively. More details about the amount of poultry product movement, their sources and destinations, and the Kruskal Wallis test results with accompanying post hoc test results are presented in Table 5-3.

Table 5-3: Movement of poultry products among rural poultry farms and trading premises per responses from poultry farmers and traders in eastern Zambia.

Premise	**Nature of Movement**	**Origin/destination**	**Quantity (Median)***	**Test statistic (x^2)**	**Degrees of freedom**	**Significance (P)**	**Significant Post hoc test results (adj. sig)**
Rural farming household	Entry	Rural farmer	455	8	5	0.154	None
		Village market	56				
		Butcher shop	9				
		Commercial farm	63				
		Other shop	160				
	Exit	Rural farmer	10	3.5	2	0.172	None
		Village market	403				
		Butcher shop	23				
Trading premises	Entry	Middleman	2190	7.6	6	0.269	None
		Own backyard	1825				
		Butcher shop	18250				
		Rural farmer	3285				
		Commercial farm	29200				
		Village market	1825				
		Other shop	127750				
	Exit	Butcher shop	5475	3.6	3	0.311	None
		Consumers	3650				
		Other shop	14600				
		Restaurant	4380				

*1 unit of livestock product was either 1 egg, 1 kg of poultry manure, 1 dressed poultry carcass or 1kg of poultry meat and offal.

Eggs were the most common product that entered farming households (72%), followed by chicken meat (8%), whole chicken carcasses (6%) and offal (6%). Similarly, eggs were the most common product that left farming households (31%), followed by manure (23.8%), whole bird carcasses (11.9%), offal (7.1%) and chicken meat (2%).

Identification of biosecurity risk hotspots within the poultry value chain

Seasonality of trade

Only 48.4% of farmers experienced months with increased trade in poultry and its products. These farmers were then asked to give details of the month during which they experienced more trade of poultry and its products. Most poultry trade occurred in December, followed by January and June; March had the least trade. Christmas was the most common occasion associated with increased trade, followed by weddings, New Year celebrations and crop harvests (Figure 5-1A).

Only 73.2% of traders were aware of periods of increased poultry trade and associated occasions. December was identified as having the most trade (due to Christmas celebrations), followed by January (associated with New Year celebrations). Again, the least trade occurred in March (Figure 5-1B).

Occasions associated with increased trade that were unique to farmers were breeding, annual general meetings, family needs and purchase of farm inputs while garden labour and hidhi were unique to traders.

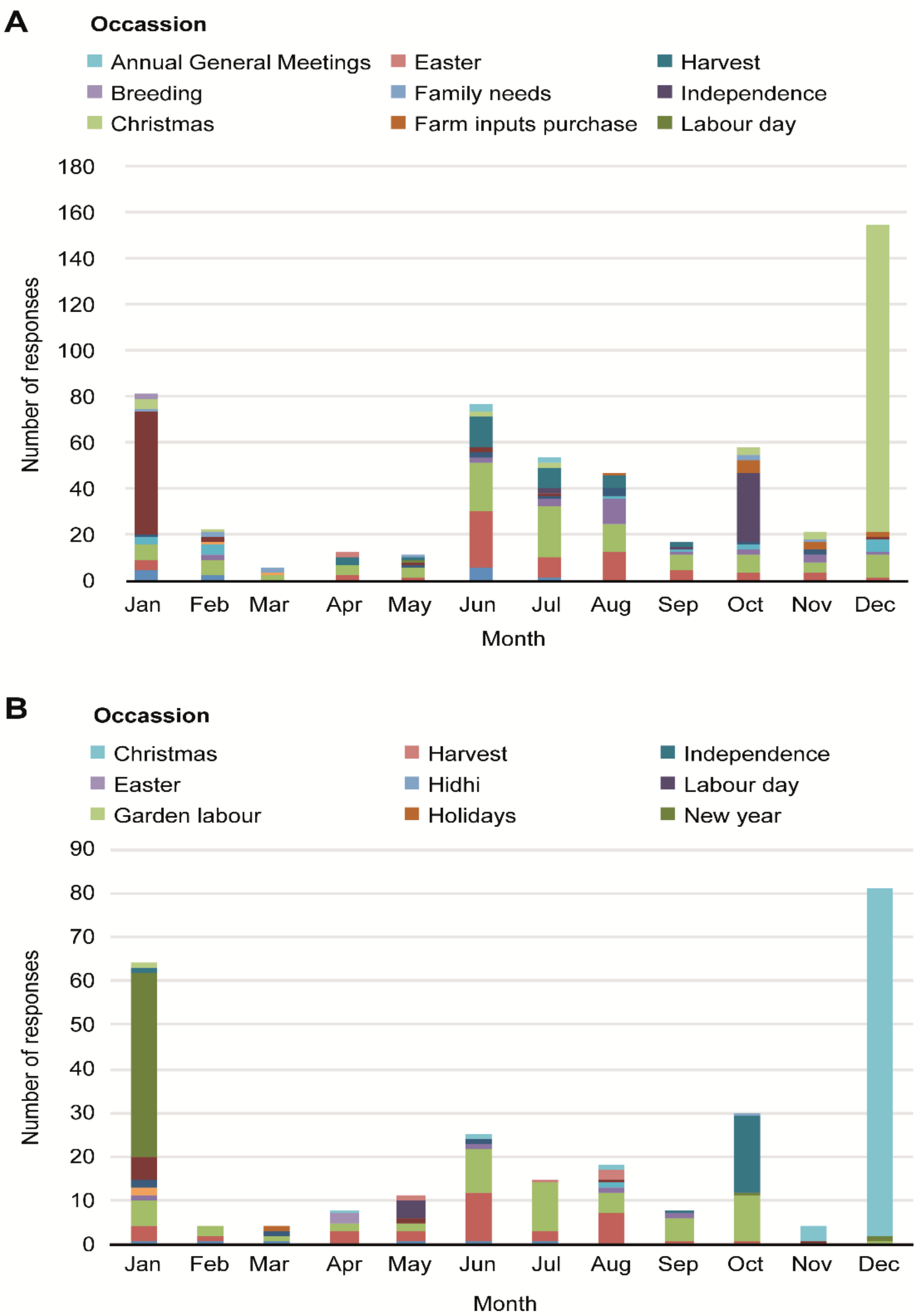


Figure 5-1: Monthly trends of poultry trade in Eastern Zambia according to data provided by farmers (A) and traders (B) during the poultry survey conducted from October 2014 to January 2015. Blocks labelled undefined in A and B represent increased trade that was not matched with any occasion in respective months.

Regulations for poultry trade

Among traders, 64.5% were aware that they needed to obtain authorisation to trade in live poultry from the veterinary department and local councils. Furthermore, 61.6% of them were aware of the need to obtain authorisation to trade in poultry products. In addition, 70.7% of service providers were aware that traders need authorization to trade in poultry and its products. However, only 26.8% of them reported that farmers obtain this authority. When asked the percentage of traders that they thought obtained authority in their operational areas, the median response was that 30% of traders obtained authority.

Poultry trading arrangement

Among farmers, only 5.2% reported using middlemen to purchase poultry, while 3.5% reported using middlemen for poultry sales. Additionally, only 3.9% and 5.4% of farmers used middlemen in the purchase and sale of poultry products, respectively. For traders, 12.3% and 3.6% of them used middlemen for the purchase and sale of their poultry and its products, respectively. In addition, 31.7% of service providers said that middlemen were involved in the trade of poultry and its products.

Poultry trading practices

Containment and transportation of live poultry

When traders were asked when they collected live poultry from its sources, 20% of them said they collected them a few days before sales, while 36% of them said they collected the poultry the same day of sales. There was no response from 44% of traders to this question. To transport live poultry to markets, bicycles were the most popular, followed by cars, trucks, walking and public buses (Figure 5-2A). When at the market, 97% of traders said they kept their poultry in cages, while 2% and 1% of them tied birds together to a fixed point and used other means, respectively. For the unsold poultry, 83% of traders brought them back home and took them back to the market for sale the following day for sale.

Storage and transportation of poultry products

Poultry traders said they kept poultry products at home for an average of 8 days before taking them to the shop or market (responses=19, standard deviation=5.58, range: 2-20). The car was the most popular means of transporting poultry products, followed by a bicycle, a truck and walking (Figure 5-2B). Fifty-one percent of traders reported that poultry products were not refrigerated during transportation, while 39% of them did not give a response. Furthermore, only 21% said that they kept their poultry products refrigerated at the market or shop.

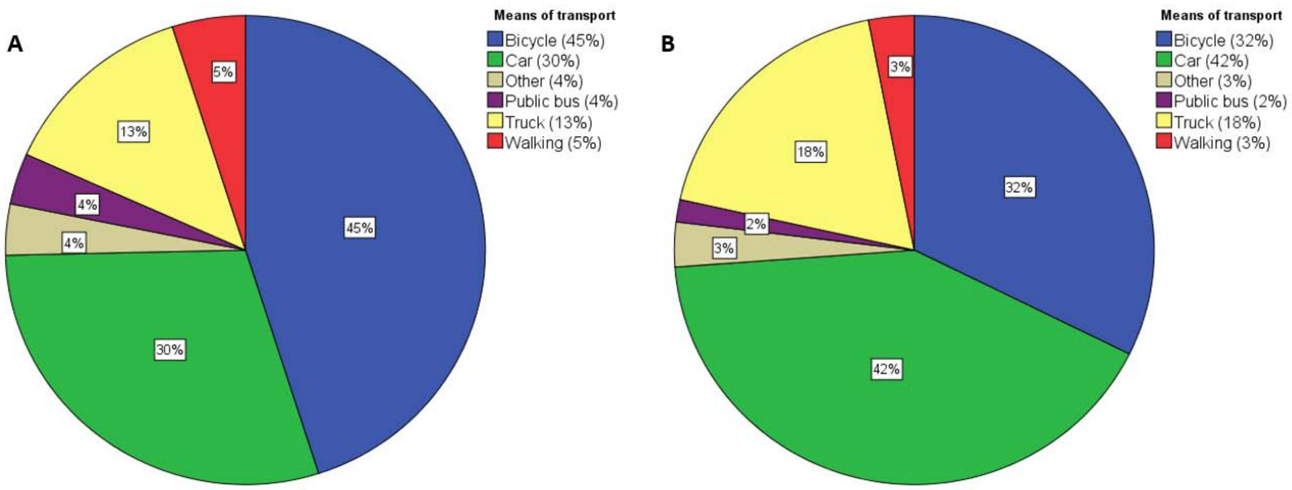


Figure 5-2: Means of transporting live poultry (A) and poultry products (B) to markets in Eastern Zambia according to data provided by traders and farmers during the poultry survey conducted from October 2014 to January 2015.

Overview of the poultry value chain

According to the data provided by poultry farmers and traders, stakeholders of the value chain in Eastern Zambia could be grouped into four levels. The first and highest level was that of primary poultry producers (hatcheries and agents), followed by secondary poultry producers, traders and consumers (Figure 5-3).

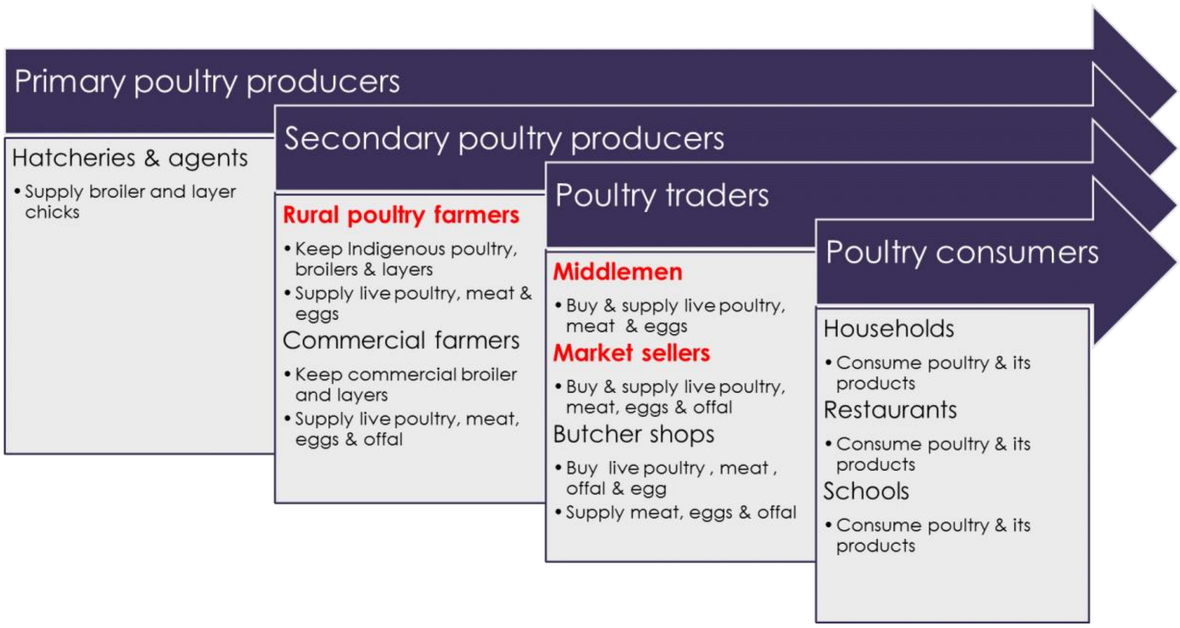


Figure 5-3: An overview of the poultry value chain and the identified biosecurity hotspots (red) in Eastern Zambia according to the data provided by farmers and traders during the poultry survey conducted from October 2014 to January 2015.

5.5.3 SNA of poultry movement in the rural poultry sector

Only 43% (197 from 459 farmers interviewed) of farmers reported details of destinations and origins of poultry and its products in the previous year while all the 82 traders interviewed provided these details.

Network Visualisation

A total of 11 nodes were identified in the network for poultry and its products (Fig. 5). The first nine nodes were districts where farmer and trader interviews were conducted, while Lusaka (the capital city of Zambia) and other countries were identified by respondents who mentioned them as either destinations or origins of their live poultry and products. All districts in the Eastern Province of Zambia conducted trade of poultry and its products among themselves and thus had reflexive ties (Figure 5-4).

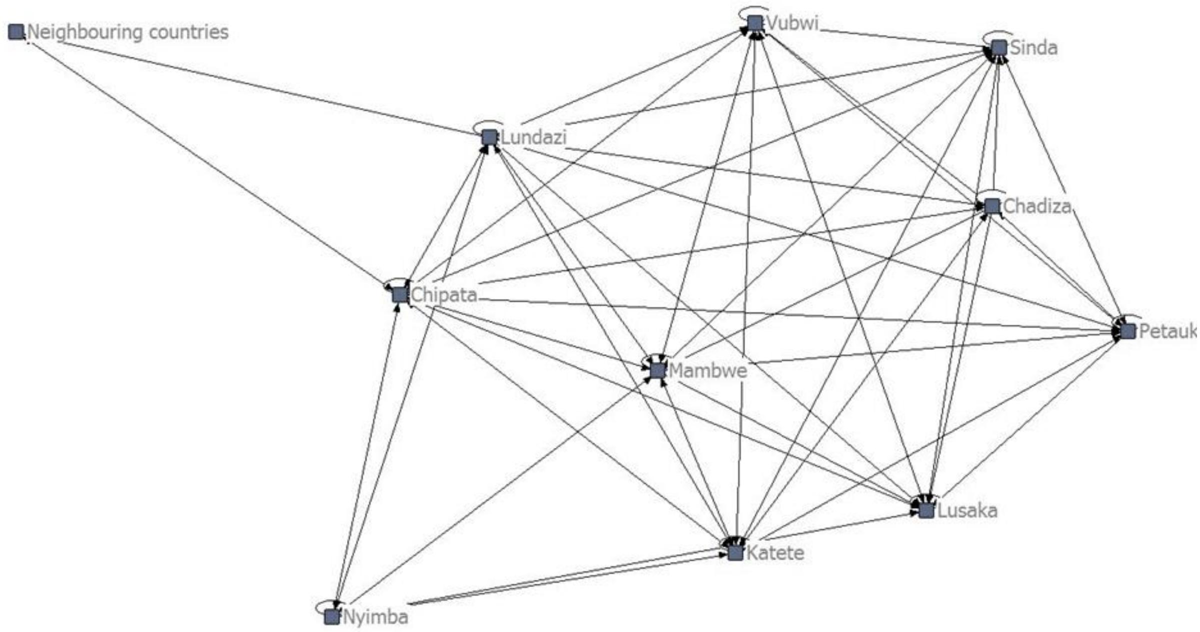


Figure 5-4: Network visualisation for annual poultry and product movement among each district of Eastern Zambia according to the data provided by rural poultry farmers and traders during the poultry survey conducted from October 2014 to January 2015.

Whole-network analysis

The Freeman degree centrality results revealed that Chipata District was the most central and thus the most influential node in the network, with a normalised degree of 0.16, followed by the districts of Katete, Lundazi, Petauke and Mambwe (Table 5-4).

Table 5-4: Freeman centrality measures for annual poultry movement in each district of Eastern Zambia and other regions that trade with them according to data provided by farmers and traders during the poultry survey conducted from October 2014 to January 2015.

District (node)	Degrees	Normalised degrees
Chipata	467	0.16
Katete	181	0.06
Lundazi	177	0.06
Petauke	147	0.05
Mambwe	120	0.04
Sinda	105	0.04
Chadiza	96	0.03
Vubwi	69	0.02
Nyimba	57	0.02
Lusaka	22	0.01
Neighbouring countries	4	0.00
Network centralisation		**0.14**

Ego networks analysis

Chipata had the largest network (size=10, ties=51, normalised brokerage=0.43, and normalised betweenness=25), followed by Lundazi, Katete, Chadiza, Mambwe (Table 5-5). Lusaka was an altar for most egos (districts). Larger ego networks also had the highest normalised brokerage and ego betweenness (Table 5-5). A higher normalised brokerage implies that a high number of altars depends on the ego for a connection, while a higher normalised ego betweenness indicates how central the egos are in their network. Thus, normalised brokerage and normalised ego betweenness indicate how powerful and central a district is within its neighbourhood.

Table 5-5: Ego network density measures of annual poultry movements for each district of Eastern Zambia according to data provided by farmers and traders during the poultry survey conducted from October 2014 to January 2015.

Ego (district)	Size	Ties	Pairs	density	N. brokerage	N. betweenness
Chipata	10	51	90	56.67	0.43	25
Lundazi	10	54	90	60	0.4	6.67
Katete	8	42	56	75	0.25	6.16
Vubwi	8	46	56	82.14	0.18	4.18
Mambwe	9	53	72	73.61	0.26	3.01
Nyimba	5	15	20	75	0.25	2.92
Petauke	8	45	56	80.36	0.2	2.46
Sinda	8	46	56	82.14	0.18	0.87
Lusaka	8	42	56	75	0.25	0.74
Chadiza	8	47	56	83.93	0.16	0.51
Other country	2	2	2	100	0	0

Identification of poultry trade hubs

Based on centrality within the whole poultry network (Table 5-4) and size, high brokerage and betweenness within their ego networks (Table 5-5), the districts of Chipata, Lundazi, Katete and Mambwe were identified as important poultry trade hubs of Eastern Zambia.

5.6 Discussion

Assessing seasonality of trade for poultry and its products enables efficient timing of disease surveillance (Brioudes and Gummow, 2017) i.e., surveillance can be conducted during or just before the anticipated increase in trade of poultry and its products. Increased trade of poultry and its products occurred in the months of January, June, October and December, as associated with several commercial and social occasions (Figure 5-1). Because of the high level of interaction with poultry during these periods, the risks of poultry disease transmission and outbreaks may increase. Interestingly, reaction to disease outbreaks was also mentioned as one of the occasions that trigger high sales of poultry and its products, which may worsen disease dissemination. For instance, from the 24 outbreaks reported in 2014 (World Animal Health Information System data base, 2014), reaction to disease outbreak as a reason for selling poultry received one, six, four and two responses from rural farmers in August, October and December respectively (not displayed in Figure 5-1 due to scaling).

Obtaining authority for trade in poultry and its products is meant to act as a critical control point for service providers. Despite 64.5% of traders being aware of the need for authorization to move and trade poultry, only 26.8% of them obtained it. This outcome could be a result of the cost associated with acquiring the stock movement permit (Parliament of Zambia, 2010) and the long distances between most rural farms and district veterinary offices where permits are obtained, thus demotivating farmers and traders. The implication of this condition is that in the event of an outbreak, only 26.8% of traders would have the source and destination of their poultry and their products traced. Therefore, adequate sensitization of traders on the need to obtain authorization would have a positive impact on poultry disease surveillance and follow up during outbreaks.

Rural poultry farmers, middlemen and poultry market sellers were identified as biosecurity hotspots whose poultry could be targeted for disease surveillance because of the way they conducted poultry trade (Figure 5-3). Middlemen can play a key role in the spread of poultry diseases from one village to another as they buy and sell poultry and its products (Martin et al., 2011). Knowledge of these movements would therefore aid in locating hotspots for disease transmission thus facilitating targeted surveillance. In this study, only 5.2% of farmers indicated use of middlemen to trade their poultry. Middlemen might have been missed due to possible bias in sampling and selection of respondents. Alternatively, Zambia might not have many middlemen in its poultry trade networks. The former is most likely because other studies conducted in Asia (Van Kerkhove et al., 2009) and Africa (McCarron et al., 2015) identify middlemen as critical players in the transmission of poultry diseases.

Restricting movement of manure by ensuring that only manure from ND-free flocks can leave its farm of origin would be another important target for reducing the spread of ND because manure was revealed as the second most popular poultry product that left farming households. Manure was typically sold directly to other rural farmers and farming households and through village markets. Manure has been identified as one of the largest risks to the spread of the NDV (Kinde et al., 2004) because the virus can survive in manure for as long as 53 days (Lancaster, 1966; Kinde et al., 2004); thus, awareness of the risks by farmers before they transport their manure to other farms may significantly reduce the spread of the disease. In addition, the veterinary department could reduce risk by including manure on the list of poultry products and by-products that require a mandatory movement permit for transportation.

The finding of this study that bicycles and cars were the most popular means of transporting poultry is consistent with other reports that indicate bicycles are the most common form of transport within Eastern Zambia (Minde and Nakhumwa, 1998; Davis, 2000) and most developing regions of the world where rural live-poultry trade exists (Minde and Nakhumwa, 1998). Viruses in manure on bicycle and car tyres also make them important fomites in disease transmission, and feathers that may also harbour viruses can be dispersed by vehicles and bicycles as poultry is being moved. Thus, bicycles and cars should be targeted when controlling outbreaks to reduce spread.

The Freeman centrality measure for each district assessed the centrality of each district within the whole poultry network of Eastern Zambia. Since this method assesses the entire network, its results are more reliable than that of ego networks analysis where identifying poultry trade hubs is concerned. Thus, if disease surveillance is placed in a district with a high normalised degree such as Chipata, the probability for early detection of poultry disease is high. SNA results further revealed that a risk exists of poultry disease transmission from other provinces within Zambia and neighbouring countries into Eastern Zambia (Fig. 3). Such a scenario requires regional collaboration when conducting poultry disease surveillance.

The ego networks analysis further demonstrates that it is possible to target districts that have large networks and are centrally located within their ego networks as targets for disease surveillance. For instance, conducting disease surveillance in Chipata District would indirectly encompass 10 other districts within its neighbourhood. The efficiency and justification for extrapolating survey results to other districts or camps may depend on the brokerage and ego betweenness of the respective ego network. In this study, the brokerage and ego betweenness of the districts identified as poultry trading hubs was high, implying that if a disease outbreak occurred within the neighbourhood, the probability of detecting it within that neighbourhood before it spreads further is higher because most districts within the neighbourhood are not connected to each other but directly connected to a district in focus. Furthermore, if the outbreak were first detected at the ego (district), a quick disease-prevention response would be instituted because its neighbourhood would be known. The SNA results where bigger and more densely populated districts where identified are similar to some studies conducted in Kenya (McCarron et al., 2015).

Education and experience for most farmers and traders were sufficient for them to provide reliable information on poultry movement and trade. However, the accuracy of reports from farmers, particularly for seasonality of trade, may be influenced by memory bias (Schacter, 1999), which was not accounted for in this study.

Despite the possibility of memory bias, the results of this study form the risk assessment component of the ensemble model (Figure 1-2) by showing that hubs of high poultry interaction through trade and other movements exist within Zambia. This condition may be similar within the Southern African region, and a need therefore exists to expand the study to neighbouring countries. These hotspots may be associated with high disease transmission and could serve as targets for early disease detection. Bearing in mind that developing countries have limited resources, targeted surveillance may provide a cost-effective option for enhancing poultry disease surveillance (Brioudes and Gummow, 2017). Additionally, prior knowledge of hotspots and actors for respective ego networks could assist in disease control by isolating these components promptly (Poolkhet et al., 2013) through livestock movement bans in the event of disease outbreaks. Furthermore, the findings of this study can be used by other stakeholders in the poultry sector. For instance, poultry input suppliers would know areas where they need to take more products, and pharmaceutical companies could distribute poultry drugs and vaccines to these hotspots since more outbreaks would be anticipated in these areas.

5.7 Conclusion

This study forms the risk assessment component of the ensemble model (Figure 1-2). its findings demonstrate that it is possible to use value chain and SNA, as a tool for informing targeted surveillance within a rural African environment where resources and data to study complete networks are either inadequate or non-existent.

5.8 Ethical Considerations and Acknowledgements

Permission to perform the study was obtained from the Departments of Veterinary and Livestock Development, Ministry of Agriculture and Livestock in Zambia. The study was approved by the Human Research Ethics Committee of James Cook University (Application ID; H5830) and was funded by Australian Aid and James Cook University, Australia, with contributions from the National Research Foundation in Pretoria, South Africa.

The authors acknowledge D. Chilembo, C. Hapoma, C. Moono, E. Kafundanga, P. Mwango, N. Mulombwaluse, N. Alibandila, J. Ngambi, C. Mainza, J. Kabucha, W. Sinyangwe and K. Mbumwae for their role in data collection. They also thank N. Bilima and E. Sinzala for entering data. Finally, Dr A. Songolo, Dr A. Mumbolomena, Dr M. Sinzala, Mr J. Sikazindu and Ms M. Mwanza from the veterinary department and Mr D. Phiri from the Petauke District Council in Zambia are also acknowledged for their numerous contributions towards the success of this study.

5.9 References

Alders, R. G., Spradbrow, P. B. & Young, M. P., 2009: Village chickens, poverty alleviation and the sustainable control of Newcastle disease, ACIAR, Dar es Salaam, Tanzania, 5–7 October 2005.

Borgatti, S. P., Everett, M. G. & Freeman, L. C., 2002: Ucinet 6 for Windows: software for social network analysis. Analytic Technologies, Harvard.

Brioudes, A. & Gummow, B. (2017). Understanding pig and poultry trade networks and farming practices within the Pacific Islands as a basis for surveillance. Transboundary and Emerging Diseases, 64, 284-299.

Calba, C., Goutard, F. L., Hoinville, L., Hendrikx, P., Lindberg, A., Saegerman, C. & Peyre, M. (2015). Surveillance systems evaluation: a systematic review of the existing approaches. BMC Public Health, 15, 448.

Copland, J. W. & Alders, R. G., 2009: The comparative advantages of village or smallholder poultry in rural development. Village chickens, poverty alleviation and the sustainable control of Newcastle disease, ACIAR, Dar es Salaam Tanzania, 5–7 October 2005.

Davis, A. (2000). Transport and sustainable rural livelihoods in Zambia: a case study. Egypt Social Fund for Development, Transport Research Laboratory, Zambia.

Drewe, J. A., Hoinville, L. J., Cook, A. J., Floyd, T., Gunn, G. & Stark, K. D. (2015). SERVAL: a new framework for the evaluation of animal health surveillance. Transboundary and Emerging Diseases, 62, 33-45.

Firestone, S. M., Ward, M. P., Christley, R. M. & Dhand, N. K. (2011). The importance of location in contact networks: describing early epidemic spread using spatial social network analysis. Preventive Veterinary Medicine, 102, 185-195.

Fringe, R., Bosman, A. M., Ebersohn, K., Bisschop, S., Abolnik, C. & Venter, E. (2012). Molecular characterisation of Newcastle disease virus isolates from different geographical regions in Mozambique in 2005. The Onderstepoort Journal of Veterinary Research, 79, E1-7.

GRZ, 2010a: Census of population and housing, agriculture analytical report. In: CSO (ed). Lusaka.

GRZ, 2010b: Protocols of livestock disease control in Zambia. Lusaka: Department of Veterinary Services.

GRZ. (2013). Annual report for the Departments of Veterinary Services and Livestock Development-Eastern province of Zambia. 1-49.

Gueye, E. F. (2002). Employment and income generation through family poultry in low-income food-deficit countries. World's Poultry Science Journal, 58, 541-557.

Hanneman, R. A. & Riddle, M., 2005: Introduction to social network methods Riverside: University of California, Riverside.

Harrison, J. L. & Alders, R. G. (2010). An assessment of chicken husbandry including Newcastle disease control in rural areas of Chibuto, Mozambique. Tropical Animal Health and Production, 42, 729-736.

Hoinville, L. J., Alban, L., Drewe, J. A., Gibbens, J. C., Gustafson, L., Hasler, B., Saegerman, C., Salman, M. & Stark, K. D. (2013). Proposed terms and concepts for describing and evaluating animal-health surveillance systems. Preventive Veterinary Medicine, 112, 1-12.

Kinde, H., Utterback, W., Takeshita, K. & McFarland, M. (2004). Survival of exotic Newcastle disease virus in commercial poultry environment following removal of infected chickens. Avian Diseases, 48, 669-674.

Laerd-Statistics. (2015). Kruskal-Wallis H test using SPSS Statistics. Statistical tutorials and software guides.

Lancaster, J. E., 1966: Newcastle disease-a review between 1926 and 1964. Ottawa: Health of Animals Branch, Canada Department of Agriculture.

Martin, V., Zhou, X., Marshall, E., Jia, B., Fusheng, G., FrancoDixon, M. A., DeHaan, N., Pfeiffer, D. U., Soares Magalhaes, R. J. & Gilbert, M. (2011). Risk-based surveillance for avian influenza control along poultry market chains in South China: the value of social network analysis. Preventive Veterinary Medicine, 102, 196-205.

McCarron, M., Munyua, P., Cheng, P. Y., Manga, T., Wanjohi, C., Moen, A., ... & Katz, M. A. (2015). Understanding the poultry trade network in Kenya: Implications for regional disease prevention and control. Preventive veterinary medicine, 120(3-4), 321-327.

Minde, I. J. & Nakhumwa, T. O., 1998: Unrecorded cross-border trade between Malawi and neighboring countries. Office of Sustainable Development, Bureau for Africa, US Agency for International Development.

Msoffe, P. L., Bunn, D., Muhairwa, A. P., Mtambo, M. M., Mwamhehe, H., Msago, A., Mlozi, M. R. & Cardona, C. J. (2010). Implementing poultry vaccination and biosecurity at the village level in Tanzania: a social strategy to promote health in free-range poultry populations. Tropical Animal Health and Production, 42, 253-263.

Mtileni, B. J., Muchadeyi, F. C., Maiwashe, A., Chimonyo, M., Mapiye, C. & Dzama, K. (2013). Influence of socioeconomic factors on production constraints faced by indigenous chicken producers in South Africa. Tropical Animal Health and Production, 45, 67-74.

Mudenda, G. S. (2008). 5 on the road to cultural preservation emerging trends in Zambia. Preserving the cultural heritage of Africa: crisis or renaissance?, 1, 64.

Mwansa, P. K. (2004). African traditional religion: its status? Religion and Education in Zambia, 1, 34.

Parliament of Zambia, 2010: Animal Health Act. Act No. 27 of 2010. Lusaka: National Assembly of Zambia.

Paul, M., Baritaux, V., Wongnarkpet, S., Poolkhet, C., Thanapongtharm, W., Roger, F., Bonnet, P. & Ducrot, C. (2013). Practices associated with highly pathogenic avian influenza spread in traditional poultry marketing chains: social and economic perspectives. Acta Tropica, 126, 43-53.

Poolkhet, C., Chairatanayuth, P., Thongratsakul, S., Yatbantoong, N., Kasemsuwan, S., Damchoey, D. & Rukkwamsuk, T. (2013). Social network analysis for assessment of avian influenza spread and trading patterns of backyard chickens in Nakhon Pathom, Suphan Buri and Ratchaburi, Thailand. Zoonoses Public Health, 60, 448-455.

Schacter, D. L. (1999). The seven sins of memory. Insights from psychology and cognitive neuroscience. American Psychologist, 54, 182-203.

Scharrer, S., Widgren, S., Schwermer, H., Lindberg, A., Vidondo, B., Zinsstag, J. & Reist, M. (2015). Evaluation of farm-level parameters derived from animal movements for use in risk-based surveillance programmes of cattle in Switzerland. BMC Veterinary Research, 11, 149.

Snoeck, C. J., Ducatez, M. F., Owoade, A. A., Faleke, O. O., Alkali, B. R., Tahita, M. C., Tarnagda, Z., Ouedraogo, J. B., Maikano, I., Mbah, P. O., Kremer, J. R. & Muller, C. P. (2009). Newcastle disease virus in West Africa: new virulent strains identified in non-commercial farms. Archives of Virology, 154, 47-54.

Songolo, A. & Katongo, J. C., 2000: 'Country report: Zambia'.

Stark, K. D., Regula, G., Hernandez, J., Knopf, L., Fuchs, K., Morris, R. S. & Davies, P. (2006). Concepts for risk-based surveillance in the field of veterinary medicine and veterinary public health: review of current approaches. BMC Health Services Research, 6, 20.

Thrusfield, M., 2005: Veterinary epidemiology, 3 edn. Oxford: Blackwell Publishing.

Van Kerkhove, M. D., Vong, S., Guitian, J., Holl, D., Mangtani, P., San, S., & Ghani, A. C. (2009). Poultry movement networks in Cambodia: implications for surveillance and control of highly pathogenic avian influenza (HPAI/H5N1). Vaccine, 27(45), 6345-6352.

Chapter 6

ASSESSMENT OF SYNDROMIC DATA OBTAINED DIRECTLY FROM POULTRY FARMERS AS A VIABLE DISEASE REPORTING TOOL AND MEANS OF EVALUATING REMEDIES AND MEASURES FARMERS USE TO MITIGATE POULTRY DISEASES IN EASTERN ZAMBIA

Publications

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018. Is syndromic data from rural poultry farmers a viable poultry disease reporting tool and means of identifying likely farmer responses to poultry disease incursion? Preventive veterinary medicine 153, 84-93.

Conference Presentations

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B., 2017. An evaluation of syndromic data from rural poultry farmers as a viable disease reporting tool using Eastern Zambia as a model In, Proceedings of the 9th South African Veterinary & Para veterinary & SASVEPM Congress.

6.1 Abstract

Syndromic surveillance is a well described tool used in developed countries for alerting authorities to livestock disease incursions. However, little work has been done to evaluate whether this could be a viable tool in countries where disease reporting infrastructure and resources is poor. Consequently, a syndrome-based questionnaire study in Eastern Zambia was designed to gather data on previous encounters farmers had had with poultry diseases. Descriptive statistics and logistic regression were used to analyse the data.

Farmers reported an overall annual disease incidence in rural poultry for eastern Zambia of 31% (90% CI 29-32%). Occurrence of poultry disease in the last 12 months was associated with use of middlemen to purchase poultry products (p=0.05, OR=7.87), poultry products sold or given away from the farm (p=0.01, OR=1.92), farmers experiencing a period with more trade of poultry and its products (p=0.04, OR=1.70), presence of wild birds near the farm or village (p=0.00, OR=2.47) and poultry diseases being reported from neighbouring farms or villages (p=0.00, OR=3.12). The study also tentatively identified three poultry diseases (Newcastle Disease, Gumboro Disease and Fowl Pox) from the thirty-four disease syndromes provided by farmers. Farmers reported an incidence of 27% for Newcastle Disease in 2014. When compared with the state veterinary services data which reported Newcastle Disease incidence at 9% in 2014, it seems syndromic data obtained from farmers may be more sensitive in identifying disease incursion but may be significantly less specific.

This study shows that syndromic data obtained from farmers is a useful disease reporting tool and could be used as an effective means of alerting authorities to disease incursion. In addition, it shows that these data can provide an estimate of incidence for certain diseases and could be also useful in assessing significant risk factors associated with disease occurrence.

6.2 Key Words

Rural poultry, syndromes, surveillance, traditional remedies.

6.3 Introduction

Rural poultry production has a great potential for providing food security in developing countries, because it requires a relatively small investment to initiate its production (Mtileni et al., 2012). The low capital inputs required make small-scale poultry farming ideal for disadvantaged community members, like widows and orphaned children, whose numbers continue to increase because of the huge impact the HIV/ AIDS pandemic exerts in these regions (Mutenje et al., 2008; Moreki and Dikeme, 2011). Poultry is a reliable source of protein and as a commodity, has the potential to increase household income. For instance, Zambia, a developing country within the tropical sub-Saharan region with a human population of 13 million, has over 11 million rural poultry kept by an estimated number of 1, 164, 000 households (GRZ, 2011; Songolo and Katongo, 2000).

Unfortunately, successful production of rural poultry in developing countries like Zambia is hindered by high poultry mortalities which are mostly due to infectious poultry diseases (Songolo and Katongo, 2000), like Newcastle Disease (ND). The current disease surveillance strategy for poultry diseases in this region is mainly passive. It involves farmers reporting poultry diseases to the nearest veterinary technician who reports the disease/s monthly to the epidemiology unit based on clinical cases reported by farmers and collects samples which are submitted to the district and regional veterinary diagnostic laboratories for confirmation. Unfortunately, field technicians often face logistical challenges that prevent them following up cases to confirm disease syndromes (Mumbolomena A., Provincial Veterinary Officer, Personal communication). It is therefore highly likely that this passive nature of disease data collection results in underreporting of outbreaks.

Regular active surveillance for poultry diseases is vital in order to reduce reporting and response times (Jebara, 2004; Perry et al., 2009). Unfortunately, active surveillance for poultry diseases is infrequently conducted because it requires significant amounts of resources, which the government may not provide because of other socio-economic priorities (Perry, 2002; Graham et al., 2013). Consequently, a form of surveillance which targets areas with a high risk or incidence of poultry disease outbreaks would be beneficial (Brioudes and Gummow, 2015). Syndromic surveillance systems, which may involve using farmers in reporting syndromes may be beneficial as an early warning system for livestock disease detection (Mack et al., 2007; Sawford, 2011), if they are placed in identified disease hotspots.

Whereas syndromic surveillance has been utilised for early detection of outbreaks, to follow the size, spread, and tempo of outbreaks, to monitor disease trends, and to provide reassurance that an outbreak has not occurred in developed countries and some countries in Asia (Wu et al., 2008; Van Metre et al., 2009), it has been underutilised in real time detection of livestock diseases in sub-Saharan Africa. Establishing it in such regions requires a reliable and efficient source of disease data, yet little has been published as to availability and reliability of such data sources in these regions. Rural poultry farmers are a possible source of this data as they are usually the first to observe disease syndromes amongst their flocks, but it is not known how viable this data is.

In this context, rural poultry farmers in Eastern Zambia were interviewed to find out how they would report poultry diseases with the view of assessing whether rural farmers in developing countries would be a viable source of data for a syndromic reporting system. This study formed part of the syndromic surveillance component of the ensemble model (Figure 1-2).

6.4 Materials and Methods

Study design

The same 459 farmers sampled in chapters 4 and 5 were used as an extension of the poultry farmer survey (Table 4-1 and Figure 4-1) whose aim was to evaluate the usefulness of syndromic data derived from farmers as a means of improving the current disease reporting system utilised within veterinary services, as well as assess control measures and remedies farmers use to mitigate syndromes.

Study procedures and data analysis

Interviews

An information sheet and consent form were provided to respondents before the commencement of interviews. After reading and understanding these documents, they were requested to sign the consent form. Interviews for each of the questionnaires lasted approximately 80 minutes per respondent. GPS coordinates for all respondents were captured by the enumerators at the time of the interviews.

Poultry farmer questionnaire

The questionnaire for poultry farmers had four sections, 1. personal details that included the name, gender, address and exact location of the poultry farming household, 2. farm structure and income, 3. information on poultry movement and trade, 4. interaction of poultry with wild birds and poultry syndromes, which included information on poultry morbidity, mortality and existing disease control measures, and 5. Famers' access to veterinary services. This article focusses on questionnaire data that enabled analysis of access to veterinary services, production, morbidity and disease syndromes including possible risk factors associated with occurrence of poultry diseases among the rural poultry farming households of Eastern Zambia in the last 12 months. Table 6-1 shows the questions that were used to assess the relationship between possible risk factors and occurrence of poultry disease in the last 12 months. The entire questionnaire is available in Appendix 2.

Table 6-1: Questions derived from the questionnaire and used as predictor variables (Risk factors), in the Univariate logistic regression model for determining significantly associated risk factors associated with poultry disease in the preceding 12 months (Y/N) in Eastern Zambia during a survey conducted in 2014.

Serial	Section	Question
1	Poultry husbandry practices	Mixing of poultry with other animals from other
2	Poultry movement and trade	Any new live poultry entering the farm or household
3		Use middlemen to purchase live poultry
4		Use middlemen to sell live poultry
5		Use of middlemen to purchase poultry products**
6		Use middlemen to sell poultry products
7		Any poultry products sold or given away from the farm
8		Noticed a period with more trade of poultry and its products
9	Interaction of poultry with wildlife	Noticed any presence of wild birds near the farm or village
10		Noticed wild birds sharing common habitat with poultry
11	Poultry diseases	Noticed any disease occurrence from other farmers

**Poultry products included chicken meat, eggs, chicken offal and poultry manure

To determine poultry farmer's level of contact with the existing disease control extension system, they were asked who they contacted first to assist them when an outbreak of disease occurred in their respective poultry flocks.

For syndromic data, poultry farmers were initially asked whether they had any deaths or sick birds in their flocks over the last 12 months. If the response to this question was positive, they were further asked to give details of the number and type (indigenous, broiler and layer chickens, ducks, guinea fowl etc.) of poultry affected. They were then requested to describe syndromes they observed for respective types or categories of poultry that was affected. Syndromic responses were given as farmers understood them, local names for conditions and diseases were also recorded and translated to English by enumerators who understand and speak the local languages used in Eastern Zambia.

Some experienced farmers could give a diagnosis for common diseases and conditions in the region based on their previous encounters and feedback from veterinary extension services as well as poultry disease handbooks. Once farmers gave a response for the disease or conditions, follow up questions on syndromes regarding the disease or condition they reported were asked to the farmers to check whether they were consistent with the reported disease. For instance, a farmer that observed greenish diarrhoea, paralysis, twisted necks and high mortalities among their flock could report the event as ND. Nevertheless, these reports were still assumed to be syndromes since most of them were not confirmed.

Data storage

The questionnaire data and their associated tables were recreated and stored in EpiInfo®, and later exported to either Microsoft Excel®, IBM SPSS statistics version 24® or NCSS version 11® for analysis. To maintain confidentiality, all the data was de identified.

Data analysis

Descriptive analysis was used to analyse quantitative and qualitative data using the statistical software. Results were reported as frequency scores presented as a number or percentage of responses.

Syndromic data provided by farmers was sorted and aligned with known poultry diseases and conditions in the region based on literature and clinical presentation of confirmed respective poultry disease cases from past laboratory reports obtained from veterinary services.

Crude morbidity rates were computed by dividing the total number of sick birds reported by the total population of poultry recorded for the study. Breed specific morbidity rates were calculated by dividing the number of sick birds from a specific breed by the total number of birds from that breed recorded in the study (Tottori et al., 1997; Thrusfield, 2005).

Logistic regression

Univariable analysis

Based on plausibility, eleven factors were identified from the questionnaire as possible risk factors for poultry disease occurrence on the farms in the last 12 months (Table 6-2,) and were included in the initial univariable analysis as dependant or predictor variables. In this analysis, the eleven factors were tested individually for their unconditional association with the occurrence of poultry diseases on the farm in the last 12 months (outcome variable) using the Chi square test (Chaka et al., 2013) in the IBM SPSS® version 24 software. The outcome variable was based on the question "Have there been any deaths or sick birds in your flock over the last 12 months".

Multivariable analysis

Risk factors with a p value of ≤ 0.15 in the univariable analysis, were included in the multivariable logistic regression model which involved a stepwise forward model building algorithm using NCSS® version 11. The likelihood ratio Chi-square test was used in the algorithm as a selection criterion for inclusion and exclusion of a factor at the next step of the model (Gilbert et al., 2006; Laerd-Statistics, 2015). Thus, at each stage, a risk factor was only included if its removal from the model would lead to a significant change in the likelihood ratio ($p<0.05$).

For each variable included in the model's equation, the regression coefficient (B), estimated odds ratio (OR), 95% confidence interval (CI) for OR and the P values were reported. The analysis of deviance was used as a goodness of fit test for the final logistic regression model (Laerd-Statistics, 2015).

Modelling of poultry morbidity

Ninety percent confidence intervals for true annual disease incidence among each poultry type was computed using @Risk, a risk analysis and simulation software (Pallisade-corporation, 2015) which was set at 10000 iterations using the Latin Hypercube sampling technique. For this analysis, poultry type specific disease incidence rates were converted to a Pert distribution function (Pallisade-corporation, 2015) which has three parameters: a minimum, maximum, and most likely (mode). Unlike the triangular distribution, the Pert distribution is a special type of Beta distribution which uses these parameters to create a smooth curve that fits well to the normal or lognormal distributions (Vose et al., 2004). This was done using the 'fit distribution' button to fit the incidence data to the pert distribution followed by running the 'simulate' button within the @Risk software. In this study, the Pert distribution was used to determine the probability of the incidence of poultry disease, in each poultry population at risk if annual poultry disease incidence was measured 10000 times. Selection of the Pert distribution function was also based on the assumption that syndromic data was obtained from farmers who were assumed to be experienced in identifying syndromes but not specific poultry diseases.

Comparison of farmer ND incidence reports with state veterinary reports

To determine how effective syndromic data directly obtained from farmers was at detecting poultry diseases within the rural poultry population of Eastern Zambia, ND apparent incidence for this study was calculated by dividing the total number of cases that were tentatively identified by farmers as ND by the population of poultry at risk in the study period. The population at risk was the total number of birds owned by farmers who were sampled in the study at the beginning of 2014. Computed provincial apparent ND incidence was then compared to the 2014 ND data for Eastern province supplied by veterinary services to the OIE through their Word Animal Health Information System data base (OIE, 2017).

6.5 Results

6.5.1 General Information

A total of 459 poultry farmers were interviewed across the Eastern province of Zambia. Among these, 169 (36.8%) were female and 290 (63.2%) were male. Their average experience of poultry farming was 14.1 years (SD=11.79). Only 14% of farmers had no education background while 59.5%, 21.8% and 1.1% attained primary, secondary and tertiary education respectively.

6.5.2 Rural poultry farmers' access to veterinary services

When poultry farmers were asked who their first contact in case of a poultry disease was, 56.1% of them said they never asked anyone, 18.1% asked another experienced farmer, 10.4% contacted veterinary department personnel, 9.4% contacted private para-veterinarians and 3.7% contacted community leaders or headmen while 1.7% of them said they contacted other people not specified above.

6.5.3 Poultry diseases

Two hundred and sixty-nine (59%) farmers said they had witnessed an incidence of poultry disease at their farm in the past 12 months. Among these farmers, only 25% of them obtained laboratory diagnosis for the observed diseases. Additionally, 63.4% of them said they were aware of poultry diseases affecting other neighbouring villages. Lastly, all farmers that reported disease in their flocks had found at least one dead bird in their flock at some point in time during the study period.

Poultry diseases and syndromes

Thirty-four poultry disease syndromes were identified by farmers (Table 6-2). From these, three diseases namely, Newcastle Disease, Fowl Pox and Gumboro disease were tentatively identified.

Additionally, chronic respiratory disease, ectoparasite and endoparasite infestations, were also identified as conditions (Figure 6-1). The highest number of disease syndromes was reported in indigenous chickens (568 events) followed by broilers (99 events) (Table 6-2). An event represents a single time when a syndrome was reported by the respondents.

Table 6-2: Cross tabulation of disease syndromes (rows) according to poultry types (columns) reported by farmers in Eastern Zambia during a survey conducted in 2014. The values represent a number of times the syndrome was reported for a respective poultry type.

Syndrome	**Broilers**	**Guinea fowl**	**Indigenous**	**Layers**	**Others**	**Total**
Bloody diarrhoea	8	0	18	3	0	29
Chronic Respiratory Disease	1	0	2	0	0	3
Coughing	11	1	93	3	0	108
Death	2	0	19	0	0	21
Diarrhoea	5	1	52	1	0	59
Difficulty in breathing	4	0	2	0	0	6
Droopy wings	21	0	7	0	0	28
Dullness	0	1	17	0	1	19
Emaciation	0	0	1	0	0	1
Fever	0	0	1	0	0	1
Fowl Pox	0	1	5	0	0	6
Froth	0	0	2	0	0	2
Green diarrhoea	0	0	1	0	0	1
Gumboro	0	0	1	0	0	1
Inflamed skin	8	0	0	0	0	8
Lacrimation	0	0	8	0	0	8
Lameness	0	0	2	0	0	2
Loss of appetite	1	0	17	0	0	18
Mites	0	0	3	0	0	3
Newcastle Disease	20	2	164	3	2	191
Paralysed limbs	6	0	33	0	0	39
Rough feathers	0	0	12	0	0	12
Sneezing	0	0	1	0	0	1
Sores	0	0	1	0	0	1
Swollen eyes	1	1	16	2	0	20
Swollen heads	2	0	35	3	0	40
Ticks and fleas	2	0	15	0	0	17
Twisted necks	1	0	5	0	0	6
Vomiting	0	0	2	0	0	2
Weakness	0	1	2	0	0	3
Weight loss	1	0	4	0	0	5
White diarrhoea	2	1	23	0	0	26
Worms	0	0	1	0	0	1
Yellow diarrhoea	3	0	3	0	0	6
Total	**99**	**9**	**568**	**15**	**3**	**694**

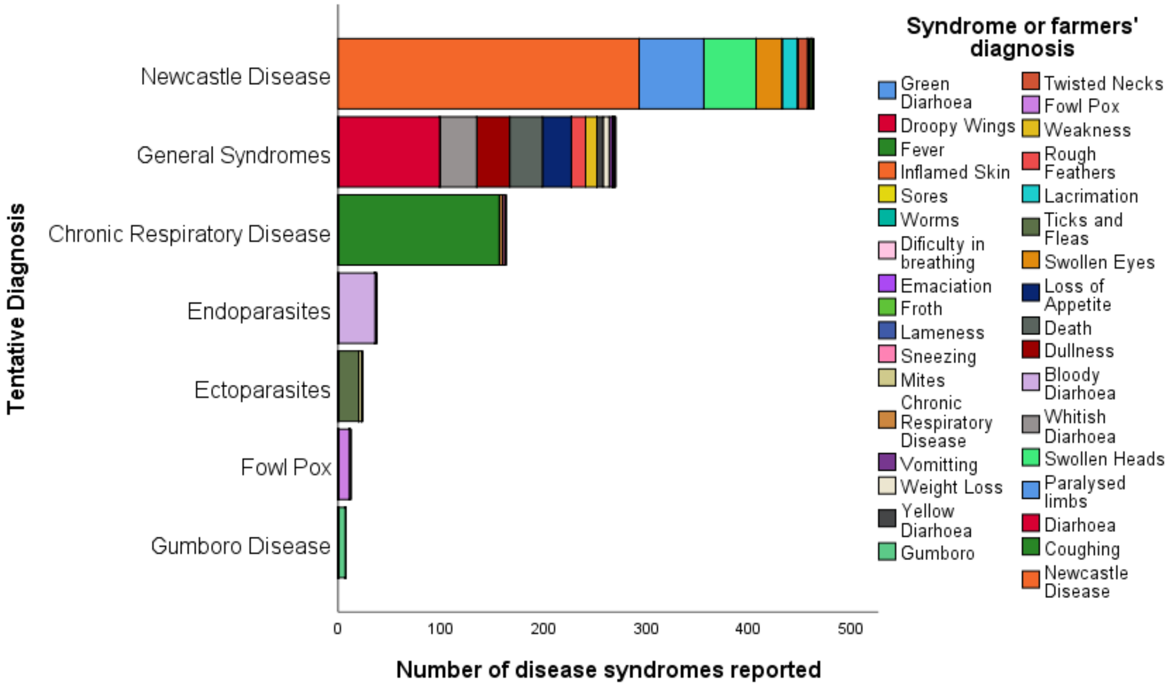


Figure 6-1: A tentative diagnosis of poultry diseases and conditions derived from 34 syndromes reported by poultry farmers of Eastern Zambia during a survey conducted in 2014. The colour of the band in a stacked bar corresponds to the name and colour of the reported syndrome or diagnosis in the legend.

Annual crude morbidity among rural poultry

Farmers reported that the five most frequent syndromes ("Newcastle Disease", bloody diarrhoea, greenish diarrhoea, coughing and paralysis), resulted in an overall annual crude disease incidence of 31%. The highest breed specific disease incidence in 2014 was among indigenous chickens (40%) followed by broilers (30%), guinea fowl (29%), and layers (5%).

Risk factors associated with occurrence of poultry diseases

From the 459 farmers interviewed only 447 farmers could give a yes or no answer for the variables being evaluated while questionnaires from the rest of farmers had missing answers, thus only 447 farmers were included in the logistic regression model.

Univariable analysis

From the eleven identified independent variables (possible risk factors) only six factors; mixing of poultry with other animals from other farms ($p<0.01$), use of middlemen to purchase poultry products ($p=0.04$), poultry products sold or given away from the farm ($p<0.01$), farmers experiencing a period with more trade of poultry and its products ($p<0.01$), presence of wild birds near the farm or village (p≤0.001) and poultry diseases being reported from neighbouring farms or villages (p<0.01) (Table 6-2) were identified as significantly associated with poultry disease occurrence by the univariable analysis and thus were included in the final multivariable analysis.

Table 6-3: Univariable logistic regression model of risk factors associated with poultry disease in the last 12 months (Yes/No) in eastern Zambia according to responses provided by 447 farmers during a survey conducted from October 2014 to January 2015.

Variable and Level	Frequency	P value*
1. Mixing of poultry with other animals from other farms?		**<0.01**
No	274	
Yes	148	
2. Any new live poultry that entered the farm in the last 12 months?		0.45
No	288	
Yes	128	
3. Use of middlemen to purchase live birds?		0.29
No	340	
Yes	23	
4. Use of middlemen to sell live birds?		0.21
No	391	
Yes	15	
5. Use of middlemen to purchase poultry products		**0.04**
No	364	
Yes	16	
6. Use of middlemen to sell poultry products?		0.26
No	353	
Yes	24	
7. Any poultry products sold or given away from the farm in the last 12 months?		**<0.01**
No	228	
Yes	188	
8. Noticed a period with more trade of poultry and its products?		**<0.01**
No	207	
Yes	214	
9. Noticed any presence of wild birds near the farm or village?		**<0.01**
No	132	
Yes	301	
10. Noticed wild birds sharing common habitat with poultry?		0.69
No	274	
Yes	148	
11. Noticed any disease occurrence from other farmers within the village or nearby villages?		**<0.01**
No	128	
Yes	281	

Multivariable analysis

The final multivariable regression model reported that five factors, use of middlemen to purchase poultry products in the last 12 months (p=0.05, OR=7.87), poultry products sold or given away from the farm in the last 12 months (p=0.01, OR=1.92), farmers experiencing a period with more trade of poultry and its products in the last 12 months (p=0.04, OR=1.70), presence of wild birds near the farm or village in the last 12 months ($p<0.01$, OR=2.47) and poultry diseases being reported from neighbouring farms or villages in the last 12 months ($p<0.01$, OR=3.12) were significant risk factors for increased incidence of poultry disease in a poultry farming household of eastern Zambia (Table 6-3).

The final log likelihood and R^2 for the regression model were -194.24 and 0.62 respectively (Table 4). The analysis of deviance test reported that all significant risk factors with P in the final logistic model (Table 6-4) would lead to a significant change if they were removed from the model ($p<0.01$).

Table 6-4: Final multivariable logistic regression model of risk factors associated with poultry disease in the last 12 months (Yes/No) in eastern Zambia per responses provided by 447 farmers during a survey conducted in 2014.

Independent variable	**Regression Coefficient**	**Odds Ratio (OR)**	**95% CI (OR)**	**P-Value***
Use of middlemen to purchase poultry products = Yes	2.06	7.87	0.96-64.5	0.05
Any poultry products sold or given away from the farm = Yes	0.65	1.92	1.16-3.16	0.01
Noticed a period with more trade of poultry and its products = Yes	0.53	1.70	1.03-2.81	0.04
Noticed any presence of wild birds near the farm or village = Yes	0.90	2.47	1.46-4.16	<0.01
Noticed any disease occurrence from other farmers within the village or nearby villages = Yes	1.14	3.12	1.89-5.16	<0.01

* Significant associated risk factors have $p\leq0.05$.
The analysis of deviance test reported that all significant risk factors in the final logistic model significantly improved model fit (Increase from model deviance or chi square= 66.56, $p<0.01$).

Modelling of overall annual poultry crude morbidity

Modelling of overall annual disease incidence of rural poultry estimated a 90% confidence interval (CI) for true disease incidence of between 29-32% (Table 6-4).

Table 6-5: Computed breed specific disease incidence rates and their respective 90% confidence interval for true incidence using a pert distribution function when simulating disease incidence reported by rural poultry farmers of eastern Zambia during a survey conducted in 2014.

Breed	**Disease incidence**	**90% confidence interval for true incidence**
Broilers	0.30	28.1-31.9%
Guinea Fowls	0.29	27.2-30.8%
Layers	0.05	4.7-5.3%
Indigenous Chickens	0.40	37.5-42.5%
Overall disease incidence	0.31	28.9-31.6%

6.5.4 Comparison of farmer ND incidence reports with state veterinary services reports

The total number of poultry disease cases reported by farmers in 2014 was 5092 and the total population of poultry owned by farmers in the survey was 18834. Therefore, the incidence of ND for this study in 2014 was 27%. This was much higher than the OIE data reported ND incidence of 9% in 2014, calculated from ND reports retrieved from the WAHIS site of the OIE (Table 6-6).

Table 6-6: Incidence of Newcastle Disease in the Eastern province of Zambia in 2014 according to the World Animal Health Information System data base (OIE, 2017).

Month	**Number of outbreaks**	**Number of birds at risk**	**Number of cases**	**Incidence**
January	3	3993	134	0.03
February	1	342	56	0.16
March	1	712	146	0.21
April	2	700	166	0.24
May	2	51	10	0.20
June	2	357	71	0.20
July	4	15587	461	0.03
August	3	1340	266	0.20
September	4	1901	643	0.34
October	1	540	220	0.41
November	1	484	83	0.17
December	No data	No data	No data	No data
Overall	**24**	**26007**	**2256**	**0.09**

6.6 Discussion

It seems syndromic data obtained from farmers may be more sensitive in identifying poultry diseases than the current system being used in Zambia because it reported a higher incidence of ND than the later. Rural farmers in Eastern Zambia rarely report poultry diseases to competent authorities. Additionally, many of them do not implement recommended disease control measures for respective poultry diseases and conditions (Mubamba et al., 2018). This reveals a serious gap in liaison between rural poultry farmers and their local veterinary service providers which may lead to underreporting of poultry diseases. This may be the reason why this study, which obtained data directly from farmers, reported a higher incidence of ND (27%) compared to the ND reports provided by state veterinary services to OIE (9%). The other reason why there is under reporting is because the current disease reporting system uses a top to down approach where farmers are mandated by veterinary services to report livestock diseases instead of the Participatory Epidemiology approach where farmers and veterinary services are equal partners and share responsibility in disease reporting (Jost et al., 2007; Ozcatalbas et al., 2011). On the other hand, the apparent high incidence of ND reported by farmers may also be due to misclassification of the disease and memory bias (Schacter, 1999), since some farmers may be inconsistent in identifying syndromes especially when they are reported in local languages (Queenan et al., 2017).

The disparity of ND incidence between results of this study and the OIE reports may also be because Zambia is not a poultry exporting country and thus may have less commitment to report to the OIE. In this regard, a recent retrospective study that followed up monthly morbidity reports submitted to the district and provincial office in Eastern Zambia reported an even lower annual ND incidence of 1.7% in 2014 where only 72% of the expected reports reached the provincial office (Mubamba et al., 2016). In the same year, OIE reported an annual ND incidence of 9%. Thus, even though most of the ND cases reported by farmers in this study were not confirmed, the high incidence recorded makes it more sensitive as an early warning tool for poultry diseases than state veterinary and OIE reports.

Farmers reported thirty-four disease syndromes that affected their poultry (Table 6-3) which could be further identified as three diseases and three conditions (Fig. 6-1), supporting the usefulness of syndromic data for disease surveillance and early detection of poultry disease outbreaks. However, this approach has not yet been utilised for early detection of livestock diseases in sub-Saharan countries like Zambia where surveillance has been passive and mainly dependant on morbidity reports (Mubamba et al., 2016). Thus, under-reporting and late response to disease outbreaks is not uncommon in this region. Placement of a syndromic surveillance system that utilises syndromic data provided directly by farmers could be an effective solution to this problem (Brioudes and Gummow, 2015; Goutard et al., 2015). Particularly, because the field veterinary technician to poultry farmer's ratio in developing countries like Zambia can be very low. For instance, based on the 2013 annual provincial veterinary report (GRZ, 2013), in Chipata district of eastern Zambia, this ratio is estimated at 1:5000. Implying one technician must monitor and report disease occurrence among 5000 farming households. Thus, the probability of technicians covering all these households is low and could lead to late reporting of poultry diseases. A possible solution to this problem would be to select sentinel farmer groups who could routinely provide syndromic data in hubs where disease transmission of poultry diseases is most probable (Brown et al., 2015; Goutard et al., 2015). In Eastern Zambia, hubs have been identified in Chipata, Lundazi, Katete and Mambwe towns by Mubamba et al. (2018a) using Social Network Analysis.

Logistic regression results revealed key risk factors for presence of disease among rural poultry of Eastern Zambia (Table 6-4), and another extension of what syndromic data could be used for. The identification of these factors may be used as a criterion for prioritizing disease surveillance. For example, a farm or poultry rearing household that trades poultry and its products, has wild birds present near it and whose poultry mixes with animals from other farms (Table 6-4), could be prioritized during sampling for disease surveillance thus leading to more cost-effective and efficient detection of disease in the population (Martin et al., 2011; Brioudes and Gummow, 2015; Schärrer et al., 2015). However, the significance of the result for the variable regarding presence of wildlife near the farm or village was not expected because the role of wild birds in transmitting poultry diseases is mostly not highlighted in literature except for their role in the transmission of Avian Influenza.

Even though presence of wild birds near the farm or village was identified as a significant risk factor associated with presence of poultry disease in the last 12 months (Table 6-4), their role in transmitting the NDV is reported to be less significant compared to other modes of transmission like introduction of infected birds and fomites to non-infected flocks (Gilchrist, 2005). However, the vast NDV genomic diversity which is favoured by the availability of highly mobile wild bird reservoirs (Miller et al., 2010), may lead to transmission of highly pathogenic strains of NDV by wild birds in this region in the future. For instance, NDV of low virulence known to be present in wild birds in Australia had undergone mutation and occasionally infected poultry (Alexander et al., 2012).

The low layer chicken morbidity (0.05) reported by this study compared to indigenous chicken, broiler and guinea fowl morbidity (0.40, 0.30 and 0.29) may indicate better competence in following proper husbandry practices and vaccination programs by farmers. Morbidity due to diseases among unvaccinated indigenous chickens and guinea fowls that were previously viewed to be more disease resistant, could also be due to more virulent strains of NDV recently isolated from Eastern Zambia

(Abolnik et al., In Press). Thus, the high indigenous chicken morbidity reported by this study indicate a need to prioritize extension and disease control programs such as mass vaccinations among the indigenous chicken sector to reduce losses.

Other than “Newcastle Disease”, the syndromes most frequently reported by farmers were related to the gastrointestinal tract (diarrhoea, greenish diarrhoea, yellowish diarrhoea, whitish diarrhoea and bloody diarrhoea) followed by the respiratory system (coughing, difficulty in breathing and “chronic respiratory disease”) (Table 6-2). Thus, for poultry disease control programmes in this region to be effective, they could prioritise mitigating and prevention of diseases that show diarrhoea and respiratory syndromes using mass treatments and vaccinations respectively. On the other hand, there were very few reports of ectoparasites despite odds favouring them to be easily noticed as they are usually visible (Table 6-2). More still, there were equally few reports of endoparasites and fowl pox (Table 6-2 and Figure 6-1). This could imply that parasite and fowl pox control methods currently used by farmers in this region could be working effectively or it may also be due to a low presence of poultry parasites and low prevalence of fowl pox in the region.

A weakness for this study was that syndromes were reported by farmers and in most cases not physically verified by veterinarians or veterinary technicians. Thus, analysis of this type of data could only effectively assist as an early warning tool for veterinary services rather than as a diagnostic tool for specific poultry diseases. Furthermore, since the data was collected from a sample of poultry farming households it could be prone to selection bias. This could lead to under reporting as well as exaggerated conclusions on the disease status of poultry flocks in the region. Nevertheless, this method of disease data collection where poultry farmers were actively followed, would reduce under reporting compared to the current system where farmers are encouraged to report poultry disease outbreaks to the nearest veterinary technicians, who may be as far as 20km away in most rural communities of Eastern Zambia.

6.7 Conclusion and Recommendations

This study forms part of the syndromic surveillance component of the ensemble model (Figure 1-2) by demonstrating that syndromic data obtained from farmers is a useful disease reporting tool and could be used as an effective means of alerting authorities to poultry disease incidence.

6.8 Ethical Considerations and Acknowledgements

Permission to do this study was obtained from the Departments of Veterinary and Livestock Development, Ministry of Agriculture and Livestock in Zambia. The study was approved by the Human Research Ethics Committee of James Cook University (Application ID; H5830). It was funded by Australian Awards (OASIS ID: STOOOK8) and James Cook University, Australia, with contributions from the National Research Foundation in Pretoria, South Africa.

Authors would like to acknowledge D. Chilembo, C. Hapoma, C. Moono, E. Kafundanga, P. Mwango, N. Mulombwaluse, N. Alibandila, J. Ngambi, C. Mainza, J. Kabucha, W. Sinyangwe, K. Mbumwae, N. Bilima and E. Sinzala for their roles during data collection and entry. Finally, Dr Y. Sinkala, Dr A. Songolo, Dr A. Mumbolomena, Dr M. Sinzala and Ms. M. Mwanza from the veterinary department as well as Mr D. Phiri from Petauke district council in Zambia are also acknowledged for their intellectual, in-kind and material contributions towards the success of this study.

6.9 References

Abolnik, C., Mubamba, C., Dautu, G., Gummow, B., In Press. Complete genome sequence of a Newcastle disease genotype XIII virus isolated from indigenous chickens in Zambia. Genome announcements, 5(34), e00841-17.

Akinola, L.A.F., Essien, A., 2011. Relevance of rural poultry production in developing countries with special reference to Africa. World's Poultry Science Journal 67, 697-705.

Alexander, D.J., Aldous, E.W., Fuller, C.M., 2012. The long view: a selective review of 40 years of Newcastle disease research. Avian pathology 41, 329-335.

Brioudes, A., Gummow, B., 2015. Understanding Pig and Poultry Trade Networks and Farming Practices Within the Pacific Islands as a Basis for Surveillance. Transboundary and Emerging Diseases, 1-16.

Brown, M., Moore, L., McMahon, B., Powell, D., LaBute, M., Hyman, J.M., Rivas, A., Jankowski, M., Berendzen, J., Loeppky, J., 2015. Constructing rigorous and broad biosurveillance networks for detecting emerging zoonotic outbreaks. PloS one 10, e0124037.

Chaka, H., Goutard, F., Roger, F., Bisschop, S.P.R., Thompson, P.N., 2013. Household-level risk factors for Newcastle disease seropositivity and incidence of Newcastle disease virus exposure in backyard chicken flocks in Eastern Shewa zone, Ethiopia. Preventive Veterinary Medicine 109, 312-320.

Gilbert, M., Chaitaweesup, P., Parakamawongsa, T., Premashthira, S., Tiensin, T., Kalpravidh, W., Wagner, H., Slingenbergh, J., 2006. Free-grazing ducks and highly pathogenic avian influenza, Thailand. Emerging Infectious Diseases 12, 227-234.

Gilchrist, P., 2005. Involvement of free-flying wild birds in the spread of the viruses of avian influenza, Newcastle disease and infectious bursal disease from poultry products to commercial poultry. World's poultry science journal 61, 198-214.

Goutard, F.L., Binot, A., Duboz, R., Rasamoelina-Andriamanivo, H., Pedrono, M., Holl, D., Peyre, M.-I., Cappelle, J., Chevalier, V., Figuié, M., 2015. How to reach the poor? Surveillance in low-income countries, lessons from experiences in Cambodia and Madagascar. Preventive veterinary medicine 120, 12-26.

GRZ, 2011. Twenty ten Zambia census of population and housing. Volume 11; national descriptive tables.

Henning, K.J., 2004. What is Syndromic Surveillance? Morbidity and Mortality Weekly Report 53, 7-11.

Hoinville, L.J., Alban, L., Drewe, J.A., Gibbens, J.C., Gustafson, L., Häsler, B., Saegerman, C., Salman, M., Stärk, K.D.C., 2013. Proposed terms and concepts for describing and evaluating animal-health surveillance systems. Preventive Veterinary Medicine 112, 1-12.

Jost, C., Mariner, J., Roeder, P., Sawitri, E., Macgregor-Skinner, G., 2007. Participatory epidemiology in disease surveillance and research. Revue Scientifique Et Technique-Office International Des Epizooties 26, 537.

Laerd-Statistics, 2015. Ordinal logistic regression using SPSS Statistics. Statistical tutorials and software guides. Retrieved from https://statistics.laerd.com/.

Martin, V., Zhou, X., Marshall, E., Jia, B., Fusheng, G., FrancoDixon, M.A., DeHaan, N., Pfeiffer, D.U., Soares Magalhães, R.J., Gilbert, M., 2011. Risk-based surveillance for avian influenza control along poultry market chains in South China: The value of social network analysis. Preventive Veterinary Medicine 102, 196-205.

Miller, P.J., Decanini, E.L., Afonso, C.L., 2010. Newcastle disease: evolution of genotypes and the related diagnostic challenges. Infection, genetics and evolution 10, 26-35.

Moreki, J.C., Dikeme, R., 2011. Small livestock, food security, nutrition security and HIV/AIDS mitigation. [Online] Available: http://www.intechopen.com/download/pdf/pdfs_id/22357.

Mtileni, B.J., Muchadeyi, F.C., Maiwashe, A., Chimonyo, M., Mapiye, C., Dzama, K., 2012. Influence of socioeconomic factors on production constraints faced by indigenous chicken producers in South Africa. Tropical Animal Health and Production 45, 67-74.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2016. A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia. Preventive Veterinary Medicine 133, 97-107.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018a. Combining value chain and social network analysis as a viable tool for informing targeted disease surveillance in the rural poultry sector of Zambia. Transbound & Emerging Diseases, 1-11.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018. Is syndromic data from rural poultry farmers a viable poultry disease reporting tool and means of identifying likely farmer responses to poultry disease incursion? Preventive veterinary medicine 153, 84-93.

Mutenje, M.J., Mapiye, C., Mavunganidze, Z., Mwale, M., Muringai, V., Katsinde, C.S., Gavumende, I., 2008. Livestock as a buffer against HIV and AIDS income shocks in the rural households of Zimbabwe. Development Southern Africa, 25(1), 75-82 http://dx.doi.org/10.1080/03768350701837754.

Mwacalimba, K.K., 2012. Globalised disease control and response distortion: a case study of avian influenza pandemic preparedness in Zambia. Critical Public Health 22, 391-405.

OIE, 2017. World Animal Health Information System (WAHIS) database.

Ozcatalbas, O., Boz, I., Demiryurek, K., Budak, D.B., Karaturhan, B., 2011. Developing participatory extension applications in Turkey. African Journal of Agricultural Research 6, 407-415.

Pallisade-corporation, 2015. @RISK: Risk Analysis and Simulation Add-In for Microsoft® Excel Version 7. http://www.palisade.com.

Pinner, R.W., Rebmann, C., Schuchat, A., Hughes, J., 2003. Disease surveillance and the academic, clinical, and public health communities. Emerging Infectious Disease 9.

Queenan, K., Mangesho, P., Ole-Neselle, M., Karimuribo, E., Rweyemamu, M., Kock, R., Häsler, B., 2017. Using local language syndromic terminology in participatory epidemiology: Lessons for One Health practitioners among the Maasai of Ngorongoro, Tanzania. Preventive Veterinary Medicine 139, 42-49.

Schacter, D.L., 1999. The Seven Sins of Memory: Insights from psychology and cognitive Neuroscience American Psychologist 54, 182-203.

Schärrer, S., Widgren, S., Schwermer, H., Lindberg, A., Vidondo, B., Zinsstag, J., Reist, M., 2015. Evaluation of farm-level parameters derived from animal movements for use in risk-based surveillance programmes of cattle in Switzerland. BMC Veterinary Research 11.

Sonaiya E.B., 2007. Family poultry, food security and the impact of HPAI. World's Poultry Science Journal 63, 132-138.

Songolo, A., Katongo, J.C., 2000. 'Country report: Zambia'. In: Alders, R.G., Spradbrow, P.B. (Eds.), SADC planning workshop on Newcastle disease control in village chickens: Proceedings of an international workshop, ACIAR Proceedings 103, Maputo, Mozambique. 43-45.

Thrusfield, M. (Ed.), 2005. Veterinary Epidemiology. Blackwell Publishing Oxford UK

Tottori, J., Yamaguchi, R., Murakawa, Y., Sato, M., Uchida, K., Tateyama, S., 1997. The use of feed restriction for mortality control of chickens in broiler farms. Avian diseases, 433-437.

Van Metre, D.C., Barkey, D.Q., Salman, M., Morley, P.S., 2009. Development of a syndromic surveillance system for detection of disease among livestock entering an auction market. Journal of the American Veterinary Medical Association 234, 658-664.

Vose, D., Koupeev, T., Groenendaal, T., 2004. ModelAssist. Project managed by Risk Thinking Ltd, SB Premium, Vladikavkaz, Russia.

Wu, T.-S.J., Shih, F.-Y.F., Yen, M.-Y., Wu, J.-S.J., Lu, S.-W., Chang, K.C.-M., Hsiung, C., Chou, J.-H., Chu, Y.-T., Chang, H., Chiu, C.-H., Tsui, F.-C.R., Wagner, M.M., Su, I.-J., King, C.-C., 2008. Establishing a nationwide emergency department-based syndromic surveillance system for better public health responses in Taiwan. BMC Public Health 8, 18.

Chapter 7

TRIAL AND ASSESSMENT OF POULTRY CLUBS AS DRIVERS OF DISEASE SURVEILLANCE RISK COMMUNICATION AND CAPACITY BUILDING AMONG THE RURAL POULTRY SECTOR OF EASTERN ZAMBIA

Publications

Mubamba, C., Ramsay, G., Dautu, G., Abonlik, C., Gummow, B., 2018. Using community-based poultry clubs to effectively and sustainably drive disease surveillance in the rural poultry sector. Submitted to the Journal of Agriculture and Rural Development in the Tropics and Subtropics (Manuscript ID 3545).

7.1 Abstract

Establishing active disease surveillance systems in developing countries like Zambia requires huge amounts of resources which are scarce. Consequently, a study to try and assess poultry clubs (PCs) as a community platform involving rural poultry farmers in syndromic disease reporting that is sustainable was conducted using Eastern Zambia as a model. Efficiency of PCs was assessed by computing the proportion of meetings conducted by PCs compared to the actual meetings planned. Sustainability was assessed by comparing the mean ranks of report submission of farmers over the 24 months post PC inception using the Friedman test. The effectiveness of disease surveillance using PCs was evaluated by determining the minimum number of reports required from club members to detect at least one household with poultry disease in the population. This was modelled further using a geometric distribution function to establish the sensitivity of the reporting system. Additionally, PCs were evaluated using focussed group discussions and structured questionnaire interviews. The syndrome reporting efficiency of PCs was 0.8. The PC approach was sustainable because there were no significant differences in report submission between the 24 months post inception (Friedman test, $\chi 2(23) = 32.93$, $p = 0.08$). The probability of detecting outbreaks in disease hotspots of Eastern Zambia was estimated at 98% (51-100). Most respondents were either very satisfied or extremely satisfied with the approach. PCs can be used as a community-based platform for low cost syndromic surveillance that is sustainable provided the approach is incentivized with a community driven tool that encourages farmers' participation.

7.2 Key Words

Syndromic surveillance, poultry clubs, rural poultry.

7.3 Introduction

The importance of small-scale poultry farming in enhancing food security and generating income among rural households in developing countries has been emphasised by various authors (Copland J.W. and Alders R.G., 2009; Akinola and Essien, 2011). Unfortunately, optimum production is hindered by infectious poultry diseases like Newcastle Disease (ND), which cause high mortalities in the rural poultry sector (Songolo and Katongo, 2000; Akinola and Essien, 2011; Simainga et al., 2011; Mubamba et al., 2016). Lack of effective disease surveillance worsens this problem because by the time outbreaks are reported to state disease control agencies, huge poultry losses have already occurred. Establishing an effective active disease surveillance system in developing countries like

Zambia requires considerable resources which are often inadequate or non-existent. This highlights the need for a targeted surveillance system that rationalises the limited resources available in areas where disease outbreaks are most likely to occur (disease hotspots) (Brioudes and Gummow, 2015).

Hotspots for poultry disease outbreaks have been partially identified in Eastern Zambia through retrospective studies that described spatial and temporal trends of poultry diseases (Mubamba et al., 2016). Disease hotspots have also further been identified through assessment of poultry movement and its products, which identified places where the greatest interaction between birds (and thus with the highest probability of disease transmission) takes place (Mubamba et al., 2018b). Hence it is possible to rationalise animal health resources within these hotspots in Eastern Zambia based on existing studies.

However, sampling of birds in the hotspots to assess their disease status is still difficult due to insufficient funding. A cheaper alternative to active surveillance would be to utilize farmers to report the syndromes they observe, which could then be used to identify diseases and conditions (Stärk et al., 2006; Schärrer et al., 2015). This would fulfill the syndromic surveillance component of the ensemble model (Figure 1-2). The validity of using syndromic data from rural farms in developing countries has been previously assessed (Byaruhanga et al., 2015; Mubamba et al., 2018c) but the sustainability of such a system is usually the main constraint (Yombo, 2010). The primary challenge being to incentivise rural farmers to report since animal health, unlike in developed countries, is not regarded as important enough to invest time and effort in (Mwacalimba and Green, 2014). When incentives are provided, they are often in the form of material goods such as deworming, provision of cell phones or dipping of cattle (Umali et al., 1994; Walker et al., 2011; Muhanguzi et al., 2014). The problem being that when funding for these goods is no longer available, there is no incentive to report cases and the system becomes unsustainable. Hence an incentive that does not require a substantial amount of resources or funding is required to make syndromic reporting sustainable in developing countries.

Recent studies have shown that despite the interest in poultry farming, rural poultry farmers in Eastern Zambia, are unable to cost their enterprise and thus are unable to determine whether they make profits or not (Mubamba et al., 2018a). Introducing financial analysis tools to farmer groups where syndromic data is obtained could therefore act as a low-cost sustainable way of incentivising disease reporting.

Thus, the objectives of this study were 1. to create the syndromic surveillance component of the ensemble model (Figure 1-2) by establishing community-based poultry clubs (PCs) as a basis for disease reporting in rural communities, while using financial templates as an incentive for maintaining farmer membership to the PCs 2. to test the sustainability and effectiveness of the PC syndromic surveillance approach using qualitative and quantitative analysis.

7.4 Materials and Methods

7.4.1 Study design

A syndromic surveillance platform was created using four poultry clubs (PCs) that were formed on a volunteer basis. Data on poultry disease syndromes was collected from consenting members of the clubs by veterinary assistants (VAs). Feedback on reported syndromes and training of members was also provided through VAs over 24 months. Each club was based in a previously identified hotspot for disease transmission in Eastern Zambia (Mubamba et al., 2018b). The study was conducted from September 2015 to August 2017.

The study was broadly divided into three parts. The first part involved formation of the PCs. The second part involved the running of PCs (presented in study procedures). The third part involved assessing the usefulness and effectiveness of the PC syndromic surveillance platform (presented in results). Figure 7-1 provides an overview of the study from inception of PCs to their operation and then the tools used to assess the surveillance platform.

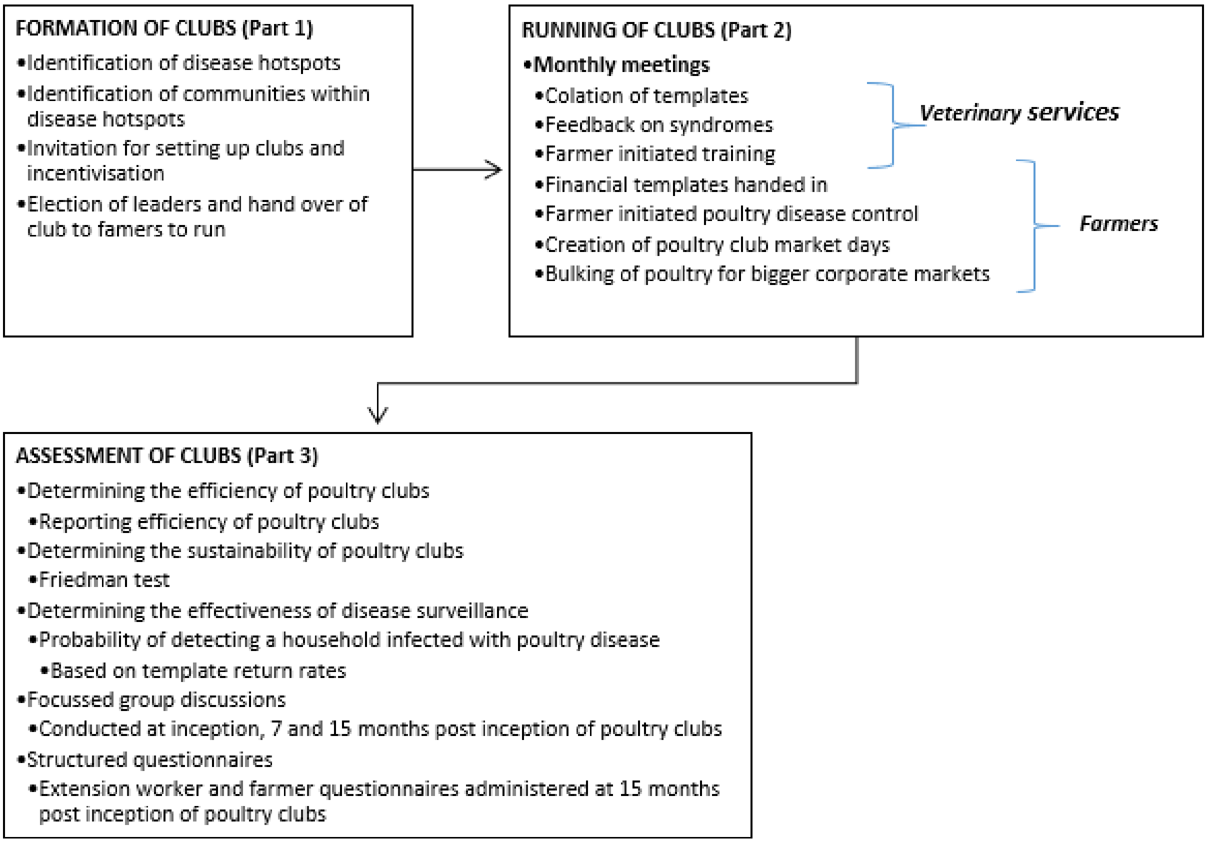


Figure 7-1: Overview of the process for the formation and running of poultry clubs as vehicles for syndromic poultry disease surveillance and the assessment of their effectiveness and usefulness.

7.4.2 Study procedures

Formation of poultry clubs

Identification of Disease Hotspots

For veterinary and livestock purposes, the Eastern Province of Zambia is divided into nine districts namely; Chipata, Chadiza, Katete, Lundazi, Mambwe, Petauke, Nyimba, Sinda and Vubwi (Figure 7-2.). Districts are further divided into veterinary camps which are further divided into crush pen zones. Crush pen zones are further divided into villages. Rural farming households produce 80 to 90% of the poultry in the province (Mumbolomena A., Provincial Veterinary Officer, personal communication).

Selection of hotspots for setting up PCs was based on a previous study that identified districts and veterinary camps where high poultry interaction occurs based on their centrality within the whole network and influence as egos using whole network and ego network analysis respectively (Mubamba et al., 2018b). Thus, Chipata, Lundazi, Katete and Mambwe districts were selected and

Figure 7-2: The position of Eastern Zambia and location of established poultry clubs among communities of some identified poultry disease hotspots (red dots)

within these districts, Chipata, Lundazi, Boma and Mphomwa veterinary camps were selected as host areas for the groups respectively (Figure 7-2).

Identification of communities within Hotspots

Working in liaison with local veterinary assistants (VAs), community livestock auxiliaries (CLAs) and traditional leaders, host communities for setting up the clubs were identified within the veterinary camps. Selection was based on the abundance of poultry farmers within the community, willingness of farmers within the community to form a club and centrality of location within the selected veterinary camp.

Invitation for setting up clubs and provision of incentives for sustainability

An invitation for a meeting on specific dates and venues was sent to all poultry farmers in a veterinary camp area through a local VA where attendance and participation was voluntary. At the meeting, introductions of researchers were done by the local VA.

A focused group discussion (FGD) was held with farmers where they were questioned on what challenges they faced with their poultry production. Identified challenges were used to justify the need for a PC and were noted for possible future continuing education topics.

The idea of the possible formation of a poultry club, which could serve as a platform where veterinary services and the farmers could work together to resolve these challenges was introduced at the meeting. Farmers were then requested to indicate by means of raising hands if they would be interested in the initiative. Where farmers agreed to form a club, they were informed that entry and exit to the club was on a voluntary basis. An information sheet and consent forms were then provided to group members at the beginning of their membership. After reading and understanding these documents, they were requested to sign the consent form.

The FGD revealed that farmers had poor record keeping, poor costing skills and lack of marketing information for their enterprises. A financial template form (Fig. 3) was suggested that could be used to resolve these problems and the farmers were introduced to the template. The form captured information on purchasing, production and included syndromes seen by the farmer (Fig. 3). Thus, whilst serving as an incentive to enhance record keeping, accounting and marketing capacity for poultry farmers, the template would indirectly collect poultry disease data needed by veterinary services for disease surveillance. Poultry club members that wished to use the template were requested to submit a copy of the filled form to their VA at each monthly club meeting.

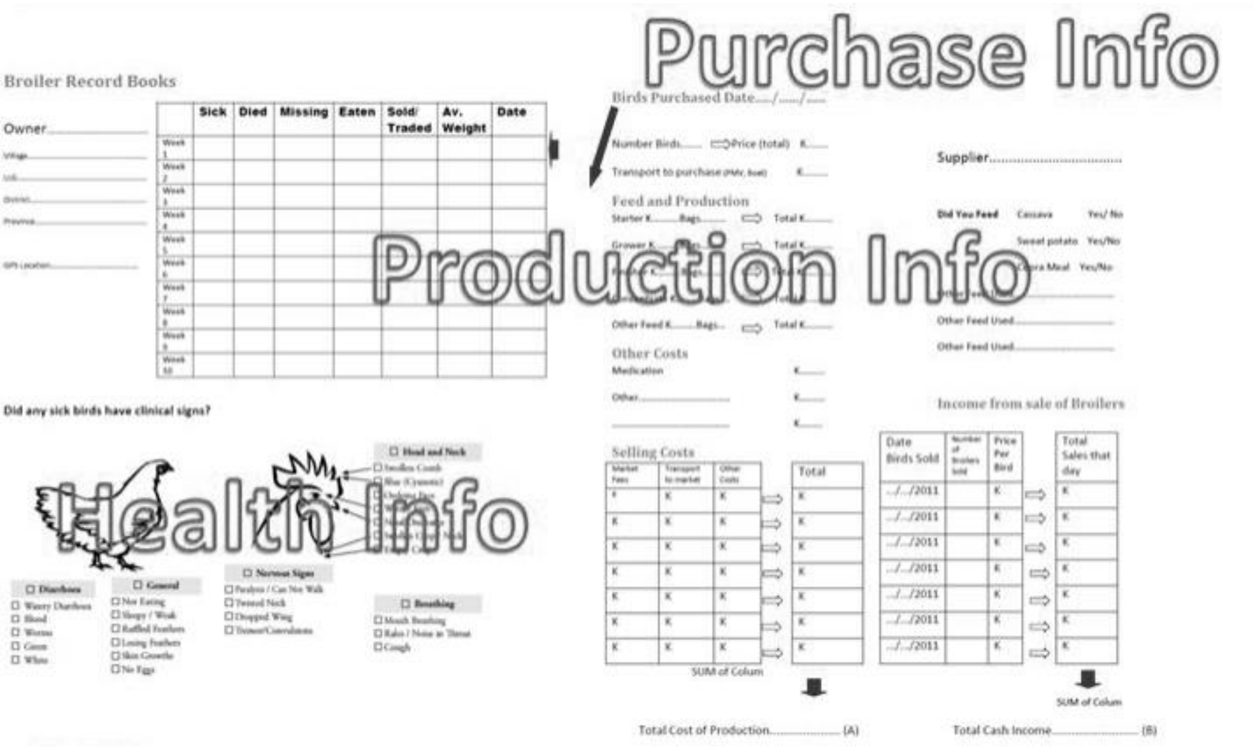


Figure 7-3: Contents of the poultry financial template that poultry farmers within poultry clubs of Eastern Zambia were requested to submit monthly from September 2015 to December 2016.

Election of group leaders and hand over of running of poultry clubs to communities

For the newly formed groups to be sustainable and provide contact persons, a PC committee was formed, which comprised the chairperson, vice chairperson, secretary, treasurer and six committee members. All club members were initially requested to nominate members they thought could be best suited for each position. This was followed by a secret ballot where all members voted to elect one nominated person to serve as their leaders for each respective position. It was agreed that a term of office for each committee would be two years.

Running of each respective club was then handed over to the elected committees who in liaison with the local VA and members agreed on the agenda and date for the next and consecutive club meetings.

Running of poultry clubs

Standard agenda for poultry club meetings

Meetings were officially opened by the chairperson and facilitated monthly by local VAs in liaison with the chairperson at their nearest farmer training facility, if one was available. If not available, meetings were conducted at the premises of a volunteering poultry farmer.

The first activity of each meeting was registration of farmers, which included noting new members. This was followed by presentation from the VA on the disease risks in the area based on previous submissions by farmers and current disease reports within veterinary services, which was followed by facilitation of a requested topic for training. In the next session poultry farmers were requested to present completed monthly financial templates that were given to them at the previous meeting. Farmers could elect to discuss these with the facilitator privately for advice on how their enterprise was faring. Advice centered on health, production and marketing successes and challenges for the previous month. The last agenda item was the setting of a date for the next meeting after which the meeting was officially closed by the chairperson.

The data collected from templates by VAs was captured into Epi Info® where it was collated and stored for further analysis at the district and provincial veterinary offices.

Assessment of poultry clubs

Assessment of the clubs was based on examining how effectively they contributed to disease surveillance and other outcomes. This was achieved by analysing the monthly data submitted by farmers, two sets of structured questionnaires administered to field veterinary staff and club members, and a focused group discussion held with stakeholders (club members, veterinary extension staff, civic and traditional leaders) 15 months from inception of groups.

Efficiency of poultry clubs

Efficiency of PCs was the proportion of the number of times the PC met (regardless of the number of templates or forms submitted) against the number of times the PC was expected to meet. Thus, each PC was expected to meet 24 times over 24 months post PC inception. The overall disease syndrome reporting efficiency of the PCs was the total number of times PCs reported compared to the total number of times all PCs (n=4) were expected to report. All PCs were expected to report 96 (N=4X24) times at 24 months post inception.

Sustainability of poultry clubs

To assess the sustainability of the PCs over several months from inception, the mean ranks (Laerd-Statistics, 2015; Mubamba et al., 2016) were used to analyse the differences in report submissions because the data were not normally distributed (Kolmogorov-Simonov test; $p<0.001$ and the Shapiro-Wilk test; $p<0.001$). Where comparisons between months were required, the Friedman test (Laerd-Statistics, 2015; Mubamba et al., 2016), followed by pairwise comparison with a Bonferroni adjustment (Laerd-Statistics, 2015), was conducted to test for statistical significance and identify which months significantly differed from others in terms of report submissions. The Friedman test was used because data obtained from the same poultry clubs over a period of 24 months was not independent (Laerd- Statistics, 2015). Thus, for this study, lack of statistically significant differences in report submission over 24 months would imply that the approach was sustainable. The SPSS 22® statistical package was used for statistical analysis.

Effectiveness of disease surveillance

The effectiveness of PCs in catering for disease surveillance was analysed by firstly determining the minimum number of filled monthly poultry templates required from households, to detect at least one household infected with poultry diseases within each hub. This was done using Equation 1 derived and modified from Cameron and Baldock (1998).

Equation 1: $n= [1-(1-a) \wedge (1/D)]\ [N-(D-1)/2]$

Where n was the required number of reports received by each district to detect at least one household affected by poultry disease, a was the confidence level set at 95%, N was the total number of poultry farmers within four districts estimated at 147815 according to the 2010 Zambia census of population and housing (GRZ, 2010) and D was the number of households affected by poultry disease using the assumption that the surveillance system could detect disease at the low prevalence of 5% within a population of 147815 poultry farmers. Thus, 58 was computed as the minimum number of household poultry templates required per district per month to detect at least one household or farm that is affected by poultry diseases in this study.

Given that 58 templates were required to be 95% confident that an infected household would be detected, a model was developed to determine the sensitivity of the reporting system if less than 58 templates were received per month. A geometric distribution function (1+Geometric (p)), selected based on the guidelines provided by Covello and Merkhoher (2013), was used to determine the probability of detecting an infected household based on the number of templates received, where p was the assumed prevalence of households with diseased poultry (p=0.05). The model was run in @Risk using 10000 iterations (Pallisade-corporation, 2015). Running of the model produced a similar result to Equation 1 for the number of households needed to be sampled to detect an infected household with 95% confidence.

The simulated cumulative ascending distribution curve could then be used to obtain the corresponding probability of finding an infected poultry farming household (p), given the number of templates submitted per month.

Feedback questionnaires

Poultry farmers and extension workers were each given a separate questionnaire to complete 15 months post inception of PCs (The two questionnaires are available as supplementary information). The questionnaire asked extension workers about how the PC enhanced poultry disease surveillance. Farmers were asked whether they had completed the monthly poultry template and participated in PC meetings in the past 15 months. If the template had been used, farmers were asked how useful it was based on scores of 1 to 5 for being not useful, somewhat useful, useful, very useful and extremely useful respectively.

A sample size of at least 50% of the median farmers that attended PC meetings was targeted for the questionnaire interviews while a minimum of 80% of the extension workers serving in the veterinary camps and districts were targeted for the interviews.

Questionnaire data was analysed and presented as frequencies of responses given by respondents or word clouds using SPSS version 24® and Epi Info.

Focused group discussions

FGDs were conducted at inception, 7- and 15-months post inception of PCs. They were facilitated by the principal researcher (PR), two co researchers (CRs) and the local VA for each respective PC. Details of how the FDGs at inception were conducted have been presented above, thus this section only focusses on FDGs conducted at 7- and 15-months post PC inception.

Prior to conducting FGDs in the field a checklist was created containing the following questions for the FGDs at 7- and 15-months post inception; What are the benefits of having a PC? What are the benefits of being a PC member? What changes has being a PC member brought to your poultry business? What are the challenges faced by your PC? What are your recommendations for future improvement of your PC? Would you like the PC initiative to continue? During discussions, farmers were encouraged to freely participate.

A total of twelve FGDs (3 per PC) were conducted in the study period. FGDs were conducted in Chewa, the local language but minutes were translated and recorded in English by the PR and VA. At the end of each discussion a wrap up meeting was held by the PR, CRs and local VA at respective district veterinary offices where minutes where consolidated and a final draft of the proceedings was kept by the PR and VA. FGD responses were presented in a Table and as quotes in the results.

Quality control

The PR who is also a Senior Veterinary Officer in the Zambian Department of Veterinary Services, visited the clubs once every seven months. The main objective of these visits was to ensure the methodology was correctly applied, working and consistent between the PCs. The other objective was to collect more feedback from group members and veterinary extension staff regarding the successes and challenges that PCs encountered.

7.5 Results

7.5.1 General Overview

Efficiency of poultry clubs

Chipata PC had the highest efficiency of 0.9 followed by Mphomwa and Lundazi PCs (0.8). The lowest efficiency of 0.7 was recorded by Boma PC. The overall syndrome reporting efficiency of PCs was 0.8.

Sustainability of poultry clubs

A total of 1869 completed templates were submitted by PC members from all four clubs over 24 months. Number of templates submitted was highest at 1 (209 templates) and lowest at 6 (13 templates) months after inception of PCs (Table 7-1). Highest number of submitted templates were recorded in Lundazi (490 templates) followed by Chipata (469 templates), Mphomwa (433 templates) and Boma PCs (291 templates).

The Friedman test showed that there were no statistically significant differences in the mean ranks of submitted templates between the 24 months post inception of PCs, $\chi2(23) = 32.93$, $p = 0.08$. This shows consistent submission rate throughout the survey period thus providing a statistical basis for proving the sustainability of the PC disease reporting system. The mean ranks of template submissions for each month post inception are shown in Table 7-1 below.

Table 7-1: Submission of household completed templates for each month that elapsed from inception to the 15th month post inception of poultry clubs in Eastern Zambia from September 2015 to December 2016.

Month from inception	n= Number of PCs	No. of templates submitted	Median	Mean Rank (Friedmans test)
1	4	209	57.5	21
2	4	51	9	9
3	4	73	16	12
4	4	65	18.5	12
5	4	33	8	7
6	4	13	2	5
7	4	27	6.5	8
8	4	31	6.5	9
9	4	18	3	6
10	4	40	4	9
11	4	58	10	11
12	4	76	21	14
13	4	53	8	12
14	4	59	8.5	12
15	4	97	23	17
16	4	124	30.5	20
17	4	75	15	12
18	4	87	21.5	17
19	4	79	19.5	15

Month from inception	n= Number of PCs	No. of templates submitted	Median	Mean Rank (Friedmans test)
20	4	84	21	15
21	4	71	19	13
22	4	81	19	15
23	4	91	23	17
24	4	88	23	15
Totals (N)	**96**	**1683**		
Overall Median (Min-Max)		**53 (13-209)**		

Despite the lack of statistically significant differences between template submissions over the 24 months post inception of PCs, veterinary extension staff that facilitated PCs were followed up as to what might have led to the drop in submission of completed templates by farmers at months 2 as well as months 5 to 9 post inception. The high template submission in the first month were attributed to an initial curiosity by the community in what the activity was all about. Only those really interested attended the second month explaining the marked drop of template submission from the first to the second month. For months 5 to 9 post inception, all of them cited the changed political environment during the presidential and parliamentary election campaign period in Zambia that coincided with this period during the trial as the most probable cause of low attendance at monthly club sessions, thus the small number of reports submitted.

Feedback questionnaires

A total of 38 feedback questionnaires were completed by PC members (Lundazi= 14, Mphomwa= 14, Chipata= 4 and Boma= 6) thus representing a sample size of 75% of the median number of farmers that attended PC meetings in all four PCs per month (median 51, range 1-209). From these farmers 24 (63%) were women and 14 (27%) were men. Seven extension workers were interviewed using the structured questionnaire at 15 months post inception of PCs. This included 4 veterinary assistants and 3 veterinary officers serving in the respective veterinary camps and districts were PCs were established. Detailed feedback from questionnaires is presented in subsections 3.2 to 3.4.

Focused group discussions

A total of 204, 151 and 159 participants composed of mostly poultry farmers (about 95%) and extension workers, attended FGDs held on inception, 7 months and 15 months post inception of PCs respectively (Table7- 2). Table 2 also outlines some key issues and resolutions, or recommendations passed at the FGDs. Some specific quotes recorded in FGDs are presented in subsections that follow.

Table 7-2: Number of participants, issues raised, and some main recommendations passed during focussed group discussions held with poultry club members in Eastern Zambia from 2015 to 2017

Month post inception	Poultry club/ participants	Issues raised by participants	Progress	Resolutions
0	Boma (38) Chipata (73) Lundazi (29) Mphomwa (64)	• Poultry mortality • No veterinary drugs • No markets for poultry • No veterinary services nearby • No knowledge on poultry husbandry • No resources to expand businesses		Formation of poultry clubs, election of the executive, monthly submission poultry financial template
7	Boma (47) Chipata (43) Lundazi (22) Mphomwa (39)	• No capital to expand businesses • Increased knowledge on poultry diseases, increased risk awareness on poultry diseases,	•Market for poultry created •Increased knowledge on marketing costs	Registration of poultry clubs as cooperatives
15	Boma (41) Chipata (45) Lundazi (32) Mphomwa (41)	• Lack of capital to grow businesses	•Two PCs registered as cooperative •Increased poultry numbers •Farmers able to control poultry diseases	Continue with PC initiative and increase number of PCs within Veterinary camps

7.5.2 Disease surveillance

Syndromic data derived from the farmer's monthly reports were analysed by veterinary services using the dashboard analysis tool in Epi Info where frequency data was presented as word clouds or frequency tables that identified the most frequent disease syndromes. After analysis, the most frequent syndromes were displayed to farmers with the largest font and vice versa. Based on the prominent disease syndromes reported by farmers, veterinarians at the district or provincial veterinary office could develop tentative diagnosis by aligning them with known poultry diseases and conditions.

For instance, word cloud analysis which revealed that coughing, paralysis, watery eyes, nasal discharge, dropped wings and twisted necks were prominent syndromes reported by farmers at Boma, Chipata, Mphomwa and Lundazi PCs at 15 months from inception is displayed in Figure 7-5 A-D. From these syndromes, a tentative diagnosis of ND and/or Chronic Respiratory Disease was made based on case history of previously confirmed cases in the region. This initiated a follow up vaccination campaign driven by the PC and a dramatic drop in poultry mortality rates amongst these farms.

Effectiveness of the disease surveillance approach

The median number of templates received over the 24-month study period was 53 (13-209) templates per month (Table 1). Reading off the geometric distribution model shown in Figure 7-4, that would mean the current reporting system would have had an estimated 94% (51-100) probability for detecting an infected poultry household.

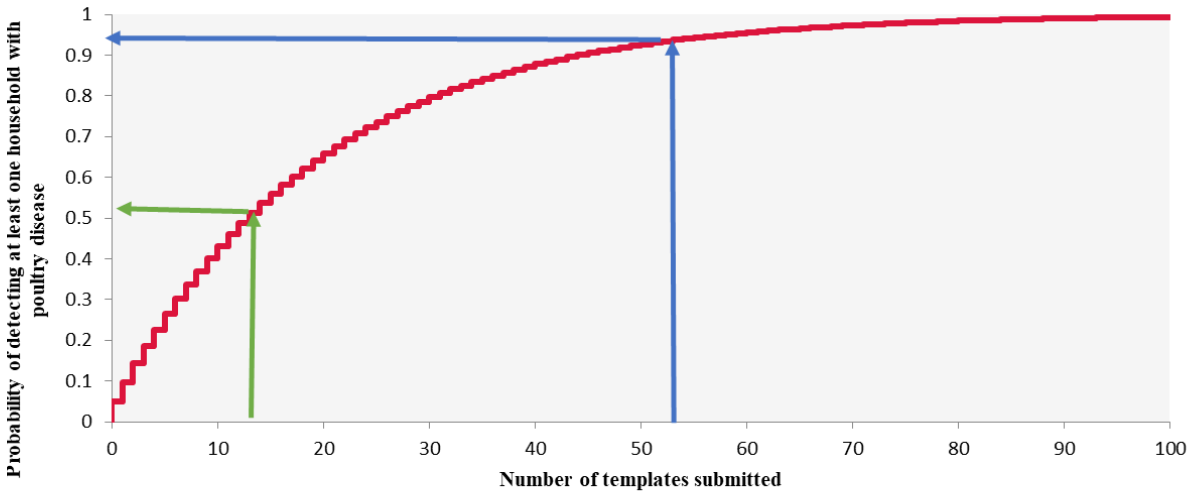


Figure 7-4: Cumulative ascending probability curve for number of completed templates submitted by poultry farming households with corresponding probability for detecting at least one household with poultry disease. Blue arrows indicate the median of 53 reports per month which corresponds to a 94% (51-100) probability of detecting at least one household with poultry disease.

Feedback from veterinary field staff on the disease surveillance approach

Eighty six percent of veterinary extension staff surveyed said they used the disease data that went into routine morbidity reports they submitted monthly to the National Livestock Epidemiology and Economics Information Centre (NALEEIC) of Zambia. When asked how useful the form had been for their disease reporting, 67% of them said it was very useful while the rest said it was extremely useful.

7.5.3 Additional benefits of poultry clubs

Risk communication

Monthly, the deidentified processed disease data were shared with club members by the local VA as a feedback loop for them to be aware of the disease outbreaks within their communities. Furthermore, an update on other diseases and syndromes reported in neighbouring regions was also given to the farmers.

Effectiveness of risk Communication

Twenty seven percent of PC members said they found feedback on poultry diseases from the local VA extremely useful, while 41%, 29% and 3% of them said it was very useful, useful and somewhat useful. None of the respondents said it was not useful.

Furthermore, statements from FGDs at 7 months post inception of PCs revealed that farmers were more aware of the diseases within the community because of being PC members. “We meet our local VA more often at our monthly meetings where he gives as more information regarding poultry diseases” (PC member, Lundazi). “We are now able to vaccinate our poultry at an appropriate time before we anticipate a big outbreak” (PC member, Chipata).

Capacity building

At each monthly meeting, a local VA and any subject matter specialist they invited from the district veterinary and livestock development offices provided some training on the needs that were identified at earlier meetings. Training was mainly conducted as information sharing sessions where each member was free to contribute at any time. Lessons covered included but were not limited to poultry diseases, poultry husbandry and poultry marketing.

To give farmers an idea of how profitably their respective enterprises were performing, a simple gross margin analysis (McCown, 2005) was performed confidentially for each farmer within the groups using production and marketing information obtained from their respective monthly poultry templates. Other than capacity building, this initiative was also being used as a means of encouraging farmers to remain in the programme thus making this approach more sustainable. At district and provincial levels, the data was collated, and the median expenditures and income were used to perform gross margin budgets that estimated overall financial performance of poultry enterprises within the PCs and their neighbourhood.

Effectiveness of capacity building

Fourty nine percent of PC members said the PC approach was very useful in enhancing their record keeping while 31% and 20% of them said it was extremely useful and useful respectively. Furthermore, when poultry farmers were asked how useful the PCs were in assisting them tracking production, marketing and financial performance of their enterprises, 37% said it was very useful while 33%, 17% and 13% said it was extremely useful, useful and somewhat useful respectively. None of the respondents said it was not useful.

Statements from stakeholders during FGDs at 15 months post PC inception provided further evidence that the PCs were effective in building the capacity of poultry farmers.

“Because of the poultry monthly report, I now have accurate records for my chickens” (PC member, Mphomwa). *“Because of the marketing training we received from the assistant marketing officer from the district, we now group our chickens and sell them as bulk to our customers in the city once a week”* (PC member, Mphomwa). *“Our training in poultry diseases has enabled us to identify poultry diseases like fowl pox and we now know where to buy vaccines for the disease”* (PC member, Chipata).

7.5.4 Challenges and recommendations for improvement of poultry clubs

Challenges

Feedback questionnaire results of extension workers revealed that illiteracy among poultry farmers was identified as the most common challenge encountered by PCs. Poultry club members also mentioned working out of costs for enterprises as another challenge that some farmers still encountered (Figure 7- 5 E and F).

Other challenges identified through FGDs were as follows; long distances to monthly meeting venue (Chipata PC), lack of resources to stock and sell more poultry and its products (all PCs), lack of group registration with registrar of societies to allow access to other facilities offered by government such as loans and grants (all PCs) and lack of nearby drug store to purchase vaccines and drugs (Mphomwa PC).

Recommendations

To improve the quality and efficiency of reporting using the monthly poultry templates, questionnaire results revealed that both veterinary extension officers and poultry farmers recommended that the template be translated into Nyanja, a local language that is widely spoken within Eastern Zambia (Figure 7-5 G and H).

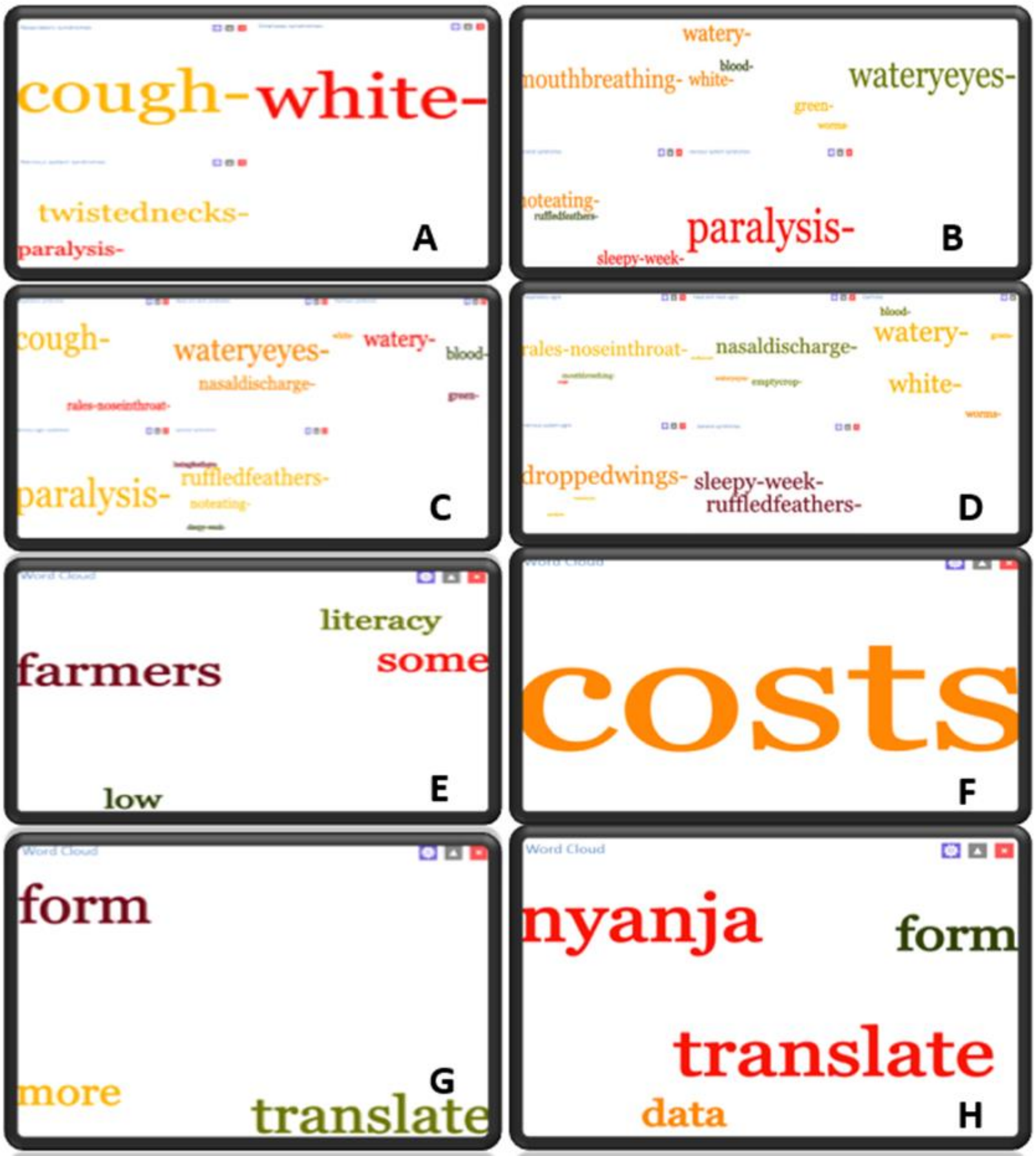


Figure 7-5: Examples of word cloud analysis for prominent syndromes reported by poultry farmers in selected disease hotspots (A= Boma, B= Chipata, C= Mphomwa and D= Lundazi), challenges observed by veterinary extension officers (E) and poultry farmers (F) and recommendations for future success and sustainability of the poultry clubs given by veterinary extension staff (G) and poultry farmers (H) in Eastern Zambia between September 2015 and December 2016.

Other recommendations obtained from focussed group discussions were as follows;

"PCs could be registered as clubs or cooperatives so that they are linked to running government and non-government organisation livestock projects for more sustainability" (Provincial Veterinary Officer), *"Venues for monthly club meetings could alternate between 2 to 3 locations to increase*

attendance" (PC member, Chipata) and *"consider extending the approach to other species such as cattle, pigs and goats"* (District Veterinary Officers, Chipata and Katete).

7.6 Discussion

Syndromic reports from poultry clubs have complemented the current passive surveillance of poultry diseases in Eastern Zambia (Figure 7-5 A-D). This could further serve as an alternative for increasing the sensitivity of detecting disease incursions in the rest of Zambia and other countries with resource constrained rural communities. Furthermore, this approach provides an alternative for expanding the implementation of livestock disease syndromic surveillance globally. Syndromic surveillance of livestock diseases has been implemented in developed countries, but its implementation has been a challenge in developing countries (Yombo, 2010) and is rarely sustainable. Syndromic surveillance in developing countries could potentially contribute to future international, national, and local-level animal health intelligence, going beyond the detection and monitoring of disease events by contributing solid situation awareness of animal health at various stages along the food-producing chain (Dorea and Vial, 2016).

Poultry clubs provide a platform for risk communication by veterinary services to farmers by providing a contact point where farmers and veterinary services can come together (Figure 7-5 A-D). This helps farmers prepare for the most likely disease outbreaks among their flocks thus having a significant impact on disease prevention and control (Smith, 2006; Palmer et al., 2009). Extension officers were also able to communicate financial and marketing risks using feedback from the gross margin and marketing data PC members provided in completed monthly templates. Since farmers in the PCs attached importance to feedback from veterinary services (risk communication), its continuous inclusion in monthly meeting agendas would be critical in sustainability of the approach.

Capacity building of all livestock farmers including poultry farmers is vital and forms an important cornerstone for enhancing livestock production (Kitalyi, 1998; Permin et al., 2001; GRZ, 2017). PCs create a conducive platform for farmers and extension services to identify unique needs of poultry farmers through participatory approaches. The outcome of this approach was reflected by 92% of PC members interviewed who stated that the training they received assisted them in improving their poultry production and marketing.

In this study, at a current median reporting rate of 53, there is a high probability of detecting households with poultry disease (Figure 7-4). Coupled with the positive feedback from PC members and extension workers, the PC approach seems to be sustainable and efficient in complementing poultry disease surveillance in resource constrained communities. This disease detection efficiency can further be enhanced by increasing reporting efficiency of PCs from the current 0.8 to 1 and increasing the number of PCs within the veterinary camps.

The site where PC meetings are conducted may affect attendance and number of completed templates submitted by poultry farmers. The PC in Lundazi, where farmers met at a fellow poultry farmer's residence recorded a higher number of templates returned compared to the PCs in Chipata, Mambwe and Katete districts where farmers gathered at an institutional site. This may be due to the distance that farmers had to travel to a meeting site. More still it could have been because farmers felt more comfortable meeting at a peers' residence than at an institutional venue. In the future, it would be interesting to see how submission rates may change after venues for PCs in the latter districts are changed from an institutional site to one of the volunteering club members' premises.

Political environment appeared to have a role in the sustainability and efficiency of the PCs. This was evidenced by a drop in meeting attendance and subsequently low submission of monthly poultry templates by farmers during the election period (Table 7-1). This may have been due to club members preferring to attend political rallies or other similar events rather than attending scheduled PC meetings. To maintain attendance, facilitators of clubs may need to renegotiate with members alternative venues and times when to conduct their meetings when other large events are on in their district. Another factor which seemed to affect the efficiency and sustainability of the PCs was the composition of members. Lundazi PC was formed using a local women's club as its base (Nsamba Kashweka, Veterinary Assistant, Lundazi Veterinary camp, Personal Communication), and had a high proportion of women as members. Women are more active in poultry farming than men in resource challenged regions like Zambia (Guèye, 2000; Songolo and Katongo, 2000; Wong et al., 2017) and this may explain better attendance in women predominated PCs.

Similar to other rural communities of developing countries, Iliteracy (Ardila et al., 2010) and lack of understanding of the language used on the poultry template form may negatively affect efficiency and sustainability of the PCs. This is validated by the fact that both veterinary extension staff and poultry farmers in interest groups identified illiteracy as the most prominent challenge and suggested that forms and lessons be translated to a local language that is commonly used in Eastern Zambia (Figure 7-5 E-H). Literacy levels among farmers could be raised by collaborating and inviting other organisations that offer adult literacy education to provide this service within PCs to act as another incentive for more attendance and hence lead to increased monthly report submissions. In Zambia, literacy services are offered by the Department of Community Development which has officers placed in most districts of Eastern Zambia (GRZ, 2003). This would embrace a more one health approach for disease surveillance.

A weakness of the PC approach is that syndromes were reported by farmers and in most cases not physically verified by veterinarians. Thus, analysis of this type of data could only efficiently assist as an early warning tool for veterinary services rather than as a diagnostic tool for specific poultry diseases (Mubamba et al., 2018c). Secondly, since the data on observed syndromes was collected from farmers over a period of one month, it was prone to memory bias (Schacter, 1999). Furthermore, as templates were only collected from PC members and not all poultry farmers within the communities, it could be prone to selection bias (Thrusfield, 2005). This can lead to exaggerated conclusions on the poultry disease status in the communities. The other weakness of the study was that the sustainability of PCs was assessed using the Friedman test, a less robust test compared to a one-way analysis of variance test (Laerd-Statistics, 2015), because the data on template submissions were non-parametric. The other weakness was that there was high interval between the lowest and highest probability of detecting a household with poultry disease (51%-100%) (Fig.3). This can be reduced by ensuring that PC members submit high numbers of templates at each monthly PC meetings.

Despite some highlighted challenges, the study demonstrates that PCs can drive syndromic disease surveillance, risk communication and capacity building of rural poultry farmers sustainably and effectively. These are vital aspects of a successful animal health and production system at farm, district, provincial, national, regional and global levels within a resource poor context (Kitalyi, 1998; GRZ, 2017).

Since this model addresses the financial need of the rural farmers (Mubamba et al., 2018a) as the primary objective with disease reporting being the secondary objective, it addresses the needs of the farmer first and those of veterinary services second. This change in mindset for veterinary services is a key component to the success and sustainability of the model. More still, the PC approach devolves the responsibility of livestock disease reporting to farmers who begin to share this responsibility with veterinary services as they are made aware of disease risks and incentivised by capacity building according to their needs. Thus, implementing this approach may contribute to reduction of the negative impacts of diseases on rural poultry production which would lead to increased food security and reduced poverty in the region.

7.7 Conclusion and Recommendations

Poultry clubs can be used as a community-based platform involving rural poultry farms in disease reporting that is potentially sustainable while at the same time allowing capacity building and disease risk communication among resource constrained poultry farming communities provided the farmers are incentivised with a tool such as routine financial analysis of their individual enterprises, which motivates them to remain members of the PC. For the model to maintain its sustainability, flexible adjustments in running of PCs that suit the local poultry farmers' political, social and educational environments are recommended. This study forms the syndromic surveillance component of the ensemble model (Figure 1-2).

7.8 Ethical considerations and acknowledgements

Permission to do this study was acquired from the Departments of Veterinary and Livestock Development, Ministry of Agriculture and Livestock in Zambia. The study was approved by the Human Research Ethics Committee of James Cook University (Application ID; H5830). It was funded by Australian Awards (OASIS ID: STOOOK8) and James Cook University, Australia, with contributions from the National Research Foundation in Pretoria, South Africa.

Authors would like to acknowledge D. Chilembo, C. Moono, N. Kashweka, J. Mwelwa and G. Mukwalantila from the veterinary department for facilitating the FFS. They would also like to thank Dr A. Mumbolomena, Dr J. Samuwika, Dr K. Kampamba and Dr D. Mweemba for the support during inception and conducting of the PC trials.

7.9 References

Akinola, L.A.F., Essien, A., 2011. Relevance of rural poultry production in developing countries with special reference to Africa. World's Poultry Science Journal 67, 697-705.

Ardila, A., Bertolucci, P.H., Braga, L.W., Castro-Caldas, A., Judd, T., Kosmidis, M.H., Matute, E., Nitrini, R., Ostrosky-Solis, F., Rosselli, M., 2010. Illiteracy: the neuropsychology of cognition without reading. Archives of clinical neuropsychology 25, 689-712.

Brioudes, A., Gummow, B., 2015. Understanding Pig and Poultry Trade Networks and Farming Practices Within the Pacific Islands as a Basis for Surveillance. Transboundary and Emerging Diseases, 1-16.

Byaruhanga, C., Oosthuizen, M.C., Collins, N.E., Knobel, D., 2015. Usingparticipatory epidemiology to investigate management options and relativeimportance of tick-borne diseases amongst transhumant zebu cattle inKaramoja Region, Uganda. Preventive veterinary medicine 122, 287–297.

Cameron, A.R., Baldock, F.C., 1998. A new probability formula for surveys to substantiate freedom from disease. Preventive veterinary medicine 34, 1-17.

Copland J.W., Alders R.G., 2009. The comparative advantages of village or smallholder poultry in rural development.Village chickens, poverty alleviation and the sustainable control of Newcastle disease Proceedings of an international conference held in Dar es Salaam Tanzania, 5–7 October 2005. ACIAR Proceedings No. 131, 235 pp. In: Alders, R.G., Spradbrow, P.B., Young, M.P. (Eds.).

GRZ, 2003. Ministry of Community Development and Social Services, Department of Community Development, Confintea V Mid Term Review : Status and Future Prospects of Adult Learning.

GRZ, 2010. Census of population and housing, agriculture analytical report. In: CSO (Ed.), Lusaka.

GRZ, 2017. The Seventh National Development Plan 2017-2021. Mininstry of National Development Planning. Lusaka, Zambia.

Guèye, E.H.F., 2000. Women and Family Poultry Production in Rural Africa. Development in Practice 10, 98-102.

Kitalyi, A.J., 1998. Village chicken production systems in rural Africa: Household food security and gender issues. Food & Agriculture Org.

Laerd-Statistics, 2015. Statistical tutorials and software guides. Retrieved from https://statistics.laerd.com/.

McCown, R.L., 2005. New Thinking About Farmer Decision Makers. . In The Farmer’s Decision: Balancing Economic Successful Agriculture Production with Environmental Quality (J.L. Hatfield, ed), Soil and Water Conservation Society, Ankeny, Iowa, USA. pp 11–44.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2016. A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia. Preventive veterinary medicine 133, 97-107.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018a. Analysing production and financial data from farmers can serve as a tool for identifying opportunities for enhancing extension delivery among the rural poultry sub-sector in Zambia. Preventive veterinary medicine 158, 152-159.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018b. Combining value chain and social network analysis as a viable tool for informing targeted disease surveillance in the rural poultry sector of Zambia. Transbound & Emerging Diseases, 1-11.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018c. Is syndromic data from rural poultry farmers a viable poultry disease reporting tool and means of identifying likely farmer responses to poultry disease incursion? Preventive veterinary medicine 153, 84-93.

Muhanguzi, D., Picozzi, K., Hatendorf, J., Thrusfield, M., Welburn, S.C., Kabasa, J.D., Waiswa, C., 2014. Improvements on restricted insecticide application protocol for control of human and animal african trypanosomiasis in eastern Uganda. PLoS neglected tropical diseases 8, e3284.

Mwacalimba, K.K., Green, J., 2014. 'One health' and development priorities in resource-constrained countries: policy lessons from avian and pandemic influenza preparedness in Zambia. Health Policy and Planning 1.

Pallisade-corporation, 2015. @RISK: Risk Analysis and Simulation Add-In for Microsoft® Excel Version 7. http://www.palisade.com.

Palmer, S., Fozdar, F., Sully, M., 2009. The effect of trust on West Australian farmers' responses to infectious livestock diseases. Sociologia Ruralis 49, 360-374.

Permin, A., Pedersen, G., Riise, J., 2001. Poultry as a tool for poverty alleviation: Opportunities and problems related to poultry production at village level. In, ACIAR proceedings, 143-147.

Schacter, D.L., 1999. The Seven Sins of Memory: Insights from psychology and cognitive Neuroscience American Psychologist 54, 182-203.

Schärrer, S., Widgren, S., Schwermer, H., Lindberg, A., Vidondo, B., Zinsstag, J., Reist, M., 2015. Evaluation of farm-level parameters derived from animal movements for use in risk-based surveillance programmes of cattle in Switzerland. BMC veterinary research 11.

Simainga, S., Moreki, J.C., Banda, F., Sakuya, N., 2011. Socio-economic study of family poultry in Mongu and Kalabo Districts of Zambia Livestock Research for Rural Development 23.

Smith, R.D., 2006. Responding to global infectious disease outbreaks: lessons from SARS on the role of risk perception, communication and management. Social science & medicine 63, 3113-3123.

Songolo, A., Katongo, J.C., 2000. 'Country report: Zambia'. In: Alders, R.G., Spradbrow, P.B. (Eds.), SADC planning workshop on Newcastle disease control in village chickens: Proceedings of an international workshop, ACIAR Proceedings 103, Maputo, Mozambique. 43-45.

Stärk, K.D., Regula, G., Hernandez, J., Knopf, L., Fuchs, K., Morris, R.S., Davies, P., 2006. Concepts for risk-based surveillance in the field of veterinary medicine and veterinary public health: Review of current approaches. BMC Health Services Research 6.

Thrusfield, M. (Ed.), 2005. Veterinary Epidemiology. Blackwell Publishing Oxford UK

Umali, D.L., Feder, G., Haan, C.d., 1994. Animal health services: finding the balance between public and private delivery. The World Bank Research Observer 9, 71-96.

Walker, J.G., Ogola, E., Knobel, D., 2011. Piloting mobile phone-based syndromic surveillance of livestock diseases in Kenya. Epidémiologie et Santé Animale 59, 19-21.

Wong, J., de Bruyn, J., Bagnol, B., Grieve, H., Li, M., Pym, R., Alders, R., 2017. Small-scale poultry and food security in resource-poor settings: A review. Global Food Security.

Yombo, A., 2010. Syndromic animal health surveillance in Papua New Guinea. Is it working? . Veterinary Sciences. MTVSc, James Cook University, Australia.

Chapter 8

GENERAL DISCUSSION AND CONCLUSION

Conference Presentations

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B., 2016. A study of Newcastle Disease and the utilisation of social networks and market chains to enhance food security in Zambia In, University of Pretoria Faculty Congress, Pretoria, South Africa.

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B., 2016. A study of Newcastle Disease and the utilization of social networks and market chains to enhance Poultry disease surveillance in Zambia (3 Minute Thesis and poster presentation). CBTID and CBMDT scientific retreat, Fitzroy Island, Cairns, Australia, 15-17th July 2016.

Mubamba, C., Ramsay, G., Dautu, G., Abolnik, C., Gummow, B. Fighting malnutrition through securing rural poultry in the third world: A Zambian case study (Oral presentation). Townsville science week 2016, Townsville, Australia. 12th September 2016

8.1 Discussion

The working hypothesis for this research was that updating the knowledge of ND and studying the role of social networks and market value chains in propagation of the disease would facilitate establishment of a syndromic surveillance platform that would reduce losses in the rural poultry sector of Zambia. Its overall objective was to set up an effective and sustainable system for early detection of priority diseases like ND, which utilises social networks and value chains within the rural poultry sector of Zambia using ensemble modelling. The six specific objectives of the project were, 1. to carry out a retrospective study on the trends of Newcastle Disease from 1989 to 2014 (25 years) through assessment of disease reports on Newcastle Disease submitted within Zambia Veterinary Services, 2. to assess the level of knowledge of ND and its control among rural poultry farmers of eastern Zambia through questionnaire surveys, 3. through the same surveys, assess the financial sustainability of rural poultry enterprises, assess social networks and map out trade of birds within informal markets and identify hubs or hot spots where most interaction of poultry takes place, 4. to assess the serological prevalence of ND in social and trade poultry hubs with a view of obtaining baseline knowledge on prevalence of the disease in these hubs that would assist in future disease monitoring, 5. to carry out molecular characterization of the circulating ND viruses in Zambia as a baseline for identifying new strains of the viruses that would be introduced or that would emerge because of mutations, antigenic drift and shift of the virus and 6. to place and assess a syndromic surveillance platform of ND and other poultry diseases in some poultry social and commercial hubs of Eastern Zambia to improve cost effectiveness of disease surveillance in the rural poultry sector.

Newcastle Disease was identified as a priority poultry disease causing huge losses in the rural poultry sector of Eastern Zambia. The findings enabled mapping of high-risk areas of the disease according to history of outbreaks. By evaluating the seasonal index for the disease, this study also provided information to Veterinary services needed to prepare for anticipated outbreaks where they could enhance their disease control programmes. The 25 years prediction of the ND prevalence provides vital information for long term planning and monitoring of the disease. For instance, veterinary services may use the time series model (Figure 2-7) as a reference to check the effectiveness of their disease control programmes in the future. Some of this work has been published in the journal of Preventive Veterinary Medicine (Mubamba et al., 2016).

The level of knowledge of ND and its control among rural poultry farmers of Eastern Zambia was partly assessed in chapter 6 where farmers were requested to provide syndromes, they had observed among their flocks with an extension of how farmers manage poultry diseases outlined by Mubamba et al. (2018). The third objective was covered in Chapter 5 which analysed the movement of live poultry and its products among key players of its value chain followed by social network analysis which identified hubs of high poultry interaction. This work provides examples of how social network analysis and value chain analysis can be used to conduct trace back and trace forward during poultry disease outbreaks. Because of this work, poultry diseases are now being rapidly diagnosed in Eastern Zambia (Arthur Mumbolomena, Provincial Veterinary Officer, personal communication).

The serological prevalence and molecular characterisation of NDV in poultry hubs was conducted in Chapter 3. The high seroprevalence of ND indicates that indigenous chickens of Eastern Zambia may be highly exposed to virulent NDV strains. This was confirmed by isolation and characterisation of genotype VIIh and genotype XIII of the NDV. Isolation of these genotypes contributed to the work which traced the origin of NDV sub-genotype VIIh conducted by Abolnik et al. (2017). Additionally, some recent studies in Namibia characterised sub-genotype VIIK in Namibia Molini et al. (2017). All this work forms a baseline for studying future changes in NDV genotypes within the Southern African region. The work also reveals key information for traceback and trace forward of outbreaks to veterinary services within the region and demonstrates how vulnerable African countries like Zambia remain to exotic sources of infection, and how quickly disease spreads within a region.

The last objective was covered by formation of poultry clubs which used a financial template as an incentive that attracted farmers to join the clubs. Because of positive feedback from veterinary extension workers and poultry farmers, PCs are viable in enhancing disease surveillance, risk communication and capacity building as a community-based approach that devolves the responsibility of poultry diseases to poultry farmers who act as partners rather than clients to veterinary services. Three out of the four poultry clubs have now been registered as cooperatives under the registrar of cooperatives in Zambia. This implies that the clubs will be included into other programmes that support the development of small scale and medium scale enterprises in Zambia and in turn contribute to the sustainability of the clubs (David Mweemba, Veterinary Officer, Personal communication). This work underpins the value of devolving some responsibilities to farmers when dealing with issues that cause low productivity in the livestock sectors of resource challenged countries.

All the studies conducted were fitted in an ensemble model composed of hazard analysis, risk assessment and syndromic surveillance (Figure 1-2) based on work done by Brioudes and Gummow (2017). Hazard analysis identified ND as a priority disease of poultry and identified indigenous poultry production as sustainable enterprises to be targeted for disease surveillance in Eastern Zambia. Risk analysis identified and provided recommendations on high risk areas and pathways to be targeted for surveillance. Syndromic surveillance enhanced disease surveillance through syndromic data provided by farmers and had an overall outcome of developing a targeted, Low cost and sustainable disease reporting system in Eastern Zambia (Figure 8-1). This approach has also been implemented to improve targeted allocation of resources to disease surveillance and risk communication in the Pacific island countries (Tukana et al., 2016; Brioudes and Gummow, 2017). Furthermore, the successful application of ensemble modelling in these studies has stimulated similar studies on pig diseases in south Africa (Vincent Simbizi, Veterinary Officer, Eastern Cape, Personal communication).

Priority livestock diseases may differ between countries and regions. Hazard analysis using literature reviews, priority setting meetings, serosurveys and molecular characterisation of disease-causing microorganisms can assist in identifying priority livestock diseases. For example, systematic literature reviews and priority setting workshops have been used to identify priority poultry and pig diseases in the Pacific Island countries (PICS) (Brioudes et al., 2014, 2015). Additionally, this work has also used molecular characterisation and serosurveys of ND as a priory disease for the rural poultry sector of Zambia. This approach can be used to rationalise and direct more resources to comprehensively understand a disease that affects a priority sector for resource constrained countries (Brioudes et al., 2015). For instance, the approach can be applied to identify priority diseases for small ruminants and aquaculture since these sectors have been prioritised by the Zambian Government but there is insufficient information on the prevalence and characteristics of diseases affecting these species in Zambia (Dr Arthur Mumbolomena, Provincial Veterinary Officer, Zambia, personal communication). The financial hazard is another hazard among rural livestock farmers that can be identified using focussed group discussions and structured questionnaires. In this work, this hazard is analysed by using gross margin analysis to demonstrate current financial performance of rural poultry farmers in Eastern Zambia. This work can be extended to the rural cattle, pig, small ruminant and aquaculture sectors to ensure that there is value for money when investing in disease control programmes for the rural livestock diseases. Without analysing financial performance of the rural livestock sector, veterinary services in developing countries like Zambia, risk investing resources meant for disease surveillance on unsustainable enterprises thus rendering their efforts futile.

Analysing risk of disease transmission using socionetworks and value chains provides an opportunity that enhances livestock disease surveillance. In veterinary science, risk to disease transmission and causation is mostly measured using incidence, odds ratios relative and attributable risk etc. (Thrusfield, 2005) but this work involving socionetworks and value chain adds another dimension in assessing risk to poultry and other livestock diseases in Zambia. Thus, this work underpins the need for veterinary services to adopt an interdisciplinary approach to disease surveillance by working with socio scientists who are more competent with tools like socionetworks and value chain analysis. This shift in disease surveillance strategy requires development of a new policy paper that will facilitate adjustment of the current livestock disease control strategy in Zambia.

Ensemble modelling has grown in popularity as more organizations realise the need for a multisectoral approach in finding solutions to problems. For instance, this model could be used to answer other livestock related challenges like the low productivity among the indigenous cattle, piggery and aquaculture sectors. By analysing and mitigating poultry diseases through improved disease reporting, this work is in line with the main objectives of Zambia's national development plans (GRZ, 2011). All these documents emphasize on increasing livestock production through sustainable control of diseases. Thus, the work enhances food security and income generation among resource constrained rural communities which leads to increased Gross Domestic Product (GDP) of this region.

8.2 Conclusion and Recommendations

This work demonstrates that a viable system for poultry disease surveillance can be set up using ensemble modelling. Through its studies it reveals key poultry disease surveillance issues which could be extrapolated to other regions and the model may be applied to enhance disease reporting for other livestock such as rural pigs, goats, cattle as well as aquaculture. To adapt to the disease surveillance approach demonstrated by this work, the Zambian veterinary services and other related institution in the sub-Saharan region are required to formulate policies that would accommodate a multisectoral approach to facilitate ensemble modelling when developing disease surveillance systems.

8.3 References

Abolnik, C., Mubamba, C., Wandrag, D.B.R., Horner, R., Gummow, B., Dautu, G., Bisschop, S.P.R., 2017. Tracing the origins of genotype VIIh Newcastle disease in Southern Africa. Transboundary and Emerging Diseases 1-11.

Brioudes, A., Gummow, B., 2017. A framework for targeted allocation of resources for livestock disease surveillance in selected pacific island countries. In, 9th Veterinary, Paraveterinary & SASVEPM Congress 2017 Proceedings, Johansburg, South africa.

Brioudes, A., Warner, J., Hedlefs, R., Gummow, B., 2014. A review of domestic animal diseases within the Pacific Islands region. Acta tropica 132, 23-38.

Brioudes, A., Warner, J., Hedlefs, R., Gummow, B., 2015. Diseases of livestock in the Pacific Islands region: setting priorities for food animal biosecurity. Acta tropica 143, 66-76.

GRZ, 2011. Sixth National Development plan for the Republic of Zambia, 2011-2015. 108-119.

Molini, U., Aikukutu, G., Khaiseb, S., Cattoli, G., Dundon, W.G., 2017. First genetic characterization of Newcastle disease viruses from Namibia: identification of novel VIIk subgenotype. Arch Virol 162, 2427-2431.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2016. A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia. Preventive veterinary medicine 133, 97-107.

Mubamba, C., Ramsay, G., Abolnik, C., Dautu, G., Gummow, B., 2018. Is syndromic data from rural poultry farmers a viable poultry disease reporting tool and means of identifying likely farmer responses to poultry disease incursion? Preventive veterinary medicine 153, 84-93.

Thrusfield, M. (Ed.), 2005. Veterinary Epidemiology. Blackwell Publishing Oxford UK

Tukana, A., Hedlefs, R., Gummow, B., 2016. Brucella abortus surveillance of cattle in Fiji, Papua New Guinea, Vanuatu, the Solomon Islands and a case for active disease surveillance as a training tool. Tropical animal health and production 48, 1471-1481.

Appendices

SUPPLEMENTARY INFORMATION

APPENDIX 1

Short questionnaire on the expert opinion for passive Newcastle Disease surveillance in the eastern province of Zambia
1. Name: …………….
2. Qualifications: …………….
3. Title/ Location: …………….
4. Experience in the Province (Years): …………
5. Sensitivity of Newcastle Disease Diagnosis
What is the ability of veterinary assistants to diagnose Newcastle Disease in the field? Please give your answer as a percentage (0-100%)? Answer: ………………………………………………………………………..
6. Positive predictive value of Newcastle Disease Diagnosis
What do you think is the ability of the field veterinary assistants (V.As) to identify ND cases correctly? Please give your response as a percentage (0-100%)..

APPENDIX 2

QUESTIONNAIRE FOR POULTRY FARMERS

INFORMED CONSENT FORM

This administrative form has been removed

This administrative form
has been removed

This administrative form has been removed

Survey on Poultry movements and trading practices within eastern Zambia

Date of the survey:	
District	
Interviewer's name: *(Capital letters)*	
Contact details:	**Telephone:** **Email:**

The survey questionnaire below is divided into 4 parts:

(A) Personal information,

(B) Farm structure and income,

(C) Trading practices,

(D) Wild life interaction

(E) Livestock diseases.

A. Personal information

Questions
Q1- Name of the farmer? *(Capital letters)*
Q2- Gender of farmer? ☐Male ☐Female

Q3 - Telephone contact of the farmer?
Q4- Locality of the farm? *(Capital letters)* District: Block; Agriculture Camp: Zone; Village:
Q5 – Please record the GPS coordinates of the farm/Village:
Q6 - Please detail the residential address of the farmer <u>if</u> it is different from the farm locality: Province: Block; Agriculture Camp: Zone; Village:
Q7 - For how many years has the interviewee been a farmer?
Q8- What is the highest level of education of the farmer?

B. Farm Structure and income

Questions (Please fill in or cross ☒ where appropriate)
Q9- Do you keep Poultry? ☐ **Yes** ☐ **No**
Q10 - What types and total number of poultry are kept in the farm? Please detail for each species: ☐ Chicken: ☐ Ducks: ☐ Pigeons: ☐ Other (Please detail):
Q11 - Please indicate the breed of poultry kept in the farm: ☐ Local (Village) poultry breed (Please detail): ☐ Imported breed (Please detail): ☐ Mixed breed (Please detail): ☐ Other breed (Please detail):
Q12 - Please indicate which categories of poultry are kept in the farm?

CATEGORY	CHICKS	PULLETS	COCKERELS	HENS	TOTAL
Layers					
Broiler					
Indigenous					
G. Fowls					
Ducks					
Others					
TOTAL					

Q13- Do you know how much you spend in ZMW on each category of poultry per month?

☐ Yes ☐ No

If the answer above is yes, please fill the table below

CATEGORY	CHICKS/INITIAL STOCK	HOUSING	FEED	FAMILY LABOUR	HIRED LABOUR	VET VACCINNES/DRUGS	OTHERS	TOTALS
Layers								
Broiler								
Indigenous								
G. Fowls								
Ducks								
Others								
TOTAL								

Any comments;

Q14- Do you sell your poultry and their products?

☐ Yes ☐ No

If the answer above is yes, please fill in the table below

CATEGORY	CHICKS	PULLETS	COCKERELS	HENS	ROOSTERS	EGGS	MANURE
Layers							

Broiler							
Indigenous							
G. Fowls							
Ducks							
Others							

Q15- Do you know how much money you get from selling your poultry and it products in ZMW per month?

☐ Yes ☐ No

If the answer to the above question is yes, please fill in the table below

CATEGORY	**Amount in ZMW**
Layers	
Broiler	
Indigenous	
G. Fowls	
Ducks	
Others	
TOTAL	

Q16- How would you rate the contribution of income from poultry to your total monthly income in your household?

Please place a cross in the appropriate box.

PERCENTAGE	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**

Q17 - Please indicate the farm raising system?

☐ Free range poultry farming (with poultry allowed to wander around the village)

☐ Traditional /Semi-intensive poultry farming (with poultry kept in fields or in a small poultry-house)

☐ Large scale / Intensive poultry farming (with poultry kept in confined spaces)

☐ Other (Please detail):

Q18 - Do you mix your flock with animals from another farm(s)? (any animals, not only poultry)

☐ No, go to question Q19

☐ Yes, please detail the **location** (District, Block, Agriculture camp, zone and Village) of another farm(s):

OTHER SPECIES

Q19 - What are the other species kept on this farm?

(Cross ☒ where appropriate)

☐ **Pigs**, please give the total number:

☐ **Poultry**, please give the total number:

☐ **Cattle,** please give the total number:

☐ **Goats**, please give the total number:

☐ **Sheep**, please give the total number:

☐ **Donkeys**, please give the total number:

☐ **Rabbits**, please give the total number:

☐ **Dogs**, please give the total number:

☐ **Cats**, please give the total number:

☐ **Other**, please detail and give total number:

Trading practices

ON-FARM MOVEMENTS
LIVE POULTRY

Q20 - During the previous 12 months, did you have any new live poultry entering your farm?

☐ **No,** go to question Q22

☐ **Yes,** please detail in the table below for each time new poultry were entering the flock:

- **Category of poultry:** day old chick, pullets, chicken, ducks ...
- **Origin of poultry:** Please detail where these live birds were coming from (E.g.: Farm or market ...),
- **Location:** detail where these new birds were coming from (precise location with the District, Block, Veterinary camp, village),
- **Number of new poultry birds:** total number of new birds entering the herd / flock,
- **Period / Frequency:** detail when or how often the new birds were entering your farm (which month of the year or frequency of live poultry supply- e.g.: once per month or every 3 months...).

Category of poultry	Origin of birds	**LOCATION (important field)** *(Province, District, Veterinary camp, village/farm)*	Number of birds entering the flock	
•				

Additional comment (if required):

Q21 - Did you use a middleman for purchasing and bringing these new birds into your farm?

☐ **No**

☐ **Yes,** please detail where this middleman is based (location: Province, District, Veterinary camp, Zone and Village):

The objective of this section is to describe the type and the frequency of **live poultry and poultry product movements to the farm** (section “on-farm movements”) **and from the farm** (section “off-farm movements”).

POULTRY PRODUCTS *(refer to material derived from the body of a live animal)*

Q22 - During the previous 12 months, did you bring any of the following Poultry products into your farm?

Please cross ☒ where appropriate:

- Carcass (dead poultry): .... ☐ No ☐ Yes - Blood: ....☐ No ☐ Yes
- Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes - Bones: .... ☐ No ☐ Yes
- Swill (restaurant left over): .... ☐ No ☐ Yes - Eggs: .... ☐ No ☐ Yes
- Waste meat from butcher /slaughterhouse: ....☐ No ☐ Yes - Skin: .... ☐ No ☐ Yes - Feathers: .... ☐ No ☐ Yes
- Meat and bone meal: .... ☐ No ☐ Yes - **Other**, please detail:

If you crossed ☒ Yes for any of the animal products above, please detail in the table below:

- **Category of poultry products:** as ticked in boxes above (E.g.: carcass, eggs ...)
- **Origin:** Please detail where these poultry products were coming from (Ex: Abattoir, market, farmer, hatchery...),
- **<u>Location:</u>** Detail the location where these poultry products were coming from (district, veterinary camp, village).
- **Quantities of poultry products:** Total number of poultry products entering the farm (e.g.: 20 egg trays, 10kg of swill ...)
- **Period or Frequency:** detail when or how often these poultry products were brought into your farm? (E.g.: in January and July or once per semester or every 3 weeks);

Category of poultry products	Origin of poultry products **(**Abattoir, market, farmer, hatchery...)	**<u>LOCATION</u> (important field)** *(Province, Veterinary camp, village / town)*	Quantities of poultry products	Period of the year or Frequency
•				

Additional comment (if required):

Q23 -Did you use a middleman for purchasing and bringing these poultry products into your farm?

☐ **No**

☐ **Yes,** please detail where this middleman is based? (location: Province, District, Veterinary camp, zone and Village):

OFF-FARM MOVEMENTS

LIVE POULTRY

Q24 - During the previous 12 months, did you sell or give any live poultry from your farm?

☐ **No,** go to question Q26

☐ **Yes,** please detail in the table below for <u>each time</u> animals were sold or given:

- **Category of poultry:** e.g.: day old chick, pullets, chicken, ducks...
- **Destination:** Please detail where these birds were sent to (E.g.: Abattoir, slaughter house, market, farm...),
- **<u>Location:</u>** Detail the location where these birds were sent to (precise the Province, District, Veterinary camp, village),
- **Number of new poultry:** total number of birds leaving the flock,
- **Period / Frequency:** detail when or how often poultry have been leaving your farm (which month of the year or frequency of live animal selling- e.g.: in March 2012 or once per month or every 3 months...).

Category of poultry	Destination (Ex : Abattoir, market, Farmer...)	**<u>LOCATION</u> (important field)** *(Province, District, Veterinary Camp, village)*	Number of animals	Period of the year or Frequency
•				

<u>Additional comment (if required):</u>

Q25 - Did you use a middleman for selling these animals from your farm?

☐ **No**

☐ **Yes,** where is this middleman based? (Please detail the location: Province, District, Veterinary camp, Crush pen zone and Village):

POULTRY PRODUCTS

Q26 - During the previous 12 months, did you sell or give any of the following poultry products from your farm?

Please cross ☒ where appropriate:

- Carcass (dead poultry): .... ☐ No ☐ Yes - Blood: ....☐ No ☐ Yes
- Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes - Bones: .... ☐ No ☐ Yes
- Meat: .... ☐ No ☐ Yes - Skin: .... ☐ No ☐ Yes
- Fat: ....☐ No ☐ Yes - Feathers: ...... ☐ No ☐ Yes
- - Manure: ...... ☐ No ☐ Yes
- Eggs: .... ☐ No ☐ Yes - **Other**, please detail:

If you crossed ☒ Yes for any of the poultry products above, please detail in the table below:

- **Category of poultry products:** as ticked in boxes above (E.g.: carcass, eggs ...),
- **Destination:** detail where these poultry products were sent to (E.g.: butcher, market, farmer, relative/friend ...),
- **<u>Location:</u>** detail the location where these poultry products were sent to (the Province, District, Veterinary camp, village),
- **Quantities of poultry products:** total number of poultry products sent off your farm (e.g.: 2 carcasses, 5 kg of offal...),
- **Period of the year or Frequency:** detail when or how often these poultry products were sold and sent off your farm (in March and December or once per month or every 3 months...).

Category of poultry products	Destination (E.g.: butcher, market, farmer...)	**<u>LOCATION</u> (important field)** *(Province, District, Veterinary camp, village)*	Quantities of poultry products	Period of the year or Frequency
•				

Additional comment (if required):

Q27 – Did you use a middleman for selling these poultry products from your farm?

☐ **No**

☐ **Yes,** where is this middleman based? (Please detail the location: Province, district, veterinary camp and zone and village):

SEASONALITY OF TRADE

Q28 – Are there periods over the year when you sell more live poultry or poultry products than usual?

☐ No

☐ Yes, please detail the period of the year and the associated occasion if any:

(E.g.: increased trade of poultry for the “Wedding season”; increased trade of poultry late December –early January for Christmas...)

Categories of poultry or poultry products (E.g.: chickens, eggs...)	**Periods with increased trade** (E.g.: Dec-Jan; Easter...)	**Occasion** (E.g.: Christmas, Wedding...)
•		

D. Contact with wild birds

Q29- Are there wild birds in or near your farm/village

☐**No** ☐**Yes**

Q30- Does any of your poultry share a common habitat (ex: water source, feeding point etc.)

☐**No** ☐**Yes**

Q31- If any of your answers in question 29 and 30 was yes, please give details of the wild birds

-

-

E. Poultry diseases

Q32 - Based on your knowledge and experience, what are the diseases the most at risk for your flock? *If the farmer doesn't know the name of the disease, write down the signs of diseases observed on animals.*

-

-

Q33 - What measures do you implement for preventing OR controlling diseases among your flock? Please detail the nature of the measures: (in case of vaccination programme, please detail for which diseases).

-

-

Q34 - Did your flock get any disease during the previous 12 months? *If the farmer doesn't know the name of the disease, write down the signs observed.*

☐ No

☐ Yes, please detail

- Which disease(s):

DISEASE	A;	B;	C;	Others;	TOTAL
CATEGORY					
Layers					
Broiler					
Indigenous					
G. Fowls					

Ducks					
Others					
TOTAL					

- Was the diagnostic confirmed by laboratory testing for this/these disease(s)? ☐ No ☐ Yes

Q35- Based on your knowledge and experience, what diseases have been occurring on poultry in your village or in the neighbouring villages in the previous 12 months? *If the farmer doesn't know the disease name, write down the signs observed.*

☐ No

☐ Yes, please detail:

-

-

Q36 - When your birds are sick or present abnormal signs, who do you contact for assistance?

☐ You never ask assistance to anyone

☐ Another experienced farmer

☐ Community /village chief

☐ Para vet, please detail his/her location (Province, district, agriculture camp, village):

☐ Government animal health or production staff, please detail his/her location:

☐ Other (please detail):

Q37 - During the previous 12 months, did you ask for assistance from these people for health problems among your herd/flock?

☐ No

☐ Yes, please detail:

- The period when it happened (which months over the past year):

- What kind of health problem it was:

Q38 – During the previous 12 months, did you find any dead birds among your flock?

☐ No

☐ Yes, please detail the approximate total number of dead animals in the table below:

CATEGORY	CHICKS	PULLETS	COCKERELS	HENS	TOTAL
Layers					
Broiler					
Indigenous					
G. Fowls					
Ducks					
Others					
TOTAL					

Q39 – Usually, what do you do with the carcasses / dead bodies? (Cross ☒ where appropriate)

☐ Burn ☐ Burry ☐ Family consumes ☐ Dog consumes

☐ Sell ☐ Nothing ☐ Other, please detail:

COMMENT : Please provide any additional comment or detail of relevance from the interview

APPENDIX 3

QUESTIONNAIRE FOR POULTRY TRADERS

INFORMED CONSENT FORM

This administrative form has been removed

This administrative form
has been removed

This administrative form
has been removed

Survey on livestock movements and trading practices in eastern Zambia

Date of the survey:	
District:	
Interviewer's name: (*Capital letter)*	
Contact details:	**Telephone:** **Email (optional):**
Interview conducted at :	☐ **Market** ☐ **Butcher shop**
Location of the market or butcher shop:	District: Ward: Veterinary Camp; Crush pen Zone; Village / suburb:

The survey questionnaire below is divided into 3 parts; these are:

(A) Market seller /butcher information,

(B) Trading practices,

(C) Operating procedures.

B. Market seller / butcher information

Questions
Q1 - Name of the market seller /butcher? (*Capital letters)*

Q2 - Gender of the market seller / butcher? ☐Male ☐Female
Q3 – Please record the GPS coordinates of the market / butcher shop:
Q4 - Postal address of the market seller /butcher: (*Capital letters)* District: Ward: Veterinary camp; Crush pen Zone; Village/suburb/Township:
Q5 - Telephone contact of the market seller / butcher?
Q6 - For how many years have you been selling poultry or poultry products in this market /in your butcher shop?
Q7 - How often do you sell poultry or poultry products in this market / in your butcher shop? : (E.g.: Everyday, once a week ...)

C. Trading practices

LIVE POULTRY
Q8 - Do you sell live poultry at the market / butcher shop? (Please cross ☒ where appropriate) ☐ No, go to question Q17 ☐ Yes, please detail: ☐ **Poultry**, please detail: ☐ Chicken ☐Duck ☐Other, please detail: ☐ **Pigs**

Q9 – Where do you buy or get these live birds from?

☐ From **poultry farms,** please detail how many:

☐ From **live poultry markets**, please detail how many :

☐ From **your own farm**

☐ **Other**, please detail:

For each **"place"** where you buy live poultry (as ticked above), please detail:

- **Location:** Detail the location where these birds are coming from (Province, Ward, camp, village /town) for all the different places you buy live birds from. (Example: if bird bought in 3 different farms, detail the location of the 3 farms)
- **Category of poultry:** as ticked in boxes above in Q8
- **Quantities of poultry bought:** total number of birds bought from each different place. (E.g.: 10 chickens...)
- **Frequency of trade:** detail how often you buy these quantities of poultry from each place (e.g.: every day, once per week...)

Place / Source of birds (farms, markets...)	**LOCATION (important field)** *(Province, District, Block, Veterinary camp, village / township)*	**Categories of poultry**	**Quantities of birds bought**	**Frequency of trade**
•				

Q10 - Do you use a middleman to buy these live birds? ☐ No ☐ Yes, where is he/she based (detail the Province, District, camp, crush pen zone and Village/township):
Q11 - When do you (or the middleman) usually pick these birds up from these different places? ☐ The same day of selling at the market (early morning before going to the market) / in your butcher shop; ☐ Few days before selling at the market / at your butcher shop. Please detail: • Usually how many days before selling at the market / butcher shop? : • Where do you keep these birds while waiting for selling them to the market / at your butcher shop (detail location Province, District, Ward, Camp, village):
Q12 - How are these live birds usually transported to the market / to your butcher shop? Describe the mean of transport: ☐ Truck ☐ Bicycle/motorbike ☐ Car ☐ Public bus ☐ Walking ☐ Other, please detail:
Q13 - How are these live birds being contained within the market / in your butcher shop? ☐ Tied together or to a fixed point ☐ Caged ☐ Free range in a delimited area ☐ Other, please detail:
Q14 – Whom do you usually sell these live birds to? Please detail the different categories of customers: ☐ To **poultry farms,** please detail how many: ☐ To **live poultry markets**, please detail how many: ☐ To **abattoir / slaughter houses**, please detail how many: ☐ To **butcher shops**, please detail how many: ☐ To **consumers**, please detail how many: ☐ **Other**, please detail: For each "**customer**" purchasing live birds from your stall / shop (as ticked above), please detail in the table below:

- **Location:** Detail the location where these birds are sent to (precise the Province, veterinary camp, village /town),
- **Category of poultry:** day old chick, pullets, chicken, ducks...
- **Number of new poultry:** total number of birds sold per destination,
- **Period / Frequency:** detail when or how often you sell birds to each different destination (which month of the year or frequency of live bird selling- e.g.: in March 2012 or once per month or every 3 months...).

Customer (Ex : Consumer, market, Farmer...)	**LOCATION (important field)** *(Province, veterinary camp, village / township)*	**Category of birds**	**Number of birds**	**Period of the year or Frequency**
•				
•				

Q15 - How do you transport these live birds from the place you buy them to the place you sell them?

☐ Truck ☐ bicycle/motorbike ☐ Car

☐ Public bus ☐ Walking ☐ Other, please detail:

Q16 – When selling, do all the live birds get sold?

☐ Yes

☐ No. Please detail what you do with the unsold birds to at the end of the day:

☐ **B**ring them home and take them again the following day for selling at the market /butcher shop

☐ **B**ring them home and slaughter them

☐ **Other**, please detail:

POULTRY PRODUCTS *(Poultry products refer to material derived from the body of a live bird)*

Q17 - Do you sell any of the following <u>POULTRY</u> products at the market / in your butcher shop?:

- Carcass: .... ☐ No ☐ Yes
- Eggs: ....☐ No ☐ Yes
- Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes
- Feathers: ....☐ No ☐ Yes
- Meat: .... ☐ No ☐ Yes
- **Other**, please detail:

Q18 – Where do you usually buy or get these poultry products from?:

☐ **Farms**, detail from how many:

☐ **Abattoir / Slaughter houses**, detail from how many:

☐ **Butcher shops**, detail from how many:

☐ **Other**, please detail:

For each **“place”** where you buy poultry products (as ticked above), please detail in the table below:

- <u>**Location:**</u> Detail the location where these poultry products are coming from (precise the Province, District, camp, village /township).

Detail all the different places you buy poultry products from (E.g.: if poultry products bought in 3 different farms, detail the location of the 3 farms).

- **Category of poultry products:** as ticked in boxes above in Q17 & 18 (E.g: carcass, offal, eggs ...)

- <u>**Quantities of poultry products:**</u> total number of poultry products bought in each place (Ex: 3 carcasses, 10 trays of 30 eggs, 10kg offal...). Please detail for each category of poultry product (as ticked in Q17 & 18)

- <u>**Frequency of trade:**</u> detail how often you buy these poultry products in each place (ex: every day, once per week...)

Places / Sources of animal products (Farm, abattoir, butcher...)	<u>**LOCATION**</u> **(important field)** *(Province, district, camp, village / township)*	**Category of animal products**	**Quantities of animal products**	**Frequency of trade**
• •				

Q20 - Do you use a middleman to buy these poultry products? ☐ No ☐ Yes, where is he/she based (detail the Province, district, camp and Village/townships):
Q21 - When do you (or the middleman) usually collect these poultry products from these different places? ☐ The same day of selling at the market (early morning before going to the market) / at your butcher shop; ☐ Few days before selling at the market / at your butcher shop. Please detail: • How many days before selling at the market / at your butcher shop? • Where do you store these poultry products while waiting for selling them to the market / at your butcher shop (detail <u>location:</u> Province, camp, village/township):
Q22 - How are these poultry products usually transported to the market / to your butcher shop? Describe the mean of transport: ☐ Truck ☐ Bicycle/Motorbike ☐ Car ☐ Public bus ☐ Walking ☐ Other, please detail:
Q23 - Are these poultry products maintained in a refrigerated container during the transport? ☐ No ☐ Yes ☐ Don't know
Q24 - Are these poultry products maintained in a refrigerated container on the stall at the market / in your butcher shop? ☐ No ☐ Yes

Q25 – Whom do you usually sell or give these poultry products to? Please detail the different categories of customers:

☐ To **restaurants**, please detail how many approximately:

☐ Direct to **consumers**, please detail how many approximately:

☐ To **butcher shops**, please detail how many approximately:

☐ To **farmers**, please detail how many approximately:

☐ **Other**, please detail:

For each category of "**customer"** purchasing poultry products from your stall or shop (as ticked above), please detail in the table below:

- **<u>Location:</u>** Detail the location where these poultry products are coming from (precise the Province, Ward, village /town).

Detail all the different places you buy poultry products from (E.g.: if poultry products bought in 3 different farms, detail the location of the 3 farms).

- **Category of poultry products:** as ticked in boxes above in Q17 & 18 (E.g: carcass, offal, eggs ...)
- **<u>Quantities of poultry products:</u>** total number of poultry products bought in each place (E.g: 3 carcasses, 10 trays of 30 eggs, 10kg offal...). Please detail for each category of poultry product (as ticked in Q17 & 18)
- **<u>Frequency of trade:</u>** detail how often you buy these poultry products in each place (e.g.: every day, once per week...)

Customers (Restaurant, consumer, butcher ...)	**<u>LOCATION</u> (important field)** *(Province, Ward, camp, village / town)*	**Category of animal products**	**Quantities of animal products**	**Frequency of trade**

• •				

SEASONALITY OF TRADE
Q26 – Are there periods over the year when you sell more live poultry or poultry products than usual?

☐ No

☐ Yes, please detail the period of the year and the associated occasion if any:

(E.g.: increased trade of poultry late December –early January for Christmas...)

Categories of poultry or poultry products (E.g.: chickens, eggs,)	**Periods of the year with increased trade** (E.g.: Dec-Jan; Easter...)	**Occasion** (E.g.: Christmas, Wedding...)
• •		

•		

D. **Operating procedures**

Q27 - Do you need a <u>license / a permit</u> for selling your live poultry or poultry products in this market/butcher shop? (refers to any permit paper required to be allowed to sell live poultry or poultry product in this market / at your butcher shop) ☐ No ☐ Yes
Q28 - Do you need a <u>sanitary</u> authorisation for selling your live poultry or poultry products in this market/butcher shop? (refers to any permit relating to the health condition of the birds or to the hygiene quality of the poultry products that needs to be presented for being allowed to sell live poultry/poultry product in this market / at your butcher shop) ☐ No ☐ Yes

APPENDIX 4

QUESTIONNAIRE AND CONSENT FORM FOR SERVICE PROVIDERS

(Vet Department, Poultry association, local council and others)

INFORMED CONSENT FORM

This administrative form has been removed

This administrative form
has been removed

This administrative form
has been removed

Survey on livestock movements and trading practices in eastern Zambia

Date of the survey:	
District:	
Interviewer's name: (*Capital letters)*	
Contact details:	**Telephone:** **Email (optional):**
Interview conducted at:	
Location of the office:	District: Ward: Veterinary Camp;

The survey questionnaire below is divided into 3 parts; these are:

(D) Details of the service provider

(E) Poultry industry structure

(F) Poultry movement and trading practices,

(G) Operating procedures

(H) Poultry contact with wild birds

(I) Poultry Diseases

E. Service provider information

Questions
Q1 - Name of the service provider? (*Capital letters)*
Q2 - Gender of the service provider? ☐ Male

☐ Female
Q3 – Please record the GPS coordinates for the official workplace of the provider:
Q4 - Postal address of the service provider: (*Capital letters)* District: Ward: Veterinary camp; Village/suburb/Township:
Q5 - Telephone contact of the service provider?
Q6- Category of service provider ☐ Government Vet service ☐ Poultry association ☐ Private para vet ☐ Local council ☐ Others
Q7- Level of operations for the provider ☐ Province ☐ District ☐ Ward ☐ Veterinary Camp ☐ Village/Suburb
Q8- For how many years have you been providing the service?
Q9- What service/s do you provide? ☐ Disease control ☐ Extension services ☐ Public Health ☐ Others;
Q10- How often do you provide your service/s to poultry farmers, traders and retailers? ☐ Daily ☐ Weekly ☐ Monthly ☐ Quarterly ☐ Annually

F. Structure of the poultry industry

Questions

Q11- What is the composition of Poultry in your service area? Could you give the approximate composition of each category?

CATEGORY	Present or absent (please tick)	Composition in percentage
Layers		
Broiler		
Indigenous		
G. Fowls		
Ducks		
Pigeons		
Others		
TOTAL		

Q12- What are the management system/s used to rear poultry in your area?

☐ Free range poultry farming (with poultry allowed to wander around the village)

☐ Traditional /Semi-intensive poultry farming (with poultry kept in fields or in a small poultry-house)

☐ Large scale / Intensive poultry farming (with poultry kept in confined spaces)

☐ Other (Please detail):

Q13- What is the current approximate price for each of the poultry category and bi products being offered by; A. The farmer B. Market trader/middlemen

a. **Farmers price/s per bird**

CATEGORY	CHICKS	PULLETS	COCKERELS	HENS	ROOSTERS	EGGS	MANURE
Layers							
Broiler							
Indigenous							
G. Fowls							

Ducks							
Others							

b. Middlemen/Marketeers/ retailers price/s of poultry and its products

CATEGORY	CHICKS	PULLETS	COCKERELS	HENS	ROOSTERS	EGGS	MANURE
Layers							
Broiler							
Indigenous							
G. Fowls							
Ducks							
Others							

G. Poultry movement and trading practices

LIVE POULTRY

Q14 – Are there sales of live poultry at the markets and butcher shops in your operational area? (Please cross ☒ where appropriate)

☐ No

☐ Yes, please detail: ☐ **Poultry**, please detail: ☐ Chicken ☐Duck ☐Other, please detail:

☐ **Pigs**

Q15- To the best of your knowledge would you say where this poultry comes from?

☐ From **poultry farms within your operational area,** please approximate how many:

☐ From other **live poultry markets within your area**, please approximate how many :

☐ **Other**, please detail:

Q16- For poultry that comes from outside your operational areas, using your poultry movement control and regulatory system (movement permits and sanitary certificates), would you give details where the live poultry comes from?

☐ Yes ☐ No

If yes, please fill in the table below;

For each **"place"** where you buy live poultry (as ticked above), please detail:

- **Location:** Detail the location where these birds are coming from (Province, Ward, camp, village /town) for all the different places you buy live animals from. (Example: if bird bought in 3 different farms, detail the location of the 3 farms)
- **Category of poultry:** as ticked in boxes above
- **Quantities of poultry bought:** total number of birds bought from each different place. (Ex: 3 piglets, 10 chickens...)
- **Frequency of trade:** detail how often you buy these quantities of poultry from each place (ex: every day, once per week...)

Place / Source of animals (farms, markets...)	**LOCATION (important field)** *(Province, District, Block, Veterinary camp, village / township)*	**Categories of poultry**	**Quantities of birds bought**	**Frequency of trade**
•				

Q17 - Do you think there are middlemen involved in the trade of live poultry?

☐ No

☐ Yes, could you give details of the location where some middlemen you could know reside? (detail the Province, District, camp, crush pen zone and Village/township):

Q18 - When do middlemen usually pick these birds up from these different places?

☐ The same day of selling at the market (early morning before going to the market) / in your butcher shop;

☐ a few days before selling at the market / at their butcher shop. Please detail:

- Usually how many days before selling at the market / butcher shop?
- Where do they keep these birds while waiting for selling them to the market / butcher shop (detail location Province, District, Ward, Camp, village):

Q19 - How are these live birds usually transported to the market / butcher shops? Describe the means of transport:

☐ Truck ☐ Bicycle/motorbike ☐ Car

☐ Public bus ☐ Walking ☐ Other, please detail:

Q20 - How are these live birds being contained within the market / butcher shop?

☐ Tied together or to a fixed point ☐ Caged

☐ Free range in a delimited area ☐ Other, please detail:

Q21 – When selling, do all the live birds get sold?

☐ Yes

☐ No. Please detail what you think is done with the unsold animals at the end of the day:

☐ **B**ring them home and take them again the following day for selling at the market /butcher shop

☐ **B**ring them home and slaughter them

☐ **Other**, please detail:

Q22- Using data from your poultry movement control and regulatory system (Movement permits and sanitary certificates), would you be able to give details of live poultry that leaves your operational area?

☐ **Yes** ☐ **No**

If yes, please fill in the table below;

For each "**client**" taking live birds from your operational area (as ticked above), please detail in the table below:

- <u>**Location:**</u> Detail the location where these birds are sent to (precise the Province, agriculture camp, village /town),
- **Category of birds:** day old chick, pullets, chicken, ducks...
- **Number of new birds:** total number of birds per destination,
- **Period / Frequency:** detail when or how often birds go to each different destination (which month of the year or frequency of live bird selling- e.g: in March 2012 or once per month or every 3 months...).

Client (Ex : Consumer, market, farmer...)	<u>**LOCATION**</u> **(important field)** *(Province, veterinary camp, village / township)*	**Category of birds**	**Number of birds**	**Period of the year or Frequency**
•				

POULTRY PRODUCTS *(Animal products refer to material derived from the body of a live animal)*
Q23- Is there sell of any of the following <u>POULTRY</u> products at the market / butcher shops in your operational area? - Carcass: .... ☐ No ☐ Yes - Eggs: ....☐ No ☐ Yes - Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes - Feathers: ....☐ No ☐ Yes - Meat: .... ☐ No ☐ Yes - **Other**, please detail:
Q24- Would you know where the poultry products entering your operational area are sourced from? ☐ **Farms**, detail from how many: ☐ **Abattoir / Slaughter houses**, detail from how many: ☐ **Butcher shops**, detail from how many: ☐ **Other**, please detail: -

Q25- Through data captured by your poultry movement monitoring and regulatory system (Movement permits, Sanitary certificates) would you give details of poultry products that enter your operational area?

☐ Yes ☐ No

If yes, please attempt to fill in the table below for poultry products entering your area;

For each **"place"** where poultry products (as ticked above) are bought, please attempt to give details in the table below:

- **Location:** Detail the location where these poultry products are coming from (precise the Province, District, camp, village /township).

Detail all the different places poultry products come from (E.g.: if poultry products bought in 3 different farms, detail the location of the 3 farms).

- **Category of poultry products:** as ticked in boxes above in Q23 & 24 (E.g.: carcass, offal, eggs ...)
- **Quantities of poultry products:** total number of poultry products bought in each place (E.g.: 3 carcasses, 10 trays of 30 eggs, 10kg offal...). Please detail for each category of poultry product (as ticked in Q23 & 24)
- **Frequency:** detail how often you issue movement permits from the source of these animal products (e.g.: every day, once per week...)

Places / Sources of animal products (Farm, abattoir, butcher...)	**LOCATION (important field)** *(Province, district, camp, village / township)*	**Category of animal products**	**Quantities of animal products**	**Frequency of trade**
•				

Q26 - Do you think middlemen are used to buy these poultry products?

☐ No

☐ Yes, would you know where they are based (detail the Province, district, camp and Village/townships)?

Q27 - To the best of your knowledge, when do middlemen usually collect these poultry products from these different places?

☐ The same day of selling at the market (early morning before going to the market) / butcher shop;

☐ Few days before selling at the market / butcher shop. Please detail:

- How many days before selling at the market / butcher shop?
- Where do they store these poultry products while waiting for selling them to the market / butcher shop (detail <u>location:</u> Province, camp, village/township):

Q28 - How are these poultry products usually transported to the market / butcher shops? Describe the mean of transport:

☐ Truck ☐ Bicycle/Motorbike ☐ Car

☐ Public bus ☐ Walking ☐ Other, please detail:

Q29 - Are these poultry products maintained in a refrigerated container during the transport?

☐ No ☐ Yes ☐ Don't know

Q30 - Are these poultry products maintained in a refrigerated container on the stall at the market / butcher shops?

☐ No ☐ Yes

Q31 – Who usually buys these poultry products? Please detail the different categories of customers:

☐ To **restaurants**,

☐ Direct to **consumers**,

☐ To **butcher shops**,

☐ To **farmers**,

☐ **Other**, please detail:

Q32- Through your monitoring and regulatory system (Movement permits, sanitary certificates) would you be able to give details on the movements of poultry products that leave your operational area? Please fill in the table below

☐ Yes ☐ No

Clients (Restaurant, consumer, butcher ...)	**<u>Destination; LOCATION</u> (important field)** *(Province, Ward, camp, village / town)*	**Category of animal products**	**Quantities of animal products**	**Frequency of trade**
•				

SEASONALITY OF TRADE

Q33- Are there periods in the year when more live poultry or poultry products are sold than usual?

☐ No

☐ Yes, please detail the period of the year and the associated occasion if any:

(E.g.: increased trade of poultry late December –early January for Christmas...)

Categories of poultry or poultry products (E.g.: chickens, eggs,)	**Periods of the year with increased trade** (E.g.: Dec-Jan; Easter...)	**Occasion** (E.g.: Christmas, Wedding...)
•		

H. Operating procedures

Q34 - Do marketeers and retailers need a license / a permit for selling their live poultry or poultry products in this market/butcher shop? (refers to any permit paper required to be allowed to sell live poultry or poultry product in this market / at butcher shop)

☐ No ☐ Yes

Q35 - Do farmers, middlemen and retailers need a sanitary authorisation for selling your live animals or animal products in this market/butcher shop?

(refers to any permit relating to the health condition of the animals or to the hygiene quality of the animal products that needs to be presented for being allowed to sell live poultry/poultry product in this market / at your butcher shop)

☐ No ☐ Yes

Q36- Do you think all the farmers, middlemen, marketeers and retailers get the appropriate authorisation for trading in poultry and poultry products in your operational area ☐ **No** ☐ **Yes** **If the answer to the above question no, please give, (a) an approximate percentage that gets permits……….** **(b) Please give a probable reason why other trader do not get appropriate authorisation for doing their poultry trade.**

I. CONTACT WITH WILD BIRDS

Q37- Are there wild birds in your operational area? ☐**No** ☐**Yes** **If yes please give details of bird species and place where they are found**
Q38- If the answer to the last question was yes, among these wild bird species, have you ever seen migratory species in your operational area? ☐ **No** ☐ **Yes** **If the answer is yes, please give the details of the bird species and the place where they are found**
Q39- Does any of the poultry in your operational area share a common habitat (e.g: water source, feeding point etc.) with wild birds? ☐**No** ☐**Yes**
Q40- If any of your answers above was yes, please give details of places in your operational area where you feel greatest interaction with domestic and wild poultry species occurs.

- -

J. POULTRY DISEASES

Q41 - Based on your knowledge and experience, what are the diseases the most at risk for poultry in your operational area? -
Q42 - What measures do you implement for preventing OR controlling diseases among the poultry in this area? Please detail the nature of the measures: (in case of vaccination programme, please detail for which diseases). -
Q43 - Did any of the categories of poultry contract a disease during the previous 12 months? ☐ No ☐ Yes, please detail - Which disease(s):

DISEASE	**A;**	**B;**	**C;**	**Others;**	**TOTAL**
CATEGORY					
Layers					
Broiler					
Indigenous					
G. Fowls					
Ducks					
Others					

TOTAL					

- Was the diagnosis confirmed by laboratory testing for this/these disease(s)? ☐ No ☐ Yes

Q44- During the previous 12 months, did you receive reports of dead birds found among flocks in your area of operation?

☐ No

☐ Yes, please detail the approximate total number of dead birds in the table below:

CATEGORY	**CHICKS**	**PULLETS**	**COCKERELS**	**HENS**	**TOTAL**
Layers					
Broiler					
Indigenous					
G. Fowls					
Ducks					
Others					
TOTAL					

Q45- Usually, what do the farmers, middlemen and retailers do with the carcasses of poultry that is found dead? (Cross ☒ where appropriate)

☐ Burn ☐ Burry ☐ Family consumes ☐ Dog consumes

☐ Sell ☐ Nothing ☐ Other, please detail:

Q46- Do you have any poultry disease surveillance system in place for your operational area?

☐ No

☐ Yes, please detail:

Q47- How often do you report on poultry diseases about your operational area to your superior office?

☐ Weekly ☐ Monthly ☐ Quarterly ☐ Bi annually ☐

Q48- Relying on your experience, how would you rate the following poultry farmers' abilities in your area? Please give your answer in percentages

Ability	**Score**
Correct identification of Newcastle Disease	
Knowledge on the control and prevention of Newcastle Disease	
Willingness to report the outbreak to your office	
Willingness to implement biosecurity measures on the farm	
Ability to abide by the poultry movement bans enforced by government	

Q49- Relying on your experience, how would you rate the following poultry middlemen and retailer's abilities in your area? Please give your answer in percentages

Ability	**Score**
Correct identification of Newcastle Disease	
Knowledge on the control and prevention of Newcastle Disease	
Willingness to report the outbreak to your office	
Willingness to implement biosecurity measures on the farm	

Ability to abide by the poultry movement bans enforced by government	

Q50- How do you deliver your service/s to farmers?

☐ Visit individual farmers ☐ Visit groups of farmers ☐ Both

Q51- How do you deliver your service/s to middle men and retailers?

☐ They come to your office individually ☐ They come to your office in groups

☐ You follow them up through regular inspections and patrols

Q52- Do you know how much it approximately costs you per year to run your service/s?

☐Yes ☐No

If the answer to the question above is yes, please only fill the table below where the service/s applies to your organisation

Service	**Cost in ZMW**
Disease control extension (e.g Disease awareness campaigns)	
Disease control programmes (e.g Vaccinations)	
Poultry disease surveillance	
Routine poultry and poultry movement patrols and inspections	
Inspection of markets and butcheries	
Issuing of licences and other documentation to clients	
Others	
Total	

Q53- What challenges is your institution facing in delivering its services in your operational area?

Q54- What suggestions would you have that could improve service delivery in your operational area?
COMMENT: Please provide any additional comment or detail of relevance from the interview

APPENDIX 5

POULTRY MONTHLY RECORD-TEMPLATE FOR POULTRY CLUB TRIALS

FARMERS' MONTHLY POULTRY RECORD

(Sourced and modified from FABN project in the South Pacific Islands)

Month/ Year..
Farmer's Name..
Village...
Veterinary Camp..
District...
Province...

GPS coordinates (To be given by Veterinary Assistant) ....

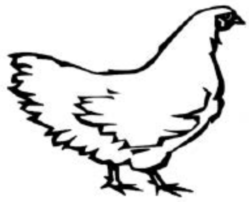
How many birds did you have at the close of the month?

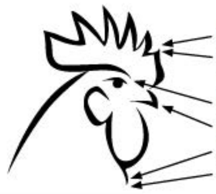
	No. Of Young birds (Chicks/Pullets)	**No. Of Adult Birds**	**Totals**
Layers			
Broilers			
Village Chickens			
Guinea fowl			
Ducks			
Others			
Totals			

What Happened to your poultry last month?

WEEK	**SICK**		**DIED**		**MISSING**		**EATEN**	**SOLD/TRADED**	**AV. WEIGHT**	**DATE**
	Young	Adults	Young	Adults	Young	Adults				
1										
2										
3										
4										

What did you notice on the sick birds?





☐ Head and Neck
- ☐ Swollen Comb
- ☐ Blue (Cyanotic)
- ☐ Oedema Face
- ☐ Watery Eyes
- ☐ Nasal Discharge
- ☐ Swollen Crop / Neck
- ☐ Empty Crop

☐ Diarrhoea
- ☐ Watery Diarrhoea
- ☐ Blood
- ☐ Worms
- ☐ Green
- ☐ White

☐ General
- ☐ Not Eating
- ☐ Sleepy / Weak
- ☐ Ruffled Feathers
- ☐ Losing Feathers
- ☐ Skin Growths
- ☐ No Eggs

☐ Nervous Signs
- ☐ Paralysis / Can Not Walk
- ☐ Twisted Neck
- ☐ Dropped Wing
- ☐ Tremor/Convulsions

☐ Breathing
- ☐ Mouth Breathing
- ☐ Rales / Noise in Throat
- ☐ Cough

Did you do any activities to prevent Disease among your birds?

Measure	Date	Number of birds treated
1. Vaccination		
Newcastle Disease		
Gumboro Disease		
Other....................		
2. Deworming		
3. Cleaning/ disinfection		
4. Medication (anti biotics)		
5. Stresspacs/Vitamin/Minerals		

Birds Purchased Date.... /....../......

Number Birds....... ⇨Price (total) ZMW.......

Transport to purchase (PMV, Boat) ZMW........

Feed and Production

Starter ZMW..........Bags........⇨ Total ZMW..........

Grower ZMW.........Bags.......⇨ Total ZMW..........

Finisher ZMW.........Bags.......⇨ Total ZMW..........

Concentrate ZMW........Bags....⇨ Total ZMW..........

Other Feed ZMW.........Bags.⇨ Total ZMW..........

Other Costs

Medication ZMW.........

Other................................. ZMW.........

.... ZMW........

Selling Costs

Trips to Markets	Market Fees (ZMW)	Transport to market (ZMW)	Other Costs (ZMW)		Total
1				⇨	ZMW
2				⇨	ZMW
3				⇨	ZMW
4				⇨	ZMW
5				⇨	ZMW
6....				⇨	ZMW
Totals				⇨	ZMW

SUM of Colum

Total Cost of Production.................... (A)

Supplier.................................

Did You Feed Maize Yes/ No?

Sorghum Yes/No

Sunflower cake Yes/No

Other Feed Used..................................

Other Feed Used..................................

Other Feed Used..................................

Income from sale of Birds/Eggs (Tick what is appropriate)

Date Birds Sold	Number of Broilers / Eggs Sold	Price Per Bird/Egg (ZMW)		Total Sales that day

.../.../2015			ZMW
.../.../20....			ZMW
.../.../20....			ZMW
.../.../20....			ZMW
.../.../20....			ZMW
.../.../20....			ZMK
.../.../20....			ZMK

SUM of Colum

Total Cash Income.......................... (B)

Cash Profit from Operation (B – A) = ZMW**.............**

APPENDIX 6

QUESTIONNAIRE ON THE PERFORMANCE OF POULTRY CLUBS

Veterinary Extension Staff (District & camp staff)

1. Name………………………………………………………………………………………
2. Rank……………………………………………………………………………………….
3. Veterinary Camp (If applicable) ……………………………………………………………………….
4. District………………………………………………………………………………………
5. GPS coordinates

   S………… E…………
6. Are you a field member of staff in the Veterinary Services Department? Yes/No
7. If yes, for how long have you been serving in the department (please give your answer in months) ………………….
8. Have you used the monthly poultry record form for your disease reporting in the poultry interest group? Yes/No
9. If the answer to 8 is Yes, how useful has it been?

Not useful	Somewhat useful	Useful	Very useful	Extremely useful
1	2	3	4	5

10. Have you used the poultry monthly record form for records on disease occurrence as a source of information for your monthly NALEEIC report? Yes/No
11. If the answer to 10 is yes. How useful has it been for recording disease events on the NALEEIC monthly report)

Not useful	Somewhat useful	Useful	Very useful	Extremely useful
1	2	3	4	5

12. Have you used the poultry monthly record for records on production and marketing costs including income derived from poultry in your routine reporting? Yes/No
13. If the answer to 12 is yes. How useful has the form been in helping with tracking the financial performance of poultry enterprises?

Not useful	Somewhat useful	Useful	Very useful	Extremely useful
1	2	3	4	5

14. Have you experienced any challenges in facilitating farmers filing in the form? Yes/No
15. If the answer to 14 is yes. What are the challenges?

………
………
………
………
………..

16. Do you have any suggestions on how we could improve the form? Yes/No
17. If the answer to 16 is Yes. What are your suggestions?
……
……
……
……
……
……
……
……
…………………………………………
18. Overall, how satisfied are you with the initiative of the monthly poultry record form and the poultry interest groups regarding improving the quality of poultry disease reporting?

Not satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied
1	2	3	4	5

APPENDIX 7

QUESTIONNAIRE ON PERFORMANCE OF POULTRY CLUBS TRIAL

CLUB MEMBER (POULTRY FARMER)

1. Name……………………………………………………………………………………………
2. Village…………………………………………………………………………………………
3. Veterinary Camp…………………………………………………………………………
4. District………………………………………………………………………………………
5. GPS coordinates

   S……….. E………..
6. Are you a member of the poultry interest group? Yes/No
7. If yes, for how long have you been a member (please give your answer in months)

   ………………….
8. Have you used the monthly poultry record form for your record keeping? Yes/No
9. If the answer to 9 is yes, how useful has it been?

Not useful	Somewhat useful	Useful	Very useful	Extremely useful
1	2	3	4	5

10. Have you used the poultry monthly record form for records on disease occurrence on your farm? Yes/No
11. If the answer to 10 is yes. How useful has it been for knowing disease events on your farm and surrounding areas

Not useful	Somewhat useful	Useful	Very useful	Extremely useful
1	2	3	4	5

12. Have you used the poultry monthly record form for records on your production and marketing costs including income derived from poultry? Yes/No
13. If the answer to 12 is yes. How useful has the form been in helping with tracking the financial performance of your poultry business?

Not useful	Somewhat useful	Useful	Very useful	Extremely useful

1	2	3	4	5

14. Have you experienced any challenges in feeling in the form? Yes/No
15. If the answer to 14 is yes. What are the challenges?

………

………

………

………

………

………………………..

16. Do you have any suggestions on how we could improve the form? Yes/No
17. If the answer to 16 is yes. What are your suggestions?

………

………

………

………

………

………

………

………

………………………………………

18. Overall, how satisfied are you with the initiative of the monthly poultry record form and the poultry interest group?

Not satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied
1	2	3	4	5