A STUDY Of THE EPIDEMIOLOGY AND SOCIO-ECONOMIC IMPACT OF ANTHRAX IN LUANGWA VALLEY IN ZAMBIA

By

Victor M Siamudaala

Supervisor : Prof D G A Meltzer

Co-Supervisors : Professors J.F Kirstein & C.S Blignaut
Department of Agricultural Economics
Faculty of Agricultural Sciences
University of Pretoria, Pretoria 0002

Submitted in partial fulfilment of the
requirements for the degree
MSc in Veterinary Science

in the Faculty of Veterinary Science
University of Pretoria, Pretoria,
South Africa.

June 2003

ACKNOWLEDGEMENTS

I wish to thank the Zambia Wildlife Authority (formerly the Department of National Parks and Wildlife Service) for funding the study and granting me leave from my official work in order to undertake the study.

I thank my supervisors Professors D.G.A Meltzer, J.F Kirsten and C.S Blignaut for their guidance and support through out the study. Their advice and encouragement made it possible for me to successfully complete the study.

I am grateful to my supervising officers at Zambia Wildlife Authority, Messieurs H.K Mwima, W. Chisulo, F.E.C Munyenyembe, A.N Mwenya and G.B Kaweche for the valuable discussions and encouragement during the study period. I extend my gratitude to all members of staff who assisted me during data collection.

I am also grateful to my veterinary colleagues, A. Nambota, K Samui and J.M Bwalya for the interest shown in the study and for their constant encouragement. Others are E. Mogoa, G. Gross, G. Bakampaka, A. Madiya and C. Schoener.

My special thanks go to my wife, Jill Siamudaala, for allowing me to leave her alone at home with our son Nathan Chabota during the study period. Her words of encouragement always made me continue with the study even when circumstances seemed unfavourable to do so.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Anthrax is endemic in Luangwa National Park and the adjoining Game Management areas. The first official case of the disease was reported in 1922 in Luambe National Park. In 1987 a large-scale anthrax epidemic ravaged almost the entire Luangwa Valley. Since then at least three epidemics of the disease have been reported. Localised sporadic cases of the disease occur almost annually. Despite the frequent epidemics little is known of anthrax in terms of its epidemiology and impact on conservation. Mortalities were not investigated as wildlife officials attributed the mortalities to natural factors, animal population densities were not estimated and a no systematic disease surveillance programme exists.

The number of animals that have died of the disease is not known. Anthrax mortalities are estimated in thousands. For example it is estimated that 4200 hippos and 1000 other animals, including five wild dogs, succumbed to the disease in 1987. No wild dog has been reported in the area since the 1987 epidemic.

The objectives of this study were:

to describe the epidemiology and the socio-economic impact of anthrax in the Luangwa Valley ;

to examine the control measures adopted when epidemics occur;

to suggest alternative methods of dealing with disease outbreaks in the light of a quantitative risk and cost benefit analyses.

Data was collected from reports was undertaken at the veterinary department, the wildlife offices and the national archives. Informal discussions were held with the local community on anthrax epidemics using the rapid rural appraisal technique. Data on animal demographics and rainfall

were collected from National Parks and Wildlife Service and the National Meteorological Department.

Soil, faeces, and bone samples were collected where large numbers of carcasses had been found during epidemics in the Luangwa National Park. These samples were examined for viable anthrax spores by the Department of Scientific Services in the Kruger National Park, South Africa.

Information gleaned from official and verbal reports were collated and are presented in tabular from. The information found is inadequate to enable comprehensive quantitative risk and cost/benefit analyses. The economic cost of the disease arises mainly from the trade embargo resulting from veterinary quarantine regulations and the value of animal carcasses.

Different scenarios were developed and are examined to present a risk analysis for proposed alternative control measures that could be adopted by the veterinary department when anthrax occurs in the Luangwa Valley. The probability of spreading anthrax by allowing trade in game trophies after treatment with formalin is estimated to be 0.0003-0.5.

Although the impact of the disease on the economic utilisation of wild herbivores and community based natural resource management in the area has never been investigated the potential cost of anthrax epidemics is significant. The estimated cost of anthrax epidemics, depending on the size, as a result of the current disease control strategy are 124,3 – 2079,5 million Zambian Kwacha. The proposed alternative disease control measures could decrease the cost to 43,5 – 852, 6 million Zambian Kwacha.

It is suggested that various measures be adopted to enable a better understanding of the dynamics of anthrax in the Luangwa Valley. These include :

the establishment of a veterinary unit with in the park

improved surveillance and reporting of diseases

regular censuses and estimates of population densities within the Park

improved communication between the veterinary Department and the Wildlife Authority.

Chapter 1

INTRODUCTION

Anthrax appears to be endemic in Luangwa Valley. Although the disease was first confirmed as the cause of an epidemic in the Luangwa Valley in 1987 it is likely that it has occurred regularly since it was first reported in the area in 1922. Since 1987 anthrax outbreaks, either as epidemic or sporadic cases, are not uncommon.

As a result of the a poor infrastructure and a lack of sufficient funding the approaches adopted to control the disease leave a lot to be desired. During the epidemics veterinary authorities focus their attention on the diagnosis of the disease and thus the disease is viewed in isolation and not from the overall ecological perspective taking cognisance of the land use practices in the area. No systematic disease surveillance program has been established. As a result the data is patchy and incomplete in terms of its epidemiology, its impact on biodiversity conservation and the economy both at local and national level. Specific anthrax districts have not been identified. This results in misunderstandings between veterinary and wildlife workers regarding the extent of the area to be quarantined during epidemics. The search and count of anthrax carcasses is usually incomplete. Financial values based on the loss of revenue as a result of veterinary quarantine measures are used to assess the impact of disease epidemics. In addition estimates of the value of carcasses was based on game licence fees. The impact of the disease on species and population conservation have not been considered and little has been done to assess the presence of the disease in the human population.

Co-operation between the wildlife and veterinary authorities regarding enforcement of disease control measures is non existent. Wildlife authorities have showed an inability to regulate themselves and comply with veterinary regulations, especially disease surveillance, even where resources are available.

The Zambian veterinary authority pursues a ‘zero-risk’ policy regarding trade in animal products. Under this policy the veterinary authority observes strict regional quarantine regulations that result in a trade embargo and no consumptive wildlife utilisation is allowed during this period. The policy is based on the biology of the disease and not on a formal risk analysis. These measures are generally in compliance with veterinary regulations prescribed by international institutions such as the *Office Internationale des Epizootics* (O.I.E) to control the disease. The resulting trade embargo has forced the wildlife authority to regard veterinary regulations as the major constraint to the economic utilisation of wild ungulates. Under the current economic pressure wildlife officials favour the application of alternative risk mitigation measures to avoid the trade embargo.

The principle objective of the study was to describe the epidemiology and socio-economic impacts of anthrax in Luangwa Valley in terms of :

- Its temporal and spatial distribution in the area;
- the extent of environmental contamination by the anthrax bacilli;
- the estimated risk of spreading the disease through wildlife utilisation during anthrax epidemics; and
- the direct and indirect costs of anthrax epidemics to the wildlife sector.

Chapter 2

LITERATURE REVIEW

Anthrax

Anthrax is a per-acute, febrile, infectious bacterial disease that mainly affects herbivores and man resulting in fatal septicaemia (Hambleton, Carman & Melling, 1984; Lyon, 1973). The disease kills its host and is a significant cause of mortality in wildlife (O.I.E, 1992). Cases of anthrax in captive wild animals have been widely reported (Ikede, Falder & Golding, 1976; Lyon, 1973; Jordan, 1964). It is considered to be the major and primary cause of mortality in various species of herbivores in Etosha National Park (Turnbull, Hofmeyr, McGeterick & Oppenheim, 1986; Berry, 1981; Ebedes, 1976).

Incidence of anthrax varies with time and place. The disease may occur on a regular basis in some areas while years may elapse between epidemics in others (Kaufmann, 1990). Anthrax epidemics in Kruger National Park appear to have a cyclic pattern of occurrence (De Vos & Bryden, 1996). According to De Vos (1994) anthrax epidemics are initiated by the interaction of interrelated factors involving the anthrax bacilli, the environment and factors that facilitate the dissemination of the bacilli. Critical to the occurrence of the disease is the ability of the anthrax bacilli to survive outside its host, be taken up, and infect its host by multiplying in its system.

Opinions differ as to the mechanism that triggers anthrax epidemics. According to the 'incubator area' hypothesis of Van Ness (1971) perpetuation of the anthrax bacilli in the soil is maintained through a cycle of germination, multiplication and sporulation of the anthrax bacilli in the soil. Favourable conditions such as low-lying areas; heavy rainfall; a soil pH>6, ambient temperature>15.5°C; and the presence of organic material; form 'incubator areas' that lead to the multiplication of the anthrax bacilli thereby triggering an outbreak.

Other workers disagree with this propagation theory. Studies on the Gruinard Island showed that numbers of anthrax spores decreased over time away from the site where bombs containing anthrax spores had been detonated (Manchee, Broster, Stagg, Hibbs & Patience, 1981). Gainer and Saunders (1989) and Gainer (1987) believe that anthrax bacteria that have multiplied outside the hosts' body loose their virulence and thus do not cause the disease. They believe that anthrax outbreaks are associated with exposure over long periods to low numbers of the anthrax spores. To support their argument they compare anthrax to clostridial diseases. In these soil borne and non-contagious diseases, infection is not dose dependent. Instead the disease occurs following the effects of stress on the hosts' immunity and in the absence of stressful conditions the host animal continues in its carrier state. This observation is supported by the isolation of the anthrax bacilli from apparently health impalas in the Kruger National Park. These animals had been vaccinated against the disease. Subsequent experiments on impalas showed that the animals could carry the anthrax bacilli and that the disease only manifested following stressful conditions (De Vos, 1990).

Results from laboratory experiments also appear to disprove the propagation theory. De Vos (1990) reported a decrease in anthrax spore counts over time in soil from 30 different locations in Kruger National Park. B. *anthracis* did not germinate in infected soil from Gruinard Island incubated at 37°C (Manchee *et al,* 1981). Minnet and Dhanda (1941) observed that the vegetative form of the anthrax bacilli failed to survive or multiply in soil that had not been sterilised and attributed this to the presence of antagonistic bacteria which inhibited the multiplication of the anthrax bacilli even when other conditions were optimal for it to do so.

Anthrax epidemics in wild animals have been linked to climatic factors, over utilised areas and high animal densities (Ebedes, 1976; Kellog, Prestowood & Noble, 1970; Pienaar, 1967). De Vos and Bryden (1996) could not find direct correlation between the cyclic occurrence of anthrax epidemics and the long-term climatic changes in the Kruger National Park. De Vos (1990) reported that the disease in the park had adapted to the ecosystem, was density dependent and self-limiting, resulting in a near perfect culling mechanism leaving behind a population of young hosts. Interestingly, Pienaar (1967) reported that only a small number of impala died of anthrax although impala were the most abundant species in the affected area of the park. In contrast, mortality losses were severe in the rare roan antelope (*Hippotragus equinus*) during previous epidemics. Similarly, no relationship was found between impala density and anthrax mortality in the Lake Manyara National Park, Tanzania (Prins & Weyerhaeuser, 1987).

Disease control

Control of the disease in wildlife rests primarily on rapid disposal of carcasses through burial or incineration, management practices such as fencing off of the known anthrax districts and enforcing of a continuous disease surveillance program (De Vos, 1994; Choquette & Broughton, 1981). Enforcing such measures in large and free-range wildlife areas is difficult (Gate, Elkin & Dragon, 1995; Berry, 1993; Ebedes, 1976). Predators and scavengers quickly open the carcasses in the field. This results in the sporulation of the bacteria and environmental contamination. In addition locating of anthrax carcasses is generally incomplete, as many carcasses remain unobserved (Choquette & Broughton, 1981; Pipper & Willoughby , 1964)

Anthrax in human beings

There are three different forms of anthrax seen in man, cutaneous, gastrointestinal and pulmonary (Harrison & Ezzell, 1989). Any one of these forms may give rise to one of two major complications: septicaemia or anthrax meningitis (Davies , 1983). Cutaneous or intestinal anthrax are common amongst rural populations in third world countries (Hambleton et al, 1984). Man acquires the disease through contact with contaminated materials or by eating under-cooked infected meat. Anthrax is commonly seen in the human populations living in close proximity nature reserves.

In man the clinical signs of anthrax vary depending on the route of infection. Cutaneous anthrax is seen as characteristic dark necrotic eschar. The fatality rate in untreated cutaneous cases is 20% (Clark, 1998; Harrison *et al.*, 1989;

Davies, 1983). The clinical signs in the gastrointestinal form of the disease include acute gastro-enteritis, diarrhoea, vomiting, abdominal pain and prostration with varying degrees of severity (Davies, 1982). Death occurs in 25-60% of untreated cases (Ndyabahinduka, Chu, Abdou & Gaifuba, 1984). In pulmonary anthrax the clinical signs are non-specific. Early clinical signs mimic a common cold with mild fever and malaise. These may exacerbate within a few hours with the development of hypoxia, dyspnoea, cyanosis and high temperature. Untreated cases have a fatality rate of 99% (Clark, 1998; Hambleton *et. al*., 1984).

Diagnosis of the disease in humans is based on blood smears and bacterial isolation (Harrison, *et. al.*, 1989). The use of antibiotics lowers the chance of culturing *B. anthracis*. Retrospective serological investigation for antibody titre is advised (Sirisanthana, Nelson, Ezzel & Abshire, 1988). Diagnosis of the disease is complicated in areas where gastro-enteritis of multiple causes such as typhoid fever, dysentery, cholera, and systemic diseases like malaria occur (Ndyabahinduka *et. al*., 1984). Prompt diagnosis and treatment are critical to the control of the disease (Choquette & Broughton, 1981)..

Impact of anthrax epidemics

It is universally accepted that epidemics of diseases in general can result in catastrophic depopulation of the host population with possible local extinction in small populations (Prins & Weyerhaeuser, 1987; Houston & Cooper, 1975). However, little is known about diseases in wild animals (Kirkwood, 1993). The impact that diseases may have on biodiversity conservation has received little attention (Dazskat, Cunningham & Hyatt, 2000). The importance of disease epidemics in regulating animal populations has not been widely investigated (Prins & Weyerhaeuster, 1987; Houston & Cooper, 1975) except in the case of roan antelope (*Hippotragus equinus*) in Kruger National Park (Harrington, Owen-Smith, Viljoen, Biggs, Masson & Funston, 1999). De Vos (1990) and Ebedes (1976) suggested that anthrax should be viewed from the standpoint of its effects on the population and ecosystem and not individual animals. It seems the disease behaves as a natural cull that regulates over population. The socio-economic cost of anthrax in wildlife has not been investigated. However, the disease is of economic importance as no utilisation of wild herbivores is allowed during the period of the epidemic and quarantine (Ebedes, 1992).

The socio-economic impact of anthrax has not been investigated. It is clear however that it is a disease which has a severe impact wild animal populations and thus also effects on the human populations that benefit from the utilization these resources. Anthrax may cause severe disease in humans with a potentially high mortality rate.

Animal diseases and their control are an economic problem (McInerney, 1996). They negatively affect the transformation of resources into products resulting in extra use of resources or less production than before (Dijkhuizen, Huirne & Jalvingh, 1995). Decisions on disease control were, previously, adopted without any economic analysis (Ellis & James, 1979). Inadequate funding of state veterinary services now force veterinary authorities to justify, using economic analyses, to illustrate the merits of disease control programs

(Morris & Meek, 1980). The analyses estimate the economic costs of the disease, costs of achieving control and benefits arising from controlling the disease (Ott, Seitzinger & Hueston, 1995; Dorn, 1992). This favors the adoption of flexible and economically rational disease control strategies (McInerney, Howe & Schepers, 1992; Morris, 1971& 1969). However, information on the technical feasibility of control options is required before deciding which alternative strategy to adopt (Bennett, Christiansen & Clifton-Hadley, 1999).

Benefits and costs of disease-control programs fall into three categories: readily quantifiable benefits and costs; non-readily quantifiable benefits and costs, and benefits that exist but can not be evaluated economically (Morris & Meek, 1980). Animal health policies regarding zoonoses should not be exclusively based on economic costs due to the presence of externalities, that is there is no market that can capture the costs, and the resulting 'free riding' among the population at risk (Ekboir, 1999). The economic impacts of zoonoses are difficult to both, predict and quantify. No true estimate can be assigned to the value of human life or cost of misery. Generally, their effects are complex (Daszak, Cunningham & Hyatt, 2000; Ellis & James, 1979; Morris, 1971). Difficulties arise when assessing the cost of diseases in wildlife in a free-range ecosystem. Generally, the economic value of biodiversity based ecotourism can be readily calculated. However, little has been done to assess the cost of disease with regards to biodiversity loss, especially at global level (Daszak *et al.*, 2000)

Economic evaluation of the impact of the disease looks at the potential threats and effects of the disease and its control on economic surplus (Ott *et al* 1995; Berentsen, Dijkhuizen & Oskam, 1992), technical feasibility and effectiveness of control programs; alternative strategies and distribution of costs and benefits (McInerney, 1996; McInerney, Howe & Schepers, 1992; Morris, 1969). In the case of highly infectious diseases the public policy regarding control of the disease depends on the endemic or exotic status of the disease in the area of concern, production and environmental conditions of the sector and ecosystem, legislation on disease control; the biology of the disease; available technical and economic alternatives to control the disease (Ekboir, 1999). Critical to economic analyses is valid data on; the disease and production system; disease prevalence and information on the biological impacts of the disease (i.e. the mortality rate among the population at risk and effect of the disease on production, including reproduction); available options regarding control f the disease (Bennett, 1992; Morris, 1971).
Various techniques are used in evaluating the socio-economic impact of the disease. The Social Cost Benefit Analysis (SCBA) is widely used to assess public disease-control programs (Bennet 1992; Ngategize & Kaneene 1985; Morris & Meek, 1980).

A risk analysis on anthrax has been undertaken only in livestock (Ryan & Livingstone, 2000; Cox & Ryan, 1998; McDiarmid, 1991). The levels of risk were insignificant and trade was allowed. In contrast no risk quantitative analysis has been done in wildlife, especially in less developed countries.

Instead a zero risk policy is enforced in anthrax endemic areas in these countries especially during epidemics.

The use of rapid rural appraisal

Participatory rural appraisal is preferred to formal questionnaires in gathering information regarding disease outbreaks (Brown, 1985). Questionnaires are long, difficult to administer and process and fail to recognise the indigenous knowledge on many subjects. An inherent weakness of questionnaires is that data from the respondents can not be double-checked by probing questions (Chambers, 1992). The principle of rapid rural appraisal is probing of indigenous knowledge directly on the site, face-to-face. It, therefore, allows interaction and crosschecking as no blue print programme is followed. Key informants are critical in this approach (Vlaenderen, 1995; Chambers, 1992).

Chapter 3

ANTHRAX IN LUANGWA VALLEY

Introduction

Prior to 1987 animals died in large numbers in Luangwa Valley from time to time with no effort made to investigate the cause of the mortalities. Wildlife officials attributed the mortalities to natural factors especially nutritional stress. In 1987 large-scale mortalities due to anthrax took place and hippos (*Hippopotamus amphibius*) were most severely affected. Since then reports of anthrax epidemics have been common but no systematic disease surveillance programme has been adopted to monitor the disease and little is known of the epidemiology of the disease in the valley. Veterinary officials focused their attention on the diagnosis and 'control' anthrax which resulted in patchy and incomplete data sets for epidemiological studies. The particular areas affected by previous epidemics have not been identified and delineated. As a result the extent of the area to be quarantined during epidemics is unknown. In addition anthrax mortalities have never been quantified. The search for the anthrax carcasses was generally inadequate and incomplete. Wildlife officials estimate that thousands of animals succumbed to the disease. It was estimated that 4200 hippos and 1000 other animals succumbed to the disease in 1987.

The disease in the human population was never investigated during the epidemics in the wild animals. There was no official case of human anthrax reported in the area despite evidence that people take meat to eat from anthrax carcasses. Anecdotal evidence suggests the disease in humans went unnoticed by the health and veterinary officials.

This chapter reviews anthrax in Luangwa Valley with the aim of establishing:

- the temporal and spatial distribution of the disease in the area
- the possible factors that influence anthrax epidemics
- baseline data on anthrax mortality
- quantify the mortalities resulting from anthrax

Material and methods

Study area

Luangwa Valley is located in the north-eastern part of Zambia and covers more than 40 000 Km^2 (Phiri, 1987; Astle, Webster & Lawrence, 1969). The area is comprised of South Luangwa; North Luangwa; Luambe and Lukusuzi National Parks and the surrounding Game Management Areas : Musalangu; Lumimba; Munyamadzi; Lupande and Sandwe Game Management Areas (Figure 1.) (Lewis, Kaweche & Mwenya, 1990). Ecologically, Game Management Areas are buffer zones for national parks (Saiwana, 1995; Balakrishna & Ndhlovu, 1992).

Topography

Luangwa Valley is a more or less flat-bottomed trough bounded by steep, deeply dissected escarpments that rise to 700-800m above its floor. Its gradient rises from 400m above sea level at the Luangwa-Zambezi River confluence near Luangwa Boma to 1 000m at its upper end near the Nyika plateau (Astle *et al.,* 1969).

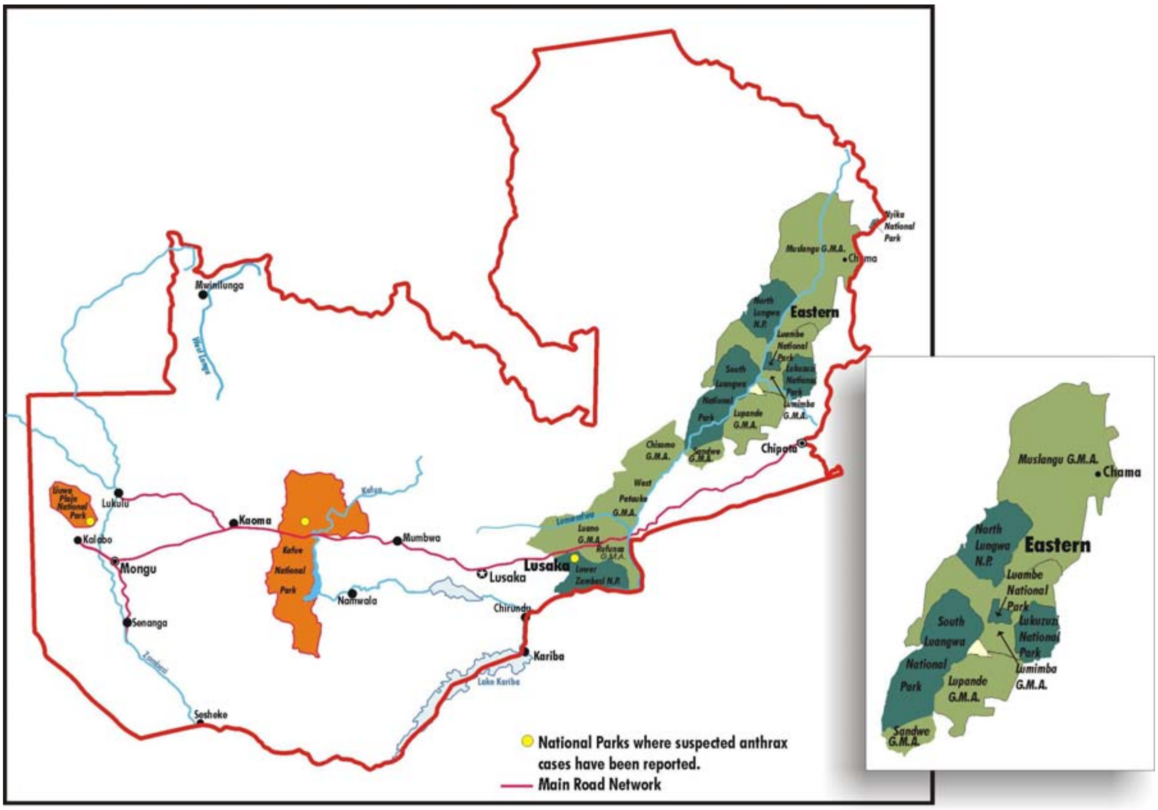

Figure 1. Map of Zambia showing the study area and other nature reserves

Climate

The area has a semi-arid climate with two main seasons: the dry season from May to October and the wet season from November to April. Average annual rainfall is approximately 800mm. Temperatures vary greatly with the mean ranging between 32 and 35°C (Smith, 1997; Balakrishna & Ndhlovu, 1992). The mean annual relative humidity at Mfuwe Meterological Station is 62 % (Phiri, 1989).

Hydrology

The Luangwa River is the only permanent river in the area. Its tributaries flow only during the rainy season and earlier parts of the dry season when the area is flooded (Astle *et al,* 1997; Balakrishna & Ndhlovu, 1992; Astle *et al,* 1969).

Soils

The soils in the valley are heterogeneous. Each soil type supports a different vegetation-type. Mopane woodland, the thick riparian forest and miombo woodland are found on deep soils. The flood plain grassland and miombo savannah grow on the freely draining alluvium while miombo shrub is found on shallow soils (IUCN/GRZ, 1995; Astle *et al.,* 1969).

Vegetation

The principle vegetation in the valley is the mopane woodland dominated by *Colophospermum mopane,* which occurs in pure and dense stands. Other woodland types are *Combretum-Terminalia*; *Acacia-Combretum* and the *Brachystegia-Julbernardia*. Common grasses include *Cynodon dactylon; Digitaria milanjiana; Heteropogon contortus; Hyperrhenia filipendula; Oryza barthii; Paspalum commersonni* and *Setaria phragmatoides* (Astle, Phiri, & Prince, 1997a & b).

Wildlife

The Luangwa Valley supports diverse and abundant wildlife (Lewis *et al.,* 1990) a large crocodile (*Crocodylus niloticus*) population and an estimated 20 000 hippos (*Hippopotamus amphibius*). The hippo density of the Luangwa river in the South Luangwa is estimated to be 40 hippos per river kilometer (Mushingo, 1999). Other animal species are elephant (*Loxodonta africana)*; buffalo (*Syncerus caffer*); bushbuck (*Tragelaphus scriptus*); eland (*Taurotragus oryx*); giraffe (*Giraffa carmelopardalis)*; impala (*Aepyceros melampus*); kudu (*Tragelaphus strepsiceros*); puku (*Kobus vardonii*); warthog (*Phacochoerus aethiopicus*); waterbuck (*Kobus ellipsiprymnus*); wildebeest (*Connochaetes taurinus*); zebra (*Equus burchelli*); and. Carnivores found in the area include, leopard (*Panthera pardus*); and lion (*Panthera leo*) (IUCN/GRZ, 1995).

Communication

Major access to Luangwa Valley is by the Great East Road from Lusaka via Chipata and the Mfuwe International Airport is close to South Luangwa National Park. A series of airstrips exist in the area. The road network is poor within Luangwa Valley and becomes impassable in the wet season (IUCN/GRZ, 1995).

Wildlife utilization

Consumptive and non-consumptive wildlife utilization are the principle land-use in Luangwa Valley. Eco-tourism is the only wildlife utilization permitted inside the national parks of Zambia (Balakrishna & Ndhlovu, 1992; Lewis *et al,* 1990) and is implemented in the South Luangwa National Park. Lodges in the park are located in the riverine area (IUCN/GRZ, 1995). The state operates two community based wildlife management programmes: the Luangwa Integrated Resource Management Project which covers South Luangwa National Park and Lupande Game Management Area. The rest of Luangwa Valley is under the Administrative Management Design for Game Management Areas (Saiwana, 1995; FAO, 1992).

Historical surveys

A review of reports was undertaken at the veterinary department, the wildlife offices and the national archives. Informal discussions were held with the local community on anthrax epidemics in the area. Data on animal demographics and rainfall were collected from National Parks and Wildlife Service and the National Meteorological Department. A possible trend between animal numbers and disease epidemics was assessed. Similarly, a correlation between annual rainfall and anthrax epidemics was examined.

Three research assistants were selected from among wildlife workers at the National Parks and Wildlife Service office in Mfuwe. The assistants were taught how to conduct informal discussions based on the rapid rural appraisal technique. As part of their training they interviewed three wildlife scouts under close supervision. Interviews were then held with the local community and wildlife workers in the area. Informal discussions were held with the local community in Kakumbi, Chitungulu and with the Chikwa Chiefdoms. Initial discussions were held with the respective chiefs in these chiefdoms. Later the Chiefs assisted in the identification of key informants who could provide valuable historical information. The chiefs assured the informants that data collected during the discussions was for the study. This allayed the initial fears that the study was a under cover to apprehend people involved in unlawful wildlife practices such as poaching.

Results

Anthrax epidemics

Spatial distribution

Areas where anthrax had occurred were identified primarily in the riverine habitat. The disease was reported in North Luangwa National Park and the

Musalangu Game Management Area in 1987 and 1988. Multiple anthrax districts, formed an ‘anthrax belt’ in the central Luangwa Valley which stretches from Luambe National Park and Lumimba Game Management Area in the north to the Lusangazi/Luangwa river confluence in South Luangwa National Park and the Lupande Game Management Area further south. The disease is reported to be confined to the Chipuka plains In Luambe National Park and Lumimba Game Management Areas. Anthrax occurs regularly in the Mfuwe and Nsefu sectors of the South Luangwa National Park and Lupande Game Management Area (Figure 2.). In Mfuwe area the disease concentrates around Mfuwe and Katete bridges; Mfuwe air strip; Chichele and Mfuwe lodge; Manchesa and Lusangazi wildlife camps; Mulenga fishing camp; and a series of lagoons in South Luangwa National Park (Figure 3). In the Nsefu sector anthrax carcasses are common around the lagoons on the Milyoti-Kauluzi region (Figure 4.). Carcasses with bloody discharges from natural orifices were reported in 1989 at the Luangwa/Zambezi and Kafue/Zambezi river confluence in Lower Zambezi National Park (Anon, 1989).

Figure 2. Anthrax areas in South Luangwa and Luambe National Parks. Areas where anthrax cases have been reported frequently are within the highlighted portion of the map.

Figure 3. Anthrax areas in the Mfuwe Sector of South Luangwa National Park

Figure 4. Anthrax areas in the Nsefu Sector of the South Luangwa National Park

Anthrax in Zambian wildlife

Anthrax was first diagnosed in wildebeest and zebra during 1922 in Luambe National Park (Tuchili, Pande, Sinyangwe & Kaji, 1993). No records of the disease are available until 1987 when a large-scale anthrax epidemic ravaged almost the entire Luangwa Valley. However a study in the Luangwa Valley undertaken during the 1960's had suggested that anthrax was a potential threat to wildlife conservation there and that the disease occurred in the area in its epizootic form(FAO, 1969).

It seems that earlier anthrax epidemics, prior to 1922, in the area went unnoticed. Large-scale animal die-offs were not uncommon in the northern sector of Luangwa Valley before 1920. The mortalities were known as 'kalila' among the Tumbuka speaking people of the area. During the period 1938-1945 animals died in large numbers in Luambe National Park and Musalangu Game Management Area in central Luangwa Valley. Similar die-offs were observed in Lumimba Game Management Area in the northern sector of Luangwa Valley. In Musalangu Game Mabagement Area the mortalities were called 'Mleenga', in reference to God as people attributed the animal die-off to God's wrath against them. The majority of the mortalities were seen during the dry season from August to November. The most vulnerable species appear to have been hippo, impala, puku, waterbuck and zebra. Mortalities were known as 'Chipumpu' a term used to refer to a mysterious disease in the Lupande Game Management Area. Hippo carcasses with bloody discharges were observed in Mfuwe area in 1966.

A large-scale mortality, especially in hippos, was reported in Mfuwe area in 1987. This time anthrax was identified as the cause of the mortalities. The initial focus of the 1987 epidemic occurred in June around Old Lion Camp and Milyote lagoon in the Nsefu sector of South Luangwa National Park. The epidemic spread rapidly to other areas. By July the epidemic had covered extensive areas of the park and the lower sector of Lupande Game Management Area including parts of Sandwe Game Management Area. The epidemic ended with the onset of rains in November (Anon, 1988). Anthrax reappeared in June 1988 at Lufila/Luangwa river confluence in central Luangwa Valley and spread quickly both up- and downstream. It was reported in several sectors of the North Luangwa National Park, the Musalangu Game Management Area and reached the Mushilashi/Luangwa river confluence in North Luangwa National Park in October 1988.

In June 1991 an anthrax epidemic, which lasted two months, occurred in Luambe National Park. A short lived epidemic which lasted only two weeks ravaged Nsefu sector of South Luangwa National Park in April 1997.

<u>Factors that predispose anthrax epidemics</u>

Luangwa Valley is generally low lying and floods extensively in the wet season. During this time food and water are plentiful. As the flood subsides it leaves behind organic debris particularly in the riverine areas. During the dry season when food resources are limited water is found only in the riverine area. Animals migrate and concentrate in this area resulting in increased inter- and intraspecific competition for resources. During this period animals tend to graze on the short grass almost to ground level. Water is limited to a series of lagoons in of the Luangwa River which are often stagnant. Hippos collect in these pools, the mean school size increases and the number of schools per river kilometer declines.

Crocodiles quickly open the carcasses of hippos that succumb to the disease in the water. Similarly, scavengers soon open carcasses of other animal species on land. This results in the contamination of pasture and soils. Herds continue grazing in these areas and the disease spreads among the crowded and already stressed animals. Anthrax in hippos is common in areas with high hippo densities. These areas are found inside the South Luangwa National Park.

In 1981 and 1984 hippos died in large numbers in central Luangwa Valley. During these years the area experienced severe droughts. Total rainfall during December-March was 484.3mm and 449.1mm for 1981 and 1984 respectively. The cause of the mortalities was not investigated as nutritional stress was suggested to be responsible for the deaths.

The actual origin of the 1987 epidemic is not known. It is likely that there is a link between the epidemic and drought. An analysis of the rainfall data shows that the 1987 epidemic was preceded by a period of severe drought. Total annual rainfall during the 1986/87 rain season was 664.6mm, 17% below the Long-term Mean Annual Rainfall of 800mm. This contrasts with the rainfall during the 1984/85 and 1985/86 which exceeded the mean by 32% and 22 % respectively. During 1987 food and water were inadequate for the animals except for a few isolated places along the river.

Anthrax was also reported in 1988 and 1989. The epidemics ravaged almost the entire riverine area. During these years the rainfall measured at the Mfuwe meteorological station in the central area of the valley was far above the Long-term Mean Annual Rainfall. The epidemics however occurred in the northern sector of Luangwa Valley where reports indicate that the rainfall was poor. No rainfall data is available from these areas. Suspect anthrax carcasses were reported during 1992, 1994 and 1996. Total rainfall during these years was below the Long-term Mean Annual Rainfall. The 1997 epidemic was preceded by a dry spell followed by heavy storms.

An analysis of hippo population in the South Luangwa portion of the Luangwa river indicates that hippos reached the highest density of 40 animals per river kilometer in 1986. A total of 6741 hippos were counted in this stretch of the Luangwa river. The hippo school sizes were generally larger than usual. The population, however, declined to 5322 in 1987 following the anthrax epidemic. A further decline was recorded in 1988 after which the population recovered steadily until 1995. The decline in the hippo population after 1995 has been attributed to the culling programme but the hippo culling quota was far less than the measured decline.

The most vulnerable species in 1987 were hippo; giraffe; buffalo and elephant in descending order. A total of 440 anthrax carcasses were counted by ground patrols in an isolated area of less than 50km^2 in central Luangwa Valley. Table 1. summarizes the number of carcasses from the different species of animals that were found in this part of the reserve.

Table 1. Anthrax carcasses in central Luangwa Valley in 1987 showing the number of deaths in different animal species.

Animal Species	Scientific Name	Estimated population size	Deaths n =
Baboon	*Papio ursinus*		2
Buffalo	*Syncerus caffer*	2 953	60
Eland	*Taurotragus oryx*	87	1
Elephant	*Loxodonta africana*	1 732	20
Giraffe	*Giraffa carmelopardalis*	29	2
Hippo	*Hippopotamus amphibius*	3 127	324
Hyaena	*Crocuta crocuta*		1
Impala	*Aepyceros melampus*	1 116	1
Kudu	*Tragelaphus scriptus*		5
Leopard*	*Panthera pardus*		2
Porcupine	*Hystrix africaeaustralis*		1
Puku	*Puku vardoni*	1337	12
Waterbuck	*Kobus ellipsiprymnus*	423	3
Warthog	*Phacochoerus aethiopicus*	45	
Wild dog	*Lycaon pictus*		5
Wildebeest	*Connochaetes taurinus*	1 395	
Zebra	*Equus burchelli*	664	1
TOTAL		12 908	440

Hippo carcasses were located on a 23 kilometer stretch of the Luangwa river between Tundwe and Nyamaluma from July to October. The average loss of hippos in the South Luangwa portion of the Luangwa River, between Lusangazi and Chibembi, was estimated at 1419 hippos, which is 21% of the 1986 count. This estimate was based on the difference between 1987 and 1986 annual ground hippo count on the assumption that there was neither emigration nor immigration of hippos in this portion of Luangwa River. The total hippo population in the entire Luangwa river at the time was estimated at 20 000. An extrapolation of this 21% loss to the population estimates that the total loss was 4220 hippos. No count of carcasses was done in subsequent epidemics.

In 1988 in the northern sector of the valley the most affected species were hippos, zebra, elephants, buffalo, impala, warthog and kudu. It was estimated that anthrax carcasses in 1988 would equal the 1987 levels. During 1991 epidemic in Chipuka plains of Luambe National Park the disease affected zebra and wildebeest more severely. The total of numbers that succumbed to anthrax in 1997 in Nsefu sector of the South Luangwa National Park and the animal species vulnerability are summarized in Table 2. The carcasses were located in an area less than 40 km^2 in Nsefu sector.

Table 2. Anthrax carcasses in central Luangwa Valley in 1997 showing animal species, numbers and vulnerability

Animal Species	Scientific Name	Estimated population size n =	Relative abundance %	Deaths	Proportion of total recorded deaths
Buffalo	*Syncerus caffer*	2872	5.75		
Bushbuck	*Tragelaphus scriptus*	1170	2.34		
Duiker	*Sylvicapra grimmia*	2362	4.73		
Eland	*Taurotragus oryx*	189	0.38		
Elephant	*Loxodonta africana*	2657	5.32		
Giraffe	*Giraffa carmelopardalis*	1016	2.04		
Hippo	*Hippopotamus amphibius*	4864	9.74		
Impala	*Aepyceros melampus*	21 839	43.75	4	9.52
Klipspringer	*Oreotragus oreotragus*				
Kudu	*Tragelaphus scriptus*	676	1.35		
Lion	*Panthera leo*	227	0.45		
Oribi	*Ourebia ourebi*				
Puku	*Kobus vardonii*	4861	9.74	4	9.00
Reedbuck	*Redunca arundinum*				
Roan	*Hippotragus equinus*				
Sable	*Hippotragus niger*				
Warthog	*Phacochoerus aethiopicus*	2996	6.00		
Waterbuck	*Kobus ellipsiprymnus*				
Wildebeest	*Connochaetes taurinus*	579	1.16	2	4.76
Zebra	*Equus burchelli*	2118	4.24	32	76.19
	TOTAL	49 921	100.0	42	100.00

The exact number of animals that have succumbed to anthrax since 1987 could not be determined from available records. Wildlife workers in Luangwa Valley estimated the anthrax mortalities in thousands. The total numbers of carcasses reported in the area during 1987-1997 period are summarized in Table 3. It was not possible to group the anthrax carcasses into sex and age groups as data on carcasses from field officers was not classified in that way. Wildlife workers reported that most carcasses were of adult animals.

Table 3. Animal mortalities in Luangwa Valley between 1987 and 1997

Common Name	Scientific Name	n =
Baboon	*Papio ursinus*	3
Buffalo	*Syncerus caffer*	97
Eland	*Taurotragus oryx*	1
Elephant	*Loxodonta africana*	41
Giraffe	*Giraffa carmelopardalis*	11
Hippo	*Hippopotamus amphibius*	1839*
Hyena	*Crocuta crocuta*	8
Impala	*Aepyceros melampus*	5
Kudu	*Tragelaphus scriptus*	5
Leopard	*Panthera pardus*	2
Lion	*Panthera leo*	7
Porcupine	*Hystrix africasaeaustralis*	1
Puku	*Kobus vardonii*	16
Warthog	*Phacochoerus aethiopicus*	4
Waterbuck	*Kobus defassa*	4
Wild dog	*Lycaon pictus*	7
Wildebeest	*Connochaetes taurinus*	3
Zebra	*Equus burchelli*	49
Total		2099

Note: * denotes estimates based on hippo total count in 1987

Anthrax in human beings

No official records of the disease in humans are available in the area. Information from local communities suggests the disease may have gone unnoticed. In 1987 three cases of suspected anthrax were reported, two at Kakumbi rural clinic and one at Kamoto rural hospital. The victims had oedema of the face and arms. Two victims, both at Kakumbi rural clinic, died in less than 24 hours of the onset of clinical signs.

Cases of explosive acute gastroenteritis and cutaneous sores were reported in Lumimba and Musalangu Game Management Areas in 1988. The cases coincided with the anthrax epidemic that ravaged the area. In Lumimba the cases occurred in Chief Chitungulu's area. All the victims responded to antibiotic therapy. In Musalangu Game Management Area the cases were reported within Chief Chikwa's area of control. The majority of the cases were observed in Pondo and Doroba villages along the riverine area. Within 48–72 hours of eating meat from anthrax carcasses people had blood-tinged diarrhoea and cutaneous sores on their arms and legs. It is estimated that at least 100 people succumbed to gastroenteritis. The victims died within three days of the on set of the diarrhoea. Other victims responded to antibiotic therapy which was provided by the Flying Doctors Services. The distance between villages and the health center forced most people to depend on traditional agro forestry medicine. Trees that were commonly used, with local names in parenthesis, were *Kigelia africana* (mvungula), *Combretum imberbe* (musimbiti), and *Cassia abbreviata* (musokansoka). Roots were dried and ground into powder, which was either applied on the sore in the case of cutaneous sores or mixed with water as a drink in the case of gastroenteritis. The response to traditional medicine varied with the severity of the case. Severe cases did not respond well to treatment. Cutaneous sores took approximately a month to heal.

Cases of diarrhoea were reported following consumption meat derived from anthrax carcasses that were smoke-dried and sold in Lundazi District. It appears no death was recorded in the area. Both in Musalangu Game Management Area and Lundazi District health officials suspected dysentery. No laboratory investigation of dysentery cases were done.

In April 1997 an unconfirmed outbreak of cholera was reported in Nsefu Chiefdom in the Lupande Game Management Area. Clinical signs of diarrhoea and vomiting were seen. This outbreak coincided with the anthrax epidemic in the area. The first victim died within 24 hours of the onset of the diarrhea. An undisclosed number of people were admitted at Kamoto Hospital. Most of the victims responded to antibiotic treatment but some succumbed to the diarrhoea. The fatal cases occurred in villages before the victims could reach the hospital for medication. At the time health officials suspected cholera. The disease could not be confirmed during laboratory investigation as no cholera organisms were isolated.

Discussion

Anecdotal evidence suggests that the disease may have been in the area much earlier than 1922 but went unnoticed. It is likely that anthrax was obscured by the rinderpest pandemic that ravaged the area in the 1890's. In the past no efforts were made to investigate the cause of the mortalities. The whole situation was exacerbated by the previous belief among wildlife officials that mortality in game animals was as a result of natural factors. Data on the disease is patchy and incomplete. No records of the disease exist for period prior to 1987. During epidemics veterinary authorities focus their attention on the diagnosis and control of the disease. Little was done in terms of systematic surveillance of the disease.

Factors that may trigger anthrax epidemics in the area were not easy to identify. Ecological and epidemiological data from most areas of Luangwa Valley is inadequate. It seems epidemics are triggered by an interplay between habitat condition; population density; feeding behavior of the most vulnerable species; and the behaviour of the pathogen, *Bacillus anthracis*. The ecological conditions described by Van Ness (1971) that trigger anthrax epidemics do occur in Luangwa Valley. These include the presence of low poorly drained areas, drought, ambient temperatures greater than15.5°C and alkaline soils rich in organic matter. In the dry season Luangwa Valley is almost devoid of vegetation except for isolated places along the riverine area. During this time the grass is short. Animals graze almost to ground level and the possibility of ingesting anthrax spores is increased.

Opening of carcasses by hyenas and vultures favours the spread of the disease.

The combination of the drought, resulting in nutritional stress, and increased hippo density, may have triggered the epidemic in 1987. Given the constraints of data no direct relationship can be shown between anthrax epidemics and hippo densities. A prediction of the occurrence of the disease can not be made on the basis of population density alone. Similarly It was not possible to determine what triggered the 1988, 1989 and 1991 epidemics that were concentrated in the northern sector of Luangwa Valley. No climatic data exist in this area. Although data from Mfuwe meteorological station indicates an annual rainfall above the mean it is possible that rainfall may have been below the mean in the areas to the north.

It is likely that drainage plays a role in dispersing anthrax spores. Crocodiles open hippo carcasses in the water and the spores are carried by water to other areas. Secondly, anthrax spores may be carried and deposited in pools in the river as floods subside. Hippos stir and mix the anthrax-contaminated mud with water and animals that drink from these areas could pick up anthrax spores.

Under reporting of anthrax carcasses during epidemics is common. No systematic disease surveillance is done during epidemics due to inadequate manpower and transport being allocated for this purpose. Epidemics monitored by ground patrols result in slow and inadequate surveillance. Scavengers remove most carcasses, especially of small antelopes. In the case of hippos only floating carcasses are reported during patrols. The area becomes impassable during the wet season and the overgrown vegetation impairs visibility.

No official record of the disease in humans exists in the area despite evidence of people utilizing anthrax carcasses. Anecdotal evidence, however, suggests that the disease may have gone unnoticed in humans during previous epidemics. Health workers in the area can not recognize anthrax cases in humans on the basis of history and clinical examination of the patient. The problem has been exacerbated by the tendency among local people not to disclose information of human cases associated with consumption of game meat. They suspect that health officials may pass over such information to wildlife authorities and that this may result in their prosecution. No official communication exists between the wildlife, veterinary and health officials as a result health officials are not notified of epidemics and do not look out for possible cases in humans.

CHAPTER 4

ANTHRAX DIAGNOSIS AND CONTROL

Introduction

Diagnosis of anthrax in Luangwa Valley is based on the positive identification of the anthrax bacilli from fresh carcasses. However, fresh carcasses are often not found. They are seldom left for longer than a few hours and very little will be found after 24 hours. In such circumstances veterinary officials depend on samples from the immediate environment of the animal remains. At times no investigation is done during the epidemics. It has been suggested that Luangwa Valley is extensively contaminated with anthrax spores. This conclusion was made following isolation of the anthrax bacilli from environmental samples (soil, water and animal remains) during the large-scale epidemics in 1987 and 1989.

Control of the disease has received little attention from both veterinary and wildlife authorities. The government's disease control strategy of choice was initially designed for livestock. The measures are recommended with no regard to their technical feasibility and effectiveness in a free-range ecosystem such as Luangwa Valley. Little has been done in terms of disease control from the standpoint of the human population in the area.

This chapter describes the diagnosis and control of the disease during previous epidemics focusing on:

- the anthrax diagnosis protocols employed at the diagnostic laboratories;

- levels of anthrax contamination in the area;
- the degree of co-operation between the wildlife and veterinary officials,

including health authorities.

Material and methods

Anthrax reports for the period 1987 to 1997 were reviewed focusing on anthrax diagnosis and control measures enforced during the epidemics. Veterinary diagnostic centres, including the Veterinary Faculty at the University of Zambia, were asked to provide diagnostic protocols used to diagnose anthrax.

A total of 208 environmental samples (soil, bones and vulture and hyena droppings) were collected from the anthrax districts in the Luangwa Valley. The anthrax districts were identified from the existing anthrax reports. A ground search for the samples was undertaken in the identified areas. Samples were collected within a radius of about 1-2 kilometre of the area in which carcasses were previously reported. Samples were collected from the upper 2-3 cm of the soil profile. The samples were packed in plastic containers, labelled with regards to nature of sample, date of collection area collected, and dispatched to the laboratory for culture of anthrax spores. The protocol for the isolation of the anthrax bacilli is summarised in Table 4. and was based on Parry, Turnbull and Gibson (1983) and Knisely (1966).

Discussions were held with the wildlife officials at the outlying camps in the reserve and focused on the disease reporting mechanism, collection of samples and disease control strategies during epidemics.

Table 4. A summary of the protocol for the isolation of the anthrax bacilli from environmental samples

	Details of the Procedure
i.	Weighed 10g of soil, crushed bone or faeces in a sterile 200ml bottle
ii.	Added an equal mass of laboratory glass beads
iii.	Added 20ml of distilled water and shook vigorously using a horizontal slide shaker for 1 hour
iv.	Left the mixture to stand for 5 minutes
v.	Strained 5ml of the supernatant through a double layer of cotton gauze into a sterile test tube
vi.	Heated in a warm bath at 62.5ºC for 30 minutes
vii.	Waited for 30 seconds to 1 minute. Then collected 100-150 µl from the top with a micropipette
viii.	Spread the material on PLET medium (prepared according to Knisely (1966)
ix.	Incubated suspicious looking colonies on blood agar overnight
x.	Placed 1.5 ml of de-fribrinated blood into sterile petri dish
xi.	Placed at least a pin head of the suspected colony into the blood and incubated overnight
xii.	Made thin smears and air dried
xiii.	Fixed in methanol for 10 minutes
xiv	Stained in Giemsa for 30 minutes
xv.	Washed in clean water
xvi.	Confirmed microscopically

Review of anthrax diagnosis and control

Disease Diagnosis

Most of the laboratory examinations were done at the Central Veterinary Research Institute and the Veterinary Faculty of the University of Zambia. A few diagnoses were done at the regional veterinary diagnostic laboratory in Chipata. Diagnosis of the disease was based on the microscopic examination of giemsa-stained smears; isolation of anthrax bacilli from animal tissues; and samples collected from the immediate area around the carcass including soil, water, faeces from vultures and other scavengers if found. In 1987 biochemical identification, antibiogram and mice inoculation were done to confirm the disease.

The initial diagnosis of anthrax was based on microscopic examination of giemsa smears. In 1987 and 1988 giemsa smears were processed and examined at Chinzombo Wildlife Offices in Mfuwe where a laboratory was established during the epidemic. The disease was later confirmed, using bacteriological culture, at the Central Veterinary Research Institute and Veterinary Faculty.

During the period 1987-1993 a total of 184 samples, all from central Luangwa Valley, were submitted for anthrax diagnosis. Details of the diagnoses are summarised in Table 5.

A total of 208 environmental samples were examined for the anthrax bacilli. The bacillus was isolated from only one sample. The type of sample collected and diagnostic results from these are summarised in Table 6.

Table 5. Results of anthrax diagnoses during epidemics of the disease in central Luangwa Valley for the period 1987-1993. (Data is presented as the number of positive diagnoses/total number of samples examined).

	Types of Sample						
Year	Blood Smear	Water	Vulture Droppings	Hyena Droppings	Soil	Animal Tissue	Total
1988	22/24	1/5	1/5	1/5	1/13	7/17	33/69
1990	-	0/15	0/3	0/3	1/30	-	1/51
1991	-	0/10	0/7	0/4	0/16	2/22	2/59
1993	-	0/1	0/1	-	0/2	1/1	1/5
Total	22/25	1/31	1/15	1/12	2/61	10/40	37/184

Table 6. Isolation of *Bacillus anthracis* samples collected from Luangwa Valley in November-December 1998

	Soil	Bone	Hyena Droppings	Vulture Droppings	Total
No. Samples Diagnosed	188	6	13	1	208
No. of Positive Diagnosis	0	0	0	1	1
% Positive Diagnosis	0	0	0	100	0.5

Disease Control

Anthrax is a notifiable disease in Zambia. During epidemics various measures were enforced. In 1987 an intersectoral Anthrax Task Force was established to control the anthrax epidemic. The team comprised wildlife, veterinary and health officials, together with representatives of the provincial political wing of Government.

The following measures were enforced in an attempt to control the disease: burning of carcasses; inoculation of the most vulnerable species, giraffe, against anthrax; and a public awareness program among the local community. A total of fifty-five carcasses were incinerated using firewood and discarded motor oil in Mfuwe and Nsefu areas in central Luangwa Valley. Elephant and hippo carcasses were enclosed in a corral and allowed to decompose before burning them. This prevented scavengers from accessing the carcasses and reduced on the amount of firewood required. Elephant and hippo tusk trophies recovered from decomposed carcasses were disinfected in 10% formaldehyde.

The giraffe population was considered to be the most vulnerable at the time. The dense bush in the area made it impossible to vaccinate giraffes effectively and the campaign to do so was abandoned after five animals had been vaccinated using the Sterne vaccine. A further difficulty that affected this programme was the absence of a means of identifying vaccinated animals.

The community were notified of the disease and warned against the consumption of meat from carcasses found.

No control measures were enforced in the field during the 1990 and 1991 epidemics. In 1997 control measures recommended by the Provincial Veterinary Office included: intensified disease surveillance, burning of carcasses, preventing animals from entering the epizootic area, a community awareness campaign and quarantine of the affected area (Lupande Game Management Area). The quarantine lasted for 60 days after which consumptive utilization was allowed. A number of conditions were attached to the resumption of consumption utilization. These conditions included:

- all trophies were to originate from healthy animals;
- disinfecting of trophies was to be carried out by a state veterinarian;
- wildlife authorities were to desist from withholding information on the disease for purposes of maximising economic gain.

None of these measures were, however, enforced in the field.

According to the wildlife officers interviewed anthrax epidemics came to their attention during their routine anti-poaching patrols. These cases reached the attention of veterinary officials after passing through a hierarchy of ranks within the administrative structure of the wildlife authorities in the area. This resulted in delayed veterinary response to the epidemic. The hierarchy in the reporting procedure used in the Luangwa Valley is represented schematically in Figure 5

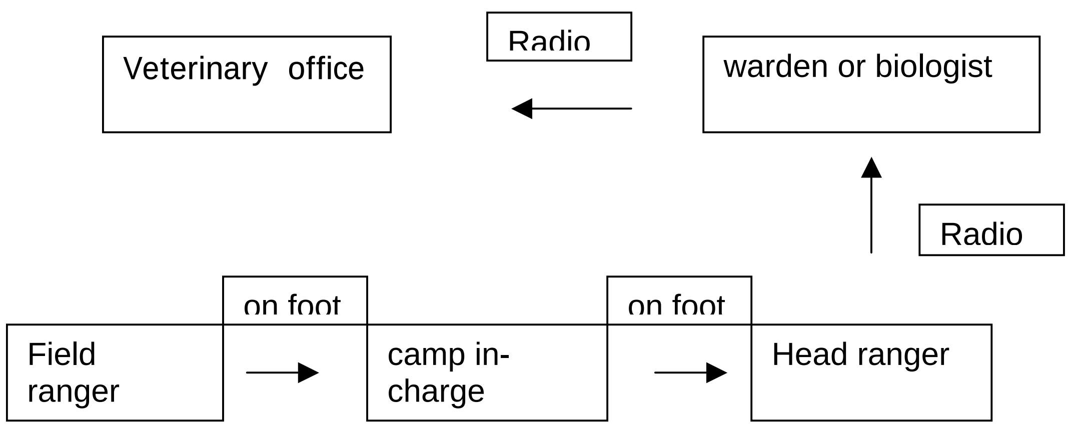

Figure 5 Schematic representation of the hierarchy of the reporting procedure in Luangwa Valley

Discussion

The veterinary department response to anthrax epidemics was slow. Wildlife field workers wasted a lot of time following the reporting procedures demanded by the authorities. The whole situation was exacerbated by the general lack of communication facilities like adequate transport and two-way radios. Often, the vehicles and radios were not available or had broken down resulting in delayed reporting. Consequently, diagnosis of the disease was delayed.

Veterinary officials spent too much time completing government procedures; obtaining authority to travel out of station; organizing transport and the necessary funds for fieldwork. By the time they got to the field carcasses had already been removed by scavengers. Chances of isolating the anthrax bacilli from the soil and water were small. Areas heavily contaminated with anthrax spores and where isolation of the pathogen may be possible are those contaminated with the blood-tinged discharges. The scavengers disturb these areas while feeding on the carcasses. Isolating the anthrax bacilli from environmental samples involves searching for anthrax spores against a background of other bacterial flora, particularly *B. cereus* (De Vos, 1994). As a result failure to isolate the anthrax bacilli from the samples does not necessarily mean the area is not contaminated with anthrax spores.

Disease control in the area was theoretical. None of the recommended measures were conducted effectively in the field. There is no veterinarian or paraveterinarian in the area to enforce veterinary regulations. Present anthrax control measures were initially designed for livestock and are impractical to enforce in free-ranging wildlife (Turnbull *et al.,* 1991). Preventing animals from entering the epizootic area is only possible by fencing off the area. The costs of fencing the area are prohibitive. The fence would cut across migratory routes for some wild animal species and have the potential of creating an ecological imbalance. Burning of carcasses on a large scale, particularly of large mammals, would require a lot of firewood. The inadequately funded wildlife authority can not undertake inoculation of wildlife. Even where funds are available the terrain and thick vegetation in the area are the major constraints to vaccination of the animals. The effectiveness of vaccinations done during epidemics are limited by the time lag before protection is afforded (de Vos, van Rooyen & Kloppers, 1973).

Problems of responsibility and accountability arise during epidemics. Disease control is traditionally a function of the sub-Directorate of Animal Production and Health. The disease occurs in an area far away from where veterinary personnel are stationed and where the sub-Directorate does not have an on-going disease surveillance program. Control of the disease has as a result been delegated to wildlife officials in the area who are reluctant to enforce veterinary recommendations. They consider this task to be an exclusive functional responsibility of regulatory veterinarians.

Chapter 5

LIVESTOCK ANTHRAX IN ZAMBIA

Introduction

Though not part of the study this component is included for purposes of comparing the disease in the two land use systems i.e. wildlife and livestock. Anthrax is a known disease of livestock in Zambia. The disease is common among cattle of the traditional farming sector and virtually absent in cattle in the commercial sector. Efforts to control the disease have not yielded the expected results and it has spread to areas not previously affected by anthrax. Anthrax is not uncommon in humans following deaths in livestock. The total number of cases in livestock and humans are unknown, as data on the disease is not properly documented.

The chapter describes the epidemiology of the disease mainly in livestock and to some extent in humans. It focuses on the disease control strategy enforced in livestock.

Material and methods

A survey of anthrax reports was done at the national veterinary office and national archives.

Distribution of anthrax

The first official diagnosis of anthrax was made and reported in 1914. Until mid 1980 the disease, both in its epizootic and sporadic forms, was frequently reported in the Southern and Western Provinces. It was extremely rare in the Central and Copperbelt Provinces. Anthrax was reported once in 1928 in the Kafue District of Lusaka Province and only once in 1971 in the Kitwe District of the Copperbelt Province (Figure 6.).

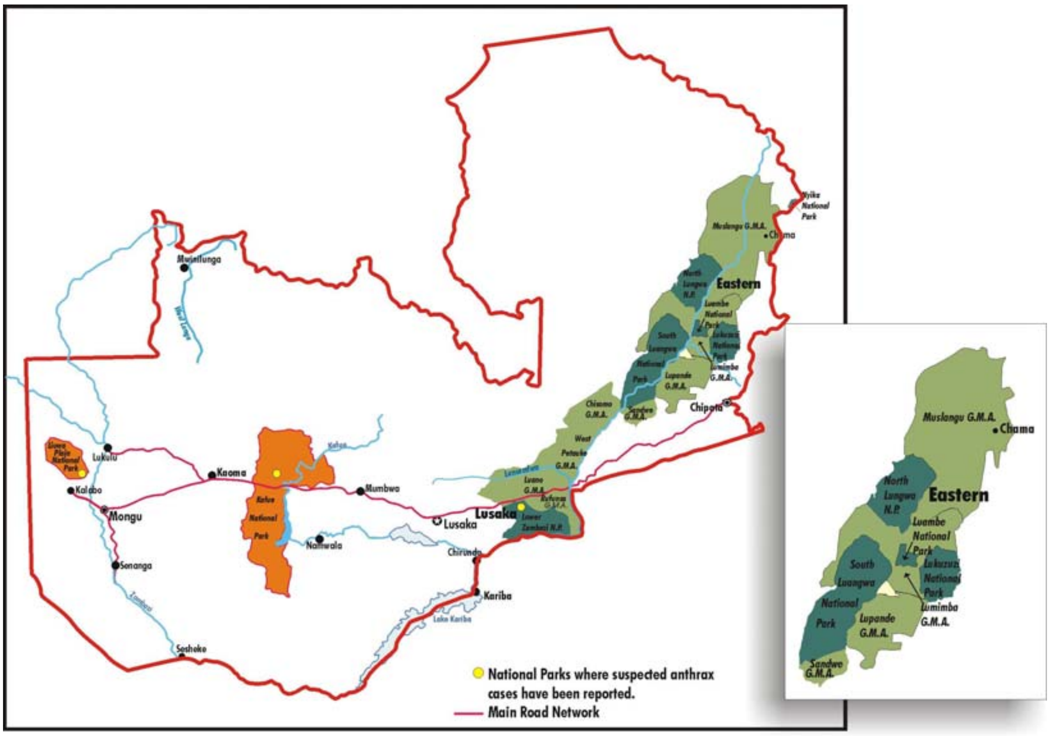

Figure 6. Map of Zambia showing past and present anthrax areas in livestock.

Recently no reports of the disease have been made in the Southern Province. The last report of anthrax in this province was in 1987 in the Mazabuka

District. Earlier the disease had been reported in Mazabuka, Namwala, Monze and Choma districts in areas where traditional cattle farming was practised.

Anthrax was confined to Mongu and Senanga districts of the Western Province but has recently spread to other districts. According to the Ministry of Agriculture, Food and Fisheries a consultancy report on the disease (MAFF, 1997 & MAFF, 1995) anthrax in the Western Province is generally confined to the Zambezi plain and is seldom seen in the higher areas. Its occurrence is usually associated with the onset of the first rains, which generally begin in November. Incidences of the disease have, however, been reported throughout the year with a peak around October and November. The disease is usually reported in areas that were either not covered during the previous vaccination campaign or where vaccinations were incomplete.

A large-scale epidemic of anthrax affected almost the entire Western Province in 1990. The initial foci of the epidemic were reported in November in Lukulu after which it quickly spread to other areas along the Zambezi plains reaching Mongu, Kalabo and Senanga districts by December. A total of 511 cases were brought to the attention of veterinary officials in the province. Most epidemics are characterised by inadequate disease surveillance and poor record keeping.

Results

Diagnosis and control of anthrax

The diagnosis of anthrax in the field is based on clinical signs and it is suspected in all cases of sudden death with the presence of bloody discharges. Definitive diagnosis is based on blood smears and bacterial isolation. During the period 1989 -1995 a total of 1 626 suspected cases of anthrax were brought to the attention of veterinary officials throughout the Western Province. Details on the isolation of the anthrax bacilli from suspected cases are summarised in Table 7.

Table 7. Diagnoses of anthrax in the Western Province during 1989-1995.

	1989	1990	1991	1992	1993	1994	1995	Total
Suspected Cases	45	747	511	111	208	4	-	1 626
Cases Investigated	-	-	27	11	44	-	64	146
Cases Confirmed	2	9	7	8	10	-	15	51
%Investigated/ Suspected	-	-	5,3	10,0	21,2	-	-	9,0
%Confirmed/ Investigated	-	-	25.9	72.7	22.7	-	23.4	34.9

Adapted from MAFF, 1997.

At times environmental samples were used to diagnose the disease. A total of 17 environmental samples was collected from the province and examined for anthrax. The examination of environmental samples for anthrax is summarised in Table 8.

Table 8. Isolation of the anthrax bacilli from environmental samples in Western Province in 1996

	Soil	Pieces of Meat/Skin	Bone	Total
No. Samples Diagnosed	1	15	1	17
No. of Positive anthrax diagnosis	1	12	0	13
% Positive Diagnosis	100.0	80.0	0.0	76.5

Historically, the anthrax control strategy adopted by the state is that of annual vaccination and notification of the public of the disease. The general public is advised against eating meat from animals that die with typical signs of anthrax. Emergency vaccinations are carried out during epidemics. During the colonial days anthrax vaccination campaigns were readily carried out by stockowners among the white community. The indigenous people in the Southern Province were opposed to vaccination campaigns. They were suspicious of the colonial government and considered the vaccination campaigns as an attempt to kill cattle in order to create more land for the white settlers. Consequently, the incidence of the disease was high among the indigenous cattle. The extensive inoculation of animals against anthrax was enforced when the Good Cattle Production Bounty Scheme came into operation in 1949. Even then, the farmers did not readily accept the vaccinations until 1960 when the increasing incidence of the disease forced them to adopt this approach. The disease received little attention from farmers in other areas when compared to other diseases such as Contagious Bovine Pleuropneumonia (CBPP), Rabies, Tuberculosis (TB), East Coast Fever (ECF) and Trypanosomiasis. In 1935 Native Authorities in Barotseland (now Western Province) who were offered free anthrax vaccination and the enforcement of control measures did not oppose these measures but requested Government to rather give priority to the treatment of CBPP.

At present livestock owners in the Western Province still do not readily accept vaccinations. People still suspect that the disease is introduced and spread through inoculations. They prefer to maintain the use of ox-draught power and milk production than rest the animals to avoid stress.

Anthrax in human beings

A total of 248 cases were brought to the attention of both veterinary and health officials during 1991 and 1997 in the Western Province and North-western Provinces (Table 9.). The average annual case fatality rate for the period was 7.2%. The data is based on records at the national veterinary office. The cases are usually reported following feasting on anthrax carcasses and fatal cases ensue. The largest number of cases was reported in 1990 in the Western Province when the epidemic was extensive. At least 220 human cases were brought to the attention of both veterinary and health officials during the period of the 1990 epidemic. The fatality rate among the reported cases was 19.1%.

Areas where anthrax cases have been reported over the years are Mpunga, Mwandi, Shekela, Mengo, Lwee, Beshe and Kauna in Senanga district; Mwanambuyu, Winda and Mulwa in Kaoma district; Lwatembo, Nasange, Mbuta and Kalundwana in Mongu district; Sikongo Buffer Zone in Kalabo district; Lukulu West in Lukulu district and; Mpidi in Zambezi district.

Table 9. Cases of human anthrax in Western and Northwestern Provinces during 1991 –1998 (with fatal cases in parenthesis).

Area	1991	1992	1993	1994	1995	1996	1997	1998	Total	Cumulative Total
Mongu	20	4(4)	-	-	-	-	-	31(2)	55(6)	55(6)
Senanga	20	9	-	-	15	19(3)	-	6	69(3)	124(9)
Lukulu	-	-	-	11	-	28	-	-	39	163(9)
Kalabo	5	-	-	-	-	5(1)	-	16(3)	26(4)	189(13)
Kaoma	20(2)	-	-	3(1)	-	3	-	21(1)	47(4)	236(17)
Sesheke	1	-	-	-	-	-	-	-	1	237(17)
Zambezi	-	-	1	-	-	-	-	-	1	238(17)
Kabompo	-	-	-	-	-	-	-	10(2)	10(2)	248(19)
Total	66(2)	13(4)	1	14(1)	15	55(4)	-	84(8)	248(19)	
Case Fatality Rate	3.0	30.8	-	7.1	-	7.3	-	9.5	7.7	
Average Case Fatality Rate				7,2						

Discussion

It is most likely that cases of anthrax before 1914 went unnoticed. The veterinary department was understaffed forcing veterinary officials to cover long distances. At that time the department directed its services mostly to the white farming community. In some cases white farmers performed most of the veterinary functions on their farms. Any incidence of the disease among traditional farming areas may not have come to the attention of veterinary authorities.

The origin of the disease is not known. It has been suggested that movement of cattle from Southern Africa introduced the disease into the country. In early 1900 livestock entering the country at the Livingstone Border were not quarantined. In 1931 it became mandatory for animals from Southern Africa to be quarantined for at least one month before entering the country. This measure was aimed at controlling the disease.

Disease incidence is high during the dry season. At this time pasture is scarce except in the plains. Animals are moved to the plains on the banks of the Zambezi River. During this time of the year grass is short and animals graze very close to the ground. This increases the chances of animals picking up anthrax spores.

Enforcing anthrax control measures in the Western Province is not easy. Regulating movement of cattle during epidemics is difficult. The area has numerous routes that people use to avoid quarantine measures. Incineration of carcasses is not always possible as a result of insufficient firewood particularly in the plains where anthrax cases are frequently reported. Disease epidemics usually occur during July - December, when farmers are busy working in their fields and have little or no time to spend on other activities. Cattle are expensive and rarely slaughtered for home consumption as a result people rather eat the meat they can take from carcasses. Veterinary response during epidemics is slow. Veterinary officials in the area can only take action after a comprehensive report of the disease has been received from the national veterinary office in Lusaka. Inadequate disease surveillance and delayed report submission have resulted in the erratic release of funds and vaccines by the national office. Delivery of the vaccines within the province is ineffective because of inadequate transport and the lack of facilities for vaccine storage.

In the plains animals scatter over long distances, and are difficult to roundup. Most people are opposed to the vaccination campaigns. As a result of insufficient vaccination coverage cases of anthrax still occur and people believe the disease has been introduced and spread through inoculations. The idea of resting animals after vaccination to avoid compromising their immune response is not readily welcome. Most farmers acquire the cattle on loan for a short period. Such people would rather maximise the use of animals for draught power and milk production.

The indifferent attitude of farmers to anthrax has resulted in poor diagnosis of the disease. Farmers' report suspected cases of anthrax to veterinary officials when more than one animal dies and people become ill after eating meat from the carcasses. In most cases the carcass has been consumed leaving no tissues for laboratory investigation. In these circumstances diagnosis of anthrax is often made from humans suffering from the disease. Prior experience on the part of health personnel is essential if anthrax in humans is to be recognised. The history and clinical examination of the patient is critical as there are no laboratory facilities to further investigate the disease.

Chapter 6

RISK ANALYSIS

Introduction

In response to international veterinary regulations the Zambian veterinary authorities pursue a 'zero risk' policy which is strictly enforced in the control of anthrax. At present the anthrax control programme that is accepted internationally requires that carcasses be incinerated or buried and that the effected area is quarantined. Recently, this policy has become contentious between the wildlife and veterinary authorities in Zambia. In the absence of internationally accepted risk mitigation procedures veterinary authorities have maintained a complete prohibition on consumptive wildlife utilisation during the period of an epidemic. This to ensure that anthrax is not spread to other areas. A formal assessment of the risk associated with each epidemic is not undertaken, to justify enforcement of these stringent veterinary regulations. Measures to control the disease are thus based solely on the epidemiology of the disease.

The disease control strategy applied in Luangwa Valley consists of quarantine of the affected areas; burning of carcasses or disinfecting carcass sites. The wildlife authorities and safari industry regard veterinary quarantine regulations as the major obstacle to the economic utilisation of wild herbivores. Rather than a complete prohibition on utilisation programmes they would favour adoption of quarantine measures based on risk analysis. This chapter deals with risk analysis during anthrax epidemics. Scenarios are developed to indicate their application in assessing the potential risk of an anthrax-contaminated trophy leaving Luangwa Valley during anthrax epidemics.

Material and methods

Two disease scenarios were suggested, the epizootic and sporadic form of the disease. In both cases the wildlife officials wish to undertake safari hunting during the time of the disease. An animal with the disease in its 'incubation period' does not show any clinical signs. Animals are usually found dead. There is a 40% to 60%, but most probably a 50% chance that a hunted animal may have the disease in its incubation period. Trophies harvested during hunting are processed at safari camps. When presented at the veterinary offices the trophies are screened for the presence of anthrax spores. The screening procedure is known to be 85% effective at detecting anthrax spores. This leaves a chance of failure of 15%. Trophies found contaminated with anthrax spores are rejected for export. Non-contaminated trophies are further treated with formaldehyde to ensure that no anthrax spores are present. There is a probability of 5% to 15%, most likely 10% that the formaldehyde treatment (veterinary sanitary processing) may fail to eliminate the anthrax spores. The national veterinary office wishes to approve the request by the wildlife department. What is the probability that trophy hunting would result in the spread of anthrax spores through trophies? The data and assumptions used in the analysis and the results of the analysis are summarised in Tables 10, 11 & 12.

Scenario pathway analysis

The schematic presentation of the scenario pathway regarding hunting during anthrax epidemics is summarised in Figure 7.

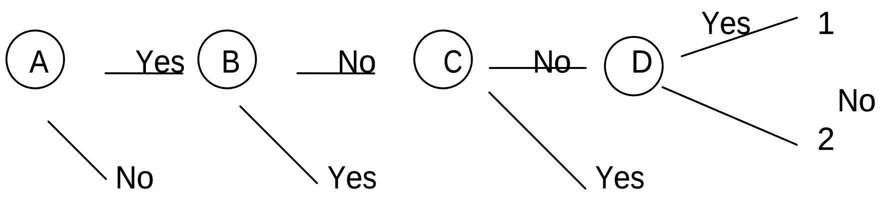

Figure 7. Schematic presentation of the scenario pathway for safari hunting during anthrax epidemics.

Key:

A Does hunting result in hunting animals with disease in its incubation period?
B Does processing of the hide eliminate the anthrax spores?
C Does the Laboratory Safety Examination (LSE) detect the trophy contaminated with anthrax spores and therefore have it eliminated?
D Does the Veterinary Sanitary Process (VSP) eliminate anthrax spores on the trophy?

1 Not exporting an anthrax-contaminated trophy
2 Export of an anthrax contaminated trophy?

Table 10. Parameters, data and assumptions used in the Risk Analysis for anthrax epidemics in Luangwa Valley

Parameter	Interpretation	Data	Assumption
N	Safari hunting quota in Lupande Game Management Area	361	One animal provides one trophy
I	Disease Prevalence = Number of anthrax carcasses divided by the population of animals at risk during the epidemic	Table 11.	The levels of incidence were provided as estimates (see Table 11.– Mortality as a fraction of population at risk).
P	Disease prevalence in the area = I X D where; D is the duration of the epidemic in the population as a fraction of the year	Table 11.	Duration of the epidemics was estimated at 5 months (0.4167); 2 months (0.1667); two weeks (0.0417)
P_1	Probability of harvesting a trophy contaminated with anthrax This is a function of the hunting quota in the area (i.e. N) and disease prevalence i.e. $P_1 = 1 - (1 - P)^N$	Table 11.	The animal from which the trophy is derived had the disease in its 'incubation' period
P_2	Probability that processing of trophies fails to eliminate anthrax spores	0.9 (Cox & Ryan, 1998)	Anthrax spores are resistant to a wide range of disinfectants, this probability was considered to be high
P_3	Probability that the Laboratory Safety Examination fails to detect a trophy and therefore wrongly passes a trophy with anthrax spores	0.15	The data was provided as an estimate. No literature and database in Zambia and elsewhere gives no indication of the success levels regarding detection of anthrax spores.
P_4	Probability that the veterinary sanitary processing of trophies fails to eliminate anthrax spores on the trophy contaminated with anthrax.	Table 11.	The values were assumed as literature and data base in Zambia and elsewhere give no indication of the success levels of the procedure
Cumulative Risk	Cumulative Risk = $P_1 * P_2 * P_3 * P_4$	Table 12.	

Results

Table 11. Prevalence of anthrax and the mortality rate as a function of the ratio of the number of anthrax carcasses to the size of the population at risk

	Duration of epidemics in the population as a fraction of the year				Duration of epidemics in the population as a fraction of the year		
	5 m	2 m	2 w		5 m	2 m	2 w
Mortality as a fraction of population at risk	0.4167	0.1667	0.0417	Mortality as a fraction of population at risk	0.4167	0.1667	0.0417
	Disease prevalence in the area				Probability of harvesting an anthrax trophy		
0.2100	0.0875	0.0350	0.0088	0.2100	1.0000	1.0000	0.9589
0.1500	0.0625	0.0250	0.0063	0.1500	1.0000	0.9999	0.8979
0.1000	0.0417	0.0167	0.0042	0.1000	1.0000	0.9977	0.7812
0.0900	0.0375	0.0150	0.0038	0.0900	1.0000	0.9957	0.7470
0.0500	0.0208	0.0083	0.0021	0.0500	0.9995	0.9506	0.5318
0.0400	0.0167	0.0067	0.0017	0.0400	0.9977	0.9117	0.4589
0.0300	0.0125	0.0050	0.0013	0.0300	0.9893	0.8363	0.3748
0.0200	0.0083	0.0033	0.0008	0.0200	0.9506	0.6968	0.2509
0.0100	0.0042	0.0017	0.0004	0.0100	0.7812	0.4589	0.1345

P1 increases with increase in level of mortality

Disease epidemics of two weeks or less were considered as sporadic cases, while cases of 2 months and longer were considered as epidemics

Table 12. Cumulative Risk of an anthrax contaminated trophy leaving Luangwa Valley undetected

	Duration of Epidemics in the population as a fraction of the year			**P_2 = 0.9000 and P_3 = 0.1500 but P_4 varies as shown**				**P_2 = 0.9000 and P_3 = 0.1500 but P_4 varies as shown**				**P_2 = 0.9000 and P_3 = 0.1500 but P_4 varies as shown**			
Mortality as a fraction of population at risk	5 months =0.4167	2 months = 0.1667	2 weeks = 0.0417	P_4 = 0.2000	P_4 = 0.1500	P_4 = 0.1000	P_4 = 0.0500	P_4 = 0.2000	P_4 = 0.1500	P_4 = 0.1000	P_4 = 0.0500	P_4 = 0.2000	P_4 = 0.1500	P_4 = 0.1000	P_4 = 0.0500
	Probability of harvesting an anthrax trophy = P1			**Cumulative risk when an epidemic lasts for 5 months**				**Cumulative risk when an epidemic lasts for 2 months**				**Cumulative risk when an epidemic lasts for two weeks**			
0.2100	1.0000	1.0000	0.9589	0.0270	0.0202	0.0135	0.0067	0.0270	0.0202	0.0135	0.0067	**0.0259**	**0.0194**	**0.0065**	**0.0004**
0.1500	1.0000	0.9999	0.8979	0.0270	0.0202	0.0135	0.0067	0.0270	0.0202	0.0135	0.0067	0.0242	0.0182	0.0121	0.0004
0.1000	1.0000	0.9977	0.7812	0.0270	0.0202	0.0135	0.0067	0.0269	0.0202	0.0135	0.0067	0.0211	0.0158	0.0105	0.0004
0.0900	1.0000	0.9957	0.7470	0.0270	0.0202	0.0135	0.0067	0.0269	0.0202	0.0134	0.0067	0.0202	0.0151	0.0101	0.0004
0.0500	0.9995	0.9506	0.5318	0.0270	0.0202	0.0135	0.0067	**0.0257**	**0.0193**	**0.0128**	**0.0064**	0.0144	0.0108	0.0072	0.0004
0.0400	0.9977	0.9117	0.4589	0.0269	0.0202	0.0135	0.0067	0.0246	0.0185	0.0123	0.0062	0.0124	0.0093	0.0062	0.0004
0.0300	0.9893	0.8363	0.3748	0.0267	0.0202	0.0134	0.0067	0.0226	0.0169	0.0113	0.0056	0.0101	0.0076	0.0051	0.0004
0.0200	0.9506	0.6968	0.2509	**0.0257**	**0.0193**	**0.0128**	**0.0064**	0.0188	0.0141	0.0094	0.0047	0.0068	0.0051	0.0034	0.0003
0.0100	0.7812	0.4589	0.1345	0.0211	0.0158	0.0105	0.0053	0.0124	0.0093	0.0062	0.0031	0.0036	0.0027	0.0018	0.0003

Assumptions: P_2 = 0.9000

P_3 = 0.1500

P_4 = 0.2000; 0.1000 and 0.0500

Cumulative Risk = $P_1 \times P_2 \times P_3 \times P_4$

Note: 1. The shorter the duration of the epidemic the lower the cumulative risk of an anthrax trophy leaving Luangwa Valley undetected. The reduction in the cumulative risk becomes greater with reduction in the duration of the epidemic as shown with bold figures.

2. The cumulative risk of wrongly allowing an anthrax-contaminated trophy leave to Luangwa Valley reduces with increased efficacy of the veterinary sanitary processing.

Implication of the quantitative risk analysis on anthrax control policy

The risk of spreading the anthrax bacilli increases with the severity of the disease and when the duration is extended but is low during sporadic outbreaks. during sporadic outbreaks the 'zero risk' policy is unjustified and uneconomical. It appears that this policy is not feasible in the Luangwa Valley where the disease is endemic. Anthrax control measures should, therefore, be based on the assessment of risk in each epidemic. Without the adoption of this approach wildlife authorities will continue to lose income through trade even where the levels of risk do not justify such measures.

Discussion

The adoption of control measures based on QRA is only possible if veterinary authorities are able to predict the 'cyclic' occurrence of both epidemic and sporadic cases of the disease. A cyclical occurrence of epidemics has been observed in Kruger National Park and these cycles appear to conform to the climatological pattern of the KNP (de Vos, 1990). Lack of ecological and epidemiological data in Luangwa Valley makes it difficult for veterinary authorities to calculate the expected levels of risk during epidemics. The problem is exacerbated by a lack of a systematic disease surveillance programme in the area. Second, there are no internationally recognised risk mitigation measures regarding the disease. Without such data any decision in favour of consumptive utilisation during epidemics is not defensible within the framework of international veterinary regulations and agreements such as the World Trade Organisation's sanitary and phytosanitary agreement. The problem is exacerbated by lack of a veterinary unit in the area to enforce the necessary risk mitigation measures such as the proposed laboratory safety examination and sanitary processing of trophies. In the absence of disease surveillance it is most likely that sporadic cases would go undetected. As a result an anthrax-contaminated trophy would leave the area undetected. In the absence of a disease surveillance programme veterinary authorities are justified with the total prohibition of consumptive utilisation of animals during the epidemics.

Chapter 7

SOCIO-ECONOMIC IMPACT OF ANTHRAX IN LUANGWA VALLEY

Introduction

Anthrax is the only known infectious disease causing mortality of wild animals in Luangwa Valley. The impact of the disease, both to the wildlife sector and other sectors of the economy, has never been quantified both at local and national level. The disease has been viewed in isolation and not from an overall ecological perspective taking cognisance of wildlife production systems practised in the area and the impact of epidemics on species and population conservation. The role of anthrax in regulating animal populations was never considered. Little data of consequence is thus available to enable a case to be made for an integrated approach of managing the conservation areas in a holistic manner.

This component of the study attempts to estimate the potential impact of anthrax on population and species conservation; direct and indirect costs of disease epidemics to the various stakeholders in the area; and to motivate the setting up of methods for collecting and recording the data to enable a rational approach to dealing with the disease in future.

Material and methods

A survey on wildlife production systems practiced in the area was undertaken at National Parks and Wildlife Service (NPWS). The survey involved searching for records on levels of utilization, income generation and distribution to the stakeholders. Interviews were held with safari hunting companies in the area to assess the economic potential of the hunting industry.

Lack of socio-economic data on previous anthrax epidemics resulted in the use of disease scenarios in which:

the value of wildlife is based on hunting revenue;

two disease epidemics are dealt with, the epizootic and sporadic forms of the disease;

two disease control strategies, blanket and area-specific quarantine, are applied to the epidemics;

a social cost benefit analysis of direct and indirect costs of the disease, from the standpoint of community based natural resource management is undertaken.

<u>Disease scenarios</u>

Scenario 1. An epizootic epidemic controlled by blanket quarantine.

An anthrax epidemic is reported in the area. The entire Luangwa Valley is considered to be at risk as no disease surveillance is undertaken. As a result the whole of Luangwa Valley is placed under quarantine.

Scenario 2. An epizootic epidemic controlled by area-specific quarantine. An anthrax epidemic was reported in the area. Disease surveillance shows that the area ravaged by the disease was South Luangwa National Park and Lupande Game Management Area. Only the affected areas are placed under quarantine.

Scenario 3: Sporadic anthrax controlled by area-specific quarantine. Sporadic cases of anthrax were reported in Luangwa Valley. Disease surveillance shows that the disease is confined to isolated places in the upper sector of Lupande Game Management Area. Only the upper sector of the Game Management Area is placed under quarantine.

Alternative disease control strategy

An alternative disease control strategy, that of disease surveillance and enforcement of veterinary regulations with quarantine in particular, based on quantitative risk analysis. Risk mitigation measures of laboratory examination of trophies for the presence of the anthrax bacilli and sanitary processing of trophies will be undertaken within Luangwa Valley. Only trophies not contaminated with the anthrax spores will be allowed to enter the market.

Two assumptions with regards to this alternative disease management strategy will be made. First, that there was no risk of spreading the disease through safari hunting and that no trophy will be discarded during the risk mitigation process. As a result safari hunting is not affected by veterinary regulations. At the same time all expenses regarding the risk mitigation measures, laboratory examination and sanitary processing, will be incurred by the safari hunting companies and not the wildlife authority.

The assumptions used in the analysis are summarised in Table 13.

Table 13. Data assumptions applied in the social cost benefit analysis of anthrax epidemics in Luangwa Valley

Assumption	Scenario 1	Scenario 2	Scenario 3
Quota Utilisation	100%	100%	100%
Duration of epidemic	Lasts till end of hunting season	Lasts till end of hunting season	1 month in June
Duration of quarantine	Lasts till end of hunting season	Lasts till end of hunting season	Lasts for two months, June & July
Number of anthrax carcasses*	440	440	42
Value of anthrax carcasses	Based on safari hunting fees	Based on safari hunting fees	Based on safari hunting fees
Is hippo culling affected	Yes	Yes	It is not affected as it takes place in summer in September.
Effect of quarantine on hunting blocks within Luangwa Valley	-	-	50% of hunting clients in the upper sector of LPGMA are affected during quarantine
Effect of quarantine on hunting blocks outside Luangwa Valley	No	No	No
Other veterinary measures	Burning of carcasses; disinfecting carcass sites; community awareness and fumigation of game trophies within Luangwa Valley;	Burning of carcasses; disinfecting carcass sites; community awareness and fumigation of game trophies within Luangwa Valley	burning of carcasses; disinfecting carcass sites; community awareness and fumigation of game trophies within Luangwa Valley

*1987 anthrax carcasses counted were used in scenario 1 &2 while carcasses counted in 1997 were used in scenario 3.

Wildlife production systems

Consumptive and non-consumptive wildlife utilisations are the principal land use practices in Luangwa Valley. Consumptive utilisation is the most widely practised as non-consumptive utilisation in the form of game viewing and photographic safaris is only well developed in South Luangwa National Park. Generally, revenue earnings from the sale of hunting licences are shared between the state treasury and the Wildlife Conservation Revolving Fund, a financial wing of the wildlife authority on a 50-50% basis. The 50% retained by the revolving fund are distributed as follows: 40% to NPWS operations in the Game Management Areas, 35% to local communities and 25% to the funds' administrative costs.

Consumptive wildlife utilisation

Consumptive wildlife utilisation is based on hunting for both meat and game trophies. Three forms of hunting are practised in the area – international safari hunting, domestic hunting by Zambians and culling programmes. Revenue is earned from the sale of safari and domestic game licences; and the sale of animal products from culling.

Safari and domestic hunting

Details of animals approved for hunting and the hunting success are summarised in Table 14. Data for the period 1996-1998 shows that the annual utilisation success of safari hunters averages 55% while domestic hunters take approximately 46% of the animals allocated to them. During the period 1994-1998 a total of 702 hunters bought game licences in the area. Income earned from hunting is summarised in Tables 15. & 16. Revenue earned per Km^2 is summarised in Table 17. During the period 1994-1998 revenue earnings per Km^2 was Zambian Kwacha (ZMK) 30,178.00 equivalent to US$ 26.00 for safari hunting and ZMK 744 for domestic hunting.

Culling programmes

The most widely practised culling programme in Luangwa Valley is the culling of hippos in the South Luangwa portion of the Luangwa River bordering Lupande GMA and South Luangwa National Park. The numbers of Hippos culled and revenue there from is summarised in Table 16. More revenue is earned from the sale of hippo skins (63%) than from sale of hippo carcasses (37%).

Table 14. Hunting utilisation success in Luangwa Valley for the period 1994-1998

	1996		1997		1998		Total		Maximum		Minimum		Average	
	Domestic	Safari	Domestic	Safari	Domestic	Safari	Domestic	Safari	Domestic	Safari	Domestic	Safari	Domestic	Safari
Hunting Quota	240	1 084	204	720	375	716	819	2 520	375	1 084	204	716	273	840
Quota utilised	78	541	87	412	213	442	378	1 395	213	541	78	412	126	465
%Utilisation Success	33	50	43	57	57	62	46	55	57	50	38	57	46	55

Table 15. Revenue earned from hunting in Game Management Areas in Luangwa Valley for the period 1994-1998.
(Safari hunting revenue earned in foreign currency (US$) in parenthesis).

	1994	1995	1996	1997	1998	Total	Maximum	Minimum	Average
Domestic Hunting	6 800 500	7 825 000	16 482 000	18 175 000	44 264 700	93 547 200	44 264 700	6 800 500	18 709 440
Safari Hunting	406 764 770 (607 683)	653 615 985 (755 975)	794 709 511 (661 090)	885 778 797 (673 760)	1 054 058 765 (565 810)	3 794 927 828 (3 264 318)	1 054 058 765 (755 975)*	406 764 770 (565 810)*	758 985 566 (652 864)*
Total	413 565 270	661 440 985	811 191 511	903 953 797	1 098 323 465	3 888 475 028	1 098 323 465	413 565 270	777 695 006

* The highest revenue earned in foreign currency (US$) from safari hunting does not necessarily indicate the highest revenue in Zambian Kwacha equivalence.

Table 16. Revenue earned from hunting by the Luangwa Integrated Resource Development Project in Lupande Game Management Area for the period 1992 and 1996 in Zambian Kwacha

	1992	1993	1994	1995	1996	Total	Maximum	Minimum	Average
Hunting Licences	103 719 752	160 537 356	182 432 700	228 250 776	258 500 387	933 440 971	258 500 387	103 719 752	186 688 194
Hippo Culling	-	-	-	125 470 940	93 000 000	218 470 940	125 470 940	93 000 000	54 617 735
Total	103 719 752	160 537 356	182 432 700	353 721 716	351 500 387	1 151 911 911	383 971 327	196 719 752	241 305 929

Table 17. Income generating capacity by the hunting activities in Luangwa Valley in Zambian Kwacha with safari hunting revenue in US$ in parenthesis

	Total Size of GMA Km^2	Average Annual Income (Domestic)	Income per Km^2 (Domestic)	Average Annual Income (Safari)	Income per Km^2 (Safari)
ADMADE Areas	25 150	18 709 440	744	758 985 566 (652 864)	30 178 (26)
LIRDP Area*	4 480	186 688 194		41 671	

Note: * Total revenue (i.e. safari and domestic and safari hunting revenue combined)

2. The calculations are made on the assumption that the entire GMA is available for hunting.

Value of wildlife to various stakeholders in Luangwa valley

Local Communities

The revenue disbursed to local communities is meant to fund socio-economic development programmes in their respective areas. The total revenue disbursed to communities in game management areas outside central Luangwa Valley is summarised in Table 18. In Lupande Game Management Area all the hunting revenue retained by Luangwa Integrated Resource Development Project is allocated to all households of the local community in the area. In addition to the household cash the Luangwa Integrated Resource Development Project disburses other funds directly to community development projects.

Most employment opportunities in the area are wildlife based. On average 20 people are employed at every safari hunting camp each hunting season. Each worker on average receives a monthly wage of ZMK 90,000 and supports an average household of five people. Other community members are employed temporarily to construct hunting camps and maintain the road network and air strips in readiness for the hunting season. Materials used to construct the camps are bought from community members. On average US$3,500 is required each hunting season to prepare these camps.

In addition Government employs village scouts from respective Game Management Areas. A total of 140 village scouts were employed by Administrative Management Design for Game Management Areas in Luangwa Valley in 1998. Each village scout earns, on average, ZMK 72 000. Salaries for village scouts are paid from the 40% revenue allocated to the game management area for operational costs.

During traditional ceremonies the state provides venison to local communities to assist them in hosting such events.

Wildlife authorities – game management area funds

A total of ZMK 1082.76 million was allocated for operational costs in the Game Management Areas during 1994-1998. The annual average revenue allocated to GMA operations is ZMK 216.55 million (Table 18.).

Central treasury

The state treasury retains 50% of the hunting revenue. Total revenue retained by the central treasury during 1994-1998 is summarised in Table 18. In addition the state collects tax from safari operators.

Wildlife conservation revolving fund

Of the revenue collected by the Revolving Fund 25% is retained by the Fund for its administrative operations. Total revenue retained by the Fund during 1994-1998 is summarised in Table 18.

Safari hunting companies

Safari hunting companies earn their revenue from the sale of safari game licences to sport hunters. On average US$ 200,000 is earned from one hunting block annually before deducting game licence fees and other operational costs.

Table 18. Disbursement of hunting revenue in Game Management Areas in Luangwa Valley in '000 000 Zambian Kwacha

	1994	1995	1996	1997	1998	Total	Max	Min	Mean
State Treasury	126.5	214.1	240.9	258.8	341.6	1181.9	341.6	126.5	236.4
Game Management Area	114.8	179.0	228.1	258.0	302.7	1082.6	302.7	114.8	216.5
Local Community	100.4	156.6	199.6	225.8	264.8	947.2	264.8	100.4	189.4
Revolving Fund	71.8	111.9	142.6	161.3	189.1	676.7	189.1	71.8	135.3
Total	413.5	661.6	811.2	903.9	1098.2	3888.4	1098.2	413.5	777.6

Impact of anthrax epidemics

Socio-biological impacts

It is estimated that 4 200 hippos and 1 000 other animals succumbed to the disease in 1987 in central Luangwa Valley (Tuchili *et al.,* 1995; Anon, 1988). Consequently, in 1988 the hippo-culling quota was reduced to allow the population to build up. This resulted in a reduction in revenue disbursed to the community in Malama Chiefdom in Lupande Game Management Area (Lewis *et. al.,* 1990).

Since the anthrax epidemic of 1987 wild dogs have not been seen in the area. During the epidemic at least 7 wild dogs, 4 adults and 3 pups, died of anthrax in a pack of 5 adults and 8 pups. Clinical signs typical of anthrax were reported in 2 adults. The fate of these animals and the surviving members of the first pack were not known at the time (Creel, Creel, Matovelo, Mtambo, Batamuzi & Cooper, 1995). It is believed that the disease may have completely decimated the small wild dog population in the area.

Mortality during sporadic cases is low. The cumulative effect of the mortalities over a long period, however, may equally have far reaching consequences on animal demographics.

Public Health Risk

No official record of the disease in humans in Luangwa Valley was available. Anecdotal evidence, however, suggests that the disease may have gone unnoticed. No value can be placed on the loss of human life or the misery of suffering from the disease.

Eco-tourism

Tourist lodges in South Luangwa National Park are located along the river where anthrax deaths are common. Delay in disposing off anthrax carcasses around tourist centres such as lodges and campsites exposed tourists to the unpleasant and offending odour from the decomposing carcasses. Burning of carcasses within lodge premises exposed tourists to smoke pollution. The presence of carcasses along game viewing roads compromised the aesthetic beauty of the area and caused concern among the tourists.

Veterinary regulations

During anthrax epidemics areas affected by the disease were placed under quarantine. No consumptive utilisation was allowed during this time. This resulted in the loss of revenue to both government and the safari hunting industry. The response of clients after the lifting of the quarantine was governed by veterinary measures enforced by the importing countries. In 1988 following the anthrax epidemic the Government of Botswana imposed a ban on the importation of hippo hides from Luangwa Valley. This decision lowered the market value of the hides as the Zambian Government was forced to find an alternative market (Anon, 1988).

Loss of employment

The estimated losses with regards to employees are summarised in Table 21.

A quantitative approach based on a cost and benefit analysis

The social cost benefit analysis focused on direct and indirect costs of the disease from the standpoint of the national wildlife authority. Details of the costs and their distribution are summarised in Tables 19. & 20. The costs were subdivided into:

- Revenue foregone during the period of quarantine;
- Cost of animal mortalities and assessment of environmental impacts;
- Cost of veterinary services during the epidemics and;
- Cost of the disease to the stakeholders

Table 19. The potential cost of anthrax in Luangwa Valley in ‘000 ‘000 Zambian Kwacha

Type of Cost	Scenario 1	Scenario 2	Scenario 3
1. Revenue Foregone			
a. Game Management Areas			
Safari Hunting	872.4	-	-
National Hunting	41.9	-	-
Sub-total	**914.3**	**-**	**-**
b. Lupande Area			
Safari Hunting	312.6	312.6	80.8
Domestic Hunting	-	-	-
Hippo Culling	93.0	93.0	-
Sub-total	**405.6**	**405.6**	**80.8**
2. Value of animal carcasses			
a. Game Management Areas	**-**	**-**	**-**
b. Lupande Area	**752.2**	**752.2**	**41.0**
3. Additional Costs			
a. Veterinary costs			
Subsistence allowance (veterinary staff)	4.1	4.1	1.1
Laboratory Diagnostic Fees	0.4	0.4	0.2
Sanitary Products (Disinfectants)	0.5	0.5	0.2
Labour	0.9	0.9	0.4
Transport (Fuel and Lubricants)	1.5	1.5	0.6
Sub-total of Veterinary Costs	**7.4**	**7.4**	**2.5**
Total	**2079.5**	**1 165.2**	**124.3**

- No count of anthrax carcasses was done

Table 20. The potential cost of anthrax to various stakeholders in Luangwa Valley in '000 '000 Zambian Kwacha

Type of cost	Central Treasury			Game Management Area			Local Community			Wildlife Conservation Revolving Fund			Lupande Area		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Revenue foregone															
Hunting Game Fees	457	-	-	183	-	-	160	-	-	114	-	-	406	406	81
Value of carcasses	-	-	-	-	-	-	-	-	-	-	-	-	752	752	41
Sub-total	457	-	-	183	-	-	160	-	-	114	-	-	1158	1158	122
Additional Costs															
Veterinary Costs	-	-	-	-	-	-	-	-	-	7	-	-	7	7	2
Total	457	-	-	183	-	-	160	-	-	121	-	-	1165	1165	124

1, 2 &3 denote scenario 1, 2 and 3 receptively.

Table 21. Potential loss of employment in the safari hunting industry in Luangwa Valley during anthrax epidemics

	Scenario 1			Scenario 2			Scenario 3		
Details	Before Epidemic	During Epidemic	% Change manpower	Before Epidemic	During Epidemic	% change of manpower	Before Epidemic	During Epidemic	% change of manpower
No. of people employed	184	0	-100	184	143	-22,2	184	163	-11,1
Loss of income by labour force	0	82 620 000	-100	0	18 360 000	-22,2	0	3 672 000	-11,1
Total No. Of dependants affected	0	918	-	0	204	-	0	102	-

Besides the financial losses in Tables 19 - 21 other costs include the ecological cost of firewood used to burn carcasses; the cost of relocating man power and other resources to anthrax control; loss of genetic material; loss of revenue to companies and individuals that depend on hunting and hippo culling.

The cost of alternative anthrax control strategy based on risk analysis

The cost of the disease under the alternative disease control strategy based on quantitative risk analysis is summarised in Tables 22 – 24.

Table 22. The potential cost of anthrax in Luangwa Valley in '000 '000 Zambian Kwacha if an alternative control strategy is applied.

Type of Cost	Scenario 1	Scenario 2	Scenario 3
1. Revenue Foregone			
a. Game Management Areas			
Safari Hunting	-	-	-
National Hunting	-	-	-
Sub-total	-	-	-
b. Lupande Area			
Safari Hunting	-	-	-
Domestic Hunting	-	-	-
Hippo Culling	93.0	93.0	-
Sub-total	93.0	93.0	-
2. Value of animal carcasses			
a. Game Management Areas	-	-	-
b. Lupande Area	752.2	752.2	41.0
3. Additional Costs			
a. Veterinary costs			
Subsistence allowance (veterinary staff)	4.1	4.1	1.1
Laboratory Diagnostic Fees	0.4	0.4	0.2
Sanitary Products (Disinfectants)	0.5	0.5	0.2
Labour	0.9	0.9	0.4
Transport (Fuel and Lubricants)	1.5	1.5	0.6
Sub-total of Veterinary Costs	7.4	7.4	2.5
Total	852.6	852.6	43.5

* No count of anthrax carcasses was done

Table 23. The potential cost, in '000 '000 in Zambian Kwacha, of anthrax to various stakeholders in Luangwa Valley with the application of an alternative control strategy

Type of cost	**Central Treasury**			**GMA**			**Community**			**WCRF**			**LIRDP**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Revenue foregone															
Hunting Game Fees	-	-	-	-	-	-	-	-	-	-	-	-	**93**	93	**-**
Value of carcasses	-	-	-	-	-	-	-	-	-	-	-	-	845	845	41
Sub-total	-	-	-	-	-	-	-	-	-	-	-	-	938	938	41
Additional Costs															
Veterinary Costs	-	-	-	-	-	-	-	-	-	7	-	-	7	7	2
Total	-	-	-	-	-	-	-	-	-	7	-	-	942	942	43

1, 2 &3 denote scenario 1, 2 and 3 receptively.
WCRF – Wildlife Conservation Revolving Fund

Table 24. Levels of employment by the safari hunting industry in Luangwa Valley during anthrax epidemics when the alternative strategies are applied

	Scenario 1			Scenario 2			Scenario 3		
Details	**Before Epidemic**	**During Epidemic**	**% Change of manpower**	**Before Epidemic**	**During Epidemic**	**% change of manpower**	**Before Epidemic**	**During Epidemic**	**% change of manpower**
No. of people employed	184	184	0	184	184	0	184	184	0
Loss of income by labour force	0	0	0	0	0	0	0	0	0
Total No. Of dependants affected	0	0	-	0	0	-	0	0	-

Implication of the socio-cost benefit analysis on anthrax control policy

The cost of the present disease control strategy is substantial. The cost is greater when the blanket quarantine strategy is applied compared to that of an area specific quarantine. During the large-scale epidemic the loss prevented in form of revenue foregone is about ZMK 914.3 million in favour of the area specific quarantine. In addition about 143 jobs i.e. 78% of the total labour force employed by the safari hunting companies in the area are saved.

The costs of the veterinary quarantine are reduced significantly in the case of the alternative disease control strategy based on quantitative risk analysis. Evidence from the study shows that the risk of spreading the anthrax bacilli and, therefore, the need for quarantine is low. The risk is reduced significantly with enforcement of risk mitigation factors. No costs are incurred in form of revenue foregone when the alternative strategy is applied as no trade embargo is enforced. The only revenue lost is that from domestic hunting which is generally insignificant.

As a result it is unjustified on economic grounds to continue with the present disease policy. In situations where domestic hunting is allowed during disease epidemics it is suggested that boiling the meat at 120°C would render the meat safe for consumption. It is doubtful whether people would boil their meat to this degree. This observation is supported by reports of people suffering from anthrax following feasting on anthrax-contaminated meat especially in livestock areas. As a result domestic hunting is considered to be more risky. It is doubted that the present control strategy is technically effective to control anthrax epidemics. Reports indicate that epidemics continued unabated despite enforcing such measures in Lake Manyara National Park (Prins & Weyerhaeuser, 1987) and Kruger National Park (Pienaar, 1967; Pienaar, 1961). To continue with veterinary quarantine would deny wildlife authorities revenue for their wildlife management operations.

Direct and indirect links exist between the disease and biodiversity conservation. The wildlife authority depends heavily on hunting revenue for its administrative and operational costs especially law enforcement (anti-poaching), as poaching is one of the major threats to biodiversity conservation in the country. A trade embargo would, therefore, negatively affect its operation. In the absence of financial and other benefits the support of local communities to community based natural resource management programmes is doubted. People may resort to poaching. It is, therefore, recommended that veterinary authorities should adopt a disease control policy based on quantitative risk analysis. At present veterinary regulations do not take cognisance of the socio-political and socio-economic realities of biodiversity conservation, including sustainable wildlife utilisation.

Anthrax control measures aim at reducing the risk of disease transmission, especially to humans. Any alternative control measures must, therefore, be based on quantitative risk analysis as this places emphasis on the risk inherent of each of the alternative strategies (Meltzer, 1996). At this stage quantitative risk analysis can not be used to persuade policy makers to consider alternative anthrax control measures in Luangwa Valley due to the inadequate epidemiological and ecological data available. This strategy will require investment in disease surveillance and animal population censuses.

Discussion

The economic significance of the wildlife sector in Luangwa Valley can not be readily quantified. No social accounting matrix is available at both regional and national level. However, the sector is considered the economic backbone of the area. Almost the entire Luangwa Valley is under wildlife management. Other sectors in the area provide social services to the community such as health and education. Safari hunting and sale of hippo skins are critical to consumptive wildlife utilisation. Safari hunting earns more income per km^2 than other forms of utilisation. Sale of safari hunting licences and hippo skins earn the country foreign exchange as they are sold in United States dollar. Over the years revenue from safari hunting in terms of the United States dollar has declined. The Zambian Kwacha equivalence has, however, continued to increase. The continuous depreciation of the Zambian Kwacha against the dollar has resulted in high exchange rates. As a result revenue from sale of safari hunting licences in terms of the Zambian Kwacha equivalence has continued to rise despite the decrease in the actual sales in dollar terms.

Financial values do not reflect the complete value of wildlife. Non-market values of wildlife are not readily captured in financial analysis. Game licence fees are determined on an ad hoc basis by government officials and, therefore, may not reflect the real economic value of the resource. Furthermore, financial analyses do not reflect the profitability of the wildlife production systems. Revenue earnings are quoted without providing the costs of wildlife operations and the opportunity cost of wildlife production. The value of wildlife in terms of game viewing and photographic safaris was not included in the study. Gathering of data from this segment of the wildlife sector is not easy.

CHAPTER 8

GENERAL DISCUSSION

Veterinary aspects

It is not known whether anthrax was endemic to the Luangwa Valley or whether it was introduced. The rinderpest pandemic that ravaged the area in the 1890=s may have obscured anthrax. In the past mortalities in wild animals were attributed to rinderpest and natural factors such as drought and nutritional stress. No veterinary intervention was undertaken until 1987 when animals, especially hippos, died of anthrax in large numbers. The ecology of the disease is still poorly understood despite the frequent occurrence of disease epidemics. This is as a result of lack of a systematic disease surveillance programme resulting in patchy and scanty epidemiological data. Inadequate ecological data in terms of animal demographics and micro-climatic have exacerbated the problem. Virtually, no animal censuses are conducted in the area except in South Luangwa National Park and Lupande Game Management Area.

Though veterinary measures are usually recommended during epidemics there is no veterinarian in the area to supervise the regulations. Regrettably, wildlife officials have shown inability to regulate themselves and to comply with veterinary regulations, especially disease surveillance, even when resources are available.

Veterinary measures are put in place late due to delays in diagnosing the disease. In most cases the measures come when the epidemic has already died off and are cosmetic in effect. Enforcing the measures at this time is uneconomical, especially if they result in a ban on consumptive utilization. The measures are applied without consideration of their effect on the ecosystem and, the ecological and the economic costs of enforcing them.

Ecological aspects

Ecologically, anthrax epidemics appear to indicate the presence of ecological imbalance. The epizootic form of the disease acts as a >natural cull= that reduces the population size to levels that the ecosystem may sustain. In this regard regulating animal populations through regular culling may be profitable, both ecologically and economically, to wildlife management.

Opening of infected carcasses by scavengers result in environmental contamination. The extent of the contamination is not well known. No work has been done following the epidemics to assess environmental contamination by anthrax spores. However, it is doubtful that the contamination of the local reserves is severe. On Gruinard island it was established that soil contamination with anthrax spores was relatively localized (Stevens, 1989). Lindeque (1991) reported that the area of high contamination at the site of an anthrax carcass is within a five-meter radius. Continued occurrence of the disease in Luangwa Valley suggests continued contamination of the soil and >pastures= in the areas where anthrax cases occur.

Preventing animals from entering the epizootic area is only possible by fencing off the affected area. Erection of fences may cut off access to water and food and interfere with natural migration. The decision to erect fences would require an impact assessment otherwise the wildlife department would object the interference it may cause on the ecosystem (SADC; 1997). In any case erection of fences is not practical due to inadequate finances.

The control of anthrax epidemics in wildlife through the burning of carcasses is probably not effective. Reports of epidemics continuing unabated despite enforcing such measures were observed in Lake Manyara National Park (Prins & Weyerhaeuser, 1987) and Kruger National Park (Pienaar, 1967; Pienaar, 1961). The burning of carcasses on a large scale results in the destruction of combustible material and may reduce the efficacy of the annual veld management fires. At the same time poor surveillance during anthrax epidemics results in a relatively large proportion of carcasses not being found.

The efficacy of decontaminating the soil using formaldehyde is debatable. It is probably a cosmetic and academic exercise. To be effective the disinfectant must be sprayed at a rate that would readily penetrate into the soil at the localized contaminated areas (Stevens, 1989). Otherwise decontamination of underlying soil profile may not be effective (Manchee, Broster, Anderson & Henstridge, 1983**)**. On Gruinard island workers managed to decontaminate 4.1 Ha soil using 5% formaldehyde at a dose of 50l/m^2 . A total of 280 tons, about 200 000 liters, of stabilized formalin (i.e. 37% formaldehyde) were transported to the island and 2000 tons of sea water were required to dilute the formaldehyde (Manchee *et al.,* 1990; Stevens, 1989). According to

Lindeque (1991) an estimated 4 000 liters of 5% formaldehyde would be required to decontaminate a radius of five meters at a dosage of 50l/m^2. To decontaminate 10 carcasses, more than 5 meters apart, would, therefore, require 40 000 liters of 5% formaldehyde.

Decontamination of the soil in the multiple and vast anthrax districts in Luangwa Valley is both impractical and costly. The large quantities of the disinfectant needed would be costly. Decontamination during the wet season is impractical and of no value. During this time the area becomes impassable and the floods would wash the disinfectant away.

The effects on both fauna and flora of formaldehyde at the dosage that would guarantee penetration into the soil is not known (Stevens, 1989) and should be investigated before its use is considered.

Anthrax mortalities may constrain biodiversity conservation. Epizootic of the disease may impact negatively on population dynamics. Population sizes are reduced and there is loss of genetic material. In Etosha National Park anthrax was considered a primary and major factor in the reduction of the population (Berry, 1981; Ebedes, 1976). In Lake Manyara National Park the impala population fell from 1476 to 112 (i.e. a 92% reduction) during the period 1983-1984 following an anthrax epidemic (Prins & Weyerhaeuser, 1987).

Economic aspects

The direct economic costs of anthrax result from the veterinary regulations that are enforced during the epidemics and the quarantine measures cause the most economic loss. These costs of the disease in wildlife are unfortunately not easy to quantify.

The importance of financial loss is emphasized by the wildlife sector when attempting to persuade veterinary officials not to enforce quarantine measures. As a result aspects of conservation which do not have an apparent effect on income are not considered economic factors and weigh heavily upon management at policy level when decisions are made (Morris & Meek, 1980). Values from economic analyses should be treated with caution, as they do not represent the only benefits of the disease control strategies. Use of financial values when persuading veterinary authorities not to enforce quarantine measures is unjustified. Anthrax control measures aim at reducing the risk of disease transmission, especially to humans. Any alternative control measures must, therefore, be based on quantitative risk analysis (QRA) as this places emphasis on the risk of each of the alternative strategies (Meltzer, 1996). At this stage QRA can not be used to persuade policy makers to consider alternative anthrax control measures in Luangwa Valley due to the inadequate epidemiological and ecological data available.

According to the National Parks and Wildlife Act 10 of 1991, the department=s mandate is to conserve biodiversity. In this regard a holistic approach that combines socio-economic and ecological, including biological, aspects should be used when assessing the impact of individual anthrax epidemics.

Chapter 9

THE FUTURE CONTROL OF ANTHRAX

Strategy for future anthrax control policy

The challenge to veterinary and wildlife authorities is to develop anthrax control strategies that are supportive to wildlife production systems by ensuring continued trade in game products yet not compromising on public health requirements. The control strategies must be based on risk analysis and socio-cost benefit analysis. This will require commitment from the veterinary and wildlife authorities to support the development of alternative disease control strategies. To ensure continuity of the disease control strategies there is need to create an understanding of the basic principles of biodiversity conservation among veterinary officials and paraveterinary procedures and regulations among the wildlife officials. Critical in the training is the role of anthrax in regulating animal populations and the role of veterinary regulations in international trade in game products.

The immediate challenge is to improve on anthrax surveillance and monitoring especially on information management.

Steps to improve anthrax surveillance and control

- Wildlife authorities should establish a veterinary unit urgently to undertake disease surveillance based on an effective early warning and efficient information management system (Appendix I). The disease surveillance programme should be supported by adequate provision of resources such as communication facilities, transport, equipment and personnel. To improve disease surveillance the programme should take advantage of the presence of wildlife officials in far outlying areas. These officials should be trained in basic veterinary concepts such as sampling and diagnostic procedures and techniques,

- There is an urgent need to adopt an adaptive disease control strategy that shall take into account the socio-political and socio-economic realities of biodiversity conservation, including sustainable wildlife utilisation. This implies a shift from the current focus on disease investigation and control to an open holistic approach that objectively supports biodiversity conservation. Veterinary authorities should, therefore, articulate the role of veterinary science in biodiversity conservation and economic utilisation of wild herbivores in a transparent and objective manner especially with regards to international trade in animal products. Without this the support of other stakeholders, especially the wildlife authorities, in the control of the disease will not be forthcoming.
- To improve transparency and objectivity when adopting disease control measures especially quarantine measures veterinary authorities should incorporate quantitative risk analysis in the setting up of control measures. The authorities should establish the probabilities and efficacy of the proposed risk scenario pathway and risk mitigation using laboratory experiments in which the attempts should be made to

subject anthrax infected animals to the risk mitigation procedures. Second, veterinary authorities should adopt disease control measures taking into account the economic cost of enforcing disease control measures; the technical effectiveness and feasibility of enforcing the measures in the area.

- There is need to adopt an intersectoral approach involving veterinary, wildlife and health authorities with regards to the control of the disease. There will be need to define specific areas of responsibility and accountability regarding disease surveillance and control to each of the sectors,
- There is need to embark on community education programme to sensitise the local community on the dangers of the disease. This will also dispel fears of possible prosecution for divulging heath problems associated with consumption of game meat to health personnel,
- Wildlife authorities should undertake regular and reliable animal counts. Without this data the impact of the disease on biodiversity conservation and other sectors of the economy both at regional and national level can not be quantified. There is need for the authorities to produce a wildlife production linkage system and social accounting matrix in order to measure the value of wildlife and its contribution to the Zambian economy from a micro and macro perspective. This will assist when assessing the impact of the disease epidemics to the regional (Luangwa Valley) and national economy. Further use of the financial values shall continue to underestimate the impact of the

disease. In addition there is need to investigate the role of the disease in regulating the animal population.

Chapter 10

CONCLUSIONS

The conclusions of the study are:

- Despite a general lack of the social accounting matrix in the country the wildlife sector is considered the economic backbone of Luangwa Valley,
- Data on the epidemiology of the disease, in terms of its spatial and temporal distribution, in the Luangwa Valley is incomplete. The available information in only limited to central Luangwa Valley. At present it is difficult to specify the factors that may trigger disease epidemics in the area due to lack of adequate epidemiological and ecological data,
- Continuous surveillance of anthrax in the area is constrained by lack of a veterinary unit and effective communication system within the area,
- The current disease control strategy of choice is incompatible with the goals of the wildlife sector and impractical to enforce in the area,
- Anthrax is both an economic and ecological problem that requires serious multidisciplinary attention. Its potential threat to biodiversity conservation including community based natural resource management programmes should be investigated further. At present the cost of the disease is difficult to quantify due to lack of disease surveillance and reliable animal census data. The potential socio-economic cost of the disease is, however, considered substantial. Investigation of the impact

of the disease should take a holistic approach and cognizance of the ecological impact of the disease including the role of the disease in regulating animal populations. There is need to adopt disease control measures on the basis of the situational risk analysis of the specific disease epidemics, the economic costs of the control measures and, the technical effectiveness of the control measures and the feasibility of enforcing the measures in the area and,

- The possibility of the disease affecting the human population should always be investigated during disease epidemics.

REFERENCES

Anon. 1997: A brief report on anthrax outbreak in South Luangwa Area. Unpublished Departmental Report.

Anon. 1996. Luangwa Integrated Resource Development Project Annual Report.

Anon. 1995. Luangwa Integrated Resource Development Project Annual Report.

Anon. 1988: Report on Anthrax in Hippopotami and other Wildlife Species in the Luangwa Valley. Report submitted to the Director, National Parks and Wildlife Service.

Anon. 1983: Department of Veterinary Services Annual Report.

Anon. 1982: Department of Veterinary Services Annual Report.

Anon. 1980: Department of Veterinary Services Annual Report.

Anon. 1979: Department of Veterinary Services Annual Report.

Anon. 1978: Department of Veterinary Services Annual Report

Anon. 1974: Department of Veterinary Services Annual Report

Anon. 1973: Department of Veterinary Services Annual Report

Anon. 1972: Department of Veterinary Services Annual Report

Anon. 1971: Department of Veterinary Services Annual Report

Anon. 1970: Department of Veterinary Services Annual Report

Anon. 1968: Department of Veterinary Services Annual Report

Anon. 1967: Department of Veterinary Services Annual Report

Anon. 1966: Department of Veterinary Services Annual Report

Anon. 1963: Department of Veterinary Services Annual Report

Anon. 1962: Department of Veterinary Services Annual Report

Anon. 1961: Department of Veterinary Services Annual Report

Anon. 1959: Department of Veterinary Services Annual Report

Anon. 1958: Department of Veterinary Services Annual Report

Anon. 1957: Department of Veterinary Services Annual Report

Anon. 1952: Department of Veterinary Services Annual Report

Anon. 1949: Department of Veterinary Services Annual Report

Anon. 1947: Department of Veterinary Services Annual Report

Anon. 1946 Department of Veterinary Services Annual Report

Anon. 1945: Department of Veterinary Services Annual Report

Anon. 1944: Department of Veterinary Services Annual Report

Anon. 1940: Department of Veterinary Services Annual Report

Anon. 1939: Department of Veterinary Services Annual Report

Anon. 1937: Department of Veterinary Services Annual Report

Anon. 1935: Department of Veterinary Services Annual Report

Anon. 1928: Department of Veterinary Services Annual Report

Astle, W.L., Phiri, P.S.M., and Prince, S.D. 1997a: Annotated checklist of the flowering plants and ferns of the South Luangwa National Park, Zambia. Kirkia. 16(2): 109-160.

Astle, W.L., Phiri, P.S.M., and Prince, S.D. 1997b: A dictionary of the flowering plants and ferns of the South Luangwa National Park, Zambia. Kirkia. 16(2): 161-204.

Astle, W.L., Webster, R. & Lawrence, C.J. 1969: Land Classification for management planning in the Luangwa Valley of Zambia. Journal of Applied Ecology. 6: 143-169.

Balakrishna, M and Ndhlovu, D.E. 1992: Wildlife Utilisation and Local People: A case study in Upper Lupande Game Management Area, Zambia. Environmental Conservation. 19(2): 135-144.

Bennett, R., Christiansen, K., and Clifton-Hadley, R. 1999: Preliminary estimates of the direct costs associated with endemic diseases of livestock in Great Britain. Preventive Veterinary Medicine. 39: 155-171.

Bennet, R.M. 1992: The use of 'economic' quantitative modelling techniques in livestock health and disease-control decision making: a review. Preventive Veterinary Medicine. 13: 63-76.

Berry, H.H. 1981. Abnormal levels of disease and predation as limiting factors for wildebeest in the Etosha National Park. Madoqua 12(4): 242-253.

Bohm, R. 1990: Resistance, Survival, Sterilization and Disinfection of Spores of *Bacillus anthracis*. Proceedings of the International Workshop on Anthrax, 11-13 April 1989, Winchester. Salisbury Medical Bulletin. Special supplement No. 68: 99-101.

Brown, L.D. 1985: People-Centred Development and Participtory Research. Havard Educational Review. 55(1): 69-75.

Brückner, G.K. 1995: The socio-economic impact of diseases of ruminants in Eastern and Southern Africa. *Journal of South African Veterinary Association.* 66(3): 121-150.

Carpenter, T.E. 1993: Veterinary economics - tips, tricks and traps. Preventive Veterinary Medicine. 18: 27-31

Chambers,R. 1992: Rapid and Participatory Rural Appraisal. 22(1): 6-15

Chidumayo, E.N. 1998. Biodiversity in Zambia: An Overview. A paper presented at the first National Biodiversity Workshop held at Lusaka 5-6 August 1998.

Choquette, L.P.E., and Broughton, E. 1981. Anthrax. In: Davis, J.W., Karstad, L.H., and Trainer, D.O. (eds). *Infectious Diseases of Wild Mammals,* 2nd edition, Ames, Iowa, USA. The Iowa State University Press. Pp 288-296.

Christensen, B. 1994: Non-quantitative risk analysis and the importation of animal products. Surveillance. 21(4): 13-14.

Clark, C.M. 1998: Anthrax - a real and present threat?. The Pharmaceutical Journal. 260: 374.

Cooper, J.E. 1998: Minimally invasive health monitoring of wildlife. Animal Welfare. 7: 35-44.

Cox, N., and Ryan, T.1998: Introduction of anthrax via green hides: risk analysis revisited. Surveillance. 25(3): 6-8

Creel, S., Creel, N.M., Matovelo, J.A., Mtambo, M.A., Batamuzi, E.K., and Cooper, J.E. 1995: The effects of anthrax on endangered African wild dogs (*Lycaon pictus*). Journal of Zoology, London. 236: 199-209.

Daszak, P., Cunningham, A.A., and Hyatt, A.D. 2000: Emerging Infectious diseases of Wildlife - Threats to Biodiversity and Human Health. Science's Compass Review. 287: 443-449.

Davies, J.C.A. 1983. A Major Epidemic of Anthrax in Zimbabwe, Part II. The Central African Journal of Medicine. 29(1): 8-12.

Davies, J.C.A. 1982: A Major Epidemic of Anthrax in Zimbabwe, Part I. The Central African Journal of Medicine. 28(12): 291-298.

De Vos, V. and Bryden, H.B. 1996: Anthrax in the Kruger National Park: temporal and spatial patterns of disease occurrence. Salisbury Medical Bulletin - Special Supplement. 87: 26-30.

De Vos, V. 1994. Anthrax. Pp 1262-1289. In: Coetzer, J.A.W., G.R. Thomson, and R.C. Tustin., (eds). *Infectious Diseases of Livestock with Special Reference to Southern Africa.* Cape Town: Oxford University Press.

De Vos, V. 1990: The ecology of Anthrax in the Kruger National Park, South Africa. Proceedings of the International Workshop on Anthrax, 11-13 April 1989, Winchester. Salisbury Medical Bulletin. Special supplement No. 68: 19-23.

De Vos, V., van Rooyen, G.L., and Kloppers, J.J. 1973: Anthrax immunization of free-ranging roan antelope *Hippotragus equinus* in the Kruger National Park. *Koedoe*. 16: 11-25.

Djkhuizen, A.A., Huirne, R.B.M., and Jalvingh, A.W. 1995: Economic analysis of animal diseases and their control. Preventive Veterinary Medicine. 25: 135-149.

Ebedes, H. 1992: Important Bacterial Diseases for the Wild Rancher - Anthrax and Tuberculosis. In Proceedings of symposium on 'Wildlife Ranching: A celebration of diversity' October, 1992, Pretoria. Eds: Van Hoven, W., Ebedes, H. & Conroy, A.

Ebedes, H. 1976: Anthrax epizootics in Etosha National Park. Madoqua 10(2): 99-118.

Ellis, P.R., and James, A.D. 1979: The economics of animal health - (1) Major disease control programs. The Veterinary Record. 105(22): 504-506.

Ellis, P.R., and James, A.D. 1979: The economics of animal health - (2) Economics in farm practice. 105 (23):523-526.

Eltringham, S. K. 1994: Can wildlife pay its way?. Oryx 28(3): 163-168.

Ekboir, J.M. 1999: The role of the public sector in the development and implementation of animal health policies. Preventive Veterinary Medicine. 40: 101-115.

FAO (Food and Agriculture Organization), 1968. Wildlife and Land-use Survey of Luangwa Valley. Report submitted to the Government of Zambia.

Gainer, R.S. 1987: Epizootiology of Anthrax and Nyasa Wildebeest in the Selous Game Reserve, Tanzania. Journal of Wildlife Diseases. 23(1): 175-178.

Gainer, R.S. and Saunders, J.R. 1989: Aspects of the epidemiology of anthrax in Wood Buffalo National Park. Canadian Veterinary Journal. 30: 953-956.

Gates, C.C., Elkin, B.T., and Dragon, D.C. 1995: Investigation, Control and Epizootiology of Anthrax in a Geographically Isolated, Free-Roaming Bison Population in Northern Canada. Canadian Journal of Veterinary Research. 59: 256-264.

Gold, H. 1967: Treatment of anthrax. Federation Proceedings. 26(5): 1563-1568.

Graham-Smith, G.S. 1941: Further observations on the longevity of dry spores of *B. anthracis*. *Journal of Hygiene*. 496.

GRZ, 1998: Ministry of Finance and Economic Development, 1998, Economic Report.

Hambleton, P., Carman, J.A., and Melling, J. 1984: Anthrax: the disease in relation to vaccines. *Vaccine*. 2:125-132.

Harrington, R., Owen-Smith, N., Viljoen, P.C., Biggs, H.C., Mason, D.R., and Funston, P. 1999: Establishing the causes of the roan antelope decline in the Kruger National Park, South Africa. Biological Conservation. 90: 69-78.

Harrison, L.H., Ezzel, J.W., Abshire, T.G., Kidd, S., and Kaufmann, A.F. 1989: Evaluation of ecological Tests for Diagnosis of Anthrax after an Outbreak of Cutaneous Anthrax in Paraguay. *The Journal of Infectious Diseases*. 160: 706-710.

Houston, D.C., and Cooper, J.E. 1975: The digestive tract of the white back Griffon vulture and its role in disease transmission among wild ungulates. *Journal of Wildlife Diseases.* 11: 306-312.

Ikede, B.O., Falder and Golding, R.R. 1976: Anthrax in captive carnivores in Ibadan, Nigeria. *Journal of Wildlife Diseases.* 12: 130-132.

IUCN/GRZ, 1995: A Development and Management Plan for South Luangwa National Park and Lupande Game Management Area.

James, A.D and Ellis, P.R. 1978: Benefit-Cost Analysis in Foot-and Mouth Disease Control Programs. British Veterinary Journal. 134: 47-52.

Jordan, W.J. 1964: An Outbreak of Acute Disease in Chester Zoo Diagnosed as Anthrax. The Veterinary Record. 76(35): 927-930.

Kaufmann, A.F. 1990: Observations of Anthrax as Related to Soil Type and Rainfall. Proceedings of the International Workshop on Anthrax, 11-13 April 1989, Winchester. Salisbury Medical Bulletin. Special supplement No. 68: 16-17.

Kellog, F.E., Priestwood, A.K., and Noble, R.E. 1970: Anthrax epizootics in White-Tailed deer. *Journal of Wildlife Diseases*. 6: 226-228.

Kirkwood, J.K. 1994: Veterinary education and wildlife conservation, health and welfare. Veterinary Record. 135: 148-151.

Kirkwood, J.K. 1993: Interventions for wildlife health, conservation and welfare. Veterinary Record. 132: 235-238.

Klem, D.M., and Klemm, W.R. 1959: A history of Anthrax. Journal of American Veterinary and Medical Research. 135: 458-462.

Koch, M.D. 1996: Wildlife, People and Development: Veterinary contributions to wildlife health and resource management in Africa. Tropical Animal Health Production. 28: 68-80.

Kopcha, M., and Bartlett, P.C. 1997: Important Zoonoses from direct contact with livestock. Veterinary Medicine. 92(4): 370-374.

Krishana, N.S., and Moyiyundeen, S. 1958: Tabanus flies as transmitters of anthrax - a field experience. The Indian Veterinary Journal. 348-353.

Krystynak, R.H.E and Charlebois. 1987: The Potential Economic Impact of an Outbreak of Foot-and Mouth Disease in Canada. Canadian Veterinary Journal: 28(8): 523-527.

Lalitha, M.K., Anandi, V., Walter, N.M., John, L., Devadatta, J.O., Pulimood, B.M., and Koshi, G. 1990: Unusual forms of Anthrax - a clinical problem. Proceedings of the International Workshop on Anthrax, Special supplement No. 68: 38-40.

Levy, L.M., Baker, N., Meyer, M.P., Crosland, P., and Hampton, J. 1981: Anthrax meningitis in Zimbabwe. The Central African Journal of Medicine. 27(6): 101-104

Lewis, D., Kaweche, G.B. and Mwenya, A. 1990: Wildlife Conservation Outside Protected Areas - Lessons from an Experiment in Zambia. Conservation Biology. 4: 171-180.

Lindeque, P.M. 1991: Factors affecting the incidence of anthrax in Etosha National Park, Namibia. Ph.D. Thesis.

Lyon, D.G. 1973: An Outbreak of Anthrax at the Chester Zoological Gardens. Veterinary Record. 92: 334-337.

MacDiarmid, S.C. 1991: Risk analysis and the importation of animals. Surveillance. 18(5):8-11.

MAFF (Ministry of Agriculture, Food and Fisheries), 1997. Report on a consultancy mission to assess the anthrax situation in Western Province, Zambia.

MAFF (Ministry of Agriculture, Food and Fisheries), 1995. Farmers' attitudes towards the control and prevention of anthrax in Western Province Zambia. Working paper 95/11.

Manchee, R.J., Broster, M.G., Stagg, A.J., Hibbs, S.E., and Patience, B. 1990: Out of the Gruinard Island. Proceedings of the International Workshop on Anthrax, Special supplement No. 68: 16-17.

Manchee, R.J., Broster, M.G., Anderson, I.S., and Henstridge, R.M. 1983: Decontamination of *Bacillus anthracis* on Gruinard Island?. Nature. 303: 239-240.

Manchee, R.J., Broster, M.G., Melling, J., Henstridge, R.M., and Stagg, A.J. 1981: *Bacillus anthracis* on Gruinard Island. Nature. 294: 254-255.

Mbise, A.N., Nsengwa, G.R.M., and Mbasha, E.M.S. 1991: Anthrax Epizootic in Tarangire National Park Tanzania: An Important Disease of Impala in a Period of 15 Years. Bulletin of Animal Health and Production, Africa. 39: 45-50.

McConnell, E.E., Tustin, R.C., and De Vos, V. 1972: Anthrax in an African Buffalo (*Syncerus caffer*) in the Kruger National Park. Journal of South African Veterinary Medical Association. 43(2): 181-187.

McKendrick, D.R.A. 1980: Anthrax and its transmission to Humans. The Central African Journal of Medicine. 26(6): 126-129.

McKenzie, A. A. 1992: The impact of disease on wildlife utilization: a case-study in asset-based conservation management. Proceedings of the International Symposium on Wildlife Utilization in Southern Africa.

McInerney, J. 1996: Old Economics for New Problems - Livestock Disease: Presidential Address. Journal of Agricultural Economics. 47(3):295-314.

McInnerney, J.P., Howe, K.S., and Schepers, J.A. 1992: A framework for the economic analysis of disease in farm livestock. Preventive Veterinary Medicine. 13:137-154.

Meltzer, D.G.A. 1996: Veterinary wildlife research and its role in community development. South African Journal of Wildlife Research. 26(2): 66-68.

Minett, F.C. 1950: Sporulation and viability of *B. anthracis* in relation to environmental temperature and humidity. Journal of Comparative Pathology. 60: 161-176.

Minett, F.C., and Dhanda, M.R. 1941 : Multiplication of *B. anthracis* and *Cl. Chauvei* in soil and in water. Indian Journal of Veterinary Science and Animal Husbandry. 11: 308-328.

Mitchell, P. 1998: Anthrax - The Practitioner's View. State - Veterinary Journal. 8(2): 5-8.

Morris, R., and Meek, A.H. 1980: Measurement and Evaluation of the Economic Effects of Parasitic Disease. Veterinary Parasitology. 6: 165-184.

Morris, R.S. 1971: Economic aspects of disease control programs for Dairy Cattle. Australian Veterinary Journal. 47: 358-363.

Morris, R.S. 1969: Assessing the economic values of veterinary services to primary industries. Australian Veterinary Journal. 45: 295-300.

Morris, R.S. 1969: The Economic basis of Planned Veterinary Services to individual farms. Australian Veterinary Journal. 45:337-341.

Mundy, P.J., and Brand, F.E. 1978. An investigation of vultures and anthrax in Southern Africa. *Rhodesian Veterinary Journal*. 9: 36-39.

Ndyabahinduka, D.G.K., Chu, I.H., Abdou, A.H., and Gaifuba, J.K. 1984: An outbreak of Human Gastrointestinal Anthrax. *Ann. Ist. Sanita*. 20(2-3): 205-208.

Ngategiize, P.K., and Kaneene, J.B. 1985: Evaluation of the Economic Impact of Animal Diseases on Production: A Review. Commonwealth Bureau of Animal Health. 55(3): 153-162.

OIE (*Office International des Epizooties*), 1992: World Animal Health in 1992. Part 1, Reports on the animal health status and disease control methods and list A disease outbreaks - Statistics.

Ott, S.L., Seitzinger, A.H., and Hueston, W.D. 1995: Measuring the national economic benefits of reducing livestock mortality. Preventive Veterinary Medicine. 24: 203-211.

Pienaar, U. de. V. 1967: Epidemiology of anthrax in wild animals and the control of anthrax epizootic in the Kruger National Park, South Africa. Federation Proceedings 26: 1496-1502.

Pienaar, U.de. V. 1961: A second outbreak of anthrax amongst Game Animals in Kruger National Park. *Kodoe*. 4: 4-17.

Prins, H.H.T. and Weyerhaeuster, F.J. 1987: Epidemics in populations of wild ruminants: anthrax and impala, rinderpest and buffalo in Lake Manyara National Park, Tanzania. Oikos. 49: 28-38.

Ryan, T., and Livingstone, P. 2000: Risk Analysis: Movement of cattle from tuberculosis infected herds. Surveillance. 27(1): 8-10.

Ryan, T.J. 1995: Disease control analyses - stochastic modelling made easy. Surveillance. 22(2): 24-26.

Ross, J.M. 1957: The pathogenesis of anthrax following the administration of spores by the respiratory route. *Journal of Pathology and Bacteriology.* 73: 485-494.

SADC/SACCAR. 1997: The Wildlife Sector. In Regional Research Priorities in the natural resources sector., January, Gaborone, Botswana.

Saiwana, L.M. 1995: Wildlife Conservation and Management in Zambia. In: Suzuki, A.K., Pandey, G.S.and Nambota A(Editors), Proceedings of the symposium on 'The effects of enlargement of Domestic Animal Pasture on the wildlife in Zambia.', 22 March 1995, Lusaka, Zambia.

Schinder, R., Sachs, R., Hilton, P. J. & Watson, R. M. 1969: Some veterinary aspects of the utilization of African game animals. Bulletin of epizootic Diseases, Africa 17: 215-221.

Siefert, L., Opuda-Asibo, J., Nakasala-Situma, J., Dahlhelm, D. & Ocaido, M. 1996: Improved training in wildlife utilisation of veterinarians in Uganda. South African Journal of Wildlife Research 26(4): 171-174.

Sirisanthana, T., Nelson, K.N., Ezzell, J.W., and Abshire, T.G. 1988: Serological studies of patients with cutaneous and oral-oropharyngeal anthrax from Northern Thailand. American Journal of Tropical Medicine and Hygiene. 39(6): 575-581.

Sirisanthana, T., Navachareon, N., Tharavichitkul, P., Sirisanthana, V., and Brown, A.E. 1984: Outbreak of oral-oropharyngeal anthrax: an unusual manifestation of human infection with *Bacillus anthracis*. American Journal of Tropical Medicine and Hygiene. 33(1): 144-150.

Smith, P.P. 1997: A preliminary checklist of the vascular plants of the North Luangwa National Park. Kirkia. 16(2): 205-245.

Smith, H. and Stoner, H.B. 1967: Anthrax topic complex. Federation Proceedings. 26(5): 1554-1557.

Stein, C.D. 1948: Incidence of Anthrax in Livestock During 1945, 1946, and 1947 with Special Reference to Control Measures in Various States. Veterinary Medicine. 43: 463-469.

Stein, C.D. 1947: Some observations on the tenacity of *Bacillus anthracis* Veterinary Medicine. 42: 13-22.

Sterne, M. 1967: Distribution and economic importance of anthrax. Federation Proceedings. 26(5): 1493-1495.

Stephen, L.O., Seitzinger, A.H., and Hueston, W.D. 1995: Measuring the national economic benefits of reducing livestock mortality. Preventive Veterinary Medicine. 24: 203-211.

Stevens, A.J. 1989. Gruinard Island - an Anthrax Incident 45 Years Long. The State Veterinary Journal. 43(122): 3-11.

Sutmoller, P., and Wrathall, A.E. 1997: A quantitative assessment of the risk of transmission of foot-and-mouth disease, bluetongue and vesicular stomatitis by embryo transfer in cattle. Preventive Veterinary Medicine. 32: 111-132.

Townsend, R.F., and Sigwele, H.K. 1998: Final Report - Socio-economic Cost-Benefit Analysis of Action and Alternatives for the Control of Contagious Bovine Pleuropneumonia in Ngamiland, Botswana.

Tuchili, L.M., Pandey, G.S., Sinyangwe, P.G. and Kaji, T. 1993: Anthrax in cattle, wildlife and humans in Zambia. The Veterinary Record. 132: 487.

Tuchili, L.M. and Pandey, G.S. 1995: The impact of anthrax on wildlife, human and the environment in Zambia. In: Suzuki, A.K., Pandey, G.S. & Nambota (Editors): Proceedings of the symposium on 'The effects of enlargement of domestic animal pasture on the wildlife in Zambia., 22 March 1995, Lusaka, Zambia.

Turnbull, P.C.B., Lindeque, P.M., Roux, J.Le., Bennett, A.M., and Parks, S.R. 1998. Airborne movement of anthrax spores from carcass sites in the Etosha National Park, Namibia. *Journal of Applied Microbiology.* 84: 667-676.

Turnbull, P.C.B., Doganay, M., Lindeque, P.M., Aygen, B., and McLaughlin, J. 1992B: Serology and anthrax in Humans, livestock and Etosha National Park wildlife. Epidemiology and Infection. 108: 299-313.

Turnbull, PC.B., Hofmeyr, J.M., McGetrick, A.M.T. and Oppenheim 1986a: Isolation of *Bacillus anthracis*, the agent of anthrax, in the Etosha National Park. Madoqua. 14(4): 321-331.

Turnbull, P.C.B., Bell, R.H.V., Saigawa,K., Munyenyembe, F.E.C., Mulenga, C.K., and Makala, L.H.C. 1991: Anthrax in Wildlife in the Luangwa Valley, Zambia. The Veterinary Record. 128: 399-403.

Turnbull, P.C.B., Carman, J.A., Lindeque, P.M., Joubert, F., Hübschle, O.J.B., and Snoeyenbos, G.H. 1989: Further progress in understanding Anthrax in the Etosha National Park. *Madoqua.* 16: 93-104.

Turner, M. 1980: Anthrax in Humans in Zimbabwe. The Central African Journal of Medicine. 26(7): 160-161.

Van Ness, G.B. 1971: Ecology of Anthrax. *Science.* 172: 1303-1307.

van Veen, T.W.S., and de Haan, C. 1995: Trends in the organization and financing of livestock and animal health services. Preventive Veterinary Medicine. 25: 225-240.

Vlaenderen van, H. 1995: Methods in socio-economic impact assessment: The use of Participatory Rural Appraisal (PRA). In Krecek, R.C., Cornelius, S.T., and McCrindle, C.M.E (Editors):Proceedings of a workshop on 'Socio-economic aspects of animal diseases in southern Africa: Research Priorities in Veterinary Science', May 1995.

Wilson, J.B., and Russel, K.E. 1964: Isolation of *Bacillus anthracis* from soil stored 60 years. *Journal of Bacteriology.* 87: 237-238.

Winter, C.T. 1985: The water quality of water-holes utilized by game in the Etosha National Park. Madoqua. 14(2): 145-153.

Young, E. 1972: Considerations on large scale vaccination of free-living game. *Journal of South African Veterinary Medical Association*. 43(2); 189-191.

Yu, P., Habtemariam, T., Wilson, S., Oryang, D., Nganwa, D., Obasa, M., and Robnett, V. 1997: A risk-assessment model for foot and mouth disease (FMD) virus introduction through deboned beef importation. Preventive Veterinary Medicine. 30: 49-59.