Limiting the northerly advance of *Trypanosoma brucei rhodesiense* in post conflict Uganda

Richard Selby

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Declaration

I declare that the research described within this thesis is my own work and that this thesis is my own composition

Richard Selby
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Abstract

In October 2006 an intervention was initiated to arrest the northerly advance through Uganda of the zoonotic parasite *Trypanosoma brucei rhodesiense*. This is a protozoal infection that is vectored by the tsetse fly. It is the aim of this thesis to review the impact of this large scale treatment programme in terms of animal health and human disease.

The Stamp Out Sleeping Sickness (SOS) campaign was designed to target the cattle reservoir of *T. b. rhodesiense* in these newly affected areas by block treating >180,000 head of cattle. This was achieved in collaboration with final year vet students from the University of Makerere, Uganda. Farmers were also encouraged to spray their animals with deltamethrin in order to suppress the tsetse population.

In order to monitor the impact of this intervention a base line survey was carried out. Evaluation of the logistics and implementation of the SOS campaign was assessed through interviews with personnel involved. Analysis by PCR revealed the prevalence of *T. brucei* s.l. as 15.57% (*T. b. rhodesiense* as 0.81%) within the cattle reservoir prior to SOS treatment. Follow up sampling was carried out at 23 locations at three, nine and 18 months. The prevalence of *T. brucei* s.l. was reduced post treatment, but in the absence of sustained vector control infections amongst the animals returned by nine months and subsequently exceeded the base line findings (P=<0.0001).

It was observed that across most of the SOS area, *T. b. rhodesiense* did not re-establish following treatment. However, a significant cluster was identified where cases of both human and animal disease were continually reported. This cluster was noted to include the area immediately surrounding the Otuboi cattle market.

This link between cattle movement and the spread of *T. b. rhodesiense* is an established one and is addressed by Ugandan governmental policy which states that ‘cattle traded at market must be treated with trypanocidal drugs prior to movement’. The findings presented here suggest that this policy may not be strictly enforced. The risk of spread is compounded at the northern districts of Uganda restock their domestic livestock following years of civil conflict. The majority of animals are traded in a northward direction – transporting infected animals from the endemic south. The scale of this trade is assessed through questionnaires, analysis of trade records and animal screening. Specific consideration is given to the implications of this cattle trade and impact this may have on the sustainability of the SOS campaign.
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1. Introduction

The Introduction of this thesis is separated into two distinct sections for ease of reading; firstly to provide a general introduction to trypanosomiasis and associated issues and secondly to specifically focus upon Uganda, where the work undertaken in this thesis has been conducted. Within the second section is included an introduction to the importance of cattle within the northern region of Uganda and a brief history of conflict in that region that has influenced cattle movements.

1.1. General introduction

Human African Trypanosomiasis (HAT) and African Animal Trypanosomiasis (AAT) are caused by infection of a susceptible individual with African trypanosomes (trypanosomes found in South America are infective of humans and animals, but cause a very different pathogenesis). These parasites are digenic and transmitted by tsetse flies belonging to the genus *Glossina*. The pathogenesis associated with trypanosome infection is responsible for a high level of economic loss within affected regions, as a result of reduced cattle productivity accompanied by human sickness, rendering infected persons unable to work. In 2006, economic losses within the African continent due to trypanosomiasis were estimated as US$4.5 billion per annum (Kristjanson, 1998, Miller et al., 2006).

In 2004, 17,616 cases of human African trypanosomiasis were reported to the World Health Organization of which 580 cases originated from areas endemic for *Trypanosoma brucei rhodesiense* and 17,036 from endemic *Trypanosoma brucei gambiense* areas (WHO, 2006). The low number of total reported cases highlights the lack of active screening within the vast majority of countries hosting HAT.
The true number of HAT cases per year is thought to be between 300,000 and 500,000 as a result of widespread under reporting of trypanosomiasis (WHO, 1998; Welburn & Odiit, 2002). Additionally people who develop trypanosomiasis frequently do not seek treatment, often confusing the symptoms with other diseases, or are wrongly or undiagnosed by poorly trained or equipped health centres that are unable to test for, or identify trypanosome infection and as such are not represented in the data (Morel, 2001, Odiit et al., 2004a, Fèvre et al., 2008b, Matemba et al., In press).

The World Health Organization estimated that HAT gave rise to the loss of 2.1 million disability adjusted life years (DALY which is in essence the number of years lived by individuals with disability due to the condition added to the numbers of years lost to the disability due to deaths) and 66,000 deaths during 1999. By means of comparison, the number of millions of DALYs lost due to malaria is estimated at 45.0, with 4.9 for lymphatic filariasis, 2.0 for leishmaniasis, 1.9 for schistosomiasis, 1.1 for onchocerciasis and 0.7 for Chagas disease (Morel, 2001, Odiit et al., 2004b, Fèvre, 2005, Fèvre et al., 2008a, Matemba et al., In press).

While several trypanosome species cause important animal disease, only two species of trypanosome cause pathogenesis in humans; *Trypanosoma brucei* and *Trypanosoma cruzi*. Within Africa there are two sub-species which are infective to humans; *T. b. rhodesiense* and *T. b. gambiense*. Traditionally these sub-species have been spatially segregated in Africa. Uganda is the only country proven to harbour both species within its borders. Within Uganda the sub-species are separated by over 150 miles, however, recently there has been concern that overlapping will soon occur, making diagnosis and treatment increasingly difficult (Picozzi et al., 2005b).

1.1.1. **Biology of trypanosomes**

Trypanosomes are unicellular eukaryotes, classified as protozoa that belong to the class Kinetoplastida, sharing generalised taxonomic characteristics with other protozoan parasites such as *Leishmania spp, Toxoplasma spp.* and *Plasmodium spp.* They all have
similar cellular compositions, incorporating the organelles associated with all eukaryotic cells. However the kinetoplastid protozoans possess additional cellular features making them distinct from other eukaryotes, for example; they are defined by the presence of the kinetoplast organelle. Kinetoplasts are large single mitochondrion organelles located near to the cell nucleus; the kinetoplast contains roughly 10 to 20 percent of the DNA present within African trypanosomes (Brown & Williamson, 1964).

The genus *Trypanosoma* are characterised by the definitive stage of the lifecycle known as the trypomastigote. In both *Trypanosoma cruzi* and *Trypanosoma brucei*, the species that cause human disease, the trypomastigote stage is found during the lifecycle phase within the parasite’s vertebrate host, (Brener, 1973).

Within the genus *Trypanosoma* there are two spatially distinct variations, American and African trypanosomes, these two trypanosome groups are quite different in terms of their life cycles and the diseases propagated by infection. The two spatially distinct groups of trypanosomes are believed to have common ancestry, dating back approximately 300 million years corresponding with the time that tectonic movements caused Africa and South America to first separate (Stevens *et al.*, 1999, Hamilton *et al.*, 2009).

### 1.1.1.1. Biology of African trypanosomes

Some trypanosome species use mechanical transmission includes *Trypanosoma evansi* and *Trypanosoma theileri*. The majority of African trypanosomes pathogenic to humans and animals are cyclically transmitted by tsetse flies of the genus *Glossinidae*. The tsetse fly cannot be seen as ‘a flying syringe’ as the trypanosomes undergo several lifecycle transformations within the insect vector - multiplication within the tsetse host ensures that successful transmission to future hosts is more likely to be successful. At the same time the vector is not a gracious host to trypanosomes with many organisms dying in the insect gut before establishment of infection (Welburn & Maudlin, 1999, Aksoy, 2000).
The lifecycle of *Trypanosoma brucei rhodesiense* is shown in Figure 1-1 transmission of infections between tsetse fly and animal and human hosts.

Trypanosomes are initially injected into the skin tissue and where then subsequently pass into the blood and lymph of the vertebrate host as a result of an infected tsetse fly taking a blood meal. Metacyclic trypanomastigotes enter the mammalian host from the tsetse whilst the fly is feeding, via the proboscis of the insect directly into the bite wound, where upon the parasite undergoes rapid reproduction increasing the chance of further survival. This replication can cause the formation of a lump known as a chancre at the bite site (Barry *et al.*, 1998, Barrett *et al.*, 2003).
Trypanosome binary fission occurs immediately after the trypanosomes have been introduced into the new vertebrate host, with the invading trypanosome population doubling within 4 to 6 hours of introduction (Raper. et al., 2001). This strategy is effective as this replication reduces the probability of the trypanosome population being eradicated by the host’s non-specific immune defences.

During its lifecycle Trypanosoma brucei spp. may undergo two stages of asexual reproduction. The first of which is within the tsetse vector while the second takes place in the blood, lymph and in some cases the spinal fluids of the vertebrate host. There are also reports that under certain circumstances sexual reproduction may place in the salivary glands of the tsetse fly (Gibson & Bailey, 2003).

Upon the ingestion of a T. brucei s.l. infected bloodmeal by the tsetse, the trypanosomes switch from bloodstream forms and enter their procyclic phase and undergo replication, becoming the mesocyclic form within the tsetse alimentary tract passing through the foregut and midgut into the hindgut where they penetrate the gut wall. Upon passing through the hindgut wall and into the ectoperitrophic space of the tsetse (A in Figure 1-2), trypanosomes of T. brucei s.l. migrate to the salivary glands (B) where they become epimastigotes and undergo further replication (C), before maturing into the metacyclic stage (D) which is the transmitted to the mammalian host when the tsetse feeds (Vickerman et al., 1988, Welburn & Maudlin, 1999).
1.1.2. African Trypanosomiasis

African trypanosomiasis is the pathogenic disease caused by infection with trypanosomes. Although the pathogenic conditions caused by different species of African trypanosomes can show great variation between species, there are generalised comparisons that can be made between the species, with more detailed comparisons between the two sub-species infective to humans.

1.1.2.1. Human African Trypanosomiasis

Trypanosomiasis in humans is caused by two sub-species, both of which belong to the *T. brucei* species complex; these are *T. b. rhodesiense* and *T. b. gambiense*. These two sub-species are classically separated spatially with *T. b. rhodesiense* being located in eastern
and southern Africa and *T. b. gambiense* located in western regions of Africa. This traditional segregation is shown in Figure 1-3.

![Figure 1-3: African countries and their status of trypanosomiasis presence or risk, black line shows extent of distribution for either species, image taken from; http://medilinkz.org/Features/Articles/june2002/tryps_files/image002.jpg. Accessed 15/12/07](http://medilinkz.org/Features/Articles/june2002/tryps_files/image002.jpg)

**1.1.2.1.1. Pathogenesis**

There are generalisations of infection between the two sub-species that commonly infect humans, such as the formation of a lump at the site of the infective fly bite, termed a chancre, which is the result of initial replication of trypanosomes (Barrett *et al.*, 2003).

Both species give rise to two distinct phases of disease. During the early stage, the parasites are restricted to the host’s blood and lymph fluid, during late stage infection the
parasites invade the central nervous system (CNS) as well as other organs. It is during this late phase that the pathogenesis is most severe, with the host experiencing headaches and malaise which become more severe over a period of time, eventually developing into hypersomnia, mental impairment and eventually coma, which are elicited by pro-inflammatory cytokines and lead ultimately to death, (Rhind & Shek, 1999, Lundkvist et al., 2004).

The timeline of development of pathogenesis associated with trypanosome infection is greatly different depending which species is involved in the infection. Although this timeline differs between the species the end result is that if left untreated HAT has a 100% mortality rate (Barrett et al., 2003).

1.1.2.1.1.1. T. brucei gambiense

*T. b. gambiense* is the cause of chronic sleeping sickness, as its onset is more gradual than that of *T. b. rhodesiense*. Typically the initial symptom that infection is a result of *T. b. gambiense* is swelling of the lymph ducts at the top of the necks posterior. This clinical manifestation is known as Winterbottom’s sign (Stich et al. 2002). Other non-specific symptoms associated with infection with *T. b. gambiense* include the development of a rash and hepatosplenomegaly (Damian et al., 1994). The development of chronic sleeping sickness takes many months and even years. During this developmental period the patient can remain asymptomatic or with only slight clinical indication of disease prior to the onset of severe disease, as a result of this any early symptoms are often overlooked (Brun et al., 2010).

1.1.2.1.1.2. T. brucei rhodesiense

Human infection with the parasite *T. b. rhodesiense* causes the disease frequently termed acute sleeping sickness and whereas the chronic form takes months and even years to come to fruition, acute sleeping sickness has a very rapid progression to severe disease, with 80% of deaths occurring within six months (Welburn et al., 2001a). Although the
progression of the disease occurs more rapidly than is exhibited by *T. b. gambiense*, the pathogenic symptoms are highly similar with the exception of Winterbottom’s sign, which is unique to Gambian sleeping sickness. Due to the swift onset of severe pathogenesis the early symptoms of acute sleeping sickness are rarely recognised. The early signs are often confused with other endemic diseases in the area, such as malaria, Tuberculosis, or HIV infection (Maudlin *et al.*, 2009).

### 1.1.2.1.3. Zoonotic nature of *T. b. rhodesiense*

The *T. brucei* sub-species *Trypanosoma brucei rhodesiense* is zoonotic with infection known to establish within humans as well as a range of animals, both domesticated and wild (Jackson, 1955, Heisch, 1958, Onyango, 1966).

The ability of *T. b. rhodesiense* to establish infection within both human and animal hosts means that it is able to survive within an area where infection has been eradicated from the human population. For example if a successful control programme is employed against *T. b. rhodesiense* associated trypanosomiasis within the human population of an area, but the animal hosts are not included then there will eventually be a resurgence of human trypanosomiasis as tsetse mediated transmission re-establish infection within a susceptible human population. As such animal hosts of zoonotic diseases are commonly referred to as reservoir hosts (Reluga *et al.*, 2007).

*T. b. gambiense* is capable of infecting a wide array of animals, including domesticated pigs, but the zoonotic transmission of the parasite does not appear to have such a profound epidemiological relevance as is reported in *T. b. rhodesiense* (Morel, 2001).

### 1.1.2.1.2. Diagnosis

The diagnosis of sleeping sickness is initially based upon recognising the symptoms displayed by a patient. After the symptoms have been identified infection is confirmed by observing the presence of parasites either within the blood, lymph or the cerebro-spinal
fluids in the case of late stage infection. Diagnosis is possible by using techniques such as PCR but due to the nature of the disease being distributed and transmitted predominantly within economically deprived rural areas, the only diagnostic method available to local physicians and health workers are basic methods such as light microscopy (Picozzi et al., 2002).

Classically blood samples are collected by finger prick. To determine the stage of infection, cerebro-spinal fluid (CSF) samples are taken by lumbar puncture from all sleeping sickness cases, late stage infection is diagnosed by the presence of parasites within the CSF or an increased white cell count (Kennedy, 2006).

Generally, no further tests are carried out to determine the sub-species involved, with the geographical location of the patient giving rise to the assumption as to which sub-species of trypanosome the patient is infected with. Appropriate treatment then follows with different drugs prescribed depending on the sub-species involved and the stage of infection. Since the parasitemia of *T. b. gambiense* is very low in infected human hosts initial serological screening in Gambian areas is carried out using a card-agglutination test with stained-trypanosomes (CATT) (Magnus et al., 1978), individuals shown to be positive are then confirmed through parasitological diagnosis.

### 1.1.2.1.3. Treatment of HAT

Treatment of human trypanosomiasis is undertaken by the administration of chemotherapy. Depending upon which of the two sub-species is involved coupled with which stage of infection is presented; different drugs are used for treatment. Although the first trypanocidal drug, Atoxyl, was developed in 1905 by Ehrlich and Hata, there are still exceedingly few drugs available for the treatment of sleeping sickness (Seed, 2001). This is as a result of trypanosomiasis being transmitted predominantly within economically deprived rural regions of the African continent which simply means that there is unlikely to be economic return generated from any drug development. As such, the drugs
presently utilised were developed over 50 years ago and generally have severe side effects associated with their use.

The drugs that are used to treat late stage disease specifically cross the blood brain barrier in order to clear the parasites from within the cerebral-spinal fluid (Enanga et al., 2002), and as such are more severe in their side-effects upon the patient than drugs targeting early stage disease (Bouteille et al., 2003). The two separate causative sub-species are each sensitive to different chemotherapeutical regimes and therefore treatment needs to be suited to the causative sub-species. At present the two sub-species are spatially distinct, so treatment can be assumed upon the species present in the local area. But if overlapping of the two sub-species occurs, accurate field diagnosis of the species involved and the administration of the correct treatment will be inaccurate with the current techniques and training available to regional health centres in the affected areas.

Throughout affected areas of Africa, including Uganda, it is the case that only certain hospitals are capable of diagnosing and treating HAT, due to the difficulty and skill required to confirm diagnosis by microscopy and the highly toxic nature of the treatment, which will be fully described later.

1.1.2.1.3.1. Treatment of \textit{T. b. gambiense}

The treatment administered in established areas of chronic sleeping sickness differs whether the disease is manifested as the early or late stage: with early stage \textit{T. b. gambiense} being treated using either suramin or pentamidine both of which were developed prior to the 1920s, suramin being effective by hindering the parasites production of energy by metabolism, while pentamidine effects the parasites nucleic acid synthesis (Maudlin et al., 2004). Late stage patients being treated with melarsoprol, an arsenaical compound developed in 1949 (Friedheim, 1949, Hide, 1999) which is effective by inhibiting the parasites ability to undergo metabolism. Or \textit{α}-difluoromethylornithine (DFMO), which is effective against \textit{T. b. gambiense} as it inhibits polyamine synthesis by the parasite. Due to a high prevalence of \textit{T. b. gambiense} resistant to melarsoprol, DFMO
is now used as the first line treatment for late stage *T. b. gambiense* in many countries, including Sudan and Democratic Republic of Congo. DFMO is widely ineffective against *T. b. rhodesiense*, only returning a cure rate of 33% of patients due to the more rapid over-turn of the target enzyme which is explain later (Keiser *et al.*, 2001, Matovua *et al.*, 2001).

### 1.1.2.1.3.2. Treatment of *T. b. rhodesiense*

Chemo-therapeutical treatment for early stage acute sleeping sickness is treated only using suramin, late stage is treated exclusively using melarsoprol, which induces encephalopathy in 10% of patients treated and is fatal in half of those instances (Milord & Milord, 1994). Melarsoprol is effective against *T. b. rhodesiense* by inhibiting the parasites ability to undergo metabolism, as it does with *T. b. gambiense* (Nok, 2003).

### 1.1.2.1.3.3. Drug development for HAT

While the drugs currently utilised for the treatment of HAT are dated and give rise to unpleasant side effects, there is little interest from the pharmaceutical industry in developing drugs that are likely to have a very low rate of economic return, as HAT is associated with the rural poor (Molyneux, 2002, Molyneux *et al.*, 2010).

Megazol was initially originally synthesized at American Cyanamid in 1968, but recently (Bouteille *et al.*, 1995) has been used for the treatment of HAT (Dumas & Bouteille, 2002) and is effective against *T. brucei s.l.* along with *T. cruzi*, although the mode of action of the drug upon the parasite is unknown (Denise & Barrett, 2001).

There are existing drugs which are able to be used for the treatment of HAT, currently licensed for the treatment of other conditions and not HAT. Such as DFMO which was originally developed as an anti-tumour drug during the 1980s but was introduced for chemo-therapeutical treatment of HAT in 1990, making it the first drug to be approved for HAT treatment in half a century. DFMO acts by selectively inhibiting the enzyme
ornithine decarboxylase, which initiates the polyamine biosynthetic pathway (Pegg, 2006, Delespaux & de Koning, 2007).

1.1.2.2. African Animal Trypanosomiasis (AAT)

AAT affects a wide array of animal species, and while only *T. b. rhodesiense* and *T. b. gambiense* are of human significance, many others are infective of livestock and wildlife of economic importance. The effects of different trypanosomes upon their differing hosts vary in both symptomology and severity of pathogenesis.

1.1.2.2.1. Animals affected and trypanosome species responsible for AAT

Trypanosomes affect a large number of species, a brief summary of some of the animals that are commonly infected by African trypanosomes shall be provided here, with preference being given to animals of economic significance. A list of all animals that have been observed infected with African trypanosomes is shown in Table 1-1.

AAT has a great economic impact on domestic livestock. The adverse effect of the disease upon the status of the animal rendering them weak and less productive, also infected cattle are often in a visibly weakened condition and as such the value of the cattle depreciates as a result of infection. In the case of zoonotic trypanosomes the domestic reservoirs of human infective trypanosome species are in much closer proximity to humans than wild reservoirs, increasing the likelihood of transmission between reservoir animals and humans.
<table>
<thead>
<tr>
<th>Disease</th>
<th>Species affected</th>
<th>Trypanosoma agents</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagana / Sleeping sickness — chronic form</td>
<td>Humans, pigs</td>
<td><em>T. brucei gambiense</em></td>
<td>Western Africa</td>
</tr>
<tr>
<td>Nagana / Sleeping sickness — acute form</td>
<td>Humans, cattle, pigs</td>
<td><em>T. brucei rhodesiense</em></td>
<td>Eastern Africa</td>
</tr>
<tr>
<td>Nagana</td>
<td>Antelope, cattle, camels, horses</td>
<td><em>T. brucei brucei</em></td>
<td>Pan-African</td>
</tr>
<tr>
<td>Nagana (chronic form)</td>
<td>Cattle, camels, horses</td>
<td><em>T. congolense</em></td>
<td>Pan-African</td>
</tr>
<tr>
<td>Nagana (acute form)</td>
<td>Domestic pigs, cattle, camels, horses</td>
<td><em>T. simiae</em></td>
<td>Pan-African</td>
</tr>
<tr>
<td>Nagana (chronic form)</td>
<td>Cattle, camels, horses</td>
<td><em>T. vivax</em></td>
<td>Pan-African</td>
</tr>
<tr>
<td>Surra (chronic form)</td>
<td>Camels and horses</td>
<td><em>T. evansi</em></td>
<td>Pan-African</td>
</tr>
</tbody>
</table>

Table 1-1: Animals commonly infected by Trypanosoma species within Africa

The species which are responsible for the most significant forms of AAT are also shown in Table 1-1 along with the distribution of the causative *Trypanosoma* species (Schares & Mehlitz, 1996). The two human infective sub species of African trypanosomes are also capable of establishing infections within animal species (Jackson, 1955, Hide, 1999, Jannin & Cattand, 2004), however no other species trypanosome responsible for AAT is frequently transmitted between animal and human hosts (*T. evansi* has been identified in human patients in India but this instance has been linked to genetic abnormalities in the host (Powar et al., 2006)). Although Table 1-1 suggests that *T. b. gambiense* is zoonotic, transmission between animal hosts (particularly domestic swine) and humans has not been proven (Simo et al., 2006).

**1.1.2.2. Diagnosis of AAT**

Generally AAT is diagnosed and treated in cases concerning domesticated animals, as wild animals are not the responsibility of local persons. With the exception of endangered wild game animals such as rhinos which live in a national park or reserve, where symptoms may be identified by a warden, guide or vet, the vast majority of wild animals are not treated letting the disease take its natural course.
While the owners of domesticated animals will be largely unable to identify the cause of symptoms to be AAT in an infected animal, they will notice deterioration in the condition of the infected animal; weight loss, lethargy, loss of strength and anaemia are common symptoms (Machila et al., 2003) along with in some instances the appearance of a chancre at the site of the infective bite as occurs in human cases (Naessens, 2006). However clinical signs vary from case to case and are not only dependent upon the infective species but also the infected animal in regards to the animal’s genetics, nutritional status, stress and co-infective status. Diagnosis is not generally confirmed by laboratory diagnosis, instead animals displaying symptoms are treated upon the basis of symptom identification (Maudlin et al., 2004).

1.1.3. Tsetse vectors

The vectors of African trypanosomiasis are the tsetse fly; these arthropods have a wide distribution throughout sub-Saharan Africa and are known to cause great irritation to both humans and animals as pests. Most of the species of tsetse are vector competent for the transmission of trypanosomiasis but with a great range in transmission efficiency, (Moloo et al., 1971, Askoy, 2002).

Tsetse are highly sensitive to changes to their specified environments, this aspect has previously been utilised highly successfully as a means of eradicating tsetse populations from areas. However, it has been observed that rapid re-colonisation occurs, enabled by the tsetse habitat becoming re-established over time (Rogers & Randolph, 2002).

Distinguishing physiological features of the tsetse fly are listed (Minchin, 1905). Tsetse possess a single pair of wings, which while the fly is at rest, are folded one above the other and not overlapping as with the other dipterans, such as Culicoides or Simulium (for example Figure 1-4) also the wings have a cell, known as the hatchet cell, in the centre of each of the wings that is curved, resembling a hatchet (Figure 1-5)
Unlike many other arthropods responsible for transmitting disease-causing pathogens to mammals, both male and female tsetse flies are obligatorily hematophagic, requiring to take a blood meal in order to acquire nutrients needed to survive, every two to three days with feeding lasting for approximately three minutes (Langley, 1967, Randolph et al., 1991). In the vast majority of other disease vectors such as mosquitoes, sandflies and midges it is only the females which take a bloodmeal and as such transmit pathogens, requiring the protein gained from the blood to undergo vitelogenesis of the eggs, acquiring the rest of their nutrients from vegetation as do the males (Raikhel et al., 2002).

Tsetse are known to be strong fliers, able to cover up to a kilometre a day at speeds of up to 60 km per hour, however, they are unable to remain in flight for much more than half an hour (Rogers & Randolph, 2002) or operate in high temperatures (in excess of 40°C). In instances of excessive temperature the flies seek shade mostly in the form of shrubs, where they rest until the heat of the mid-day sun has passed (Hargrove, 1988, Syed & Guerin, 2004).

Tsetse are also highly susceptible to insecticides and as such are suitable candidates for insecticide based control strategies (Vale et al., 1985) which will be discussed further in section 1.1.4.4.1.
1.1.4. Control

The strategies that are available for the purpose of African trypanosomiasis control include treatment of humans, animals and tsetse control. These and other aspects are summarised here with main focus upon the Rhodesian parasite species, also drawing contrasts and comparisons from the control of other vector transmitted parasitic zoonoses.

1.1.4.1. Strategies for the control of African trypanosomes

There are many tools which are applicable for the control of *T. b. rhodesiense* and associated acute HAT within the Ugandan setting, these differing tools and their applications are discussed below, split into three distinct section; drug treatment, insecticides and traps. While there are a variety of tools available which focus upon different targets to impact upon acute HAT, the most eligible mode of deployment would be an integrated approach. This would include many different tools to controlling the disease, without relying singularly upon a vector control measure or reducing the prevalence of *T. b. rhodesiense*. The most effective strategy would impact upon both vector and parasite prevalence aspects to increase the overall effect of the control.

1.1.4.1.1 Control of Rhodesian sleeping sickness

Due to the lengthy, dangerous and expensive treatment of HAT cases, it is preferable to prevent infection than to treat presenting cases. In the case of the zoonotic species *T. b. rhodesiense* intervention against the transmission of the parasite to humans has two potential targets. Firstly, the vertebrate reservoir hosts within the vicinity of the human population and secondly the tsetse vector which are vital for the action of transmission between hosts (Welburn *et al.*, 2006).

Whereas *T. b. gambiense* has no significant reservoir host in terms of human infection, with the parasite being transmitted directly between humans by the tsetse vector. As such the control of the tsetse vector is the only viable strategy for the effective control of this human disease. The ongoing programme of field screening and rapid treatment of human
cases cannot be considered a control mechanism, as it is unsuitable for blanket treatment of a population due to the highly toxic nature of drugs available (Welburn et al., 2006).

The mechanism for the control of *T. b. rhodesiense* will be discussed further below, as the control of *T. b. gambiense* is not of direct concern with this thesis, but should still be mentioned.

### 1.1.4.1.1.1. Chemotherapeutical treatment

Control of trypanosomiasis within an affected region by using chemotherapeutical treatment is appropriate when the drugs are applied to enough of the population, or reservoir population, to substantially reduce the prevalence of trypanosomes and end transmission cycles within the region (Wendo, 2002).

It has been demonstrated that treatment of more than 86% of the cattle population with trypanocidal drugs can eliminate the human-infective parasite *T. b. rhodesiense* circulating in cattle (Welburn et al., 2006). This control technique focusing upon the animal reservoir is applicable to the zoonotic species *T. b. rhodesiense*, whereas although *T. b. gambiense* is not confirmed as a zoonotic pathogen (Kioy & Mattock, 2005) it is capable of establishing infections in pigs (Penchenerier et al., 2005). However, the role of the infected pigs on the transmission of *T. b. gambiense* to humans is unclear (Scharas & Mehlitz, 1996, Kioy & Mattock, 2005). As such any attempted chemotherapeutic control of *T. b. gambiense* would be most aptly focused upon human cases whereas control of *T. b. rhodesiense* can be focused at treating the cattle reservoir population as a means to control the prevalence of the disease in the reservoir and consequently reducing zoonotic transfer to humans.

Historically the control measures implemented for *T. b. rhodesiense* have been primarily focused upon vector control as it is widely accepted to be the most vulnerable point in vector borne disease cycle (Schofield & Maudlin, 2001, Touré et al., 2004, Schofield & Kabayo, 2008). However reliance upon this option alone has rarely been employed successfully as a method of sustainable control of a zoonotic parasitic disease.
The zoonotic nature of *T. b. rhodesiense* entails that control strategies cannot be effectively focused solely upon the human host, as *T. b. rhodesiense* will remain within the animal reservoir; as such it is vital that any treatment based strategy incorporates locally present reservoir animal species.

### 1.1.4.1.2. Vertebrate host based trypanosomiasis control

Direct intervention against the prevalence of the zoonotic pathogen within the vertebrate host have previously been effectively utilised for control of zoonotic diseases (examples of this are given below). There are two methods by which this can be achieved by; firstly through the eradication of the wild reservoir host within the local vicinity of the human population, secondly through the eradication of the pathogen from the domesticated reservoir population.

The eradication of the reservoir and thusly the zoonotic disease has previously been successfully implemented against visceral leishmaniasis caused by the parasites of the genus *Leishmania*, transmitted by sandflies of the genus *Phlebotomus* in the old world. For example, within the Russian deserts *Leishmania major* was established with a lifecycle infecting wild rodents, predominantly fat sand rats, without human influence. With the establishment of the oil pipeline through much of Russia, workers were re-located to the desert for construction and as a result the inherent *L. major* became a zoonosis due to this introduction of humans. In response to workers becoming afflicted by the leishmaniasis large, high sided ditches were dug around each of the work areas. The area inside of these ditches was then ploughed, destroying the burrows and killing the mammalian hosts, therefore halting leishmaniasis affecting the workforce (Ward, 2005). However this method of control is not applicable where the reservoir hosts are difficult to eradicate, as is the case with the sylvatic cycle of *T. cruzi* in South America, or when the reservoir hosts are domesticated animals (for example) pets or livestock.
Within Uganda the major reservoir of *T. b. rhodesiense* is cattle, which are economically vital to the community, as such the reservoir eradication approach is unusable. Meaning the only option available for reservoir host focused control is the suppression or eradication of the pathogen from the reservoir population.

Within other areas of acute HAT affected Africa, the cycle of *T. b. rhodesiense* to humans does incorporate wild animals, which in some cases are applicable to control by means of controlled culling. But within Uganda control must be focussed upon treating the reservoir cattle population with trypanocides.

### 1.1.4.3. Chemotherapy of AAT

In the case of cattle which are identified as infected and treatment is an available option, drugs are usually administered by a locally operating veterinarian or vet’s assistant. Currently three drugs are available on the open market for treatment of trypanosomiasis in domestic bovines; diminazene aceturate, isometamidium chloride and homidium chloride. Isometamidium chloride has a prophylactic effect for approximately three months, whereas the other two are both curative with little or no prophylactic properties in areas of high tsetse challenge (Peregrine *et al*., 1988). Resistance to these trypanocidal drugs has been demonstrated but is geographically limited (Tewelde *et al*., 2004).

#### 1.1.4.3.1. Isometamidium chloride

The action of isometamidium chloride upon trypanosomes is focused upon the mitochondrion organelles; mitochondria are essential cellular structures which are responsible for the production of adenosine tri-phosphate (ATP) which is vital as a source of chemical energy for essential processes throughout the cell. Isometamidium chloride inhibits the establishment of potential across the membrane of the mitochondrion by blocking active transporters on the mitochondrial membrane (de Koning, 2001). With the inability to control trans-membrane potential the mitochondria are unable to produce ATP and as such the trypanosome cell perishes (Shapiro *et al*., 1989).
1.1.4.3.2. Diminazene aceturate

The active effect of diminazene aceturate within the trypanosome is due to the inhibition of the enzyme involved with the synthesis of polyamines (Bacchi et al., 1980), along with partially blocking kinetoplast DNA synthesis. Uptake of diminazene aceturate is mediated by the P2 nucleoside transporter (Denise & Barrett, 2001).

1.1.4.3.3. Homidium chloride

Finally homidium chloride which is recommended for the treatment of trypanosomiasis in cattle, this product is only recommended for the treatment of T. congolense and is not recognised as effective against T. brucei s.l. as such it is not of real relevance with regards to the control of the zoonotic T. b. rhodesiense and as such is of little concern to this work (Maudlin et al., 2004).

1.1.4.3.4. Drug resistance

Resistance of trypanosomes to trypanocidal drugs has been increasing throughout continental Africa. The mechanisms of resistance to isometamidium chloride is thought to be derived from changes to either the channel through which the compound enters the cell (thereby preventing access to the mitochondrial membrane transporters), or through alterations to the active transporters themselves resulting in the drug being unable to inhibit ATP production (de Koning et al., 2004).

Resistance to diminazene aceturate has been attributed to the drug being unable to penetrate the trypanosome membrane due to mutations in the P2 transporters (Mäser et al., 1999)
1.1.4.4. Vector host trypanosomiasis control

Vector based control of human disease has previously been successful within the African continent and indeed Uganda, with the control of onchocerciasis, this control programme is focused up the elimination of the tabanid (black fly) vector (Garms et al., 2009). As was previously mentioned the control of acute HAT through tsetse control has been employed throughout areas of Africa afflicted by acute HAT in the past.

Unlike the vertebrate host based control strategies for trypanosomiasis, which are often reliant upon the clearing the parasite from the host population. Vector based control is exclusively concerned with the elimination of the tsetse vector, as the task of clearing infection from a tsetse population body is absurdly complex in comparison to eradication, or reduction of the fly numbers.

1.1.4.4.1. Insecticides

The susceptibility of tsetse to a range of insecticides has been widely exploited over the years as a means of trypanosomiasis vector control. Despite the wide range of candidate insecticides for tsetse control, two chemical groups have been most commonly used; organochlorines and synthetic pyrethroids.

Organochlorides were the mainstay of African trypanosomiasis and tsetse control for around 40 years with DDT (dichlordiphenyltrichloroethane) being the most commonly used, due to its high impact on tsetse, low production costs and longevity (half life between 10-35 years). Spraying of organochlorines was focused upon tsetse resting and breeding sites in order to maximise the impact upon the tsetse population (Kgori et al., 2006). Due to the implicated build up of organochlorines, DDT in particular, within the ecology it has been superseded by insecticides of the synthetic pyrethroid group which are shown to be safer to both the local ecology along with the health of the workers using the insecticides (Grant, 2001).
Insecticides have been deployed utilising a variety of methods and strategies for tsetse control including aerial spraying using fixed wing aircraft and helicopters, by ground based vehicle mounted spraying and fogging machines, personnel on foot equipped with backpack spraying and upon baited targets, both live and artificial bait targets.

Assessment of the cost of delivery methods indicates that the live bait technique, for example the treatment of animals with the synthetic pyrethroid deltamethrin, is roughly half the cost of treated targets. Additionally due to the fact that tsetse preferentially feed upon sites located on the limbs and lower section of the body the cost of treating each animal with insecticides can be drastically reduced, as treating the full surface area is unnecessary (Torr et al., 2007). Restricted application targets spraying on the fore limbs, underbelly, tail switch along with the head and ears of cattle, it is highly effective against both tsetse and ticks delivering highly efficient protection from the diseases that are associated with these hematophagous vectors while minimising the cost of spraying activities to the animal owner (approximately costing 2 US cents to treat each animal), making frequent spraying more accessible and likely (Maudlin et al., 2009).

1.1.4.4.2. Traps

Trapping is deployed widely in Sub-Saharan Africa for tsetse population control, there are a variety of trapping techniques that are tsetse effective. The traps that are available for tsetse control fall into two distinct categories; these are baited and non-baited traps.

Baited traps utilise an attractant compound to lure tsetse to them, commonly using octenol that mimics the scent of ruminants. Baited traps are generally (but not always) coated with a residual insecticide so once the tsetse makes contact it dies as a result.

Non-baited traps do not use such compounds to attract the tsetse; instead they exploit the visual cues used by the tsetse during blood meal location. The most commonly deployed non-baited trap is the bi-conical trap that was introduced during the 1970s and is widely
used due to its low cost of production, small size for transportation and its easy (but vital) maintenance.

1.1.4.5. Trypanotolerant cattle

Certain breeds of cattle have been proven to be more tolerant to infection by trypanosomes such as the N’Dama breed which has widely been utilised within West Africa (Naessens, 2006) and the Orma Boran breed which is native to East Africa (Dolan 1998). Tolerant cattle have the ability to control parasitaemia along with the development of anaemia associated with trypanosome infection (McDermott & Coleman, 2001). It is implied that the introduction of these breeds that are capable of maintaining extremely low levels of parasitemia will reduce transmission of their parasites to feeding tsetse and thus result in the effect of lower impact of animal disease along with reducing the number of zoonotic parasites within the cattle population.

Within Uganda there is a strong association between the cultural identity of a region and the cattle breed that they keep, for example in the Western and Central regions of Uganda the breed kept is found to be long horned Ancoli, whereas in Eastern and Northern Uganda, Zebu are dominate. This cultural identity is so important that sale is often refused at market if import to other cultural regions is suspected (Agwai & Opio, 2010).

Considering the social importance and cultural identity aspects of cattle keeping for local populations introduction of foreign breeds may attract resistance as this may be associated with a loss of cultural identity in Uganda.
1.2.1 Geography and population

Uganda is a land-locked equatorial nation located in East Africa between the latitudes 4º.0’ north and 1º.30’ south and the longitudes 30º.0 and 35º.0 east covering an area of 242,554 km². Uganda shares borders with Kenya to the east, Tanzania and Rwanda to the south, Democratic Republic of Congo (DRC) to the west and Sudan to the north.

Uganda borders a large portion of Lake Victoria, approximately one third, along with over half of Lake Albert and Lake Edward, all of which border neighbouring countries. In central Uganda, Lake Kyoga, fed and drained by the Nile, forms vast areas of marsh and swampland around its open waterways. In total 17% of Uganda’s total surface area is water (51,000 km²).

Much of Uganda is a plateau at approximately 900 m elevation, with a range of 621 and 5110 m, with small hills and valleys. The major mountainous regions are found in the south-west at the borders of Rwanda and DRC, with the highest point being the peak of Mount Margherita (5110 m), and the eastern border with Kenya with Mt Elgon and Mt Moroto (see Figure 1-6).
Within Uganda there is a great variety of vegetation due to the variation in elevation, rainfall and landscape causing differing micro-climates. The overall natural environment and vegetation of Uganda provides exceptional grazing for cattle and goats, which are typically herded by smallholder farmers who currently own 95% of the countries cattle population. During the 1960s large-scale commercial ranch grazing was established within Uganda on areas of land that were cleared of tsetse infestation in advance. Ranching ended as a result of large scale looting of cattle that accompanied the upheaval and civil conflict of the 1970s. During the 1980s governmental aid to farmers gave rise to ranches becoming re-established throughout southern and south-eastern, Uganda with cattle being brought into south-east Uganda to stock the ranches.

The total population of Uganda was estimated in July 2007 as 30,262,210 with an approximate annual growth rate of 3.5% (CIA, 2007). The Ugandan life expectancy is
51.7 years and the median age of the population is 14.9 years of age, the young average age and low life expectancy are contributable to disease related deaths, most notably due to HIV/AIDS. HIV prevalence within Ugandan adults during 2003 was estimated to be 4.1% giving rise to 71,000 deaths in that year (CIA, 2007).

The population of Uganda is highly diverse with traditional tribal hierarchical systems co-operating alongside structured government organisations. The capital city Kampala has Uganda’s highest urban population of 1,208,544 (in 2002) with an estimated 88% of the country’s population living in rural areas (ANON, 2007).

Uganda is divided into 80 districts, spread across five administrative regions: Northern, Eastern, Central, Western and West Nile. A number of districts have been added in recent years - eight being added on July 1, 2006. Generally the districts are named after their main commercial and administrative towns. Each of the districts is further divided into counties, sub-counties, parishes and villages respectively in size order.

### 1.2.2. Brief History

Human population in Uganda can be traced back 2000 years to hunter gatherers but very little is known about these pioneer settlers. The Empire of Kitara in the fourteenth and fifteenth centuries represents the earliest forms of formal organisation within Uganda. Arab traders moved inland from the Indian Ocean coast of East Africa in the 1830s, followed in the 1860s by British explorers searching for the source of the Nile. Protestant missionaries entered the country in 1877, followed by Catholic missionaries in 1879.

Uganda was placed under the charter of British East Africa in 1888 and remained under British colonial rule until 1962 when independence was declared and power was handed over to Ugandan nationals.
1.2.3. Significance of cattle in Uganda

Uganda has a varied environmental and social landscape which has lead to a defined band of active cattle keeping, shown in Figure 1-7, this band consists of predominately flat dry lands, covering an area of approximately 84,000km$^2$, within which up to 90% of Uganda’s cattle are accounted for (Kisamba-Mugerwa, 2001).

The keeping of cattle in rural Uganda is important as there is a residual distrust within the population associated with investing money into banks, resulting from the devaluation of the Ugandan shilling by 77% in May 1987 (Belshaw et al., 1999). Due to this mistrust the local population choose to invest in cattle during times of financial prosperity, selling
animals when money is needed thereby forsaking the financial institutions. As such the wealth of a village is directly apparent, often with the wealthiest village member being the cattle herder, whom cares for others livestock upon the condition of being given the first born calves of all heifers.

Along with providing milk and meat, cattle are also heavily relied upon in the rural economy as providing traction power for ploughing, allowing for increased cultivation and associated increase in yield within the village environment as the best draught bulls are contracted to plough the villages plots (Smith et al., 2001).

1.2.3.1. Animal movement

Within Uganda trade of animals occurs both locally and over extensive distances as depending upon the traders’ wealth. Animals are moved on hoof or by truck with implications upon the distances animals are moved from their respective points of original sale. This movement is necessary as, particularly, the northern area of Uganda has had its cattle population decimated during 20 years of civil conflict.

With the fact that the Northern region’s cattle population has been severely depleted, animals will have to be imported from areas of Uganda that were not affected by the drawn-out conflict, most notably the south-west and south-east regions, as such any animals imported specifically from the south-east are at risk of harbouring *T. b. rhodesiense*, potentially introducing acute HAT.

As this is an issue in terms of the introduction of disease to naive areas, it must also be considered as a risk factor in any control strategy that targets the spread of HAT. Any cattle imported from neighbouring areas which have not benefited from intervention are risking the re-introduction of the parasite.
**1.2.4. Trypanosomiasis in Uganda**

Uganda is commonly cited as being the only nation to harbour both sub-species of human infective African trypanosome, although it is suspected that *T. b. gambiense* has now also reached Tanzania (Kibona *et al.*, 2006).

Human African Trypanosomiasis was first reported in Uganda during 1901 in the blood and cerebrospinal fluid of a patient by Dr Aldo Castellani who named the parasite *Trypanosoma ugandense* although this was later reasoned to be *T. gambiense* (Bruce and Nabarro, 1903). In 1910 a novel species of trypanosome was identified in a sample taken from Rhodesia, now Zimbabwe, (Stephens and Fantham, 1910) and was subsequently named *T. rhodesiense* (now *T. b. rhodesiense*).

Accompanying the discovery of trypanosomes in Uganda in 1901 there was a widespread epidemic of sleeping sickness in the Busoga region of south-east Uganda which was reported to the British government. This resulted in the establishment of a commission to investigate the epidemic named the sleeping sickness commission of the royal society. By 1903 the commission concluded that the reported sleeping sickness was caused by a species of trypanosome and that the trypanosomes were transmitted by a species of tsetse (Bruce and Nabarro, 1903). However, the species responsible for the early 1900s epidemic is still uncertain, as *T. b. rhodesiense* and *T. b. gambiense* are morphologically identical. The discovery of SRA (Serum Resistance-Associated Protein) as a unique marker, diagnostic for *T. b. rhodesiense*, has lead to improved specificity in the detection of this parasite through the detection of the SRA gene (Van Xong *et al.*, 1998).

More recently *T. b. rhodesiense* has spread from the heartland in south eastern Uganda into five previously unaffected districts since the disbandment of the Ugandan centrally administered animal health services in 1985. The main attributable force behind this extension of the area afflicted by the species is the movement of cattle northwards into these districts from established animal trypanosomiasis and HAT endemic areas (Welburn *et al.*, 2001b, Hutchinson *et al.*, 2003). These newly introduced animals can be infected with the human infective *T. b. rhodesiense* as well as trypanosome species.
causative of the animal disease nagana. This has resulted in the import of these the parasites to areas previously free of the human disease; which has been dependent upon the presence of vector competent tsetse within the recipient area.

Previous research has shown that up to 18% of cattle traded within the district of Soroti were infected with *T. b. rhodesiense* (Welburn *et al*., 2001), and whilst it is now governmental policy to treat cattle with trypanocides at the point of sale it is apparent that this is not effectively monitored or enforced allowing the disease to continue to spread (Fèvre *et al*., 2005).

The closest distance of separation between the two species of trypanosome responsible for HAT within Uganda has decreased to 150 km, at the most recent survey (Picozzi *et al*., 2005).

The implication of the two human infective species, *T. b. rhodesiense* and *T. b. gambiense* becoming spatially sympatric is severe. These two parasitic species give rise to similar pathogenic manifestations, which are near to impossible to differentiate in diagnosis without the use of molecular techniques. Due to the treatment of the first stage of the two forms of HAT caused by *T. b. rhodesiense* and *T. b. gambiense* being more susceptible to different drug treatments. Also it is far easier and safer to treat an individual for early stage (1) sleeping sickness than late stage (2) and the time spent mistreating is likely to allow the disease to progress to late stage (2), therefore it is greatly advantageous to get the species diagnosis correct to facilitate appropriate treatment. Speciation of HAT parasites is not undertaken in the field. Diagnosis is based on where the patient is presented for treatment and what species exists in that region.

**1.2.4.1. Increase of Rhodesian HAT infected areas since 2004**

Since 2004 the area of Uganda affected by HAT has extended, with the area harbouring *T. b. rhodesiense* increasing from its historic foci in the south-east of Uganda (indicated in Figure 1-8 as dark purple). This disease currently occupies an additional three districts
to the north of the traditional area (shown in Figure 1-8 as yellow areas), this advance has been a gradual creeping advance, associated with cattle movement as is estimated at approximately 10 km per annum (Fevre et al., 2001).

Apac district (located between the districts infected during 2005 and the *T. b. gambiense* foci in Figure 1-8) has reported a single human case of *T. b. rhodesiense* in 2007, but it is unclear whether the infection was acquired in the district whereas Dokolo and Kaberamaido districts have reported numerous cases. As such the district cannot be confirmed as being infected, but is worth mentioning as being a suspect area of infection.

**Figure 1-8:** Rate of increase in the area affected by *T. b. rhodesiense* through Uganda, in relation to the area affected by *T. b. gambiense*
1.2.4.2. Sleeping sickness case distribution

With the centrally co-ordinated network of healthcare centres within Uganda, any patient that is admitted has to register their home location, with the records also including the final diagnoses made for the individual patients. As such it is possible to analyse the originating locations of the human trypanosomiasis cases for any correlation that would indicate failure of control or reintroduction.

This method does have drawbacks, most substantially that far from all sleeping sickness cases are ever presented at a health centre, let alone diagnosed. This is due to the diagnosis of the condition being founded upon visual identification of trypanosomes which can exist at an incredibly low parasitemia within blood or CSF. Furthermore the characteristics of the disease (extreme lethargy) make it unlikely that an infected individual would be capable of gaining access to a health centre; as a result it is likely that detected HAT cases will be clustered close to the health centres as these patients will have less of a journey to seek medical assistance (Odiit et al., 2004a). Also of consideration upon potential clustering of patients presenting with HAT is that if the disease is known of in a specific area, persons with symptoms are more likely to be taken to a health centre than an individual from an area with no knowledge of, or education about, the disease. Often it is believed an infected person has HIV/AIDS, malaria or even is bewitched and as a result formal medical attention is often not sought. Frequently when medical assistance is sought at the local and more basically equipped and staffed health centres (termed HC 1, 2 and 3) the diagnosis of trypanosomiasis is often missed or not fully investigated due to training and equipment shortcomings.

1.2.5. Coverage & maintenance of sleeping sickness control

The issue of achieving substantial coverage with a sleeping sickness control programme within the rural Uganda is dependent on co-operation and involvement of trusted leaders of the local communities since these individuals impact upon the general publics’ acceptance of a control programme.
Even with the support of these community leaders, consideration must be given to mechanisms of delivery of providing information of the local community, specifically cattle herders and owners, about the benefits that treatment of their cattle with trypanocides will give to the health of both the treated animals, their families and neighbours who can potentially contract the disease from untreated cattle.

Due to the economic importance of cattle to the population of Uganda direct communication with the community is vital, as many cattle handlers will have questions concerning the treatment’s effect upon the animals. If these questions go unanswered those persons who have reservations are likely to not bring their cattle to treatment due to concerns such as fear of side effects.

Another means of addressing large audiences of the rural region include the distribution of posters which clearly portray the benefits and lack of issues with a treatment programme (Einarsdóttir et al., 2001). These posters must be interpretable by illiterate members of the community, and should be strategically displayed in the trading centres throughout any intervention area where it is almost guaranteed that village members will visit to purchase goods.

Local radio is a powerful tool for mobilisation within rural Africa (Jani et al., 2008), as such making provisions for airtime publicising treatment is likely to raise public perception. However, within Uganda there are many radio stations operating in the same region, often broadcasting in different languages to the same area. Full saturation within the target region has to be achieved to maximise the response.

Directly addressing the community at an individual or even village level is an immense task, however, it is possible to reduce the input while maximising the dissemination of information. This can be accomplished by visiting churches or mosques and addressing the congregation directly. As many of the questions that the cattle keepers will have concerning the impending treatment will be relatively similar, members of this congregation will be able to relay responses to those whom were not present.
It is very rare that a control programme can be considered a single instance operation, which occurs on one day with no subsequent follow up as such monitoring of the status of the disease, or parasite, within the intervention region must be carried out.

1.2.5.1. Monitoring of control strategies

After the implementation of any variety of control strategy it is vital that the effect of the intervention is assessed. This allows evaluation of the impact of the control strategy upon the status of the targeted disease, and if applicable a re-evaluation of the control programme can be made.

Options for monitoring the effect of disease control programme are as varied as their focal diseases. For example; within Ireland and the UK monitoring for bovine tuberculosis is active within abattoirs, upon the identification of lesions within a carcass the origin of that specific animal is traced to the specific farm and surroundings (Clegg et al., 2008). Mandatory reporting of notifiable diseases is also relied upon to detect cases of a controlled disease, as is the case with foot and mouth disease within the UK having to be reported by the diagnosing veterinarian. Within certain settings wild or stray animals can be used to sample for a controlled disease, as is the case of canine parvovirus (Gordon & Angrick, 1985) and Leishmania in India (Megat Abd Rani et al., 2010). Although not strictly a control measure but more a preventative measure, work carried out by the Institute of Animal Health (IAH) which was based on the findings of previous work from the department showing that *Culicoides* species of the UK were suitable vectors for blue tongue virus and were known to move in low level jet stream winds (Selby, 2005, Carpenter et al., 2008).

Data supplied by the meteorological office was used to identify the threat of introduction of *Culicoides* s.l. transmitted Blue Tongue Virus (BTV) into the UK. Aeolian data showed that winds had blown from the known BTV endemic country Belgium across the English Channel to Norfolk England. With the identification of this area as at risk a
sampling team was deployed to the area viraemic cattle were identified, a successful containment and eradication strategy was implemented as a result (Mellor, 2007).

China has effectively administered control of *Schistosoma japonicum* through mass chemotherapy of human and bovine population, coupled with control of the vector species of snail. Within several of its provinces (although not nationally) elimination was found to have been successful based upon the following criteria (Wu *et al.*, 2005):

1- No vector species of snail found during surveillance for at least one year
2- No new infections in humans or domestic animals for five successive years
3- Prevalence rate by faecal examination in residents and animals less than 0.2 %.

Surveillance of these stipulations was conducted as follows

1- Snail sampling
   a. At villages where snail vectors had previously been found in the past three years snail surveys are carried out annually
   b. Villages where the vector had been found in the previous 3 – 9 years snail surveys are conducted once every three years
   c. Villages where detection had been during previous 10 – 15 years surveys are once every 5 years
   d. Villages with no reports from previous 15 years no surveillance was conducted

2- Human sampling
   a. People older than 7 years screened using either indirect haemagglutination assay (IHA) or enzyme-linked immunosorbent assay (ELISA)
   b. People entering into controlled areas from endemic areas for reasons such as marriage or migrant employment (although this can be considered a maintenance strategy not surveillance)

3- Animal sampling
   a. All bovine in the control region are sampled by either IHA or ELISA
b. Bovines and pigs imported from endemic regions are also examined (also maintenance more than surveillance)

This full and active screening method encompassing the human, animal and vector hosts of the target pathogen that increases the likelihood of detecting any *Schistosoma japonicum*. The governmental involvement with this programme will have enabled a very high degree of co-operation within the communist society both in terms of the action of control intervention and the subsequent surveillance.

Within the rural African setting; control of *Echinococcus granulosus*, the causative parasite of hydatid cysts within Turkana region of north-western Kenya is transmitted from canines to human population, as a result of poor hygienic practice and water supplies being contaminated by dog faeces (Watson-Jones & Macpherson., 1988). Control was administered by treating dogs of the region with the anthelmintic drug praziquantel repeatedly (Macpherson *et al.*, 1986), as the human population of the area is nomadic and the large proportion of these dogs are stray this treatment was very difficult to implement fully. Post-treatment surveillance was carried out through serological analysis along with the use of vehicle mounted mobile ultrasound units used to diagnose suspected cysts infections in humans (Craig *et al.*, 1986, Macpherson *et al.*, 1987). *E. granulosus* status within the canine host is assessed through microscope analysis of intestinal content either obtained through necropsy (suitable for stray dogs) or purgation induced by arecoline salts. Screening by ELISA for coproantigen detection in faeces also shows the adult infection rates in the dogs (Craig *et al.*, 2007).

In the case of monitoring the effect of an acute HAT control intervention, the ideal strategy would be to monitor both the human and animal populations for *T. b. rhodesiense* occurrence. However, the ethical complications involved with obtaining samples from seemingly healthy humans that are not presenting with a condition or complaint, make it impractical to conduct this line of enquiry for this study. These investigations would require permission of the national Ministry of Health in order to gain the correct clearance necessary for the sampling of humans. Although the direct
sampling of humans is complicated without national ministerial compliance, the analysis of where any cases detected by health care professionals at health centres and hospitals can provide valuable insight to the status of the disease, this mechanism of investigation is discussed previously (see Section 1.2.4.2).

As such, the only viable large scale monitoring method for the success of this *T. b. rhodesiense* control intervention is bound to be heavily reliant upon the evaluation of the animal reservoir hosts. Within Uganda *T. b. rhodesiense* is not a notifiable disease so the findings of the sampling are not legally required to be reported, however ethically should be. In order for any sound assessment of the impact to be made it is imperative that the prevalence of the parasite is established through sampling prior to the intervention commencing. This pre-intervention baseline result is then compared to the results obtained from sampling after the control intervention has occurred.

### 1.2.6. Trypanosomiasis control interventions in Uganda

Within Africa contemporary control of trypanosomiasis has been undertaken based upon; chemoprophylaxis, chemotherapy and the elimination of the tsetse vectors (Dowler, 1989, Grant, 2001). The most effective strategy would involve an integrated approach to eliminate trypanosomiasis from a region, as reducing all aspects of the parasites life cycle capabilities is more likely to return success than focussing upon a single point in the cycle. However, implications of cost and logistics frequently render such large scale operations impossible, as they are either not deemed cost effective against the burden of disease, or simply impractical to administer and sustain (Macdonald & Laurenson, 2006, Jo-Ann Mulligan *et al.*, 2006). Trypanotolerant cattle breeds may be introduced instead of susceptible ones in order to both reduce the prevalence of trypanosomes in the cattle population as well as minimise economic loss as a result of disease burden (Perry & Randolph, 1999, Kamuanga *et al.*, 2001, McDermott & Coleman, 2001).

During colonialisation of Uganda it was general practice that areas of tsetse and trypanosome infestation were cleared of human population in order prevent transmission
of trypanosomes to the inhabitants. One such area is Murchison falls national park (Worthington, 1929, Welburn et al., 2006) but this approach is neither practical or ethically suitable for application in Uganda in contemporary times.

1.2.6.1. Tsetse based controls

Of these three practical options it is most frequently vector control which is focused upon within Africa, as it is considered to be the most vulnerable component of the host, parasite and vector cycle, as the tsetse fly is highly susceptible to insecticide based control methods (Baylis & Stevenson, 1998, Grant, 2001).

The mode of delivery of insecticide to the tsetse population has been refined over recent decades, including strategies of mass coverage of tsetse habitats, in particular preferred shrubs for resting. Spraying of tsetse habitats in Uganda was undertaken throughout mid and later twentieth century (Barker & Carswell, 1973, Okoth et al., 1991, Brightwell et al., 2001). Insecticides have been delivered using both aerial spraying by light aircraft, and ground spraying using backpack sprayers (Allsopp, 2001, Muriuki et al., 2005, Kgori et al., 2006). Within Uganda insecticide has also been delivered directly to resting sites of tsetse by using bush spraying using wet-able powder (Okoth et al., 1991).

Another method of tsetse control within Uganda is trapping using biconical traps or Challier or Lancien traps either with or without odours to attract tsetse. The tsetse ultimately become trapped in the upper of the two cones, without the need to utilise any insecticide to kill trapped flies (Okello-Onen et al., 1994, Allsopp, 2001). However, in practice, traps are often placed exclusively near roads and water pumps, and are ‘mostly for show’ rather than function. Additionally the traps that are deployed are often found to have fallen into a state of disrepair rendering them ineffective. In essence, experience shows that communities will not maintain traps as a public good.

Targets are dependent upon insecticides, the tsetse are attracted to the shape and colour of the cloth target as well as odours such as octenol and butanone dispensed from low-
density polythene bottles. The target is dipped into a synthetic pyrethroid insecticide to impregnate the fabric causing the tsetse to become contaminated upon contact, resulting in the death of the fly (Williams et al., 1992, Magona et al., 2000, Allsopp, 2001).

More recently the Sterile Insect Technique (SIT) has been successfully employed as tsetse control on the island of Zanzibar (Vreysen et al., 2000), however, in order for the technique to have been successful an over-flooding ratio of ten sterile males to one wild male was required to initiate the population collapse (Vreysen et al., 2000). While these flies are sexually sterile they are still capable of transmitting trypanosomes. The cost of producing the sheer number of sterile males needed to give the required ratio of 10 sterile insects to 1 wild type male within the tsetse infested areas of Uganda would be immense (Bhalla, 2002, Torr et al., 2005). While the technique was successful on an island wide trial in Zanzibar, clearing of tsetse in Uganda and mainland Africa will likely be only temporary as tsetse flies almost certain to eventually reinvade the eradication area (Rogers & Randolph, 2002, Coleman & Alphey, 2004, Gooding & Krafsur, 2005, Torr et al., 2005) and these regions are often infected with multiple species.

1.2.6.2. Chemotherapeutical treatment as control of trypanosomiasis

Within Uganda control of trypanosomiasis within an affected region by using chemotherapeutical treatment, using drugs with either chemoprophylaxis or chemotherapy nature is appropriate when the treatments are applied to enough of the population, or reservoir population, to substantially reduce the prevalence of trypanosomes and end transmission cycles within the region (Wendo, 2002). It has been demonstrated that treatment of more than 86% of the cattle population with trypanocidal drugs can eliminate the human-infective parasite T. b. rhodesiense circulating in cattle (Welburn et al., 2006). This control technique focusing upon the animal reservoir is applicable to the zoonotic species T. b. rhodesiense, whereas T. b. gambiense is not confirmed as a zoonotic pathogen (Kioy & Mattock, 2005). As such any chemotherapeutic control of T. b. gambiense would be most aptly focused upon human cases whereas control of T. b. rhodesiense can be focused at treating the cattle reservoir.
population consequently reducing zoonotic transfer to humans. Based on the insights discussed above, the Stamp Out Sleeping sickness (SOS) programme has been put in to effect in newly affected districts.

1.2.6.3. FITCA

The Farming In Tsetse Controlled Areas (FITCA) programme was initiated during the late 1990s in recognition of the economic impact of trypanosomiasis upon East Africa. FITCA was established as a regional programme of the African Union/Inter African Bureau for animal resources (AU/IBR), with funding from the European Union. FITCA operated through three large national projects within Kenya, Ethiopia and Uganda, along with smaller operations in Rwanda and Tanzania.

FITCA aimed to prevent the movement of both infection and tsetse flies, along with preventing the re-infestation of previously cleared intervention zones by involving the local communities in the control, with the return of increased productivity yield from livestock. (Morel, 2001)

Within Uganda FITCA operated in 12 districts in the east of the country covering an approximate area of 52,029 km$^2$, which included approximately six million people and 900,000 cattle (Anon, 2004). The FITCA programme within Uganda focused primarily on the control of trypanosomes through use of trypanocidal treatment of cattle, however, the implementation of the programme was incomplete with very low levels of treatment as such the programme has been unsuccessful at restricting trypanosomiasis, with the area effected by human trypanosomiasis increasing within Uganda since FITCA being introduced, as is shown in Figure 1-8 (Fyfe, 2007).
1.2.6.4. Stamp Out Sleeping sickness (SOS)

As a direct result of the advance of *T. b. rhodesiense* towards the established foci of *T. b. gambiense* (Picozzi *et al.*, 2005b), Stamp Out Sleeping sickness (SOS) intervention programme was initiated.

1.2.6.4.1. Background to SOS intervention

Officially launched on October 11 2006, this novel initiative against trypanosomiasis is a public-private partnership between the universities of; Makerere University (Uganda) and University of Edinburgh (Britain), the private equity firm Industri Kapital (IK) and the multi-national veterinary pharmaceutical company CEVA. This partnership provided the means for intervention through; CEVA supplying the trypanocides, IK making available the financial resources for the treatment to be undertaken, Makerere providing both; fourth year veterinary students to participate in the treatment programme and staff members to plan and supervise the programmes execution, University of Edinburgh were also involved with the planning phase of the SOS programme along with monitoring the biological impact (included within this thesis).

SOS was designed to be more than just a single point of treatment action. Accompanying the provision of staff, trypanocides and consumables for the mass trypanocidal treatment of cattle, was the supply of residual insecticide (deltamethrin) for application to the cattle during the trypanocidal treatment phase. This insecticide was applied to cattle by the Makerere veterinary student work force with backpack sprayers; administration of deltamethrin was carried out by the restricted application method effectively turning the cattle into live bait and reducing the tsetse population and re-infection (Torr *et al.*, 2007). Administration of the deltamethrin insecticide was scheduled to be a three point action; due to the temporary effect of deltamethrin it was necessary to repeat the application of the compound to the cattle population in order to effectively impact the tsetse population, this re-application shall be discussed later.
1.2.6.4.2. SOS project area

With the districts of Amolotar, Apac, Dokolo, Kaberamaido and Lira (Figure 1-9) being identified as newly afflicted by the zoonotic parasite (Picozzi et al., 2005b) combined with increasing numbers of human cases presenting at the sleeping sickness treatment centre hospitals that are local to the region, it was these districts that were selected for inclusion in the SOS treatment programme.

At the time of SOS treatment, insecurities within the northern region of Uganda rendered it unsafe to work in the entirety of Apac and Lira districts. While it would have been ideal to have include the complete cattle population of these northernmost districts, the rebel LRA (Lord’s Resistance Army) had been highly active particularly within Lira where civil populations were frequently targeted, (the insecurities will be discussed further within this thesis). Due to this level of risk to the treatment personnel the northerly areas of these districts were not treated, the southern areas were treated as the risk of attack
here was substantially lower due to the much higher numbers of governmental military forces stationed near the towns of Apac and Lira.

The land area and figures for the human population covered by the SOS programme (both as a total and with district breakdown) is shown within Table 1-2, these figures are provided to be accurate to the time SOS was initiated (2006).

<table>
<thead>
<tr>
<th>District</th>
<th>Land area covered by SOS (km²)</th>
<th>Human population within SOS operational area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amolotar</td>
<td>1581.7</td>
<td>106,800</td>
</tr>
<tr>
<td>Apac</td>
<td>1341.3</td>
<td>157,033 (estimate)</td>
</tr>
<tr>
<td>Dokolo</td>
<td>1049.3</td>
<td>147,400</td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>1627.9</td>
<td>152,900</td>
</tr>
<tr>
<td>Lira</td>
<td>2425.2</td>
<td>185,266 (estimate)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8025.4</strong></td>
<td><strong>749,399</strong></td>
</tr>
</tbody>
</table>

**Table 1-2: Area and human population of SOS region**

The SOS districts are predominantly inhabited by cattle keeping peoples and the land is well suited to cattle rearing. Cattle are the primary source of traction, deeming them essential as ploughing animals for mid-scale agricultural activities. Within the SOS region the principal economic activity is cited by the Ministry of Tourism, Trade and Industry as being agriculture with particular emphasis on food crops and to a lesser extent the cultivation of cash crops, for example cotton and coffee (Rwabwongo, 2007).

**1.2.6.4.3. Trypanocides used during SOS treatment**

Cases of HAT from the region were, at the time, exclusively from the districts of Dokolo and Kaberamaido as a result the cattle population of these two districts were treated with isometamidium chloride so as to benefit from the prophylactic property of the compound.
Cattle of Amolotar, Apac and Lira districts were treated with diminazene aceturate due to its lower cost and reduced risk of complications, which were deemed unnecessary in these districts of unreported HAT. The differing trypanocides administered in the region is indicated within Figure 1-9. Both of these drugs were manufactured and provided by CEVA specifically for the purpose of the SOS intervention.

1.2.6.4.4. Insecticidal spraying by SOS

With the residual effect of the deltamethrin upon cattle being limited between two and three months (Holmes, 1997), a single application of the insecticide would be unlikely to significantly impact the tsetse population numbers and effectively impede the re-infection of treated cattle. With this in consideration two follow up spraying operations were provided for by SOS. These follow up spraying sessions were scheduled to occur before the insecticidal agent was completely removed from the cattle.

The first follow up spraying session was organised for the recipient community to conduct, with the deltamethrin being given to community leaders for that purpose. Monitoring work showed that uptake of this approach had not been satisfactory with leaders often selling the insecticide or refusing treatment to cattle belonging to people whom had previously caused them problems.

Resulting from this the second follow up spraying was placed back under the control of Makerere staff to avoid the problems which had impacted the first follow up session.

1.2.6.4.5. Mobilisation and sensitisation for SOS treatment

Prior to the inception of the SOS treatment initiative the local community, in particular cattle keeping population, were targeted with information concerning what the treatment was for, why it was important, how it would benefit them, if there were any potential side effects of treatment and finally when and where this treatment would be operating.
The mechanisms for dissemination of this information package that were utilised by the SOS organising personnel had to be prepared within a restricted timeframe due to the rapid response nature of the SOS programme to the northerly advance of _T. b. rhodesiense_ exemplifying the dangerous likelihood of an overlapping of the two human infective trypanosome species.

For sensitisation and mobilisation within the region it was necessary to rely heavily upon the offices of the District Veterinary Officers (DVOs) as well as the district commissionaires of the specific area of operation. The involvement of the district entomologists as well as the health officers of the area were not included for the purpose of sensitisation or mobilisation for the SOS programme.

The DVOs were each requested to pass information about the programme to their subordinate veterinary staff within their district along with local community animal health extension officers. This process had to be adopted by the Makerere administered SOS operation due to the fact that Makerere had not previously been active in the region and thus was not a trusted institution by the population, therefore the support and approval of these trusted offices was vital for community acceptance.

Immediately upon the arrival of Makerere personnel within the SOS programme region the local police and security forces active within the area were notified of the planned operation and its timeline. This was a necessity as during that time the LRA was still actively operating within Northern Uganda and security of personnel needed to be given high levels of attention, as a by-product of this notification of the police and security organisations community awareness of the programme will have been increased.
1.2.6.4.6. Reported coverage of treatment programme

During treatment operations the Makerere based organisers of the treatment activity were vigilant on recording the numbers of cattle treated, with this information combined with cattle population data it is possible to establish the coverage that was achieved by the SOS treatment programme. Due to socio-political reasons within Uganda, predominantly the act that cattle were taxed until relatively recently, the census data for livestock within the country is incredibly inaccurate and what is available is over 10 years out of date. With this being the case it was decided by the stakeholders (CEVA, Makerere University and University of Edinburgh) to assess the coverage against estimates of the cattle population, in preference to using the wildly inaccurate census data that was available.

1.2.6.4.6.1. Coverage of treatment with trypanocidal drugs

The treatment programme of November 2006 aimed to achieve a coverage rate of at least 86% of cattle in order to suppress *T. b. rhodesiense* throughout the intervention area (Welburn *et al.*, 2006). In the absence of any reliable recent census data, the cattle population of the SOS programme area has been calculated as 174,851 by staff of Makerere veterinary faculty.

During the treatment programme a total of 179,478 cattle from the area were treated with trypanocidal drugs, recently born calves were not treated due to their frail status increasing the likelihood of drug related complications. This gives a treatment rate of 102.6% (based on cattle population estimates), which is well above the required treatment threshold of 86% (which is indicated on Figure 1-10). A further breakdown of the treatment is given in Figure 1-10, showing the percentage coverage of the SOS programme in each of the individual districts (note; when the population estimates were established during 2006 when Lira, Dokolo and Amolotar were still grouped as counties of Lira district) along with the combined average percentage in the whole SOS intervention region.
The breakdown of the districts shows that the estimated coverage in the districts of Kaberamaido and Lira (including Dokolo and Amolotar) are well above 100% with the coverage in Apac estimated as 90%, giving the overall trypanocidal treatment coverage rate of 102.6%.

1.2.6.4.6.2. Coverage of deltamethrin spraying

The initial spraying was carried out at the same time as the trypanocidal treatment was conducted. It was reported that there were a number of issues with the spraying most noticeably the backpack sprayers provided for the operation were fragile in the context of a mass treatment, with the pump handles being prone to breakage. Therefore the spraying rate during the treatment period was achieved to a lower level than treatment.

Since the mass treatment programme in November 2006 there have been two additional follow up spraying programmes, one conducted in January/February 2007 and one in April/May 2007. The first follow up spraying was organised so that the local communities could treat their own animals. As previously mentioned the deltamethrin spray was left for this purpose by the field teams during the initial treatment. From
talking to the herders during sampling follow ups it was apparent that in most circumstances this approach was not sufficient to ensure good coverage rates. As a result, the third spraying was centrally organised by Makerere staff and was conducted with a much higher degree of efficiency.

Due to incomplete data from the districts of Lira, Dokolo and Amolotar the coverage of spraying has only been estimated using the available data from Kaberamaido and Apac spraying activities, using the initial cattle population figures collected by Makerere for these districts (Figure 1-11).

![Deltamethrin spraying coverage combined for Kaberamaido and Apac activities](image)

It is shown in Figure 1-11 that the coverage of spraying fits the reports that the operation of January and February 2007 was greatly underactive in relation to other spraying operations with 65% coverage achieved compared to 110% during treatment (Nov 2006) and 160% during June and July 2007.
1.2.6.4.7. Follow up SOS treatment

As a result of the monitoring and evaluation work, it became clear that a follow up treatment was required in a specific area of Dokolo and Kaberamaido districts. The re-treatment was deemed necessary upon the basis of a comparison of cattle sampling results and the origins of human patients from the SOS region whom were diagnosed with HAT (see Chapter 3). The secondary ‘mop up’ re-treatment incorporated all parishes to have provided human cases along with any parish to share a boundary with these case parishes Figure 1-12.

Retreatment within the area shown in Figure 1-12 commenced during April 2008, immediately after collection of the 18 month post SOS intervention samples. Although
there was no retreatment with trypanocides conducted outside of the retreatment area it is important to emphasise that community implemented spraying with deltamethrin has been increased throughout the original SOS region.
1.3. Aims of thesis

The aim of this thesis is to assess the impact control of *T. b. rhodesiense* within Uganda. Herein this will be examined both in terms of 1) assessing methods for controlling the disease once it has become established within a region and 2) looking at the most significant drivers causing disease spread into previously unaffected areas of Uganda. This thesis is divided into two sections preceded by a common summary of the methodology for the common techniques utilised within this thesis (Chapter 2).

Analysis of the SOS control programme as a means of controlling this recently established zoonotic species is assessed within the first section (Chapters 3 and 4).

Chapter 3 examines *T. b. rhodesiense* within the cattle population of preselected monitoring sites, sampled prior to the SOS treatment and then three months, nine months and 18 months post the intervention. Samples were are analysed using molecular tools for sensitive and specific parasite detection allowing the most accurate insight to the impact of the SOS programme upon the prevalence of human infective *T. b. rhodesiense* parasites, and non human infective *T. b. brucei* within cattle in the intervention region.

Chapter 4 examines the issues that arose during the SOS treatment campaign. This included an analysis of spatial coordination to identify problematic areas shown to be remaining with *T. b. rhodesiense* in the cattle population post SOS intervention.

Section 2, examines the movement of cattle from within the *T. b. rhodesiense* afflicted south eastern region of Uganda and the potential introduction of the parasite to districts free of HAT parasites, with particular attention to the districts of north Uganda.

Chapter 5 provides a detailed examination of the social and political issues that have given rise to the current situation of cattle stock depletion within northern Uganda.
Chapter 6 investigates the spread of *T. b. rhodesiense* resulting from market trade of cattle from the southeast of Uganda to districts of the north and north-west. The numbers of cattle being moved into these naive districts were assessed alongside data showing the prevalence of *T. b. rhodesiense* within the cattle traded in the formal market system, permitting assessment of how many cattle are moved and what proportions of them are likely to be harbouring the *T. b. rhodesiense* parasite.

Chapter 6 examines the role of the market trade system in re-introducing *T. b. rhodesiense* into the SOS region post treatment intervention of November 2006. This was undertaken by analysis of cattle movement after the control programme and the molecular analysis of samples.

Chapter 7 considers the role of organisations that are conducting cattle restocking programmes within the *T. b. rhodesiense* free districts of northern and north western Uganda. To quantify the numbers of cattle being imported by these operations, the origins of cattle that are imported and to determine legal compliance as to whether these animals are treated to remove infective agents by these organisations prior to importation.

**1.3.1. Main research questions for this study**

The two foremost questions addressed by this thesis are:

1. What was the effect of the SOS programme upon the prevalence of *T. b. rhodesiense* within the regions cattle population and how could any problems with future SOS operations be minimised.

2. What is the present situation in terms of the potential passage of *T. b. rhodesiense* to areas currently thought to be free from the disease (particularly the northern region) as a result of cattle movements from the markets of *T. b. rhodesiense* endemic regions.
2. Methods

This chapter describes the protocols for collection of the biological material and subsequent laboratory analysis for the presence of trypanosome infections. The methodology described covers the general techniques that were used in this study. Where the methodology carried out for specific chapters was modified from that described here, this will be discussed within the methods section of each individual chapter.

2.1. Sample collection

Whole blood was collected from the ear vein of each cow that was sampled using a sterile lancet. Blood was collected into two heparinised capillary tubes and subsequently applied immediately onto an FTA card (Whatman, Maidstone, Kent, UK), see figures Figure 2-1 and Figure 2-2. FTA cards were left to dry and placed together with dessicant in airtight multi-barrier pouches (Whatman) with prior to transport and processing.

Information was recorded for each animal samples on cattle breed, age, sex and body condition score. Additional information collected specific to the individual chapters of this theses is explained therein.

Figure 2-1: Collection of cattle blood samples
2.2. Sample analysis

Samples were analysed in two stages. Firstly the TBR PCR (polymerase chain reaction) was used to diagnose the presence of *T. brucei* s.l. (Moser *et al.*, 1989; Becker *et al.*, 2004). Secondly, samples shown to be positive for *T. brucei* s.l. were further analysed for the presence of *T. b. rhodesiense* by using multiplex (SRA) PCR (Picozzi *et al.*, 2005). These techniques will be fully described in section 2.2.4.

2.2.1. FTA card preparation

FTA cards were placed upon a clean cutting mat and five 3mm diameter holes were punched out of each sample using a Harris uni-core 3mm punch. Disks were placed into a 1.5ml eppendorf tube. The cutting punch was cleaned by cutting five punches out of a clean piece of filter paper. The five 3mm disks that are cut from each sample represent approximately 13.4µl of blood (although this figure is dependent upon the level of saturation of the card with blood).
2.2.2. Sample preparation

The cut punch samples were washed with FTA wash solution that serves to remove inhibitors of the PCR process, inherent in the blood of the sampled animals.

Approximately 1ml FTA wash was added to an eppendorf tube containing the 5 FTA discs the tubes were placed upon an agitating roller for 15 minutes. The FTA wash was removed and a further 1ml of FTA wash solution was added and samples placed on roller for another 15 minutes. Samples were washed for a further two cycles using 1ml of 1xTE buffer to remove the FTA wash solution from the samples (which can inhibit the PCR). 100 ml 1xTE buffer comprised 1ml of 1M TRIS and 0.2ml of EDTA (0.5M) and 98.5ml double distilled water.

Negative controls cut from a blank FTA card were subjected to an identical washing procedure.

After washing the five punches were transferred into a single PCR tube. These tubes were incubated at 37ºC for thirty minutes to dry the discs.

2.2.3. Elution of DNA

To each sample (5 washed and dried discs) 100µl of 5% (w/v) Chelex solution in double distilled H₂O (ddH₂O) was added. The Chelex solution was mixed to ensure even distribution between the tubes. The samples were heated to 90ºC for 30 minutes in a PCR thermocycler. Despite the stabilising properties of the Chelex resin, eluted DNA remains prone to rapid degradation and eluted samples were stored at 4ºC during PCR analysis and subsequently archived at -20ºC.
2.2.4. PCR

The samples first undergo TBR PCR to detecting *T. brucei* s.l. parasites (including *T. b. brucei*, *T. b. rhodesiense* and *T. b. gambiense*, *T. evansi*). Samples positive by TBR PCR were then processed using Multiplex (SRA) PCR to establish whether the *T. brucei* s.l. species identified in the sample is zoonotic *T. b. rhodesiense*.

2.2.4.1. TBR PCR Method (Moser et al., 1989)

A master-mix for the TBR reaction is prepared on ice, in a 1.5ml eppendorf tube, to ensure none of the components degrade at room temperature. The total volume of each reaction is 25µl, of which 5µl is sample eluate and the remaining 20µl reaction master-mix (composition shown in Table 2-1). For each reaction sufficient master-mix is prepared for all samples and all controls (positive and negative) along with an additional two spare reactions.

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioline 10x Buffer</td>
<td>2.5µl</td>
</tr>
<tr>
<td>Bioline MgCl (50 mM)</td>
<td>0.75µl</td>
</tr>
<tr>
<td>Water</td>
<td>13.85µl</td>
</tr>
<tr>
<td>dNTP (100 mM total dNTP)</td>
<td>0.2µl</td>
</tr>
<tr>
<td>TBR1 (10 µM working stock)</td>
<td>1.0µl</td>
</tr>
<tr>
<td>TBR2 (10 µM working stock)</td>
<td>1.0µl</td>
</tr>
<tr>
<td>Bioline REDTaq (1 u/µl)</td>
<td>0.7µl</td>
</tr>
</tbody>
</table>

*Table 2-1: Components in master-mix for a single TBR PCR reaction*  

Primer sequences for TBR 1 and TBR 2 (obtained from MWG Biotech, London, UK) are shown in Table 2-2.
Since Taq becomes active at room temperature and can degrade the primers, it is added to the master-mix last, prior to initiation of PCR thermocycling. Positive controls were prepared comprising 20µl master mix, 1µl genomic *T. brucei* s.l. DNA (Liri 24) and 4µl of water making up the reaction volume to 25µl. Negative controls comprised 20µl master-mix along, 5µl elute of clean filter paper (as described in section 2.2.1) and 5µl water to detect contamination in the master-mix.

Samples and controls were placed into a thermo-cycler PCR machine and heated to 94°C for 3 minutes to denature the DNA. The following cycle was then applied to the samples a total of 35 times; 94°C for 60 seconds, 55°C for 60 seconds and 72°C for 30 seconds – each cycle approximately doubling the amount of target DNA sequence. After the amplification cycles an additional heating phase at 72°C is maintained for five minutes to allow for the final extension of replicated DNA.

Analysis of the PCR DNA products was carried out using gel electrophoresis (see section 2.2.3), to examine for the expected band produced by the TBR PCR measuring 177 base pairs in size.

### 2.2.4.2. Multiplex (SRA) PCR

Samples that were shown positive by TBR PCR were further processed using a Multiplex PCR method (Picozzi *et al.*, 2008). This method simultaneously detects the presence of two separate trypanosome sequences present in the genome of *T. b. rhodesiense*; the Serum-Resistance Associated gene (SRA) specific to *T. b. rhodesiense* and the

<table>
<thead>
<tr>
<th>Primer name</th>
<th>Sequence (5’-3’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBR 1</td>
<td>CGA ATG AAT ATT AAA CAA TGC GCA GT</td>
</tr>
<tr>
<td>TBR 2</td>
<td>AGA ACC ATT TAT TAG CTT TGT TGC</td>
</tr>
</tbody>
</table>

Table 2-2: TBR primer sequences and their expected product size
PhosphoLipase C gene (PLC) that is common to all \textit{T. brucei} s.l. The PLC sequence acts as an internal control sequence that confirms that there was sufficient \textit{T. brucei} s.l. DNA present within the sample for the SRA primers to be able detect the presence this single copy gene in human infective \textit{T. b. rhodesiense} (it is still possible to detect SRA without the PLC sequence amplification in samples of eluted DNA).

Multiplex PCR products were examined by gel electrophoresis with the difference in the sizes of the two product sequences used as identifier - the SRA product sequence is 669 base pairs (bp) in size whereas PLC is only 325bp, this difference is easily distinguished (see section 2.2.3).

For each sample two multiplex PCRs were run, one at 45 thermo-cycles and another with 50 thermo-cycles, for increased sensitivity of detection in template samples that may have low levels of target DNA (both targets are single copy genes). At 50 cycles a sample with moderate levels of target DNA sequences may lead to over-amplification resulting in loss of signal, making interpretation unreliable, conversely samples with low concentrations of template sequence are not likely to be detected at 45 cycles. The PCR methods are identical apart from the different cycle numbers.

As with TBR the reactions are run with 5µl of eluate and 20µl of master-mix, which is made at the volumes shown in Table 2-3, per reaction.
10x Hotstart Buffer          2.5µl
MgCl (25 mM)                1.0µl
Dye (Rediload)              1.25µl
Water                      12.75µl
dNTP (100 mM total)         0.2µl
SRA-F (10 µM)               0.5µl
SRA-R (10 µM)               0.5µl
PLC-F (10 µM)               0.5µl
PLC-R (10 µM)               0.5µl
Hot StarTaq (5 u/µl)        0.3µl

Table 2-3: Volumes of master-mix components used for each sample

The sequences of the primers SRA-F, SRA-R, PLC-F and PLC-R (MWG Biotech, London, UK) sequences are detailed in Table 2-4.

<table>
<thead>
<tr>
<th>Primer name</th>
<th>Sequence (5’-3’)</th>
<th>Product band size</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRA-F</td>
<td>GAA GAG CCC GTC AAG AAG GTT TG</td>
<td>669 base pairs</td>
</tr>
<tr>
<td>SRA-R</td>
<td>TTT TGA GCC TTC CAC AAG CTT GGG</td>
<td></td>
</tr>
<tr>
<td>PLC-F</td>
<td>CGC TTT GTT GAG GAG CTG CAA GCA</td>
<td>325 base pairs</td>
</tr>
<tr>
<td>PLC-R</td>
<td>TGC CAC CGC AAA GTC GTT ATT TCG</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-4: SRA primer sequences and their expected product size

Positive controls were prepared with 20µl master mix along with 1µl genomic *T. b. rhodesiense* DNA and 4µl of water making up the required 25µl. Negative controls are made up of 20µl master-mix along with 5µl water to detect contamination in the master-
mix. If the original eluate used for the TBR PCR had deteriorated fresh eluate from the original FTA card was produced; the eluate of unexposed filter paper is also used to detect contamination during washing.

Samples and controls were placed into a thermo-cycler PCR machine and heated to 95°C for 15 minutes, to activate the hotstart polymerase and to separate any template DNA sequences present. The following cycle was applied to eluate from the samples for 45 cycles or 50 cycles, 94°C for 30 seconds, 63°C for 90 seconds and 72°C for 70 seconds.

After the completion of the cycles an additional phase of 72°C is held for 10 minutes to allow for the final extension of replicated DNA. After which the products are analysed using gel electrophoresis.

2.2.5. Agarose gel electrophoresis

Agarose gels were prepared by heating 1.5% (weight/volume), agarose/1x Tris Borate EDTA Buffer (2L batches; 200ml concentrated buffer to 1.8L water with 12.5µl ethidium bromide), for two minutes or until agarose powder is completely dissolved. The solution was then poured into a gel tray in a clamp and any bubbles removed using a clean filter-less tip, well combs were placed into the gel and left to set for approximately 30 minutes.

Once the gel had set the well comb was removed ensuring that the gel between the wells remained intact, samples were added into the wells along with 100 base pair ladder and the negative and positive controls, using fresh filter-less pipette tips for each well and ensuring that the sample did not overflow into neighbouring wells.

Negative controls and positive controls were positioned with at least two unused wells between them and the nearest sample to avoid contamination.
The DNA size ladder was added at least twice to each row of wells with 15µl of 100 base pair ladder per marker well, in order to establish the size of bands observed in samples. A positive control was added to each row to assist with determining the band sizes.

Once the gels were fully loaded they were placed into electrophoresis tanks (filled with the same 1x Tris Borate EDTA Buffer used to make the gels) and ran at a voltage of 100V for 30 to 40 minutes.

2.2.6. Analysis of agarose gel electrophoresis

Once the PCR products had run through the gel matrix sufficiently the gel was removed from the tank and analysed by illumination with UV light, making the bands of DNA fluoresce in the gel matrix, Figure 2-3. When positioned and compared against the ladder the size of the bands can be predicted, and if the bands observed are the same size as the expected products of the PCR then the sample is positive for the species that the primer correlates to.

![Image of TBR PCR products ran through an agarose matrix gel](image_url)
2.3. Statistical analysis

From the results obtained prevalence of *T. brucei* s.l. and *T. b. rhodesiense* was calculated as the proportion of samples in which infection was detected by PCR at baseline, three months, nine months and 18 months follow up respectively. The 95% confidence interval was computed based on the exact binomial distribution and displayed as error bars in the respective graphs. The difference in *T. brucei* s.l. and *T. b. rhodesiense* prevalence between baseline, three, nine and 18 months follow up time points was analysed using a Chi-squared test (degrees of freedom are noted as a subscript to the $\chi^2$-statistic) with the generated P value representing significance if less than 0.05.

For the purpose of this study Chi-squared is applicable for statistical analysis as the numbers of samples being processed are sufficiently high. Also the possible outcomes of each of the results are limited to two conclusions in that they can be either positive or negative for the target pathogen of each PCR, thus the samples are binomial in nature. Analysis for this study was carried out using the statistical analysis software Minitab. While other statistical methods could provide more powerful analysis, for the basis of this research Chi-squared is entirely relevant for this particular study as the assessment is comparatively straightforward.
3. Analysis of the Stamp out Sleeping sickness (SOS) programme

3.1. Introduction

Following evidence that *Trypanosoma brucei rhodesiense* was moving northwards in Uganda (Picozzi *et al.*, 2005a), during June 2006 in Uganda a preliminary survey was conducted to establish the geographical extent of *T. b. rhodesiense* infected cattle and establish the prevalence of *T. brucei* s.l. infection within the cattle of the recently affected area (which would become the Stamp Out Sleeping sickness (SOS) intervention region). Kaberamaido, Dokolo, and Lira districts had recently presented cases of Human African Trypanosomiasis (HAT) prior to the sampling and infections in the neighbouring districts of Apac and Amolotar, were also indicated. At the time SOS was initiated no cases had been reported from Amolotar (although in late 2008 a single case was presented from the district). This survey was the first attempt to assess the risk posed by *T. b. rhodesiense* to the human population within these districts.

Following this survey the SOS program was instigated in late 2006. SOS is a public private partnership, supported by CEVA/IK and implemented by the veterinary department of Makerere University, Uganda, as a direct response to the continuing advance of the frontier of the *T. b. rhodesiense* affected area northwards towards the established foci of *T. b. gambiense* in northwest Uganda (Kabasa, 2007). The SOS public private partnership was established to prevent the overlap of the two forms of sleeping sickness in Uganda. The following districts were identified as being at risk; Amolotar, Apac, Dokolo, Lira and Kaberamaido.

Phase one of the SOS campaign aimed to treat in excess of 86% of the cattle population of Kaberamaido, Dokolo, Lira, Amolotar and at risk areas of Apac Districts with trypanocides administered by a work force comprising of final year veterinary students.
and senior staff supervisors from Makerere (Welburn *et al*., 2006). The area covered by the SOS intervention program is shown in Figure 1-9. After treatment each animal was also sprayed with a residual insecticide (deltamethrin) to limit re-infection from tsetse fly vectors, furthermore the animals were to receive follow up spraying of deltamethrin after initial treatment, this is described fully previously in section 1.2.6.4.4.

The SOS campaign targeted both the cattle reservoir of Rhodesian (acute) sleeping sickness and the tsetse fly vectors, the insecticide spraying effectively turning the cattle population into live bait as described in the main introduction.

Two different trypanocidal drugs were used within the study area; Isometamidium chloride was used in the districts of Dokolo and Kaberamaido. Isometamidium chloride has a prophylactic property which remains in effect for approximately three months (Mulligan, 1970, Leach & Roberts, 1981). Diminazene aceturate was used in the districts of Lira, Apac and Amolotar and is a curative treatment with no prophylactic effect (Mulligan, 1970). While isometamidium chloride has the advantage of providing residual prophylactic protection, over diminazene aceturate it is more expensive (Van den Bossche *et al*., 2000). There are also higher risks associated with isometamidium use as it been has associated with potentially toxic residues at the muscle injection sites that may give rise to an abscesses (Diarra *et al*., 1998). Isometamidium chloride and diminazene aceturate were utilised within different areas with isometamidium chloride used in districts that were most heavily afflicted by *T. b. rhodesiense*.

In this thesis we have looked at the impact of SOS Phase I on zoonotic trypanosomes within the area discussed during section 1.2.6.4.2.
3.1.1. Sampling overview

Brief overviews of the time-points at which sampling occurred and the numbers of samples that were collected during each of these operations is shown below, accompanied by a detailed description of the baseline survey.

3.1.1.1. Timeline of study

The work conducted for analysis of the SOS programme and follow up sampling is shown in Figure 3-1 commencing with the earlier baseline sampling session of July 2006 through to the 18 month post treatment sampling. All time-points during which activities were carried out are shown in Figure 3-1.

Prior to the initiation of the SOS programme in Uganda the prevalence of *T. brucei* s.l., specifically *T. b. brucei* and *T. b. rhodesiense*, within the cattle population of the proposed treatment area was calculated by using the methods described within sections 2.1 and 2.2. This exercise focused upon the quantification of *T. brucei* s.l. burden within the recently affected districts of Amolotar, Apac, Dokolo, Kaberamaido and Lira.
Animals were sampled during two separate visits (June 2006 and October 2006 immediately prior to treatment) from all five districts included in the treatment programme (Apac, Lira, Dokolo, Kaberamaido and Amolotar) with a total of 43 sites being sampled (samples were taken from both village sites and from cattle being traded at market, 23 of which were included in further sampling activities). All of the 23 sample sites that were continued through all sampling sessions were villages.

### 3.1.1.3. Numbers of samples collected

The numbers of cattle that were sampled during each of the sampling sessions are shown in Table 3-1. The numbers collected from the 23 sampling sites remain fairly consistently around 2000 per sampling session.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Number Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2322</td>
</tr>
<tr>
<td>3 Months post SOS</td>
<td>1786</td>
</tr>
<tr>
<td>9 Months post SOS</td>
<td>2092</td>
</tr>
<tr>
<td>18 Months post SOS</td>
<td>2059</td>
</tr>
</tbody>
</table>

Table 3-1: Numbers of cattle sampled during each sampling session

This consistency indicates that there was little effect of sensitisation of sampling fatigue and bias to the SOS analysis operations within the 23 village sample sites. These are shown later within Figure 3-2.
3.1.3. Mobilisation and sensitisation for SOS treatment

Prior to the inception of the SOS initiative the local community, in particular the cattle keeping population, were targeted with information concerning; what the treatment was for, why it was important, how it would benefit them, if there were any potential side effects of treatment and finally when and where this treatment would be operating.

For sensitisation and mobilisation within the region it was necessary to rely on the offices of the District Veterinary Officers (DVOs) as well as the district political figures of the specific area of operation. DVOs were requested to pass information about the programme to their subordinate veterinary staff along with local community animal health extension officers. This process had to be adopted by the Makerere administered SOS operation due to the fact that Makerere had not previously been active in the region and thus was not a trusted institution by the population, therefore the support and approval of these trusted offices was vital for community acceptance.

Immediately upon the arrival of Makerere personnel within the SOS programme region the local police and security forces active within the area were notified of the planned operation and its timeline. This was a necessity as during that time the Lord’s Resistance Army (LRA) were still actively operating within northern Uganda and security of the treatment personnel needed to be given high levels of attention. But as a by-product of this notification of the police and security organisations community awareness of the programme will have been increased.
3.2. Methodology for SOS sampling

The majority of the methodology used for the SOS sampling has been described within the General methodology (Chapter 2); however particulars which are specific to the analysis of the SOS programme are detailed below.

3.2.1. Project design

The aim of the project was to monitor the effectiveness of the SOS intervention mass treatment in reducing the prevalence of *T. brucei* s.l. and *T. b. rhodesiense* within the cattle reservoir. Prior to the initiation of the SOS mass treatment the baseline survey provided a prevalence of *T. brucei* s.l. and *T. b. rhodesiense* within the treatment area.

The study area is that of the SOS treatment, shown in Figure 1-9, which encompasses a total of three districts in Uganda, Kaberamaido, Dokolo and Amolotar, along with just less than half of the districts of Lira and approximately a third of Apac. In total the coverage area is approximately 8010 km$^2$ further description of this area and some demographic aspects of the regions are included within section 1.2.6.4.2.

To assess the effect of a mass treatment monitoring of target pathogen prevalence in the cattle population has to be conducted both prior to and post treatment, in order to obtain effective results the samples are needed to be taken from the same locations (Thrusfield, 1986). The present work assessed the effect of trypanocide and insecticide treatment on the trypanosome prevalence, monitoring was undertaken before and after treatment activities ensuring the same locations were sampled each time.

The locations of the sampling sites were selected as 23 villages located throughout the area of SOS treatment (how these sites were selected is detailed below). The baseline prevalence was determined from samples collected from these villages through two sampling sessions during June 2006 and October 2006, prior to treatment having taken place in the specific villages. The locations of these villages are shown in Figure 3-2.
total of 80-100 samples were collected from each of the sampling sites, however, if less than the required number of cattle were from the specified village then samples from directly neighbouring villages (less than 800 m distance) were also sampled to make up numbers. If there were no suitable neighbouring villages then only the cattle of the village were sampled.

Post treatment, samples were taken at three months, nine months and 18 month post which together with the baseline sampling gives a repeated cross section from which alterations in the prevalence of *T. brucei* s.l. and *T. b. rhodesiense* can be monitored.

![Geographical location of sampling villages](image)

**Figure 3-2: Geographical location of sampling villages**
3.2.1.1. Aim

To estimate the prevalence of *Trypanosoma brucei* s.l. infections in the cattle population of the 5 districts in central Uganda which are included in the SOS treatment area at baseline (October, 2006: prior to SOS intervention) and to detect significant changes in the prevalence of *T. brucei* s.l. in the cattle population at 3 months, 9 month and eighteen months post intervention.

3.2.1.2. Sampling methodology

To allow for rapid assessment of the *T. brucei* s.l. prevalence in the cattle population, repeated cross-sectional sampling was selected as the most appropriate sampling strategy. This strategy avoids excessive interference by the researcher with the dynamics of the local cattle trade, which can be affected by tagging of cattle, which would be required for a longitudinal study. Previous research has shown that random sampling of cattle at a central sampling point will give a good representation of the trypanosomiasis prevalence in cattle within the catchment area (v. Wissmann *et al*., in press).

Sample size calculations were adjusted for cluster sampling (Thrusfield, 1995). Based on a ground-truthing survey in the target districts conducted in July 2006, the expected overall *T. brucei* s.l. prevalence at baseline was estimated as 15% with an expected intercluster-variance (*V_c*) of 0.013 between sampling villages. On this basis, random sampling of 100 cattle in 23 sampling villages was calculated to achieve a desired absolute precision of below 5%.

Sampling villages were selected by 2-stage cluster sampling (1st stage: random selection of sub-county from within SOS area, 2nd stage selection of village) to be distributed as evenly as possible across the SOS treatment area, by allowing a maximum of 1 sentinel village per sub-county. A village within each sub-county was chosen at random from a
short-list of villages within the sub-county provided by the respective District Veterinary Officers (DVOs).

Civil unrest in central Uganda (due to the activities of the Lord’s Resistance Army) has resulted in population movements and a large numbers of internally displaced people, associated with changes in livestock keeping and in places large losses in livestock due to cattle rustling, meaning that not all villages would have been suitable for sampling.) The short-list provided by the DVOs was comprised of villages suitable for the purpose of sampling by the following criteria: suitable number of livestock, cattle owners were likely to collaborate (distrust in the wake of civil unrest insurmountable in badly affected villages), and no concurrent outbreak of infectious diseases of cattle (e.g. foot and mouth) which would limit access to the village.

3.2.2. Mobilisation of cattle for blood sampling

The mobilisation of cattle for blood collection was carried out at least two days prior to the date of planned sample collection, either by means of contacting the DVO for the district concerned and getting them to visit the village organising the congregation of the cattle at the village. Alternatively the field team would visit the village organising the cattle needed for sampling in person, ensuring messages were left with a minimum of three local persons, including the village chief. Generally the village sampling sessions where the field team had organised sampling had the best turnouts, but due to distance to some of the sites, this approach could not be employed for all sample collections. As an incentive for permitting blood samples to be taken each animal that was sampled was treated with de-wormer (10% albendazol solution).

3.2.3. Additional information collected post SOS treatment

During the three month and nine month follow up sampling, additional information to that described in section 2.1 was obtained from the owner or herdsman as to whether each
individual animal was treated in the SOS intervention i.e. if the animal had been sprayed during November 2006 treatment program and/or since using deltamethrin. During 18 month post intervention information was only collected concerning whether each of the cattle were treated during the SOS programme. This information has been analysed to assess the coverage of the SOS activities within the sampled cattle population, in order to validate the coverage rates that were established upon population estimates.

3.2.4. Additional villages included during eighteen month sampling

During the final round of sampling conducted at 18 months post SOS intervention, an additional seven sampling sites were included to verify that no subsequent follow up treatment had been conducted at the twenty three original SOS sample sites. Any other treatment that may have been carried out at these additional sample sites may have generated misleading data about the true state of trypanosomiasis within the area. Of the seven new sites, four villages; Arido, Olai and Agerinono in Apac and Aromo in Lira were previously sampled prior to the initiation of the SOS treatment but were not included in the baseline. The remaining four sites have no available previous data. Locations of the sampling site are shown in Figure 3-3.
3.2.5. Detection of HAT cases within the SOS region

Data was collected from the sleeping sickness treatment centres that passively service the SOS intervention zone. Two Health Centres (HCs) in the SOS treatment zone are equipped and staffed to confirm or treat diagnosis for human sleeping sickness (Lwala and Dokolo HC4s shown in Figure 3-4). These two hospitals are located 22km from one another in the SOS region. Outside of the SOS region there is another sleeping sickness diagnosis and treatment centre at the HC 4 in Serere located within Soroti district to the south east of the SOS region. While Serere is located out of the SOS region it was included for data collection as patients may go directly to Serere hospital. This is likely
with patients from the peninsular district of Amolotar, which is closer to Serere by boat than it is to Lwala or Dokolo hospitals.

Patients originating close to treatment centres are more likely to be correctly diagnosed. Previously reported spatial clustering of cases close to the treatment centres may be associated with transport of patients to these locations, particularly during illness from distant home villages, also personnel at the surrounding lower classed HCs are more likely to refer patients to be sampled and examined specifically for sleeping sickness due to higher awareness in the area (Odiit et al., 2004a, Odiit et al., 2004b).

Figure 3-4: Locations of the sleeping sickness diagnosis and treatment centres within the SOS intervention zone.
3.3. Results

The results of the samples that were collected and analysed during the four time points that cattle sampling was conducted, are shown together within this section for accurate comparison of the detected prevalence from each sampling time point. While the results from the different sampling sessions are most suitably analysed together, the baseline findings will first be described separately and then later included with the post SOS intervention sampling results for comparison.

3.3.1. Baseline results

While a total of 43 different sites (including the markets) were sampled during the entire operation of the initial survey into trypanosome incidence within the region (ground truthing) and baseline sampling, a total of 23 sites were selected for longitudinal study in relation to the SOS programme.

Data from the additional seven sampling sites that were included for the 18 month sampling session are not included in Figure 3-5 to aid comparison with results from the three and nine month sampling sessions, which will follow shortly.

Of the 23 village sites selected for follow-up sampling a total of 10 sample sites were shown to have cattle infected with *T. b. rhodesiense*, the spatial distribution of these sites is shown in Figure 3-5.
The *T. b. rhodesiense* positive sites are seen to be predominantly in the districts of Dokolo and Kaberamaido with an additional two sites that were seen positive found in Lira and Apac. In total, 60.9% of all the sites sampled were located within the districts of Kaberamaido and Dokolo, and these were found to have a higher detected *T. b. rhodesiense* infection, the remainder, 39.1% were in Lira, Apac and Amolotar districts. When this is approached looking at the percentage of sample sites that harboured a human infection in livestock in each of the areas (Kaberamaido and Dokolo versus Lira, Apac and Amolotar), it is clear that a higher proportion of sample sites found to be *T. b. rhodesiense* infected are located within Dokolo and Kaberamaido (50% of all sites), where as 33% of sampled sites located in the districts of Lira, Apac and Amolotar were found to harbour the parasite.
Overall baseline sampling revealed a detected prevalence of 15.57% (N = 328/2106) for *T. brucei* s.l. within the SOS region, while the detected prevalence of *T. b. rhodesiense* was found to be 0.81% (N = 17/2106) within the same sampled animals.

### 3.3.2. Post intervention results

The observed prevalence of *T. brucei* s.l. and *T. b. rhodesiense* within the post intervention samples are chronologically grouped together for direct comparison of the time-points.

#### 3.3.2.1. Prevalence of *T. brucei* s.l.

The prevalence of *T. brucei* s.l. within sampled cattle is seen to be significantly lower three months after the SOS intervention treatment (P<0.0001). With the sampled cattle at the three months sampling session presenting 4.87% (N=87/1786) prevalence, a reduction of 68.37% when compared to the baseline prevalence of 15.57% (Figure 3-6).

Analysis of the nine month sampling showed that the prevalence of *T. brucei* s.l. had increased to 16.11% (N=337/2092), an insignificant increase from the prevalence found during baseline (P=0.6422).

Finally the results provided by the 18 month sampling shows a further increase in the prevalence of *T. brucei* s.l. to 27.44% (N=565/2059), an overall and statistically significant increase of 76.23% over the pre-intervention baseline prevalence.
3.3.2.2. Prevalence of *T. b. rhodesiense*

The prevalence of *T. b. rhodesiense* (Figure 3-7) in sampled cattle is significantly reduced (P=0.0018) by 88.42% from the baseline prevalence of 0.81% (N=17/2106) to the three-month prevalence of 0.11% (N=2/1786). Furthermore there is no significant increase in prevalence of *T. b. rhodesiense* at the nine month sampling 0.48% (N=10/2092), when compared to the baseline 0.81% (p = 0.2463) nor at 18 months which returned a prevalence of 0.53% (N=11/2059) (p = 0.2588). Monitoring the prevalence of *T. b. rhodesiense* within the reservoir cattle population has indicated a reduction of the species within the area, as a direct result of the SOS programme this reduction should impact the number of people becoming infected from within the region.
3.3.2.3. Proportion of detected *T. brucei* s.l. which are *T. b. rhodesiense*

The proportion of samples that were found to be positive for *T. brucei* s.l. that were shown to be positive for *T. b. rhodesiense* is of relevance as it indicates the percentage of *T. brucei* s.l. parasites within the cattle population body that are zoonotic.
Figure 3-8 shows that during the baseline sampling session the percentage of samples shown to be infected with *T. brucei* s.l. that were infected with the zoonotic species *T. b. rhodesiense*, was 5.18%.

Analysis of the samples collected post SOS treatment intervention show that during the proportion of *T. brucei* s.l. positives that were found to be *T. b. rhodesiense* from the three month sampling session to be 2.29%. The proportion during the nine month sampling session was found 2.96%; finally the 18 month sampling session gave a *T. brucei* s.l. to *T. b. rhodesiense* proportion of 1.94%.

This reduced percentage of *T. b. rhodesiense* circulating within the pool of *T. brucei* s.l. infected cattle reflects upon the reduced prevalence of human infective *T. b. rhodesiense* circulating within the reservoir population of cattle within the SOS region since the intervention (shown in Figure 3-7).
3.3.3. Comparison of trypanosome prevalence between areas receiving differing trypanocidal treatment

Two trypanocidal treatments were applied within spatially distinct areas. Areas of perceived high human transmission, Dokolo and Kaberamaido were treated with isometamidium chloride (ISO) which is curative with up to a three month prophylactic period. While cattle in Amolotar, Apac and Lira districts were treated with diminazene aceturate (DIM) which is curative and provides no prophylaxis.

Comparison of the prevalence of both *T. brucei* s.l. accompanied by *T. b. rhodesiense* will clarify the full effect that was held by the prophylactic property of isometamidium chloride within the areas it was used.

![Bar chart comparison of *T. brucei* s.l. prevalence within isometamidium chloride and diminazene aceturate treated regions and overall prevalence across the SOS region](chart)

Figure 3-9: *T. brucei* s.l. prevalence within isometamidium chloride and diminazene aceturate treated regions and overall prevalence across the SOS region

There was no significant difference between the prevalence of *T. brucei* s.l. in cattle between the two areas selected for differing trypanocidal treatment $P=0.8266$ (see Figure 3-9). Three months post treatment this remains the case ($P=0.0794$). At nine months post treatment the area to receive treatment with isometamidium chloride showed a
significantly higher prevalence of *T. brucei* s.l. than the area that received treatment with diminazene aceturate (*P*<0.0001) but at eighteen months post SOS intervention returned to having no significant difference between the two areas (*P*=0.2991).

This indicates that there was little effect generated by the prophylactic period of isometamidium chloride upon the re-introduction of *T. brucei* s.l. after the SOS intervention.

Figure 3-10: *T. b. rhodesiense* prevalence within isometamidium chloride and diminazene aceturate treated regions and overall prevalence of SOS region

Similarly, the prevalence of *T. b. rhodesiense* within the areas that received differing treatment shown in Figure 3-10 were not shown to be statistically different at pre-treatment baseline sampling (*P*=0.6467). Three months post intervention there is again no significant difference between the areas that received treatment using isometamidium chloride and diminazene aceturate (*P*=1.0000). At the nine month sampling there is a statistical difference between the prevalence of *T. b. rhodesiense* within the areas that employed different trypanocidal agents with the area receiving treatment with isometamidium chloride showing a higher prevalence than diminazene aceturate.
At 18 months the difference in prevalence of *T. b. rhodesiense* was not found to be significantly different (P=0.1256) between the two treatment areas.

Comparison of the detected prevalence within both of the treatment areas (ISO and DIM) and the combined overall SOS region showed that there was no statistical difference between the isometamidium chloride or diminazene aceturate treated areas and the results of the overall SOS region.

As the prevalence of *T. brucei* s.l. was found to follow the same trend as *T. b. rhodesiense* it is indicated that there was very little effect of the prophylactic action upon the return rate of *T. brucei* s.l. or *T. b. rhodesiense*. The low impact of the prophylactic upon the return rate could be attributable to the fact that isometamidium chloride was deployed for use within in areas that had presented the highest number of human cases for treatment at the health centres, hence may be areas of higher risk, which will be discussed later within this chapter.

Analysis of the proportion of *T. brucei* s.l. positive samples that were found to be *T. b. rhodesiense* positive within each of the chemotherapeutical treatment areas will indicate whether there is any difference in the prevalence of the zoonotic *T. b. rhodesiense* within the circulating population of *T. brucei* s.l.
Figure 3-11 shows that the percentage of *T. brucei* s.l. positive samples that were specifically *T. b. rhodesiense* was highest prior to SOS intervention within the area that isometamidium chloride was used within, when compared to the area that received diminazene aceturate. By the three month post SOS sampling point it is shown that the percentage of *T. brucei* s.l. that is *T. b. rhodesiense* was found to be lower within the isometamidium chloride treated area than was observed within the area receiving treatment with diminazene aceturate. However analysis of the samples during both nine and 18 month time points shows that the areas of isometamidium chloride treatment had the highest proportion of *T. brucei* s.l. that were found to be *T. b. rhodesiense* when compared to the area that received treatment with diminazene aceturate.

### 3.3.4. Incidence of *T. b. rhodesiense* at village level

Looking at persistence of *T. b. rhodesiense* persistence within sample sites during the different sampling time-points it is clear that certain village sites are repetitively showing *T. b. rhodesiense* positive samples.
<table>
<thead>
<tr>
<th>District</th>
<th>Village</th>
<th>Baseline</th>
<th>3 month</th>
<th>9 month</th>
<th>18 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apac</td>
<td>Apire</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dokolo</td>
<td>Amwoma</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dokolo</td>
<td>Aneralibi</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dokolo</td>
<td>Awinyi ipany</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Dokolo</td>
<td>Enget</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Dokolo</td>
<td>Okwor</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>Amoru</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>Olap</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>Olemai</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>Olio</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lira</td>
<td>Ogengo</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Lira</td>
<td>Onyakede</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Lira</td>
<td>Tecwao</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3-2: Village sample sites with *T. b. rhodesiense* positive cattle and the sample time point of positivity.

Of the seven village sites that were found to harbour *T. b. rhodesiense* post intervention shown in Table 3-2, three had been negative for this sub species during the baseline sampling activities. Five of these seven villages were observed to harbour *T. b. rhodesiense* cattle at more than a single time point whereas only two were observed to harbour *T. b. rhodesiense* positive samples at a single time point. This may indicates re-infection of parasites within the sites that have previously been shown to harbour *T. b. rhodesiense* within the cattle population. In four of the five sites cattle were infected at the baseline, but not at three months post intervention, and then subsequently *T. b. rhodesiense* is reappears at either nine or 18 months post intervention. While re-infection
by cyclical tsetse transmission from untreated infected animals in this area is identifiable as the cause, habitual import of infected cattle may also be a factor (see section 3.3.12).

3.3.4.1. Persistence of *T. b. rhodesiense* within cattle at sampling sites with positive results from baseline

Due to the focal nature of *T. b. rhodesiense* it is worthwhile considering that only a few village locations may be contributing *T. b. rhodesiense* positive animals.

Figure 3-12: Number of villages found to be harbouring cattle borne *T. b. rhodesiense*

Figure 3-12 shows that the number of villages with *T. b. rhodesiense* detected in sampled cattle reduced directly after SOS intervention. Ten of the original 23 sampling sites presented *T. b. rhodesiense* positives during the baseline sampling. At three month post intervention the number of sampling sites providing *T. b. rhodesiense* positive samples reduced to none of the sites that had been found to harbour the parasite during baseline sampling, a statistically significant reduction P=0.0006. At nine months post intervention the number of villages (that were positive during baseline) found with *T. b. rhodesiense*
infection in cattle increased to two villages, remaining significantly lower than at the baseline (P=0.0165).

At 18 months post intervention, the number of the original 23 sample sites with detected *T. b. rhodesiense* infection had risen to six of the sample sites having cattle detected as positive for *T. b. rhodesiense* which is not statistically different to that of the baseline findings (P=0.1075).

### 3.3.5. Analysis of three and nine month sampling and proposed SOS retreatment area

By examining the location of the village sites that have provided samples that were positive for *T. b. rhodesiense* during the three and nine month post SOS sampling sessions, it is possible to assess the geographical distribution of the parasite within sampled cattle within villages. Displayed spatially it is possible to plot the locations of *T. b. rhodesiense* positive animals for any foci that may exist of the parasite. This process was first done for the three and nine month samples to provide an initial analysis giving insight to the immediate effect of the SOS programme. The 18 month sample results being later added for further comparison (including the additional sampling sites which were also sampled during baseline sampling as described in the methods).
Figure 3-13: Map of sample sites providing *T. b. rhodesiense* positive samples during 3 and 9 month sampling

Figure 3-13 shows a group of *T. b. rhodesiense* positive villages on the Dokolo and Kaberamaido district boundary. Additionally a single animal was shown to be positive for the parasite from the most northerly sampling site of Tecwao in Lira (imported...
through market sale since the time of SOS treatment) indicating poor compliance with government legislation concerning treatment of imported cattle.

Human case data was provided by the government managed sleeping sickness treatment centres at Serere (Soroti district) and Lwala (Kaberamaido district), the only two diagnosis and treatment centres within 50 km of the SOS region. Dokolo HC4 did not deal with sleeping sickness diagnosis or treatment until late 2008. When parishes of sleeping sickness patient origin were overlaid with the findings of the cattle sampling, a single focus is apparent for both human and animal associated parasites (see Figure 3-14). Case data is indicated with a 12 week / three months lag after the SOS activity so as to ensure that cases presented had acquired infection post cattle treatment.

Figure 3-14: Cattle sample *T. b. rhodesiense* results from 3 and 9 month sampling against ‘home parishes’ of sleeping sickness patients
A specific region of the SOS treatment region on the Dokolo and Kaberamaido border was still afflicted by substantial burden of *T. b. rhodesiense* parasites in both the cattle and human populations. In response to this a secondary ‘mop up’ re-treatment session was suggested, incorporating all parishes to have provided human cases along with any parish to share a boundary with the case parishes, this is shown in Figure 3-15.

![Figure 3-15: Area of retreatment programme April 2008](image)

Retreatment within the suggested area detailed in Figure 3-15 began in April 2008 after the collection of the 18 month post-intervention samples. Although there was no
retreatment with trypanocides conducted outside of the retreatment area it is important to emphasise that community uptake of restricted application spraying with deltamethrin had increased throughout the original SOS region. With this the case the analysis of cattle samples shall be conducted considering the (high risk) retreatment region separately.

3.3.6. Differences between sample sites within SOS high risk (retreatment) area and original un-retreated SOS region

Comparison of *T. brucei* s.l. prevalence between the high risk area that received retreatment during the April 2008 SOS programme shown in Figure 1-12, a statistically higher (P<0.0001) point prevalence of *T. brucei* s.l. within this high risk area than the sample sites of the original SOS region not to receive follow up treatment.

With reference to the distribution of the sample sites that were selected upon the basis of being positive control villages for HAT (Figure 3-2), all the positive control sites were located within the eventual retreatment area, thus suggesting that this area has a higher tsetse and trypanosome (particularly *T. b. rhodesiense* burden), as such they shall be termed high risk areas.
A summary of *T. brucei* s.l. point prevalence data is shown in Figure 3-16, comparing sample sites within the high-risk zone with those outside this zone. From comparing two time points; samples collected pre- November 2006 intervention (baseline samples) and those collected post intervention November 2006, it can be seen that the cattle samples from sites within the high risk zone show a higher point prevalence for *T. brucei* s.l. both before and after the SOS treatment programme when compared to the samples from sites that were outside of the high risk area. At the baseline 19.7% (N=130/662) of the cattle sampled within the high-risk area were found to be positive with *T. brucei* s.l. and 11.7% (N=141/1204) of the cattle sampled within the remaining SOS area were found infected. Post intervention 16.6% of the cattle (N=229/1379) within the high-risk area were *T. brucei* s.l. positive whereas 7.6% (N=195/2582) of the sampled cattle in the remaining SOS area were found infected.
Figure 3-17: *T. brucei* s.l. point prevalence in cattle sampled from villages within retreated and non-retreated areas of the SOS region at specific time-points.

The prevalence of *T. brucei* s.l. shown in Figure 3-17 is observed to differ between the high risk and remaining SOS areas at the baseline sampling time-point there was no significant differentiation between the sample sites from within the high risk area which received retreatment of April 2008. At three months post SOS intervention the prevalence of *T. brucei* s.l. is significantly higher in the cattle samples taken from villages within the high-risk area than from villages outside the high-risk area (P=0.0007). At nine months post treatment time-point differences between the detected prevalence from the sample sites within the high-risk area and the sites in the remaining SOS area has increased significantly (P=<0.0001). Sites inside the high-risk area have increased with both returning to the prevalence seen in the baseline sampling.

The sampling at 18 months post SOS intervention shows that the point prevalence of *T. brucei* s.l. from villages outside of the high-risk area is not significantly different (P=0.2852) to the sample sites that are within the higher risk (April 2008) retreatment area. This is the first time-point that the sample sites outside of the high-risk area are indicated to have a higher point prevalence than the sample sites within the high-risk area (although as it is not statistically significant this is not certain), with a prevalence of 27% of cattle sampled within the high risk area. Whereas the sample sites from within the
retreatment area presented a prevalence of 20% for *T. brucei* s.l. within the sampled cattle population.

The point prevalence of *T. b. rhodesiense* within the sample sites of the high risk and remaining SOS areas are shown within Figure 3-18 is significant difference at nine time point.

![Figure 3-18: Prevalence of *T. b. rhodesiense* in retreated and non-retreated villages of SOS region](image)

Figure 3-18 indicates that cattle sampled in the villages in high-risk area (included in the re-treatment programme of April 2008) have a higher prevalence of *T. b. rhodesiense* than those from villages outside of the high-risk area. The greatest difference is observed nine and 18 months post SOS sampling. This pattern may reflect that at the baseline the prevalence of *T. b. rhodesiense* was stable within the cattle population, with the majority of the parasites having been cleared by the SOS intervention. The proportion of the *T. b. rhodesiense* compared to the *T. b. brucei* s.l. population was greatly reduced and is reflected in a drop in prevalence from the three-month post intervention analysis.
Nine months post mop up intervention prevalence of *T. b. rhodesiense* is seen to have increased within the sample sites of the high-risk retreatment area, whereas the sample sites outside this area showed no *T. b. rhodesiense*. The risk of re-infection is significantly higher compared to the remaining SOS area (P=<0.0001).

At 18 months post SOS re-treatment, the prevalence of *T. b. rhodesiense* has stabilized high-risk area. Cattle samples from village sites outside of the high-risk area have a marginally increased detected prevalence which is statistically significant (P=0.0434). This may be attributed to the importation of *T. b. rhodesiense* infected cattle from areas outside of the SOS intervention region (see Chapter 6).

### 3.3.7. Analysis of original sampling villages and newly inducted villages

The original 23 villages that have been sampled at each of the time points were compared to the villages included solely during the baseline and 18 months sampling events. Of these seven new villages, four were previously sampled during the ground-truthing exercise in June 2006 and these can be used as baseline for comparison to the samples collected during the 18 months post SOS sampling session.
The prevalence of *T. brucei* s.l. increases between the baseline and combined post SOS intervention sampling results, in both the original 23 villages as well as the newly inducted villages. The *T. brucei* s.l. prevalence within the sample sites originally included in the SOS sampling was found to be 14.52% (N=271/1866) at baseline and 21.53% (N=817/3793) were found to be positive during the combined post treatment sampling. The *T. brucei* s.l. prevalence of the new villages that were included during the sampling at baseline and then again during the 18 month post treatment sampling, during baseline 23.75% (N=57/240) were positive and 38.74% (N=172/444).

Overall prevalence of *T. brucei* s.l. within the original sample sites is significantly lower than in the sample sites that were sampled only during the ground-truthing / baseline (P=<0.0001) and 18 month post treatment sampling sessions (P=<0.0001). Since the ‘new’ sample sites show higher prevalence at baseline than the 23 continually sampled sites it is likely that cattle sampled at these sites were more afflicted by these parasites.
Figure 3-20: Prevalence of *T. b. rhodesiense* within original and ‘new’ villages of SOS

The results for the prevalence of *T. b. rhodesiense* show that the both the original 23 villages and the newly included sampling sites undergo an insignificant reduction between the baseline and post SOS intervention sampling.

The combined *T. b. rhodesiense* prevalence from the original sample sites and the newly included sample sites show that the prevalence of *T. b. rhodesiense* of the baseline of the sites sampled during all sampling sessions was found to be 0.85% (N=16/1866) and 0.55% (N=21/3793) were found positive during the combined post treatment sampling sessions.

Within the samples from the newly inducted sample sites the prevalence of *T. b. rhodesiense* was found to be 0.41% (N=1/240) during the baseline sample session and 0.45% (N=2/444) was found to be positive during the post sampling time point. The differences in the effects upon the prevalence of *T. b. rhodesiense* are due to low sample numbers from the seven newly inducted villages making outcomes less dependable. It should be noted that the distribution of all seven newly included villages is outside of the high-risk area (discussed in section 3.3.5 whereas the original sites include locations within the high risk area).
3.3.8. Distribution of sample sites providing *T. b. rhodesiense* positive samples during 18 month sampling session

The distribution of sample sites that have been found to harbour the zoonotic species *T. b. rhodesiense* at the 18 months post SOS intervention sampling time-point is shown in Figure 3-21, eight sampling sites provided harboured *T. b. rhodesiense* positive. Of these eight villages two are sampling sites newly inducted into the 18 month sampling schedule, as such six are original sampling villages are found positive during the 18 month post SOS sampling.
Eighteen month post SOS intervention samples were collected immediately prior to the initiation of the SOS retreatment activity that has been described above. Sample sites that were positive for *T. b. rhodesiense*, but located within the retreatment area can be specified as the cattle at these sites are likely to have been treated with trypanocides during the retreatment activity; these sites are identified in Figure 3-22.
There is no evidence of clustering of *T. b. rhodesiense* positive cattle at sampling sites outside of the retreatment area. There is grouping of sampling sites found to have *T. b. rhodesiense* positive cattle within the sites that subsequently received retreatment in April 2008, when these sites are compared to previous findings of sampling, Figure 3-13, three of the four are seen to have *T. b. rhodesiense* infections during the nine month sampling.

The separation of prevalence within and outside of the retreatment area displayed in Figure 3-18 shows *T. b. rhodesiense* prevalence within cattle from sample sites of the retreatment area to be higher than was observed in sites in non-retreatment areas.
3.3.9. Detected HAT occurrence from sample site locations

Of the original 23 SOS villages selected for sampling five were have experienced cases of human sleeping sickness. These are listed in Table 3-3, which shows village sites that have presented human cases (numbers of cases before and after SOS intervention).

<table>
<thead>
<tr>
<th>Village</th>
<th>District</th>
<th>Cases before November 2006</th>
<th>Cases since February 2007</th>
<th>Distance to Sleeping sickness health centre (Direct line km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osirima</td>
<td>Kaberamaido</td>
<td>2</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Olemai</td>
<td>Kaberamaido</td>
<td>4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Olio</td>
<td>Kaberamaido</td>
<td>7</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Awiny ipany</td>
<td>Dokolo</td>
<td>5</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Aneralibi</td>
<td>Dokolo</td>
<td>1</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Alyecmeda A</td>
<td>Amolotar</td>
<td>0</td>
<td>1</td>
<td>67</td>
</tr>
</tbody>
</table>

Table 3-3: Village sample sites that have provided HAT cases
Figure 3-23: Locations of sample sites that have been the home village of HAT patients since early 2007

From the content of Table 3-3 and Figure 3-23 it is clear that the overall number of sampled villages within our sampling frame for HAT cases in Kaberamaido and Dokolo has not changed significantly since implementation of the SOS programme although the numbers of cases has in all cases reduced. Osirima in Kaberamaido district has not provided a HAT patient since the SOS treatment. The number of cases from original case villages, prior to the SOS intervention the sampled villages provided 19 confirmed cases (the first HAT cases from the area was reported in 2003). From early 2007 to late 2009 there have only been 10 confirmed HAT cases from these villages. Both pre and post SOS intervention most case were coming from the area that was targeted for SOS re-treatment area (see Figure 1-12).
3.3.9.1. *T. b. rhodesiense* from cattle sampling in relation to positive and negative control status of the selected village sample sites

Of the five villages that had cases of human sleeping sickness before the SOS baseline was implemented three of these villages were also found to have *T. b. rhodesiense* parasites within the blood of the cattle (a further eight villages had infected cattle but no reported cases of HAT, totalling 11) Figure 3-24.
Three of the five HAT positive villages sites were found to harbour *T. b. rhodesiense* before the SOS treatment intervention *T. b. rhodesiense* positive cattle. Eight of the 25 (32%) sites selected as HAT negative control, had *T. b. rhodesiense* in cattle but no reported cases of HAT in the village.
From the combined post SOS sampling results shown in Figure 3-25 four of the five HAT positive villages have provided samples that were detected as positive for *T. b. rhodesiense*. In addition all three HAT positive sites that provided samples found to be positive during baseline sampling also provided samples positive for the species during the post SOS sampling sessions.
From the comparison of sites providing *T. b. rhodesiense* positive cattle during the baseline sampling and post SOS sampling sessions (Figure 3-24 and Figure 3-25 respectively), 11 sites provided *T. b. rhodesiense* positive samples during the baseline of which seven were found to still harbour the sub-species during post SOS sampling. Another way of examining this is that of the nine sites that were detected to harbour the
parasite within the cattle population during baseline sampling; seven were found to have hosted *T. b. rhodesiense* prior to SOS treatment.

### 3.3.10. Treatment coverage rate within sampled cattle population

The SOS target was to treat in excess of 86% of the cattle across the intervention districts (approx 220,000). Information concerning the treatment status of each of the individual cattle that were sampled during the post SOS sampling can be examined to provide an estimated coverage rate for SOS treatment.

![Figure 3-26: Percentage of cattle reported to have been treated with trypanocides during SOS programme (treatment target 86% indicated)](image)

Farmers were asked at each sampling event how many of the animals had received and inject-able trypanocidal drug treatment as a result of SOS activities. Figure 3-26 shows that at each sampling event farmers are reporting a decreasing coverage of trypanocide
treatment by the SOS programme; from reported coverage of 78.1% (N=1394/1798) of cattle sampled three months post intervention sampling, to 62.4% (N=1305/2092) reported coverage during the nine months post intervention sampling, declining further to 45.2% (N=930/2059) of the cattle sampled (18 month post SOS sampling session) reportedly having been treated with trypanocides by the SOS programme. When the data from each of the three sampling events is compiled an overall coverage rate of 61% (N=3629/5949) is found, 25% shy of the 86% coverage rate that was needed.

The continuing reduction of the reported trypanocidal treatment coverage observed in Figure 3-26 has two explanations. Firstly, the memory recall concerning the treatment status of each animal has reduced. Secondly, over time cattle have continually been introduced into the region through both birth and import, aspects of these two theories are examined in the discussion section through the inclusion of sampling data identifying animals that were new since the SOS programme.

3.3.11. Deltamethrin spraying coverage

Alongside the analysis of the coverage of the trypanocidal treatment the coverage of deltamethrin spraying both during the SOS treatment and subsequently after the SOS intervention, the coverage of spraying was assessed during the sampling sessions through asking cattle handlers and owners if the individual animals were sprayed during the SOS treatment and also if they were sprayed with deltamethrin during the SOS treatment and since the programme of November 2006.

Due to the aspect of memory recall over time, only information collected from the three and nine month post treatment sampling was included in Figure 3-27. As by the 18 month post treatment sampling time point, the herders are likely to have inaccurate recall of the deltamethrin spraying status of each individual animal.
The analysis of spraying coverage data from the sampled cattle during three and nine month sampling shows 33% cattle were sprayed with deltamethrin (by the SOS treatment programme). Furthermore 32% of sampled cattle were reported sprayed with deltamethrin by the SOS treatment activity with a subsequent follow up deltamethrin application since the SOS treatment of November 2006. This gives an overall deltamethrin spraying coverage rate of 65% achieved within the SOS campaign region, findings of the sampling show that 18 percent of the cattle were not sprayed with deltamethrin at any point.

When considering that 17% of the cattle that were sampled were not present during SOS treatment activities and can be considered to have been either imported or born, since the SOS intervention, as such the potential coverage rate of the deltamethrin spraying of 82% of the cattle that were present at the time of the SOS intervention.

While the overall coverage of spraying with deltamethrin by the SOS treatment of November 2006 is encouragingly seen to be 82% of the cattle that were within the region at the time of treatment, the fact that only 32% of the cattle sampled had reportedly been sprayed with deltamethrin since the SOS intervention. As deltamethrin is a residual
insecticide it is imperative that it is reapplied at least every three months in order for the cattle to act as live bait and therefore have an impact vector transmission within the SOS intervention region.

Analysis of the data collected on the deltamethrin spraying coverage shows that although the coverage at the time of SOS intervention was to a high level (although not as high as the reported trypanocide coverage), the fact that there has not been continued spraying of the cattle population with residual deltamethrin means that the re-introduction of trypanosomes would be expected.

### 3.3.12. Treatment status of individual cattle shown to be positive with *T. b. rhodesiense*

With the establishment of the prevalence of *T. b. rhodesiense* within the cattle included at each of the sampling time-points, through referring back to the data collated during each of the sampling sessions about the SOS treatment status of the sampled cattle a breakdown of the treatment status and infection of cattle can be constructed. The baseline sampling time-points is not of relevance to this as none of the animals had received treatment when the samples were taken.

![Figure 3-28: Reported SOS treatment status of the cattle found *T. b. rhodesiense* positive](image)
Figure 3-28 shows that the animals positive for *T. b. rhodesiense*, three, nine and 18 month post SOS intervention were mainly cattle that had been within the SOS area during the treatment programme.

During the three month post SOS sampling session the animals shown to harbour *T. b. rhodesiense* were as likely to have been treated by the SOS intervention and un-treated but were present within the intervention region.

Ninety percent of the *T. b. rhodesiense* positive samples from the nine month post SOS sampling session are seen to come from animals that were treated during the SOS programme while ten percent of the positives came from imported cattle.

At 18 months 45% of positive samples came from animals that had been treated during the SOS programme and 45% from cattle that were not untreated by the SOS programme, but that were present in the region during the operation. Cattle that have been imported since the SOS intervention programme account for 10% of all sampled animals found to be positive for *T. b. rhodesiense*.

Some of the animals shown as present but un-treated by the SOS intervention will have been calves during the treatment period and therefore left untreated.

### 3.3.13. Ages of sampled cattle

The ages of the cattle that were sampled during each of the sampling time points is indicative of the status of herd health, as a healthier population will generally have a higher proportion of younger members.
The age groups of the animals sampled during each of the SOS monitoring sessions is shown in Figure 3-29, the data shows no change in the proportion of the three age groups that were sampled. This is indicative of stable reproductive health status of the sampled cattle population but since adult cattle are continually traded into the area it is possible that the overall cattle population has increased throughout the age group categories.

### 3.3.14. Cattle introduction post SOS intervention

Figure 3-28 shows that during the nine and 18 month sampling time points about 10% of the cattle found to be infected by *T. b. rhodesiense* were newly acquired since the SOS treatment programme of November 2006. Importation of cattle is likely to contribute to the re-establishment of *T. b. rhodesiense* within the SOS treatment area, accompanying the evidence collected indicating that approximately 10% of the cattle within the sample site had been introduced since the SOS intervention (as shown in Figure 3-28).

The rate of introduction of cattle into the SOS treatment region included in the November 2006 is examined in Chapter 6, through analysis of inter-district movement permit
records. Permits were collected from the markets trading the largest volume of cattle within the established *T. b. rhodesiense* afflicted region of south eastern Uganda.

The assessment of the cattle numbers being introduced into the SOS treatment region correlates directly chronologically with the post SOS sampling sessions for comparison with the findings of the sampling above.
3.4. Discussion

The point prevalence of *T. brucei* s.l. within the SOS intervention region (November 2006) was reduced significantly from a prevalence of 15.57% to 4.87% three months post treatment *P*=<0.0001, a reduction of 68.37%. The profound decrease in the prevalence of *T. brucei* s.l. indicates that the SOS intervention had an effective impact upon the region.

The point prevalence of *T. b. rhodesiense* prior to the initiation of the intervention was 0.81% and this shown to have significantly decreased by 88.42% (*P*=0.0018) three months post treatment to 0.11% (two cows positive of 1786 sampled). This confirms that the SOS intervention had a profound impact upon the prevalence of the zoonotic *T. b. rhodesiense* within the cattle population within the region.

By nine months the point prevalence of *T. brucei* s.l. had increased and returned to the prevalence seen at baseline with no significant difference (*P*=0.6422). Eighteen months post treatment it had significantly increased to a point prevalence of 27.44% (*P*=<0.0001) The prevalence of human infective *T. b. rhodesiense* in sampled cattle also increased nine months post intervention but this was not found to be significantly different from the baseline. However unlike *T. brucei* s.l. the prevalence was not found to increase at 18 months post intervention (*P*=0.6630).

The proportion of the *T. brucei* s.l. parasite pool that is shown to be *T. b. rhodesiense* has been shown to reduce from the baseline finding of 5.18% to 2.29% at three months post intervention this reduction, although not statistically significant (due to the low detected prevalence of *T. b. rhodesiense*) this reduction from baseline is sustained at 18 months where the percentage of *T. brucei* s.l. positive samples that were shown to be *T. b. rhodesiense* was shown to be 1.94%. This indicates strongly that the SOS intervention has reduced the proportion of zoonotic *T. b. rhodesiense* within the overall population of *T. brucei* s.l. parasites.
Analysis of the number of villages that harbour *T. b. rhodesiense* infected animals is shown to have reduced from ten sites during the baseline sampling, to only two three months post treatment, three villages during the nine month sampling (none of which were the same as the three month results) and six sampling sites at 18 months post intervention sampling.

Trypanocide treatment proved successful at initially reducing the prevalence of trypanosome species in the cattle population. In the absence of protection re-infection would be expected. However re-infection of cattle (in particular with *T. b. brucei*) is indicative of a failure to protect sufficient animals using RAP.

Data collated at post intervention sampling puts the overall treatment coverage at 61% of the animals sampled. The maximum proportion of animals reported as having been treated was recorded at the three-month sampling event as being 79% (below targeted figure of 86%). When the influence of new cattle introductions is factored - 4% of the cattle sampled had been imported to the region since the SOS intervention this puts treatment coverage at 83% of all animals present in the area during November 2006.

Areas that received trypanocidal treatment using different trypanocidal agents have showed no significant variation in terms of prevalence of both *T. brucei* s.l. and *T. b. rhodesiense* from the baseline sampling time point as well as the three month and 18 month post SOS sampling points. Interestingly the prevalence of both *T. b. rhodesiense* and *T. brucei* s.l. is seen to be statistically different between the areas treated using isometamidium chloride and DIM at the nine month sampling time point, with the area of isometamidium chloride treatment having a higher prevalence for both species. When considered with relation to the area that was designated high risk, it is clear that the area of isometamidium chloride treatment (Dokolo and Kaberamaido districts) is largely covered by the high risk area. As such it is likely that the prophylactic period has been over-powered by the higher risk nature of the area it was used in.
The SOS intervention was not just to treat the cattle with trypanocides, but also to educate the local community, particularly cattle keepers, on the benefits of sustained deltamethrin based insecticide spraying of the cattle. Spraying being specifically targeted at reducing the tsetse challenge within the SOS region, but also having beneficial effects upon the tick burden and occurrence of tick-borne diseases to the sprayed animals.

The data provided by Makerere showed that the coverage of the first of the scheduled spraying sessions after the intervention had a low coverage rate, this is attributable to the fact that the deltamethrin was left within the target area (with community leaders) for the local population to administer to the cattle. However, in practice this logical notion was resoundingly ineffective as those in charge of the deltamethrin often demanded the community pay them for each animal sprayed, or simply just sold the products on.

The second scheduled spraying session was re-designed and Makerere personnel were placed in charge of the spraying schedule and insecticide. This strategy proved to be more successful with over double the number of cattle reportedly being treated, with approximately 170% of the estimated cattle population being covered by the operation of June and July 2007 (which was carried just after the nine month sampling time point).

The data collected during the cattle sampling for molecular analysis of the SOS programme’s effect indicated that the spraying coverage achieved post treatment was far lower than calculated using the cattle population estimates. The proportion of the sampled animals (from three, nine and 18 months post intervention) that were sprayed at any subsequent points since the first SOS intervention was seen to be 32%.

Analysis of the blood samples collected for evaluation of the SOS intervention programme showed an area within the intervention region to have a continued burden of the *T. b. rhodesiense* parasite within the cattle population. Analysis of the case records of human sleeping sickness patients originating from the SOS region a correlation between the foci of human cases and the spatial distribution of the villages that provided *T. b.*
*rhodesiense* samples became apparent for the time-points of the three month and nine months sampling.

Referring back to the baseline data the area of this foci is seen have established *T. b. rhodesiense* infection prior to the intervention, thus the presence of the foci can be said to have continued from previous to treatment. However during the course of this is research a secondary follow up SOS retreatment was suggested and implemented, reinforcing the SOS action against acute sleeping sickness within the area of continued infection.

The reasons as to why a focus of *T. b. rhodesiense* persisted after the SOS treatment programme was active are examined within Chapter 4 of this thesis.

Comparison between the results from the re-treatment area and those situated outside of this higher risk area shows that samples collected from within the high-risk zone (that received re-treatment during April 2008) were higher in prevalence for *T. brucei* s.l. both prior to and subsequent of the November 2006 SOS intervention.

Likewise the prevalence of *T. b. rhodesiense* within these same sample groups was shown to be higher (not significant), due to the low detected prevalence within the high-risk area during all sampling time-points than the sites situated outside of this area.

Continually detected higher prevalence of *T. b. rhodesiense* burden within the cattle of this high-risk area also supports that the majority of human trypanosomiasis cases from within the entire SOS region are originating from villages included within the high-risk area, due to the disease being predominantly within this area. Not that it was commonly occurring (at the time) elsewhere within these regions. But these individuals are either not seeking medical assistance or are remaining undiagnosed due to inadequately trained or equipped locally available medical facilities.

For the additional sampling sites included during the 18 month sampling session it is suggested that there was a higher detected prevalence of *T. brucei* s.l. within these new
villages both at baseline (where available) and during the 18 month sampling when compared to results from the 23 that were regularly sampled. Specifically with reference to the *T. b. rhodesiense* findings, the prevalence of new villages is seen to be insignificantly different to that of the existing villages due to the small number of animals detected as positive. The most credible explanation of this is that during the baseline collection occurring within the local community, information about the impending SOS treatment and its importance to both human and animal health was shared with the community. Leading to heightened community awareness and understanding of the SOS treatments reason and effects upon the animal and human population thus causing an improved turnout for the treatment throughout the local area. As opposed to the villages that were not sampled and as such may not have received this level of understanding and reassurance concerning the SOS programme.

Spatial examination of the sample sites where samples were shown positive for *T. b. rhodesiense* during the 18 month sampling session (immediately prior to the retreatment programme of April 2008) shows that the sample site proved to harbour the species not only increased in number but also in range throughout the study region. Of the eight sample sites returning as positive (two of which were newly included for the 18 month sampling) four were located within the area determined as high-risk and allocated for retreatment. Of the remaining four, three were within the Lira district, the northern-most district of study. Lira has previously provided a positive sample during the three month sampling session but this was from a newly imported animal.

Since there is now a higher spread of detected *T. b. rhodesiense* than previous it is strongly suggested that the parasite has re-distributed throughout the area. The final remaining positive site was detected as being in the northern portion of Dokolo district and had previously been shown to harbour *T. b. rhodesiense* during the baseline sampling, but has been found clear of the species during the three and nine month sampling sessions. With this return of the zoonotic parasite to these areas found cleared during analysis of the three and nine month sampling, it is implied that the species has gradually regained strength within these areas since the SOS treatment activity. Reports
of increasing numbers of patients originating from the districts of Dokolo and Lira, correlating with the time-line of the findings from cattle sampling further galvanises the notion of the parasite either re-emerging or becoming re-introduced within this area.

Sample sites that were selected upon the basis of having been the home village locations of HAT cases predating the SOS initiative were shown during the baseline sampling to have cattle infected with *T. b. rhodesiense* at a comparable level to the remaining selected sites, three of the five HAT positive sites (60%), compared to eight of the 25 HAT negative sites (32%). Post SOS treatment sampling shows a shift in this with five of the 25 HAT negative sites (20%) harbouring cattle infected with *T. b. rhodesiense* while four of the five HAT positive sites (80%) have provided positive samples during combined post intervention sampling.

With reference to the order that treatment occurred this might be attributable to the areas of high HAT occurrence (albeit detected occurrence) receiving treatment before the remaining lesser HAT affected areas being treated. Community suspicion was a consequence of lower treatment coverage within the HAT affected areas (see Chapter 4).
3.5. Conclusion

The SOS intervention programme of November 2006 was effective at reducing the prevalence of *T. b. rhodesiense* within the reservoir body, as is documented by the reduction in detected prevalence of the species between the baseline and the three month sampling survey. However, it is clear that the pathogen was not effectively controlled to a point at which the reproduction rate was less than one and the species is eliminated from the cattle reservoir within the SOS control region.

Even at the three month sampling point, two of the 23 sampling villages proved to harbour the zoonotic species, taking into account there are in excess of 1,000 villages within the SOS region, the detected ratio indicates that at least 87 villages will have hosted cattle with the parasite within the controlled region just three months after the programme occurred. Whereas according to the baseline finding of 10 out of the 23 locations hosting the species puts the number of villages potentially harbouring the parasite near to 435, which while a drastic reduction is not an effective control.

The treatment coverage of the cattle within the region during the intervention is seen to be 83% which is 4% short of the target 86% coverage for eradication of *T. b. rhodesiense* in the region. While the treatment coverage within the sampled population was high, the reported level of spraying within the same sampled animals was substantially lower, with only 32% having been sprayed since the SOS intervention. Hence it must be concluded that the return of prevalence to the baseline level which was seen in both *T. brucei* s.l. and *T. b. rhodesiense* (with *T. brucei* s.l. surpassing the baseline prevalence by 18 month sampling) is due to the inadequate cattle spraying coverage which did not impact the tsetse population nor prevent re-infection of cattle that had been treated.

Finally it was indicated that the utilisation of prophylactic treatment had little impact upon the prevalence of target trypanosome species post treatment, upon reflection as the prophylactic was used within an area of higher risk of trypanosome infection this assessment is not made upon even environmental situations.
4. Assessment of SOS intervention as perceived by the participants

4.1. Introduction

From the spatial analysis of sites shown to have continued burden of *T. b. rhodesiense* within the cattle population and the clustering of Human African Trypanosomiasis (HAT) cases reporting to Lwala and Serere hospitals it is apparent that the SOS programme of treatment and spraying must be considered only a partial success.

With the specific localities of *T. b. rhodesiense* that have remained since the SOS treatment programme, particularly during three and nine month post treatment sample points (as shown in Chapter 3). It is highly relevant to assess the perceived affectivity and efficiency of the programme by the persons whom were involved with the treatment activities. The insight they may be able to provide has the potential to explain why the SOS intervention programme was not sustainably effective within these specific areas.

The perceived effectiveness of the SOS programme will be assessed through use of structured interviews with the veterinary student personnel who were involved with administering the treatments, also members of Makerere staff that were involved with the planning stage of the intervention programme.

By gaining the insights of the two levels of personnel that were involved with the planning and application of the SOS intervention programme, it is likely that a clear picture will be gained of the issues and problems that were encountered both at an administrative level as well as during the field treatment programme.
4.1.1. Assessing the SOS treatment programme

Along with ascertaining what problems were encountered during the SOS programme and where specifically they occurred it is important to establish the perceived coverage rate of the programme interventions. From Chapter 3 it can be observed that the rate of coverage generated from the questioning of cattle handlers during the post SOS sampling showed a different perceived SOS coverage rate (83%) to that based upon cattle population estimates, quoted by Makerere University, as service providers (103%). The responses from the personnel may provide reasons for this perceived discrepancy.

Furthermore, the accuracy of the dosage administration was investigated, since both trypanocides, ISO and DIM, are administered according to animal body weight and due to the lack of weight estimations (i.e. no weighing parameters) the weight of animals was largely based on an estimation. This has the potential to lead to under dosing of animals, resulting in trypanosome infections not being cleared by the treatment (Machila et al., 2003).

4.1.2. Community involvement and understanding of SOS programme

To accompany the administration of trypanocides by the SOS personnel, basic training was to be provided to the community member on the importance and benefits of restricted application spraying cattle with deltamethrin (sold under the brand name Vectocid). The delivery of this information is investigated as the lack of continued deltamethrin spraying is heavily indicated by the return of both T. brucei s.l. and T. b. rhodesiense within the cattle population seen since the SOS programme.

Community understanding of the SOS programme is also of relevance due to the fact that the cattle are a major commodity of households; as such if the people are not sure what the benefits of the SOS intervention was they were far less likely to bring their cattle for treatment by injection. This relates to the treatment coverage as those that are unsure or untrusting will not have participated.
4.1.3 Improvements to SOS programme

With the insight to the running of the SOS intervention programme the staff members had during operation, their views upon how the programme could have been better ran or promoted, are likely to be useful to any future operation. These matters may be seemingly trivial, but are likely to have considerable impact for those on the ground.

4.1.4. Chapter aims

This chapter aims to establish if there is any direct correlation between the continued presence of *T. b. rhodesiense*, in the areas of northern Kaberamaido and southern Dokolo, with specific problems encountered by SOS programme staff and Makerere students while in the field. The nature of these problems and how they could be overcome, or reduced, also the quality of information concerning post treatment spraying of cattle will be ascertained and assessed in terms of disease re-infection.
4.2. Methods

The method for obtaining information for qualitative evaluation of perceived problems with the SOS programme will be focussed upon the responses of the SOS personnel during structured interviews, which were conducted individually with each interviewee so as to avoid generic responses.

The focus of the interviews fall evenly upon the planning, preparation and execution of the SOS programme of November 2006, as such establishing a list of available operatives must be the first priority. While this list of operatives will serve no purpose for the results, it is vital to know who was involved with the SOS intervention programme before any interviews can be instigated.

4.2.1. Selection of interviewees

Information concerning who was active with the SOS programme was collected from two sources; firstly from Prof. Charles Waiswa who was one of the primary organisers of the treatment programme and secondly from Dr. Benard Agwaii who has close links to the student work force that were active during the treatment programme. Through the approach of gaining suggestions of available interviewees it is likely that a cross section of organisers and treatment staff will be interviewed. The interviews were carried out in person mid February and April 2009 in conjunction with other field work activities.

4.2.2. Cross section of interviewees

It is crucial that the interviewees were a selection of all involvement levels of the SOS programme, there are three levels of involvement that interviewees could have: Highest up is the organisational staff that were responsible for planning the whole treatment programme. The mid-level is the supervisory personnel whom were charged with managing the individual treatment sites (including treatment teams) while working in the field. Finally are the treatment personnel themselves, which were actively treating
animals within the SOS region, although it should be noted that the supervisory personnel also treated animals at the site but generally had more involvement with planning of operations than the treatment staff.

With this cross section of the three groups of SOS workers it is likely that any issues as regards planning, preparation and execution of the SOS intervention can be identified.

4.2.3. Timeline of questionnaire in relation to SOS programme

Due to the fact that these interviews were sought after approximately two and a half years after the SOS treatment programme was conducted, many of the student members of the treatment team will have left Makerere University. As such will need to be located if they have remained within Kampala, or the surrounding regions of Uganda.

Another aspect linked to the length of time between the treatment programme and the interviews is the ability of the interviewees to recall specifics concerning the programme. Recall of information such as what the problems were and how these may be addressed in future operations is set to remain highly accurate. Whereas recall of specific details such as the precise parishes where defined problems were encountered is highly likely to be recalled with far less clarity as many of the personnel were involved with operations in many different regions included within the treatment operation.

4.2.4. Interview structure

The interviews were structured, following a questionnaire format, where the interviewees were able to give answers in the form of free prose, or if they were in need of prompting, multiple choice answers were prepared. The interviews took between 10 and 15 minutes to conduct and it was attempted to run the interviews outside of office hours so not to disrupt the working environment too much. A copy of the questionnaire upon which the interviews were based is included within Appendix 1.
4.3. Results

In total 16 members of the personnel from the SOS intervention programme of November 2006 were interviewed. Data collected from the interviews has been analysed here to extract specific information and opinion concerning the shortfalls of the treatment programme and how these can be addressed in any future operations.

4.3.1. Roll played by interviewees during SOS operation

Analysis of the interviews show that of the 16 persons interviewed nine were supervisors of the treatment operations and six were treatment personnel during the November 2006 SOS intervention, finally one interviewee was in charge of organising the whole treatment operation.

This indicates that the interviews have been conducted with a spread of the personnel involved with the treatment operation, avoiding getting responses from just the students, whom may have encountered different issues seen by the supervisors.

4.3.2. Duration of interviewees involvement with SOS

Assessing the length of time that the interviewees were involved with the SOS programme is worthy of consideration as if all the operatives were only involved with the initiative for a brief period of time it is likely that they will have a restricted knowledge of the issues that were encountered by the SOS intervention.

With this the case this question was more to assess the interviewees’ suitability as a credible source of accurate information concerning the running of and problems associated with the SOS treatment programme.
Figure 4-1 shows that from the 16 members of staff interviewed only three had been active with the initiative for two weeks or less. With this the case the level of experience that the interviewees had with the November 2006 SOS treatment programme can be considered sufficient to give a grounded account of the problems that were encountered for analysis within this chapter.

4.3.3. Districts worked in by interviewees

The SOS treatment programme was active treating sites within five separate districts, it is important to have assessed where the interview participants were involved with the animal treatment as if the interviewees were all deployed within the same district, the information obtained will only be relevant to that specific district.

<table>
<thead>
<tr>
<th>District</th>
<th>Number</th>
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<tbody>
<tr>
<td>Kaberamaido</td>
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<td>Amolotar</td>
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<tr>
<td>Dokolo</td>
<td>13</td>
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<tr>
<td>Lira</td>
<td>5</td>
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<td>Apac</td>
<td>7</td>
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Table 4-1: Districts interviewees were active with
Table 4-1 demonstrates that the interviewed personnel were active within all five of the districts. It can be seen that there is a higher level of involvement within the districts of Kaberamaido and Dokolo than was seen from the interviewed staff members in the district of Amolotar, Apac and Lira listed respectively in order of reported involvement.

Although fewer of the interviewees reported having operated in the districts of Lira and Apac than others, these interview responses provide enough information to assess the SOS intervention within these five districts.

4.3.4. Constraints encountered during the SOS campaign

The reported problems that were experienced by the SOS intervention personnel are examined in Figure 4-2, the results show that the lesser reported issues were associated with the supply and administration of the trypanocidal drugs and deltamethrin spray.

Meanwhile issues concerning the mobilisation, community trust and uptake of the programme along with the crush facilities to restrain the cattle during treatment and finally the transportation of treatment teams to the treatment sites are all reported at least five times each as being problematic to the running of the SOS programme.

The most reported problem is seen to be that the sites were poorly equipped with crushes with ten reports; following this is reports of poor mobilisation and poor community response to the mobilisation, which had seven reports each. Lower still are the problems of community distrust of the SOS programme and the transport to and from the treatment sites with five reports each, this indicates that it is these most reported issues that were the most influential upon the SOS treatment regime.
Figure 4-2: Reported problems encountered during SOS treatment initiative

- Poor mobilisation
- Poor response to mobilisation
- Community distrust of SOS treatment
- Inadequate supply of trypanocides
- Inadequate supply of deltamethrin
- Inadequate supply of syringes and needles
- Issues with spraying mechanisms
- Difficulties assessing animal weight / correct dosage
- Too few students to treat number of cattle
- Transport to and from treatment sites
- Treatment sites had no crush

Figure 4-3: Suggested ways to improve future SOS coverage

- More mobilisation
- Improved community education
- Improved provision of trypanocides
- Improved provision of insecticides
- Improved crush construction
- More involvement of local community
- Increased community awareness of SOS programme
- Political involvement
- Better equipment
4.3.5. Methods to improve coverage of future SOS activities

Along with ascertaining the problems that were encountered by the SOS programme the interviewees were also asked how they would go about improving the coverage rate. Their responses are displayed in Figure 4-3, showing that the most cited means to improve the coverage are through improved community education and increased community awareness of SOS both had over 10 responses each. More mobilisation within the SOS region is also frequently suggested as a means of increasing the treatment coverage with nine responses, attached to this is the suggestion of having more community involvement with the programme which was recommended seven times.

Interestingly five of the interviewees suggested that improved crush construction would result in higher SOS coverage, this level of suggestion is half the number of interviewees that indicated that poor crush construction was a problem encountered by the SOS programme. The fact that a lower number of interviewees have suggested crush construction as a means to increase coverage indicated that while poor crushes were a nuisance they did not impede the coverage as much as low mobilisation activities.

Interviewees indicated that increased political involvement, better equipment, improved provision of trypanocidal drugs and the improved provision of deltamethrin insecticide are not as important to ensuring the improved coverage of future SOS programme operation. This suggests that these aspects were effective for the SOS programme of November 2006.

4.3.6. Recall of where problems with SOS programme occurred

It was the initial intention to assess the localities where problems were remembered to be most disruptive to the SOS programme to the local parish level. It quickly became apparent that this level of recall specificity was unobtainable from the majority of participants on account of the length of time between the SOS programme and interview.
As a result the responses of the 14 interviewees who were able to recall any specificity are assessed at a district level.

![Districts where specific problems were recalled](image)

**Figure 4-4: Districts where specific problems were recalled**

The data shown in Figure 4-4 shows that the highest rate of recalled problems is within the district of Kaberamaido, this correlates with the specific area of continued *T. b. rhodesiense* infection (discussed within Chapter 3). Of the three interviewees that were able to recall where the problems occurred to the parish level all named parishes within the SOS retreatment area of April 2008 (Figure 1-12).

Dokolo district had a high rate of *T. b. rhodesiense* infection within both cattle and humans but reported fewer reports of specific problems than Kaberamaido which is indicative that the SOS programme operated better within this district when compared to Kaberamaido, but the issue of continued ingress of *T. b. rhodesiense* was common to both districts.

Lira had reported no problems and this could be due to the different levels of mobilisation and sensitisation conducted by the DVO and other authorities, however it is more likely to be due to the centralised nature of the population of the district at the time. With respect to the fact that the majority of the district’s rural population was living...
either in large IDP camps or smaller satellite camps, as such the dissemination of information would have been easier than through a more dispersed civil situation.

4.3.7. Proportion of cattle treated by November 2006 SOS programme

Cattle treatment rates reported by Makerere were based upon the estimated cattle population size and are inconsistent with results from analysis of the reported treatment status of the cattle sampled for analysis of the SOS programme. Interviews with staff members (November 2006 treatment) may clarify the true coverage rate for SOS.

Figure 4-5: Interviewees' interpretation of SOS cattle treatment coverage

Figure 4-5 shows that the most frequently given response was that the 2006 SOS programme achieved a coverage rate of between 70 and 80 percent of the cattle population. While four members of the SOS personnel held the opinion that between 50 and 70 percent of the regions cattle received treatment and three reported a coverage rate of between 80 and 90 percent, furthermore three interviewees did not feel able to recall the treatment coverage. This is lower than the reported 102.6% but is still relatively close to the observed 83% coverage rate from Chapter 3 which galvanises this as being closer to the true coverage rate than 102.6%.
4.3.8. Accurate dosing of cattle

It is also necessary to consider the possibility that *T. b. rhodesiense* may have been able to remain within the SOS treatment region as a result of cattle being treated with inappropriately low volumes of the trypanocidal agent, which would be insufficient to clear the parasite from the individual and resultantly the overall population. This is a realistic option as the trypanocides are administered by volume in accordance to the body mass of the specific animal and as scales were not available, or appropriate to such a large scale operation, it is entirely conceivable that animals were misjudged on weight and resultantly under dosed.

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<td>Unconfident</td>
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</tr>
<tr>
<td>Not confident at all</td>
<td>0</td>
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*Table 4-2: Confidence with trypanocide dosing by SOS operatives*

Table 4-2 shows that the overwhelming majority of interviewees were highly confident that the correct dosage was administered to the treated cattle. In addition one was extremely confident and only one responded that they were unsure if the cattle were correctly dosed. Finally the two responses that appear in the unconfident response section are misleading, as these participants specified that they were sure that no under dosing occurred but were adamant that animals were frequently overdosed by the treatment programme, which will have increased the likelihood of parasite clearance.

4.3.9. Community understanding of SOS programme

Whether the communities within the SOS intervention region understood the purpose and methods of the control programme is an accurate gauge as to whether there were appropriate levels of sensitisation within the area. Letting the cattle keepers know firstly
what the purpose of the treatment was and secondly how the treatment worked and what potential side effects could arise in their animals. Insufficient sensitisation is highly likely to result in distrust by the community leading to low coverage of the cattle population, due to the high financial importance of the cattle to the community. To assess this, the treatment participants were simply asked if they believed the community understood the aims of the SOS programme.

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</tr>
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Table 4-3: Perceived community understanding of 2006 SOS programme

Table 4-3 show an even split in the treatment personnel’s opinions whether the community of the SOS intervention region understood the programmes purpose, aims and methods. This result provides an indication that that the communities understanding of the purpose of the SOS intervention programme was mixed. Further examination of the district that each interviewee was active within will provide further insight, since personnel active within different districts may have encountered different levels of understanding within the communities within which they worked.

Figure 4-6: Personnel’s responses to whether the recipient community understood the SOS programme, split to indicate where treatment staff were active
The data presented in Figure 4-6 show that interviewees who perceived the community as fully understanding of the SOS programme were relatively evenly spread throughout the five districts included. Interviewees whom perceived the communities to have not understood the intervention programme were more active in the districts of Dokolo and Kaberamaido. This is interesting as the results shown in Figure 4-4 indicate that the recalled problems were primarily in Kaberamaido with very few indications of Dokolo having provided specific problems.

The outcomes of Figure 4-6 are suggestive that there were also issues relating to poor community understanding and therefore, lack of trust and lower treatment coverage in Dokolo that were perhaps not remembered as well as those encountered in Kaberamaido.

4.3.10. Passing on knowledge about restricted application spraying to the recipient community

During the SOS treatment intervention, personnel were briefed to instruct and demonstrate the practice of restricted application insecticide spraying to the cattle herders and owners. The aim of this educational engagement was to encourage the uptake of this method for the control of both ticks and more importantly in terms of the SOS programme the tsetse vector of *T. b. rhodesiense*.

Together with contributing to vector population control the application of deltamethrin based insecticide to the preferred feeding sites of both the tsetse and local tick species will also reduce the incidence of re-infection of the cattle population.

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<td>Farmers knew already</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4-4: Responses to whether the interviewees felt farmers and herders understood the principles and benefits of restricted application insecticide spraying

Results from the interviewees (shown in Table 4-4) show an even split in the opinion of the interviewed treatment personnel concerning whether the farmers and herdsmen whom
attended the SOS treatments understood the principles and benefits of restricted application.

When these responses are correlated to where the individuals were active with the SOS programme, of the participants who thought that the community understood the restricted application four were active in all districts that were included, one worked in all but Lira, one worked in both Kaberamaido and Dokolo, one just in Dokolo and one only in Kaberamaido. Of the participants who did not think that restricted application was fully understood, four were working in Kaberamaido and Dokolo districts, one worked in Amolotar and one person was active in all five districts. There is a correlation in involvement only within the two districts of Dokolo and Kaberamaido and the opinion that the information concerning restricted application of insecticide to cattle was not understood by the local community.

In contrast, persons involved with treatment in other districts are more likely to be of the opinion that the principles of restricted application were understood. Kaberamaido and Dokolo were the first to host the SOS treatment activities and it is likely that positive experiences encountered in subsequent districts will supersede the recollection of poor understanding by the community in the first districts to be visited.
4.4. Discussion

The primary aim of this chapter to investigate the recalled specific problems that were encountered during the November 2006 SOS treatment programme with the area within Dokolo and Kaberamaido that was found to have continued *T. b. rhodesiense* burden within both the cattle and human populations, was seen to be partially successful through directly asking participants where they recalled issues. This method indicated that of the 13 interviewees who were able to recall where issues occurred, Kaberamaido was heavily reported as having presented problems to the conduct of the treatment, Dokolo district was far less indicated with only two of the interviewees stating issues arose while operating there.

While directly recalling which districts were problematic would have likely been highly accurate directly after the SOS activity of November 2006. The fact that the interviews were conducted after the elapse of two and a half years will undoubtedly have affected the recollection of which areas presented problems. To galvanise this point, Kaberamaido was the first district that the SOS programme was active in. As such the recollection of this location as problematic is likely to stem from it being the first place problems were encountered. If they were encountered again the individual could have became desensitised to them and therefore they are less memorable than when first encountered.

Through analysing the responses of where the individuals that thought the community had not comprehended the SOS programme in relation to where these personnel members had been active. The majority of interviewees worked in Kaberamaido and Dokolo and all held the opinion that the community did not understand the programme. The communities within these two districts were less aware of the SOS programmes activities and aims than the three other treated districts.

The treatment personnel’s opinions about the coverage rate that the November 2006 SOS programme achieved indicates that most of the individuals questioned felt that the true coverage rate was between 70% and 80% of the cattle population. With no respondents feeling that coverage was more than 90%. This is indicative that the treatment coverage
rate established from the cattle of the 23 sample sites is more accurate than the extremely high figure produced from cattle population estimates.

Combined with the treatment coverage is the assessment of the administration of correct dosage of trypanocide to the cattle. The results show that the confidence levels of the interviewees were mostly high. With only two respondents stating a lack of confidence in accurate dosing, both these individuals freely stated that the cattle were commonly overdosed and under dosing was not an issue. This means that the potential for the survival of trypanosomes within treated cattle as a result of insufficient chemotherapy is not an issue to have contributed to the continued *T. b. rhodesiense* burden within the districts of Kaberamaido and Dokolo.

Specific problems reported by the personnel showed that the most commonly cited constraint to activities was that the sites were poorly equipped with crushes to restrain the cattle in during treatment. However when the individuals were asked how they would improve the coverage of future SOS programmes, few responded that improved crush construction would be on their agenda. This indicates that the lack of suitable crushes was more an inconvenience than a major problem.

The second most commonly cited problems that were encountered by the intervention was poor mobilisation and poor response to mobilisation. This is potentially more critical to the success of the SOS intervention than crush construction as the coverage had to be at least 86% of the cattle population. If the cattle keepers were not aware of the programme or simply indifferent to the activity this coverage rate will be unobtainable.

Accompanying the poor response to mobilisation is the problem of community distrust of the activity, which is primarily based upon fears of taxation of cattle and similar activities in recent years causing side effects. Appropriately the suggested methods to improve the coverage of future SOS programmes are seen to have ranked the provision of more mobilisation prior to treatment dates, improved community education and increased
community awareness of the SOS programme as the three most commonly given means to improve overall coverage.

Few interviewees identified inadequate supplies of trypanocides and deltamethrin as hindering the programme and the application methods of treatments was rarely cited as a problem.
4.5. Conclusion

The issues surrounding the SOS intervention of 2006 perceived by the staff and students involved with the planning and treatment of the intervention, that were most significant in relation to the incomplete control of *T. b. rhodesiense* within the region leading to breakthrough of HAT species within the cattle population, were investigated.

Responses show that the overall interpretation was the SOS intervention would have been more successful if mobilisation and sensitisation (informing the local community of the treatment and why it is important in terms of animal and human health) was extended throughout the SOS region. This action would certainly have improved the coverage rate of the SOS treatment programme, making it highly likely that the prevalence of *T. b. rhodesiense* would have reduced further than was witnessed from the previous analysis.

Recall of where problems occurred has indicated that Kaberamaido was where most issues were encountered and as such is the area likely to remain afflicted by *T. b. rhodesiense* burden. When compared to the data concerning the foci of human and cattle associated *T. b. rhodesiense* presented in Chapter 3, it is apparent that there is a spatial correlation between the recall of problems in Kaberamaido district and the continued parasite burden in this area. Although one might expect Dokolo to also have been recalled in relation to problems as this district also had a high continued incidence of the zoonotic pathogen species, this may be explained as Kaberamaido was the first area to be worked, and more of the interviewees had been active in this area than were in Dokolo.

It is apparent that the problems that lead to the November 2006 treatment intervention to not be entirely successful in the region that required retreatment during April 2008, were more related to the mobilisation and sensitisation of the local community to the time and location of treatment as well as its purpose and potential side effects. This is not to say by any means that a bad job was done, the overall treatment coverage rate has been shown to be 83% of the cattle sampled for SOS analysis, shown in Chapter 3. What can be said however is that the community understanding and trust of the SOS programme within the area that needed retreatment was substantially lower than other areas. Whereas the areas
that were treated later during the programme had a better impact in the *T. b. rhodesiense* population within cattle, and fewer reports of problems during the treatment activity, than was seen within the area that needed further intervention.

As such it is clear for future operations it is of vital importance for full sensitisation to be carried out at a village level, talking to the village leaders directly so that their questions and grievances can be dealt with directly. While this is a labour intensive suggestion, with the provision of motor cycles to a team of mobilising personnel will make penetration to these rural communities most effective. Instead of reliance upon a few radio broadcasts which may not be heard at all in areas of this linguistically diverse region, or the political leaders to distribute information to their lower ranking colleagues.
5. Social aspects of cattle restocking

Within the northerly regions of Uganda there are many social factors that contribute to the situation of cattle movements that will be investigated throughout the second section of this thesis. The underlying reasons for this situation are described in Chapter 5.

5.1. Tribal distribution and power in Uganda and the northern region

The population of Uganda is sub-divided into roughly 19 different traditional tribes, the largest of which are listed in Table 5-1 along with their size as a percentage of the overall Ugandan population.

<table>
<thead>
<tr>
<th>Tribe name</th>
<th>Percentage of Ugandan population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baganda</td>
<td>16.9%</td>
</tr>
<tr>
<td>Banyakole</td>
<td>9.5%</td>
</tr>
<tr>
<td>Basoga</td>
<td>8.4%</td>
</tr>
<tr>
<td>Bakiga</td>
<td>6.9%</td>
</tr>
<tr>
<td>Iteso</td>
<td>6.4%</td>
</tr>
<tr>
<td>Langi</td>
<td>6.1%</td>
</tr>
<tr>
<td>Acholi</td>
<td>4.7%</td>
</tr>
<tr>
<td>Bagisu</td>
<td>4.6%</td>
</tr>
<tr>
<td>Lugbara</td>
<td>4.2%</td>
</tr>
<tr>
<td>Bunyoro</td>
<td>2.7%</td>
</tr>
<tr>
<td>Other</td>
<td>29.6%</td>
</tr>
</tbody>
</table>

Table 5-1: Main tribes of Uganda and their respective populations (2002 census)

With reference specifically to northern Uganda, the tribes in this area are generally spatially segregated although there is some overlap with many tribes coexisting within some districts. Figure 5-1 shows the largest tribes in terms of population numbers within each of the districts of northern Uganda.
As is the case in the majority of countries with tribal or clan based ethnography there are underlying ethnic tensions between many of the groups, with both historic and recent reasons for any grudges and mistrust.

Figure 5-1: Indication of dominant tribes within the districts of northern Uganda, shown in relation to entire country

Figure 5-1: Indication of dominant tribes within the districts of northern Uganda, shown in relation to entire country
5.1.1. Presidents of Uganda

Since independence from the British Empire on 9th October 1962 three of Uganda’s four presidents have originated from northern Uganda (Mutibwa, 1992), the driving factor behinding this is discussed in section 5.1.7.

5.1.2. Milton Obote I

Firstly President Milton Obote, a member of the Langi tribe, initially held high levels of support from the neighbouring Acholi tribe. Obote was prime-minister until March 1966 when he was implicated, along with Idi Amin (at the time deputy commander of the Ugandan army) in a gold and ivory smuggling plot, of undefined quantities from Zaire, now Democratic Republic of Congo (DRC) (Lofchie, 1972, Mujaju, 1987); Obote immediately withheld the constitution and declared himself president. Obote presided over two separate presidential periods (1966 - 1971 and 1980 - 1985), interspersed by the reign of Idi Amin (Mutibwa, 1992).

5.1.3. Idi Amin

Idi Amin was disputably a member of the relatively small Kakwa tribe of West Nile region (Woodward, 1978) dominated by the Alur and Madi tribes in Figure 5-1. He overthrew Obote’s regime by initiating a bloodless coup in 1971 while Obote was in Singapore. In 1972 Amin ordered for all Acholi and Langi officers and enlisted men to return to barracks only to then be massacred, as he felt that officers of these tribes were a treat to his power. This act resolutely affirmed competitive retaliation on an ethnic basis (Van Acker, 2004). The bloodshed of any opposition to Amin was totalitarian and is well documented, with estimated numbers of missing persons ranging between 100,000 and 500,000 with 300,000 being widely accepted as an accurate toll for missing persons during Idi Amin’s reign (Hartman, 2007). In 1979 Amin fled for exile to Saudi Arabia.
after the invasion by Tanzanian forces into Uganda in direct retaliation to the Ugandan air force’s bombing of the Tanzanian town of Mwanza under Amin’s orders.

5.1.4. Milton Obote II

After Idi Amin fled capture by the Tanzanian military Milton Obote was reinstated as president of Uganda.

5.1.5. Tito Okello

The third president from the north of Uganda was Tito Okello an Acholi who overthrew Obote’s second term but had an extremely short-lived interim presidency for six months prior to January 1986 when the NRM (National Resistance Movement) coup seized power and empowered Yoweri Museveni to presidency.

5.1.6. Yoweri Museveni

Yoweri Museveni remains in power to this time. The war that gave way to Museveni’s reign was fought mainly in the region of the Luwero triangle between 1980 and 1986 with accusations of massacres alleged against all of the combatant factions. Since Museveni seized power the constitution has been changed (made possible by the mysterious and unsolved death of the high court judge opposing the proposed change) allowing presidential terms to exceed two terms each up to four years in duration. Currently serving his fifth term in office, Museveni won the general election on the 17th February 2011 and is now set remain in power at least until the next scheduled election in 2015. Although it should be noted that the elections of 2011 were disputed within Uganda due to alleged intimidation of opposition party candidates and supporters, these allegations did not warrant investigation by the international community.
5.1.7. Summary of power within Uganda

The presidents of Uganda have consistently prioritised their own tribe over the rest of the population; this prioritisation has further exacerbated hard feelings between these different tribes (Mutibwa, 1992). The succession of power within Uganda is depicted in Figure 5-2.

![Figure 5-2: Timeline showing ruling powers and recent rebellions in Uganda](image)

It is suggested that there has been an imbalance in post independence Uganda to presidents originating from the north of the country as a result of heavy recruitment from the northern regions by the British Army into the King’s African Rifles regiment, operational from 1902 to independence. This lead to the military of post independence Uganda being overwhelmingly commanded by personnel from these northern regions, as such they were best placed to carry out highly financially prosperous overthrows of the heads of government.

5.2. Rebellion in northern Uganda

Upon the establishment of Museveni into power in January 1986, the tribal dominance of the Ugandan military was realigned from being controlled by Acholi and other northern Ugandans to being controlled by Museveni’s NRM colleagues from south-western Uganda (Kasfir, 2005). This dominance in the military forces was accompanied by the south-western tribes becoming more powerful in business and receiving more benefits of power control.
The newly unemployed soldiers from the north of Uganda resultanty returned to their home districts where rebel groups such as the Holy Spirit Movement (HSM) headed by Alice Auma were successful in recruiting them directly (as most were not familiar with civilian life). Also known as Alice Lakwena (Lakwena was the name of her guiding spirit). The HSM fought government forces for nearly two years before disbanding with Alice Auma fleeing to Kenya. With this lull in the power struggle within Uganda, Joseph Kony, a former fighter of HSM took the mantle of rebel force leader forming the Lord’s Salvation Army (LSA) in 1987; this force was renamed the Lord’s Resistance Army (LRA) in 1992. The mandate for the force was stated to be the establishment of a state ran by the ten commandments and Acholi traditions within Uganda (Doom & Vlassenroot, 1999).

The fighting tactics of the LRA focus upon terrorising the local populations, with many attacks being focused firmly upon the civil population. Abduction of children with males being taken for the bolstering of fighting troops and females being taken to be ‘wives’ of the rebel soldiers (essentially sex slaves), adult civilians are also taken to act as porters for the fighting force. Any abductees that attempted to escape are brutally beaten, often to death by their fellow captives to discourage any further attempts by others (Vinci, 2005). The LRA fighting forces are estimated to number approximately 3000 soldiers with additional 1500 women and children. The fighting forces are organised into independently operating brigades with 10–20 members.

These small fighting force have consistently evaded the much larger and better equipped governmental army known as the Ugandan People’s Defence Force (UPDF), estimated to have between 40-45,000 troops and is funded by approximately 2% of Uganda’s Gross Domestic Product (GDP) ($95 million of Uganda’s GDP $11.23 billion total). This evasion has been possible due to the LRA’s fighting tactics which are focused upon small brigades that do not directly engage the UPDF troops but instead target the civilian population. The succession of rebellion within northern Uganda is chronologically depicted in Figure 5-2.
5.2.1. Displacement of the northern population

Internally Displace Persons (IDP) camps have existed in northern Uganda for over a decade with people choosing to live in the camps that are protected from rebel attack by UPDF forces, however many of the northern residents do prefer to continue living in their villages.

During 2005 the government of Uganda ordered the communities of northern Uganda to move into IDP camps, in response to the continued attacks by the LRA against this civilian population. The IDP camps were formed to ensure the safety of the local population while the UPDF troops engaged the LRA rebels (Dunn, 2004). However the camps were greatly overcrowded with many tens of thousands of displaced civilians living in small areas giving rise to many problems such as sanitation, drinking water supply and resident safety both from LRA attacks on the camps as well as crime and abuse from the protecting forces. Risk of fire is exceptionally high in IDP camps as the grass thatched houses were extremely densely packed and finally, provision of food was also problematic for the camps as residents were unable to cultivate crops or herd livestock.

It is important that it is not thought that camps within Uganda are unique to the impact of the LRA within the Northern region; Uganda has previously had camps for refugees from southern Sudan in West Nile region during the 1980s and 1990s. During November 2008 13,000 Congolese refugees entered south-western Uganda in a single day fleeing fighting reportedly between Rwandese government forces and Tutsi militias. Likewise IDP camps are by no means unique to Uganda with IDP camps existing in Sudan, DRC, Iraq and East Timor to list a few examples.

The districts most heavily afflicted by this enforced move to the IDP camps during the peak of the IDP population during late 2005 are indicated in Figure 5-3, it is important to
note that other districts were also affected. Table 5-2 shows the numbers of each of the heavily affected districts population that were resident in IDP camps in late 2005, with a comparison to the 2006 census data for the population of each district, giving the percentage of the districts population existing in camps.

![Figure 5-3: Indication of districts heavily affected by IDP camps](image)

While the ten of the districts have been heavily afflicted by the civil population being forced into IDP camps (shown in Figure 5-3) the districts with the highest population numbers living within the IDP camps are seen to be Amuru, Gulu, Kitgum, Pader and Lira these districts also have the highest percentage of their population living within IDP camps.
<table>
<thead>
<tr>
<th>District</th>
<th>2006 total population</th>
<th>2005 IDP camp population</th>
<th>Population percentage in IDP camps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjumani</td>
<td>256000</td>
<td>54000</td>
<td>21.1</td>
</tr>
<tr>
<td>Amuru</td>
<td>195700</td>
<td>204000</td>
<td>104.2</td>
</tr>
<tr>
<td>Gulu</td>
<td>331400</td>
<td>257000</td>
<td>77.5</td>
</tr>
<tr>
<td>Kitgum</td>
<td>372600</td>
<td>310000</td>
<td>83.2</td>
</tr>
<tr>
<td>Pader</td>
<td>392600</td>
<td>339000</td>
<td>86.3</td>
</tr>
<tr>
<td>Lira</td>
<td>555800</td>
<td>351000</td>
<td>63.2</td>
</tr>
<tr>
<td>Apac</td>
<td>417000</td>
<td>115000</td>
<td>27.6</td>
</tr>
<tr>
<td>Amuria</td>
<td>244200</td>
<td>72000</td>
<td>29.5</td>
</tr>
<tr>
<td>Katakwi</td>
<td>137200</td>
<td>71000</td>
<td>51.7</td>
</tr>
<tr>
<td>Masindi</td>
<td>480000</td>
<td>67000</td>
<td>14.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3382500</strong></td>
<td><strong>1840000</strong></td>
<td><strong>54.4</strong></td>
</tr>
</tbody>
</table>

**Table 5-2: Percentage of districts population living in IDP camps**

The numbers of residents within the camps are indicated with reference to the geographical locations of each of the districts in Figure 5-4.
Figure 5-4: Indication of districts’ IDP population during late 2005

It is apparent that there is a grouping of the four most heavily afflicted districts in terms of numbers within the IDP camps (Lira, Gulu, Pader and Kitgum). Figure 5-5 shows the overall percentage of the districts population that were living with-in IDP camps in each of the heavily affected districts.
As with Figure 5-4 the neighbouring districts of Lira, Gulu, Pader and Kitgum are seen in Figure 5-5 to be heavily affected, with over half of their population being in IDP camps. Amuru can also be seen to be heavily affected, although having lower numbers in camps, it is made clear in Figure 5-5 that an extremely high proportion of the districts overall population were living in camps during late 2005.
5.2.2. Establishment of peace in Northern Uganda

Since December 2006 the government and representatives from the LRA have been involved in continued peace talks chaired in Juba, southern Sudan. While Kony himself has avoided appearing at any of the sessions due to fear of ambush, a series of high ranking LRA commanders have attended in his absence. Although there have been numerous walkouts by both parties the talks have had the affect of greatly reducing the LRA presence within Uganda, with the vast majority of the forces relocating into southern Sudan. However, the LRA have not refrained from attacks, with frequent forays attributed to them in southern Sudan, Central African Republic and most recently DRC where the LRA soldiers are accused of massacring whole villages and burning churches with the congregation locked inside over the Christmas period of 2008. Although this trail of blood and destruction has been out of Uganda it has undeniably headed in a loop and is dangerously close to re-entering from the DRC into western Uganda.

While the threat of return of the LRA insurgency remains, it is undeniable that in their absence or at the very least during this lapse in their operations in northern Uganda, the local population has been able to regain some measure of normal life.

5.2.3. Disbanding of IDP camps

With the establishment of peace in the northern region the population previously confined to living in IDP camps have been able to return to their villages of origin and enabled the population to return to some extent of their original lifestyles.

At the time of writing this thesis the complete disbanding of IDP camps was far from achieved but estimates of the numbers of persons whom have left the camps was provided by the United Nations High Commissioner for Refugees (UNHCR). While data from time points from 2007 and early 2008 were available the most up to date data from November 2008 was used to show the disbanding of the IDP population Figure 5-6.
The highest numbers of returnees to their village are seen to be in the districts of Apac, Lira, Gulu, Pader and Kitgum, which is the same districts seen to have the highest numbers of IDP residents in Figure 5-4, with the exception of Apac. Figure 5-7 shows the percentage of the late 2005 IDP camp population to have returned to villages in November 2008.
Figure 5-7 shows that the highest percentage of IDP camp populations to have returned to their villages of origins are seen to be from some of the most southerly districts to have been heavily afflicted by the insurgency. With lower return rates of IDP camp populations to villages seen in the northerly districts, the lower return is attributable to the fact that the more northerly districts are at higher risk to any return of insurgents from southern Sudan.

The return rates shown here are the return rates from IDP camps back to villages, it is important to highlight that many of the IDP camp population have left the vast IDP
camps and moved into smaller satellite camps. Which are still guarded from rebel attacks and as such are not classified as returnees in this representation, as those who are still living in satellite camps are still restricted from living fully traditional arable lifestyles with particular reference to livestock herding.

5.2.4. Risk of return of insecurity

The LRA have become increasingly active near to the Ugandan boarder. In response the UPDF are currently operating within the north-east of DRC, with the consent and compliance of the Congolese government, aiming to hunt down and capture the weakened LRA forces. With this act of pursuit it is feared that the LRA will return to frequent, co-ordinated and mercilessly bloody attacks, as opposed to smash and grab supplies raids which are currently occurring with varying brutality.

Although the UPDF have effectively established border patrols by moving divisions from towns that are now stable, such as Lira, it is widely believed that the LRA have a consignment of weapons buried in the north. It may be entirely be possible for the fighters to disarm while crossing the border (as they are not known personally as LRA combatants) and then rearm once in the areas with reduced military presence. This potential resurgence of LRA – UPDF conflict within Uganda, would likely bring about the re-establishment of the IDP camps within northern Uganda.

5.2.5. Security and the cattle population within northern Uganda

Insecurity within northern Uganda has resulted in the depletion in the numbers livestock. This decrease in numbers is resultant of two dominating factors; firstly persistent fighting in the region forced the local community to refrain from traditional lifestyles, cumulating in the formation of IDP camps (as discussed previously in section 5.2.1). With the reduced access to the rural areas cattle stock were difficult to keep as passage to watering and grazing points was highly risky in the conflict intense areas.
The second factor impacting the cattle population in the northern region is cattle raiding. During the 1980s and early 1990s the Karamojong tribe from the arid north eastern Uganda, indicated in Figure 5-1, carried out highly intensive cattle raids throughout northern and south eastern districts of Uganda, reportedly as a response to famine in their own region (Mamdani, 1982). As an example Kitgum district’s cattle population plummeted from 156,667 in 1986 to just 3,239 in 1998, while the national cattle population rose from 3.6 million to 5 million during the same period (Westbrook, 2000).

In 1997 it was estimated that the cost of replacing plundered cattle in northern Uganda would amount to approximately US$24 million (Gersony, 1997). The raids were highly successful due to the fact that the Karamojong are well armed with military grade weapons, mainly AK47 assault rifles but also reportedly possessing heavier weaponry such as light machine guns and rocket propelled grenades (Akabwai & Ateyo, 2007). It is known that a significant number of weapons came into Karamojong possession when they raided the Moroto armory as the government of Idi Amin fell (Pinto et al., 2006). The tribe’s location upon the Sudanese border has made it possible for acquisition of further armaments and ammunition; reports suggest that the majority of weaponry and ammunition currently available in northern Uganda has been plundered from locations abandoned by military forces in Sudan. There are also reports of corrupt UPDF members supplying weaponry from the Ugandan military stockpile although unlicensed firearms are illegal in Uganda it is highly difficult to effectively police this volatile and desolate district (Akabwai & Ateyo, 2007).

The Karamojong tribe are traditional warriors, also heavily recruited into the Kings African Rifles (Mburu, 2002), whom are brought up to believe that all cattle in the world rightfully belong to them; this is reportedly the result of mass cattle theft from the Karamojong many generations ago (Nanyunja, 2003). With this belief and the access to arms the Karamojong are reported to have raided in excess of one million cattle from neighbouring districts of Uganda (also taking cattle from the Kenyan districts of Pokot and Turkana), often striking at night and killing any people who resisted (Mburu, 2002).
The theft of animals on such an enormous scale left the northern districts with greatly depleted livestock numbers, and communities were unable to re-establish stock to former figures due to the on-going heavy conflict in the region.

5.3. Current cattle stock levels in northern Uganda

The figures for both human population and cattle stock are taken from data collected during the 2002 census, currently the most up to date figures available, collected by the Statistics Department of the Ministry of Finance, Planning and Economic development. Humans and cattle populations within the districts of interest are shown in Table 5-3.

<table>
<thead>
<tr>
<th>District</th>
<th>Human Population</th>
<th>Cattle Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abim</td>
<td>53000</td>
<td>2250</td>
</tr>
<tr>
<td>Adjumani</td>
<td>256000</td>
<td>35754</td>
</tr>
<tr>
<td>Amolotar</td>
<td>106800</td>
<td>38344</td>
</tr>
<tr>
<td>Amuria</td>
<td>244200</td>
<td>366940</td>
</tr>
<tr>
<td>Amuru</td>
<td>195700</td>
<td>1686</td>
</tr>
<tr>
<td>Apac</td>
<td>471100</td>
<td>65117</td>
</tr>
<tr>
<td>Dokolo</td>
<td>147400</td>
<td>20893</td>
</tr>
<tr>
<td>Gulu</td>
<td>331400</td>
<td>16426</td>
</tr>
<tr>
<td>Kaabong</td>
<td>126500</td>
<td>280090</td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>152900</td>
<td>29338</td>
</tr>
<tr>
<td>Katakwi</td>
<td>137200</td>
<td>17306</td>
</tr>
<tr>
<td>Kitgum</td>
<td>327600</td>
<td>14650</td>
</tr>
<tr>
<td>Kotido</td>
<td>151500</td>
<td>384122</td>
</tr>
<tr>
<td>Lira</td>
<td>555800</td>
<td>68726</td>
</tr>
<tr>
<td>Masindi</td>
<td>480000</td>
<td>95358</td>
</tr>
<tr>
<td>Moroto</td>
<td>235200</td>
<td>818086</td>
</tr>
<tr>
<td>Nakapiripirit</td>
<td>192300</td>
<td>198876</td>
</tr>
<tr>
<td>Oyam</td>
<td>305400</td>
<td>27288</td>
</tr>
<tr>
<td>Pader</td>
<td>392600</td>
<td>30000</td>
</tr>
</tbody>
</table>

Table 5-3: Human and cattle populations in northern and north-eastern Uganda

From Table 5-3 and Figure 5-8 it is clear that the Karamojong dominated districts of the north-eastern region hold far more cattle than the war afflicted districts of northern Uganda.
It is possible that these north-eastern districts possess more cattle than the north as a result of having a higher population than the northern regions, the relationship between human and cattle populations is examined in Figure 5-8.

Figure 5-8 shows an uneven distribution of cattle when comparing the northern districts to the majority of northeastern districts. The inequalities in ratios of cattle to human populations within northern region districts show the devastating combined impacts effect of conflict and cattle raiding by the Karamojong (Figure 5-8).
The population of northern Uganda are gradually returning to their traditional lifestyles and have a desire to restock cattle. Although it has been shown that the cattle population in north eastern Uganda is high it is the case that the animals found there are often in poor health, with Contagious Bovine Pleuropneumonia (CBPP), along with other diseases, being common place in the north-east. This is likely linked to the fact that education in this region is extremely poor; as such cattle owners are unaware of the benefits of livestock management with specific reference to health.

From conversation with community members within the cattle deprived district, the poor state of health seen in the cattle of the North-Eastern region is well known, with contacts reporting that they would actively avoid acquiring cattle from the Karamojong to avoid importing diseases to their existing cattle stock.
6. The role of Cattle market trade in expanding the geographical range of *T. b. rhodesiense* in Uganda

6.1. Introduction

Uganda demonstrates spatial variation in terms of cattle traded across the country. The intensive ranch like method (thousands of cattle kept within fenced off privately owned areas) dominates the regional cattle population in regions of the south-west. In contrast, small scale herding style (usually ranging between five and 80 heads of cattle) accounts for virtually all the animals found in the south-east and northern regions of Uganda.

The method of acquisition of cattle is generally standardised throughout the country, with cattle markets operating within areas of stable population. Whilst it is possible to acquire cattle direct from owners and ranches, it is known that the fairest price is found in the market sale environment.

It is government policy to treat all cattle sold with trypanocides at the point of sale (Wendo, 2002). This treatment is designed to help prevent the advance of *T. b. rhodesiense* into the regions where there is, at present, no burden from Rhodesian HAT. This is particularly important in northern Uganda which has an existing burden of Gambiense sleeping sickness. As the introduction of *T. b. rhodesiense* could confuse the treatment of sleeping sickness patients and also bring a new parasite into a previously naive cattle population.

6.1.1. Livestock movement and disease spread

It has previously been described in this thesis that cattle are the predominant reservoir of *T. b. rhodesiense*. Furthermore that the movement of infected cattle from a region of established Rhodesian sleeping sickness into an area previously free from the disease,
assuming competent vectors are present, may result in the advance this parasite (Onyango, 1966, Fevre et al., 2006).

The Lord’s Resistance Army (LRA) withdrew from the Northern region of Uganda, into the surrounding and less militarily controlled neighbouring countries of Democratic Republic of Congo, Sudan and Central African Republic in early 2007. Following this withdrawal there has been a reported increase in the quantity of cattle being traded from the South-Eastern region of Uganda into the north as the area’s cattle population is replenished.

Consequentially the northwards movement of *T. b. rhodesiense* is being greatly accelerated, with the effective buffer zone of the SOS (Stamp Out Sleeping sickness) project area being bypassed as cattle are driven through in trucks most commonly without therapeutic drug treatment. This animal movement may well facilitate the further reduction of the spatial separation between the two morphologically indistinguishable and highly pathogenic human infective trypanosome species; with the movement of potentially infected cattle into the established foci of *T. b. gambiense*.

### 6.1.3. Market structure, hierarchy of command and other policy

The cattle market system within Uganda was privatised from both centralised and district governmental ownership and control during the latter part of the 1980s. While the markets are currently privately operated, they are expected to abide by the rules and guidelines of the Ugandan ministry of agriculture. Included in these governmental policies are;

- Inspection of cattle by veterinary personnel prior to admittance to market site (with unfit or unhealthy animals being refused entry).
- Permits are to be issued for post sale movement from the site by veterinary staff.
- Permits are checked at police run road blocks.
- Compulsory administration of trypanocidal treatment after sale.
These policies are specifically applied to halt the spread of infectious diseases both of livestock and zoonotic nature.

Even though livestock market sites are privately owned and managed, they can only operate with the direct involvement of the district veterinary staff, meaning that often the veterinary staff may have greater influence than the site manager. Anecdotally if market site owners were apprehensive about cattle sampling at their site, the vets proclaimed that if the sampling programme was not aloud he would simply refuse to issue permits, needless to say sampling went ahead without further hindrance.

6.1.3.1. Movement permits

Movement permits issued after sale are a standardised procedure throughout Uganda, with books of perforated permits being issued by the Ministry Of Agriculture’s Entebbe based headquarters. Four separate permit books are issued for use; with two sets of books, one separately for animals being moved between districts, another set being for animals moved to a different sub-county within the district of sale. Of these two sets one book is designated for animals being transported for restocking and the other being exclusively for animals bought for slaughter within a three-week period of permit issue.

The issue of these permits is supposed to be free of charge; however it is very unusual for veterinary staff to not demand a fee of approximately 1000 shillings (£0.30) for inspection prior to authorising permits.

Whilst permits are relatively simple to obtain for movements within Uganda the act of moving animals across international boundaries is understandably much more complex. Far more formative inspections are necessary including a formal quarantine period, this is organised by veterinary officials and charged to the exporter at quite considerable cost when compared to the purchase cost of each animal.
6.1.4. Movement of cattle into SOS region

Examination of the SOS intervention within Chapter 3 shows that the intervention has not achieved sustainable control of *T. brucei* s.l. or *T. b. rhodesiense* within the target region. The role of cattle importation into the region of SOS treatment should be examined to assess the potential impact that importation of cattle to the area has had upon the success of the control programme.

6.1.5. Chapter aims

This work aims to assess the impact of market driven cattle movement between the established foci of *T. b. rhodesiense* in the southeast of Uganda and the *T. b. rhodesiense* free region of northern Uganda. The potential for the establishment of *T. b. rhodesiense* foci within northern Uganda, which would further close or even disband, the spatial segregation between the two human infective trypanosome species will be discussed.

Changes in the pattern of animal movements following the withdrawal of the LRA will be presented. The long term effects of these changes are also presented within the context of the results of molecular analysis carried out on blood samples collected from animals presented for market trade. This analysis will highlight the prevalence of human infective trypanosomes within these animals and the potential outcomes in terms of their final destination and the spread of disease.

Chapter 6 will further investigate the potential impact of the market driven introduction of cattle upon the long term effectively of the SOS programme, in terms of the importation of cattle that were likely infected with *T. b. rhodesiense* into the recently cleared SOS intervention region. This information shall give further depth of explanation to whether the market driven trade of cattle into the SOS region was a driving factor for the resurgence of *T. brucei* s.l. and more importantly *T. b. rhodesiense* that was seen after the SOS campaign.
This study will aim to be of benefit to those implementing future control interventions focused upon the livestock of an area where trade is allowed to occur unrestricted into a control area. Assessing the impacts of livestock trade and ‘enforced movement restrictions’ and recommending considerations relating to trade driven animal movement that should be taken by any future operations.
6.2. Methods

6.2.1. Project design

This project aimed to evaluate the prevalence of *T. b. rhodesiense* in cattle being traded at markets identified as most likely to trade in the direction from the south-east towards the north and north-western of Uganda.

6.2.1.1. Selection of markets for sampling

It was fundamental for the project design to establish the largest northerly trading markets; this was achieved by conducting a series of questionnaires with the District Veterinary Officer (DVO) within the areas of the south-eastern region and also the southerly districts of northern region (that were included in the SOS programme). The questionnaire used can be viewed in appendix 2. The DVOs of 13 districts; Amolotar, Amuria, Apac, Bukedea, Dokolo, Iganga, Kaberamaido, Kamuli, Kumi, Lira, Pallisa, Soroti and Tororo were each questioned personally and individually during early 2008.

The questionnaire was designed to establish data to compare of the amount of northerly inter-district trade through the markets of Uganda's cattle corridor, as well as identifying the most active inter-district trading market in each district. The names and contacts of those in charge of each of the larger markets were also collected.

Initially markets were ranked within each district solely on numbers of cattle traded, number imported into the districts as well as numbers exported out of the district. However this did not take into account either the origins or destination of trade; therefore it was decided to base the selection upon a combination of the origin and direction of trade as well as the number of cattle sold in the district.

The selection criteria discounted districts with low numbers of sales in their markets, as well as those trading animals from areas free of *T. b. rhodesiense*. Markets trading to the
south were also discounted as these cattle are mainly for slaughter and as such are not thought as contributing to the spread of the disease (Waiswa, 2007). Preference was given to the main inter-district trading markets in districts which traded from the south east to the northern districts.

6.2.1.2. Sampling of markets

Permission to do so was sought from the DVO main office prior to the collection of cattle blood samples from markets. Even though DVO permission was obtained, secondary permission was also requested from the veterinarian at the market site, the market owner as well as the cattle traders whom owned each individual animal.

Collection of whole-blood samples and subsequent analysis was conducted as described in Sections 2.1 and 2.2 giving result sets for the prevalence of both *T. brucei* s.l. and *T. b. rhodesiense*.

Sampling was conducted on two separate occasions at each of the selected markets with a view to collect a minimum of 100 samples on each visit, cattle were sampled on a first come selection basis. On occasion fewer than 100 animals were present or conditions were unsuitable. The purpose of repeating sampling visits was to minimise any abnormalities that may have occurred on a single visit.

As markets days are social as well as fiscal events, the decision was made in advance that sampling should not continue past mid-day, predominantly due to the fact that market goers tend to deviate from sobriety in the latter part of the day, often becoming aggressive.

Together with the general information about each individual animal sampled (see Section 2.1), information on which district the specific animal had originated from was recorded in order to help establish the direction of trade. In the case of animals bought at different markets, the owner was asked to recall which district the animal originated from if it had
been in their possession for less than 30 days. If more than 30 days had elapsed where it had been over then this location was taken as its origin.

6.2.1.3. Time point of field work

The fieldwork for this research was conducted over two separate time points. Interviews with the DVOs were conducted during January and February 2008. This established how many cattle markets were operating in the south-east and districts of northern Uganda relevant for onward trade of potentially *T. b. rhodesiense* infected cattle, as well as which cattle markets were most active. Sampling was conducted between late May and July 2008 (including blood sampling from cattle brought for sale), along with retrospective collection movement permit records issued for animals traded at the specified markets.

6.2.1.4. Market records

Along with the collection of blood from cattle being sold in the market on the dates of sampling records of the destination of cattle that were moved from each individual market sampled was taken from the movement permits for inter-district trade. Both breeding and slaughter permits were examined and the numbers of cattle moved were recorded for the whole months shown in Table 6-1, when they were available.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>June 2006</td>
<td></td>
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<tr>
<td>November 2006</td>
<td></td>
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<tr>
<td>February 2007</td>
<td></td>
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<tr>
<td>June 2007</td>
<td></td>
</tr>
<tr>
<td>November 2007</td>
<td></td>
</tr>
<tr>
<td>February 2008</td>
<td></td>
</tr>
<tr>
<td>May 2008</td>
<td></td>
</tr>
</tbody>
</table>

Table 6-1: Months for which inter-district trade records were collected for sampled markets
These dates were selected to give wide enough spread to show the quantify any change in trade direction resulting from the stabilisation of the northern region due to the retreat of the LRA.
6.3. Results

With the multi-focal study nature of this chapter the active markets within the south east and which of them were chosen for this study, will first be examined. Following this, past market trade associated movement of cattle from the *T. b. rhodesiense* endemic region of south eastern Uganda into regions free from the disease will be investigated from the past market trade records. The prevalence of both *T. brucei* s.l. and *T. b. rhodesiense* from cattle sampled at the market sites will then be assessed. Finally movements of cattle from *T. b. rhodesiense* endemic areas into the SOS region will be examined in relation to the risk of reintroducing the parasite.

6.3.1. Identification of main cattle markets in eastern Uganda

From structured interviews with DVOs in 13 districts throughout eastern and central Uganda, the ten most active markets of northerly destined trade were identified and selected for further investigation. In addition to these ten markets, 37 cattle markets were identified (47 in total) with varying levels of cattle trade, these markets and their respective districts are identified in order from south to north in Table 6-2.
<table>
<thead>
<tr>
<th>District</th>
<th>Number of cattle markets</th>
<th>Market names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iganga</td>
<td>1</td>
<td>Kawete</td>
</tr>
<tr>
<td>Kamuli</td>
<td>3</td>
<td>Buyende, Igwaya, Nawantale</td>
</tr>
<tr>
<td>Tororo</td>
<td>6</td>
<td>Omwonyole, Tuba, Wanela, Pasindi, Buyenbe, Mukuju</td>
</tr>
<tr>
<td>Pallisa</td>
<td>2</td>
<td>Kamuge, iki iki</td>
</tr>
<tr>
<td>Bukedea</td>
<td>3</td>
<td>Bukedea, Cuchumba, Dubai</td>
</tr>
<tr>
<td>Kumi</td>
<td>7</td>
<td>Odeko, Ngora, Mukuro, Ogino, Kapir, Kobuin, Murkongoro</td>
</tr>
<tr>
<td>Soroti</td>
<td>5</td>
<td>Brookes corner, Kasilo, Arapai, Katinae, Kabulabula</td>
</tr>
<tr>
<td>Amuria</td>
<td>5</td>
<td>Akuromit, Wera, Obalanga, Onyamiguroia, Amiwmill</td>
</tr>
<tr>
<td>Amolotar</td>
<td>2</td>
<td>Anyangoga, Alemere</td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>2</td>
<td>Ochero, Otuboi</td>
</tr>
<tr>
<td>Dokolo</td>
<td>1</td>
<td>Chwagere</td>
</tr>
<tr>
<td>Apac</td>
<td>7</td>
<td>Aganga, Abuli, Akwon, Adograo, Anekapiri, Bala, Aduku</td>
</tr>
<tr>
<td>Lira</td>
<td>3</td>
<td>Amach, Apala, Amugu</td>
</tr>
</tbody>
</table>

Table 6-2: Cattle markets identified by DVOs in south-east and central Uganda

The GPS co-ordinates of the ten selected markets were recorded for future reference, these markets are listed on Table 6-3 and their location shown on Figure 6-1.

<table>
<thead>
<tr>
<th>District</th>
<th>Market name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apac</td>
<td>Adograo</td>
</tr>
<tr>
<td>Bukedea</td>
<td>Bukedea</td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>Ochero</td>
</tr>
<tr>
<td>Kamuli</td>
<td>Buyende</td>
</tr>
<tr>
<td>Kumi</td>
<td>Ngora</td>
</tr>
<tr>
<td>Lira</td>
<td>Amach</td>
</tr>
<tr>
<td>Pallisa</td>
<td>Kamuge</td>
</tr>
<tr>
<td>Soroti</td>
<td>Arapai</td>
</tr>
<tr>
<td>Soroti</td>
<td>Brookes Corner</td>
</tr>
<tr>
<td>Soroti</td>
<td>Kasilo</td>
</tr>
</tbody>
</table>

Table 6-3: Finalised list of markets selected for sampling
6.3.1.1. Samples collected

The number of samples collected during each of the market sampling sessions is shown in Table 6-4.

<table>
<thead>
<tr>
<th>District (market name)</th>
<th>Round 1</th>
<th>Round 2</th>
<th>Market total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apac (Adograo)</td>
<td>52</td>
<td>0</td>
<td>52</td>
</tr>
<tr>
<td>Bukedea (Bukedea)</td>
<td>108</td>
<td>110</td>
<td>218</td>
</tr>
<tr>
<td>Kaberamaido (Ochero)</td>
<td>100</td>
<td>28</td>
<td>128</td>
</tr>
<tr>
<td>Kamuli (Buyende)</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Kumi (Ngora)</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Lira (Amach)</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Pallisa (Kamuge)</td>
<td>100</td>
<td>88</td>
<td>188</td>
</tr>
<tr>
<td>Soroti (Arapai)</td>
<td>60</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Soroti (Brookes Corner)</td>
<td>100</td>
<td>120</td>
<td>220</td>
</tr>
<tr>
<td>Soroti (Kasilo)</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>920</strong></td>
<td><strong>846</strong></td>
<td><strong>1766</strong></td>
</tr>
</tbody>
</table>

Table 6-4: Breakdown of samples collected during each session

The total collected from Apac Adograo was only 52 due to the fact that misleading information was provided during the initial questionnaire stage of the study. This falsely
identified it as large and also as bi-weekly, when it is in-fact a monthly market. This made it impossible to sample twice due to a conflicting scheduling. Also the second sample set taken from Kaberamaido Ochero is low in number due to the onset of a very heavy storm during sampling, resulting in the majority of people fleeing the market. The number of animals sampled during the first sampling session conducted in Soroti Arapai was also relatively low at 60, although there were more animals present, sampling had over-run past noon and as intoxication of persons at the market was increasing, sampling was therefore halted on safety grounds.

6.3.2. Results of past market trade analysis

The market records on past trade from each of the individual markets shows that the average direction of animal movement after sale has shifted from equal northerly and southerly movement during June 2006 to 75% of all animals sold moving to districts further north than the district of sale during May 2008, Figure 6-2.
Figure 6-2: Direction of cattle movement of inter-district traded animals after sale at market, with time point that the LRA / Ugandan peace talks started indicated as a yellow line

The destination of cattle permitted for inter-district movement from the markets included in the study has shifted over time (as shown in Figure 6-2). The changes in direction of trade for individual markets throughout the time periods (for which records were available) will be described later in the markets specific results section.

Due to the ongoing severe instability in southern Sudan (resulting from combatant forces, both non-native and local in origin, operating in a relatively lawless region) demand for cattle, predominantly for meat, is high in that area (notably to feed aid workers). Traders from Sudan travel down to the busy markets in central Uganda to acquire animals for the Sudanese market (mainly the southern Sudanese state capital of Juba). However international movement is strictly controlled and licensed so animals are often moved to northern districts, notably the border districts of Kitgum and Amuru and are smuggled across the permeable international border. While this is illegal, traders were surprisingly upfront about their intentions. In total 17 animals from Brookes Corner (Soroti), were destined for Juba (information gained during personal discussion with buyers at the
market), potentially taking *T. b. rhodesiense* 340 kilometres further north than the currently referenced northerly perimeter of the disease (Welburn *et al.*, 2006).

It is important to point out that different markets had maintained their market records to different levels. For example, Lira (Amach) did not have a separate set of books for movement permits and as a result the only information available for analysis was from the whole district level, which includes locally facilitated trade as well as some restocking related movements. While the market records for Apac (Adograo) were not available at all as Adograo was very recently established and as such had no records to give.

Within Uganda there are two types of inter-district movement permits that are issued, permits for animals destined for slaughter as well as permits for animals destined for breeding purposes in the destination district. While these two data sets are theoretically available, information presented during conversation with veterinary personnel indicated that the wrong books were often used, depending on which books is available at the time of sale. Information on the destination purpose of the animals permitted for movement is likely to be an inaccurate representation and will be disregarded.

Further analysis of both data from permitted cattle movements from markets alongside information of animal origin collected during sampling prior to sale (looking at movements on an individual market level) will indicate which of the markets are responsible for the highest levels of trade to districts in northern regions of Uganda. The information presented here is generated by different data sets the figures in each map do not correlate exactly but are to be interpreted as a comparison. Also apparent from informal conversation with market personnel is the fact that quite often cattle are taken illegally from the market and moved inter-district. This is possible because cattle market sites are often poorly maintained with no perimeter fences, and as the issuing of movement permits is subject to a charge (related to an inspection of each animal to be moved for evidence of communicable diseases), purchasers often avoid the official permit process and the associated fee.
6.3.2.1. Kamuli Buyende

Market records for Buyende were unavailable for the whole two-year period from July 2006; the record books for May 2008 were also unavailable for analysis.

![Figure 6-3: Cattle moved from Buyende market, Kamuli District](image)

From the records of permits it can be seen that the direction of movement from Buyende was generally in a northerly direction throughout the sample period (as seen in Figure 6-3).

Of the 200 animals sampled during market proceedings, the vast majority originated from within Kamuli itself (see left hand image in Figure 6-4). Animals permitted for inter-district movement after sale in Buyende were seen to involve many more districts than the incoming movements.

From the destination districts (depicted in the right hand image in Figure 6-4) which were obtained from analysis of the same past permit records used to construct Figure 6-3. It is clear that Soroti, located to the north east of Buyende market, is the most common destination for animals moved inter-district, reportedly taken by ferry across Lake Kyoga.
While sampling at Buyende market, it was apparent that the market staff (particularly the veterinary officer) were highly active, conducting inspections of animals in crushes prior to admission to sales area. The market had a well-constructed perimeter, while treatment of animals with diminazene aceturate to comply with policy, was also observed.

Figure 6-4: District of origin (blue arrows) of cattle sampled at Buyende market, Kamuli District and the destination of cattle traded (orange arrows) constructed using permit records
6.3.2.2. Pallisa Kamuge

The market records for Kamuge were unavailable to the level required with only three of the most recent data points being available.

![Cattle movement from Kamuge market, Pallisa District](image)

Figure 6-5: Cattle movement from Kamuge market, Pallisa District

Although only constructed with a snapshot of the outgoing movements from the market, Figure 6-5 indicates that the vast majority of animals moved inter-district after sale in Kamuge market were destined for districts north of the market.
The majority of animals brought for trade during the sampling sessions at Kamuge market originate from within the local district, Pallisa (see Figure 6-6). Spatial analysis of the destination of animals permitted for inter-district movement after sale, shows that the majority of cattle are moving northerly, with Lira and Amuria districts being the most frequent destination.
6.3.2.3. Bukedea Bukedea

Market records for Bukedea market were again unavailable to cover the entirety of the data points wanted for analysis.

The available records do, however, indicate that there has been a shift in the destination of cattle traded at the market (Figure 6-7), from mainly destined to southern movements during June 2007 to predominantly being northbound after sale in May 2008.
Incoming cattle have two main origins, Bukedea district itself and neighbouring Kumi (which were together as Kumi district until 2007) along with this cattle also move north from Pallisa Figure 6-8. The single animals from Iganga and Kamuli are possibly not coming directly from these districts (people often purchase animals, keep them for approximately one month to fatten prior to resale at a more profitable market).

The animals moving inter-district after sale at Bukedea market are seen in Figure 6-8 to be moving very far north from the point of sale to Gulu and Amuru districts. Information obtained from the records as well as during informal discussion with both market officials as well as employees of NGOs (Non Governmental Organisations) it is apparent that these animals were relocated as part of cattle restocking initiatives. This is facilitated by both internationally and nationally operating NGOs. As these organisations are
responsible for the movement of high volumes of cattle into the northern-most Ugandan districts, their potential role in facilitating the northerly advance of *T. b. rhodesiense* warrants further investigation. While sampling at Bukedea market an informal conversation was held with a Makerere qualified veterinarian who was employed directly by NUSAF (Northern Uganda Social Action Fund) he had acquired 30 cattle for restocking within Gulu district, each of these animals had been dosed with diminazene aceturate and inspected prior to being loaded onto trucks for transport.

### 6.3.2.4. Soroti Brookes Corner

Complete records for Brookes Corner market were available.

![Cattle moved from Brookes Corner market, Soroti District](image)

The records indicate that cattle movement has shifted from cattle heading exclusively south during the 2006 sample points to approximately 70% of inter-district moving northerly in May 2008 (Figure 6-9).
The origin of the animals sampled during the two sampling sessions was principally within Soroti district (see Figure 6-10), along with this animal were also brought in from both Kumi and Kamuli districts to the east and south of Soroti respectively. The records of destination of inter-district movement permits taken for all desired time points show that predominantly the cattle have been moving to districts in northern Uganda. Also apparent from Figure 6-10 is that the distances moved northerly are much larger than the distances moved by the cattle which were relocated to southerly districts.
6.3.2.5 Soroti Kasilo

Records from Kasilo market in Soroti district were suitable to give complete coverage over all of the desired sample dates.

![Bar chart showing cattle moved from Kasilo market, Soroti District]

The overall direction of cattle moved inter-district post sale at Kasilo market is slightly biased in a southerly direction. The information collated upon the specific districts of destination will show to what extent animals are moving further north and south from the point of sale (Figure 6-11).
Cattle brought for sale at Soroti Kasilo market are seen to mainly originate from within Soroti, the only other district from which the cattle that were sampled were brought in from was Kamuli and these animals were taken across Lake Kyoga by ferry, highlighting the fact that the lake is not a barrier restraining the spread of *T. b. rhodesiense*.

Cattle moving inter-district post sale at Kasilo market are seen to have moved predominantly in a southerly direction. While this is indeed the case, a large number of animals have been taken to districts in the northern region during the seven sample points of the permit records. Also the range of districts into which the cattle are relocated is higher in the north with five destination districts as opposed to the two destinations for permitted inter-district trade in a southerly direction.
6.3.2.6. Soroti Arapai

The records for past movement collected from Soroti Arapai were only available for May 2008, as such it is not worthwhile to present the data graphically as there is only a single data time point, but the movements were all observed to be in a northerly direction.

Figure 6-13: District of origin (blue arrows) of cattle sampled at Arapai market, Soroti District and the destination of cattle traded (orange arrows) constructed using permit records

Although the outgoing data is from only a single month, it allows direct comparative analysis between the inbound and outgoing data. Figure 6-13 shows that the majority of the cattle originate from Soroti with Kumi, Pallisa and Bukedea districts to the south-east of the market also contributing to the markets incoming cattle, whereas districts to the north of Arapai market only contribute seven cattle.
Permitted inter-district movements are all in a north-westerly direction from the market with the majority of animals heading to Lira district with Amuria district also receiving a high proportion (Figure 6-13). Animals are also observed moving to the far north districts of Amuru and Kitgum, while the numbers destined this far north are low, it is important that this information is from a single time point, and as such the true proportion destined for these northern districts may be higher than is indicated by the available data set.

6.3.2.7. Kaberamaido Ochero

Records held by market personnel of Kaberamaido Ochero are compete enough to allow for all of the desired data points to be analysed.

![Figure 6-14: Cattle moved from Ochero market, Kaberamaido District](image)

Movement of inter-district permitted cattle consistently travel mainly further north in relation to the market site, with the single exception of February 2007, as shown in Figure 6-14.
Although the majority of cattle brought to Kaberamaido Ochero market for trade originate from the immediately neighbouring districts of Amolotar, Dokolo as well as Kaberamaido district, a relatively high proportion of animals were also seen to have originated from Districts across Lake Kyoga.

The records of animals permitted for inter-district movement post sale shown in Figure 6-15 indicate that while more animals are moving north, two districts in the south also have a high rate of destination, Mbale and Tororo. Of the northerly districts Lira is a frequent destination of cattle as are Amuria, Amuru and neighbouring Dokolo district, In terms of *T. b. rhodesiense* spread the movements to Amuru, Lira and Gulu are of highest significance as high quantities of animals are moving to these districts which were not previously affected by *T. b. rhodesiense*.
6.3.2.8. Lira Amach

As discussed previously, data were not available singularly for Amach market in Lira, as such it was only possible to get monthly data from between September 2007 and May 2008 at a whole district level. Therefore this is not a fully accurate depiction of movements from the market but is more a rough indication.

![Figure 6-16: Cattle moved from Lira district](image)

The permit records for cattle moved out of Lira district in Figure 6-16 shows that the vast majority of animals were moved northerly. As Lira is the existing perimeter of the area affected by *T. b. rhodesiense* all of these northerly bound animals have the potential to introduce the disease into previously uninfected areas.
Cattle sampled at Amach market during the two sampling sessions originated mainly from the neighbouring district of Apac and from within Lira and Dokolo (see Figure 6-17) and from Hoima located to the south-west on the shores of Lake Albert.

The cattle moving out of Lira district, Figure 6-17, are predominantly moving to the districts of Amuru, Kitgum, Pader and Gulu to the north of Lira with Apac to the south also receiving a large amount of cattle from Lira. Although being to the south, Apac is still relevant to the spread of *T. b. rhodesiense* as this district, like Lira, is on the cusp of the perimeter of the area established as *T. b. rhodesiense* affected.

Also for consideration, conversational reports were given that permits for movement were often obtained allowing movement to northern districts such as Kitgum and Amuru. These animals are then illegally smuggled across into Sudan; as such the high numbers destined for these districts may be subject to this.
6.3.2.9. Movements into districts north of established *T. b.* *rhodesiense* HAT focus.

The identification of districts, assumed to be clear of the *T. b. rhodesiense* parasite, that have been importing cattle directly from markets within the districts known to be affected by the species are shown in Figure 6.18.

Figure 6-18: Movements of cattle into districts previously deemed clear of *T. b. rhodesiense* indicating districts known to harbour the parasite that have supplied the cattle
Markets located within the districts of Pallisa, Bukebea, Kumi, Soroti, Kaberamaido and Lira have supplied cattle to districts free of *T. b. rhodesiense*. Data is clarified in Figure 6-19, which identifies the accepted *T. b. rhodesiense* free districts that have been shown to have imported cattle from regions affected by the species.

![Figure 6-19: Identification of districts at risk of having introduced *T. b. rhodesiense* in relation to known extent of *T. b. gambiense* foci](image)

Figure 6-19: Identification of districts at risk of having introduced *T. b. rhodesiense* in relation to known extent of *T. b. gambiense* foci
Adjumani (known to be harbour *T. b. gambiense*) has received cattle from districts affected by *T. b. rhodesiense* HAT, identifying this as a potential point of overlap between the two human infective sub-species.

6.3.3. PCR analysis

Analysis of PCR results will first examine the findings of TBR for *T. brucei* s.l. within the sampled cattle, after which analysis for the prevalence of *T. b. rhodesiense* will be discussed.

6.3.3.1. Results of TBR PCR

PCR analysis for presence of *T. brucei* s.l. within the samples collected from the largest inter-district trading markets shows an overall prevalence of 17.5%. Three hundred and seven samples were positive out of the 1758 total collected. Table 6-5 indicates how many samples were found positive from each sampling session, with Figure 6-20 comparing the overall prevalence of all markets.
<table>
<thead>
<tr>
<th>Location</th>
<th>Round 1</th>
<th>Round 2</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number collected</td>
<td>Number Positive</td>
<td>% TBR positive</td>
</tr>
<tr>
<td>Apac Adograo</td>
<td>52</td>
<td>20</td>
<td>38.5</td>
</tr>
<tr>
<td>Bukedea</td>
<td>108</td>
<td>7</td>
<td>6.5</td>
</tr>
<tr>
<td>Kamuli Buyende</td>
<td>100</td>
<td>52</td>
<td>52.0</td>
</tr>
<tr>
<td>Kumi Ngora</td>
<td>100</td>
<td>46</td>
<td>46.0</td>
</tr>
<tr>
<td>Lira Amach</td>
<td>100</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>Pallisa Kamuge</td>
<td>100</td>
<td>21</td>
<td>21.0</td>
</tr>
<tr>
<td>Soroti Arapai</td>
<td>60</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Soroti Brookes Corner</td>
<td>100</td>
<td>8</td>
<td>8.0</td>
</tr>
<tr>
<td>Soroti Kasilo</td>
<td>100</td>
<td>5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Table 6-5: Results of PCR analysis of market samples for presence of *T. brucei* s.l.
Figure 6-20: Prevalence of *T. brucei* s.l. at individual market level

The data presented shows there is a considerable range in detected *T. brucei* s.l. prevalence within the differing cattle markets from 46.1% at Ochero market in Kaberamaido to 0.6% at Arapai market in Soroti district.

### 6.3.3.2.1. Originating districts of *T. brucei* s.l. positive cattle

Data collected for each animal sampled during market trade is cross examined with relation to the PCR analysis for *T. brucei* s.l. along with the originating district of the animal in terms to the market site location.

The results displayed in Table 6-6 shows that at each of the markets sampled cattle positive for *T. brucei* s.l. were found to have originated from within the local district. Of the 281 cattle found to be positive for *T. brucei* s.l. 152 (54.1%) originated from within the same district as the market site. Whereas 129 (45.9%) of the animals found positive for *T. brucei* s.l. came from districts neighbouring the sampled market.
<table>
<thead>
<tr>
<th>District</th>
<th>Market</th>
<th>Number of <em>T. brucei</em> s.l. positive animals</th>
<th>District of origin for <em>T. brucei</em> s.l. positive cattle</th>
<th>Number supplied by each district</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apac</td>
<td>Adograo</td>
<td>20</td>
<td>Apac 19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nakosongola 1</td>
<td></td>
</tr>
<tr>
<td>Bukedea</td>
<td>Bukedea</td>
<td>14</td>
<td>Sironko 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pallisa 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bukedea 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kumi 4</td>
<td></td>
</tr>
<tr>
<td>Kamberamo</td>
<td>Ochero</td>
<td>59</td>
<td>Amolotar 27</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dokolo 19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kamberamo 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nakosongola 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kamuli 1</td>
<td></td>
</tr>
<tr>
<td>Kamuli</td>
<td>Buyende</td>
<td>55</td>
<td>Kaliro 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kamuli 52</td>
<td></td>
</tr>
<tr>
<td>Kumi</td>
<td>Ngora</td>
<td>58</td>
<td>Kumi 58</td>
<td></td>
</tr>
<tr>
<td>Lira</td>
<td>Amach</td>
<td>13</td>
<td>Lira 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Apac 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hoima 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dokolo 2</td>
<td></td>
</tr>
<tr>
<td>Pallisa</td>
<td>Kamuge</td>
<td>64</td>
<td>Pallisa 62</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Budaka 2</td>
<td></td>
</tr>
<tr>
<td>Soroti</td>
<td>Arapai</td>
<td>1</td>
<td>Soroti 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soroti 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kumi 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Uncertain (Heading to Juba) 1</td>
<td></td>
</tr>
<tr>
<td>Soroti</td>
<td>Brookes Corner</td>
<td>9</td>
<td>Soroti 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kumi 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Uncertain (Heading to Juba) 1</td>
<td></td>
</tr>
<tr>
<td>Soroti</td>
<td>Kasilo</td>
<td>6</td>
<td>Soroti 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kamuli 1</td>
<td></td>
</tr>
</tbody>
</table>

Table 6-6: District of origin of *T. brucei* s.l. positive cattle

### 6.3.3.2. Results of SRA PCR analysis

The samples that were shown to be positive by TBR were tested further by SRA PCR to screen for the presence of *T. b. rhodesiense* within the samples. Of the 307 samples shown as *T. brucei* s.l. positive, 26 were found to be positive for *T. b. rhodesiense* using the SRA PCR diagnostic. Full results are given in Table 6-7.
<table>
<thead>
<tr>
<th>Location</th>
<th>Number collected</th>
<th>Overall TBR positive</th>
<th>Overall SRA positive</th>
<th>Minimum prevalence of <em>T. b. rhodesiense</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apac (Adograo)</td>
<td>52</td>
<td>20</td>
<td>2</td>
<td>3.8%</td>
</tr>
<tr>
<td>Bukedea (Bukedea)</td>
<td>218</td>
<td>14</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Kaberamaido (Ochero)</td>
<td>128</td>
<td>59</td>
<td>3</td>
<td>2.3%</td>
</tr>
<tr>
<td>Kamuli (Buyende)</td>
<td>200</td>
<td>55</td>
<td>4</td>
<td>2.0%</td>
</tr>
<tr>
<td>Kumi (Ngora)</td>
<td>200</td>
<td>58</td>
<td>5</td>
<td>2.5%</td>
</tr>
<tr>
<td>Lira (Amach)</td>
<td>200</td>
<td>13</td>
<td>2</td>
<td>1.0%</td>
</tr>
<tr>
<td>Pallisa (Kamuge)</td>
<td>188</td>
<td>64</td>
<td>5</td>
<td>2.8%</td>
</tr>
<tr>
<td>Soroti (Arapai)</td>
<td>160</td>
<td>1</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Soroti (Brookes Corner)</td>
<td>220</td>
<td>17</td>
<td>4</td>
<td>1.8%</td>
</tr>
<tr>
<td>Soroti (Kasilo)</td>
<td>200</td>
<td>6</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Overall market total</td>
<td>1766</td>
<td>307</td>
<td>26</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

Table 6-7: Results of SRA PCR for *T. b. rhodesiense*

Analysis of market collected cattle blood samples with SRA PCR shows that the individual markets have a range of *T. b. rhodesiense* prevalence between 0% at two of the sampled markets to 3.8%. The graphical representation of this data is given below in Figure 6-21, shown with 95% confidence intervals.
The prevalence of infected cattle brought for sale at the markets of highest northerly destined trade throughout the *T. b. rhodesiense* affected region of south-eastern and central Uganda is shown to vary from 3.8% in Adogoro market in Apac district to 0% found at two of the market sites.

The same five market sites that presented a *T. brucei* s.l. prevalence of 25% or higher: Apac (Adogoro), Kaberamaido (Ochero), Kamuli (Buyende), Kumi (Ngora) and Pallisa (Kamuge) are also seen to have *T. b. rhodesiense* prevalence of 2.0% or above.

Samples collected from the markets of Bukedea (Bukedea) and Soroti (Arapai) have returned as clear of the *T. b. rhodesiense* parasite, giving an overall prevalence of 1.5% throughout the markets sampled.

### 6.3.3.2.1. Originating district of *T. b. rhodesiense* positive cattle

From the data collected concerning each animal’s district of origin prior to movement to the market site it was possible to analyse the spatial origins of the animals that have been shown as *T. b. rhodesiense* infected.
### Table 6-8: District of origin of *T. b. rhodesiense* positive cattle

<table>
<thead>
<tr>
<th>District</th>
<th>Market</th>
<th>Number of <em>T. b. rhodesiense</em> positive animals</th>
<th>District of origin for <em>T. b. rhodesiense</em> positive cattle</th>
<th>Number supplied by each district</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apac</td>
<td>Adograo</td>
<td>2</td>
<td>Apac</td>
<td>2</td>
</tr>
<tr>
<td>Bukedea</td>
<td>Bukedea</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>Ochero</td>
<td>3</td>
<td>Amolotar</td>
<td>3</td>
</tr>
<tr>
<td>Kamuli</td>
<td>Buyende</td>
<td>4</td>
<td>Kamuli</td>
<td>4</td>
</tr>
<tr>
<td>Kumi</td>
<td>Ngora</td>
<td>5</td>
<td>Kumi</td>
<td>5</td>
</tr>
<tr>
<td>Lira</td>
<td>Amach</td>
<td>2</td>
<td>Lira</td>
<td>2</td>
</tr>
<tr>
<td>Pallisa</td>
<td>Kamuge</td>
<td>5</td>
<td>Pallisa</td>
<td>5</td>
</tr>
<tr>
<td>Soroti</td>
<td>Arapai</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soroti</td>
<td>Brookes Corner</td>
<td>1</td>
<td>Soroti</td>
<td>1</td>
</tr>
<tr>
<td>Soroti</td>
<td>Kasilo</td>
<td>3</td>
<td>Soroti</td>
<td>1</td>
</tr>
</tbody>
</table>

Twenty-five of the cattle found to be infected with *T. b. rhodesiense* 20 originated from within the local district of the market at which they were presented for sale (see Table 6-8). The five (20%) positive animals seen to have been brought in from other districts are all shown to have originated from the districts directly neighbouring the district within which the sampled market was located. This indicated that the infected animals are generally not being transported long distances into the market site. Whereas 20 (80%) animals found to be *T. b. rhodesiense* positive originated from within the same district as the market site suggesting that the largest input of the parasite to the market system is the local district as opposed to animals imported for market sale. Surprisingly the market most distanced from the established *T. b. rhodesiense* afflicted region (Adograo market in Apac district) is shown to have animals from the local area that were found infected. Likewise Ochero market in Kaberamaido shows all of the positive animals were originated Amolotar district, but as Ochero is located within two kilometres of the border between these two districts, it is highly likely that the animals were from the surrounding area of the market site.
6.3.4. Movement of cattle into SOS region

The data collected on the movement from markets shall first be analysed showing which of the *T. b. rhodesiense* afflicted districts are shown in the market records to be supplying cattle into the SOS region through market trade. Data from the results of the blood sampling exercise shall then be analysed and combined with the past movement data to construct projected figures of the rate of introduction of *T. b. rhodesiense* into the SOS region since the programme was active in November 2006.

6.3.4.1. Specific considerations for analysis of importation to SOS region

Firstly on the list of alterations is that the time points from which data was collected, shown in Table 6-9, includes one sample month that predates the SOS intervention and one that was during the treatment phase of the SOS activity. Due to the fact that data from these two sample time points is irrelevant to the effect of market trade on the re-introduction of *T. b. rhodesiense* after the SOS programme, these dates have not been included in the analysis of past movements within this phase of investigation.

<table>
<thead>
<tr>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2007</td>
</tr>
<tr>
<td>June 2007</td>
</tr>
<tr>
<td>November 2007</td>
</tr>
<tr>
<td>February 2008</td>
</tr>
<tr>
<td>May 2008</td>
</tr>
</tbody>
</table>

Table 6-9: Months for which inter-district trade records were collected for sampled markets, after the SOS treatment activities
6.3.4.1.1. Markets for which all data is included for SOS importation analysis

Care was taken to undertake analysis only from the markets that are outside of the SOS region. Using selection according to DVO recommendations it is possible that markets within the SOS region are proposed for sampling. Hence data from these markets from within the SOS region will not be included for analysis of importation to the region, but will still be used for analysis of trade into the northern region of Uganda.

Also it must made clear that this analysis is a by-product of the principle aim of this investigation into the overall spread of *T. b. rhodesiense* thus if this was the specific focus of the work the selection of the markets may well have been different.

6.3.4.1.2. Particular considerations for analysis of blood samples

Blood samples were taken personally and the seller of each of the sampled cattle was asked where each individual animal had come from. With this level of information it means that the animals sampled at the three markets of the SOS intervention region can be examined and if they are originating from outside of the districts that received SOS treatment, they may be included in terms of their *T. brucei* s.l. and *T. b. rhodesiense* infection status, along with being considered as being imported into the region.

Their inclusion will facilitate a better understanding of the dynamics of market trade in terms of the potential for the reintroduction of *T. brucei* s.l. and *T. b. rhodesiense* into areas that have received a mass treatment programme.

6.3.4.2. Supply of cattle into SOS region

The districts containing markets that are documented supplying cattle into the SOS intervention region (Kaberamaido, Dokolo, Amolotar, Lira and Apac) are shown in Figure 6-22.
It is clear that there are four districts from which markets are supplying cattle into the SOS treatment region; interestingly the cattle imported to the SOS region are not simply acquired from those districts that are immediately local. Exemplifying this is the movement of cattle from the district of Pallisa to Lira which is a distance of over 80 miles, this relates to a journey time of in excess of four hours due to the poor conditions of the roads (although it should be noted that a new tarmac road has now been opened in early 2010 making journey between the two locations approximately two hours duration). While this distance is overshadowed by the transportation of animals documented in Chapter 6 it is worth noting that the cattle stocks neighbouring to the south of the SOS region were not decimated by the insecurities to the same extent as the animals of further north.
The districts and markets documented as supplying cattle into the SOS treatment area are shown to be Kamuli (Buyende market), Pallisa (Kamuge), Bukeeda (Bukedea) and Soroti (Arapai, Brookes Corner and Kasilo markets). While this list of six markets does not immediately impact as having a high throughput it must be remembered that there are seven markets from which data was collected, as there are well over 30 other market sites operating within the *T. b. rhodesiense* endemic south east of Uganda therefore these six will not be the entire number of markets supplying cattle to the SOS region. The
relationship between the specific markets that are documented as supplying the SOS region and the prevalence of *Trypanosoma brucei* species that was detected within each of these markets will be investigated later in this chapter.

### 6.3.4.3. Numbers of cattle documented as imported into each of the SOS region’s districts from sampled markets

An overview of the total numbers of cattle documented as moving from the seven highlighted markets shown in Table 6-10. The numbers of cattle that have been imported since the time of the SOS intervention (past movement permit data collected from five months) is provided in Table 6-10.

<table>
<thead>
<tr>
<th>District</th>
<th>Cattle documented as imported</th>
<th>Supplying markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaberamaido</td>
<td>569</td>
<td>Arapai, Kasilo, Buyende, Bukedea</td>
</tr>
<tr>
<td>Amolotar</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dokolo</td>
<td>14</td>
<td>Arapai</td>
</tr>
<tr>
<td>Lira</td>
<td>878</td>
<td>Arapai, Brookes Corner, Kasilo, Kamuge</td>
</tr>
<tr>
<td>Apac</td>
<td>320</td>
<td>Kasilo</td>
</tr>
<tr>
<td>SOS region</td>
<td>1781</td>
<td>Arapai, Brookes Corner, Bukedea, Buyende, Kamuge and Kasilo</td>
</tr>
</tbody>
</table>

Table 6-10: Cattle imported into districts in SOS treatment region and markets supplying

With the exception of Amolotar, all districts included in the SOS treatment programme are mentioned, within the collected movement permit records as having received cattle from these markets. While Amolotar is seen not to have imported from these markets, conversational evidence from the veterinary staff of Kamuli indicates that animals are frequently taken there from their market. Likewise while working within the district of Amolotar during sampling for SOS analysis, community members reported that they import cattle from across the lake from districts such as Nakosongola, Kayunga and Kamuli. While Kamuli is the only district of these three that was included for market
records (as the other two are not established foci of *T. b. rhodesiense*) the fact that there are no records proving this movement indicates the common incidence of unpermitted cattle movement.

6.3.4.4. Detected prevalence of *T. brucei* s.l. and *T. b. rhodesiense* in markets trading into SOS treatment region

The combination of speculative numbers of cattle imported to the SOS region in the year since the SOS programme combined with the PCR analysis of blood samples collected from cattle brought for trade at market sites is presented below (Table 6-11). This data helps to clarify the level of *T. brucei* s.l. imported to the SOS region during the year since the intervention through permitted market trade.

<table>
<thead>
<tr>
<th>Market Location</th>
<th>Number collected</th>
<th>Overall TBR positive</th>
<th>Minimum prevalence of <em>T. brucei</em> s.l.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bukedea (Bukedea)</td>
<td>218</td>
<td>14</td>
<td>6.4%</td>
</tr>
<tr>
<td>Kamuli (Buyende)</td>
<td>200</td>
<td>55</td>
<td>27.5%</td>
</tr>
<tr>
<td>Kumi (Ngora)</td>
<td>200</td>
<td>58</td>
<td>29.0%</td>
</tr>
<tr>
<td>Pallisa (Kamuge)</td>
<td>188</td>
<td>64</td>
<td>34.0%</td>
</tr>
<tr>
<td>Soroti (Arapai)</td>
<td>160</td>
<td>1</td>
<td>0.6%</td>
</tr>
<tr>
<td>Soroti (Brookes Corner)</td>
<td>220</td>
<td>17</td>
<td>7.7%</td>
</tr>
<tr>
<td>Soroti (Kasilo)</td>
<td>200</td>
<td>6</td>
<td>3.0%</td>
</tr>
<tr>
<td>Overall market total</td>
<td>1386</td>
<td>215</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

Table 6-11: Detected *T. brucei* s.l. prevalence within markets outside of SOS region

The prevalence of *T. brucei* s.l. within the cattle presented for trade is shown in Table 6-11 as averaging 15.5% throughout the market system of south-eastern Uganda. The prevalence of *T. b. rhodesiense* within the markets supplying cattle into the SOS region shown in Table 6-12 shows that the average prevalence of the species within the cattle traded at markets outside the SOS region is 1.37%, ranging between 2.80% at Kamuge market in Pallisa and 0% at two other market sites.
Table 6-12 Detected T. b. rhodesiense prevalence within markets outside of SOS region

<table>
<thead>
<tr>
<th>District</th>
<th>Number collected</th>
<th>Overall SRA positive</th>
<th>Minimum prevalence of T. b. rhodesiense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bukedea (Bukedea)</td>
<td>218</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Kamuli (Buyende)</td>
<td>200</td>
<td>4</td>
<td>2.00%</td>
</tr>
<tr>
<td>Kumi (Ngora)</td>
<td>200</td>
<td>5</td>
<td>2.50%</td>
</tr>
<tr>
<td>Pallisa (Kamuge)</td>
<td>188</td>
<td>5</td>
<td>2.80%</td>
</tr>
<tr>
<td>Soroti (Arapai)</td>
<td>160</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Soroti (Brookes Corner)</td>
<td>220</td>
<td>4</td>
<td>1.80%</td>
</tr>
<tr>
<td>Soroti (Kasilo)</td>
<td>200</td>
<td>1</td>
<td>0.50%</td>
</tr>
<tr>
<td>Overall market total</td>
<td>1386</td>
<td>19</td>
<td>1.37%</td>
</tr>
</tbody>
</table>

Although the findings of the market inter-district movement permits implied that the Kumi Ngora market was not supplying cattle to the SOS region, due to the incomplete nature of the records collected from this market it is not definite that cattle from here have not been moved to the SOS region and the appropriate records been mislaid. The findings of the cattle sampling have been included for this aspect of the study.

Table 6-13: Minimum number of T. b. rhodesiense infected cattle moved into the districts of SOS region

<table>
<thead>
<tr>
<th>District</th>
<th>Annual import from documented sales</th>
<th>Minimum number of cattle imported with T. b. rhodesiense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaberamaido</td>
<td>1366</td>
<td>211.7</td>
</tr>
<tr>
<td>Amolotar</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Dokolo</td>
<td>34</td>
<td>5.3</td>
</tr>
<tr>
<td>Lira</td>
<td>2107</td>
<td>326.6</td>
</tr>
<tr>
<td>Apac</td>
<td>768</td>
<td>119.0</td>
</tr>
<tr>
<td>SOS region</td>
<td>4274</td>
<td>662.5</td>
</tr>
</tbody>
</table>

Numbers of cattle that have been legally imported through the market system from the south-east of Uganda into the SOS intervention region are shown to total 4274 this relates to the number of T. brucei s.l. infected cattle imported being 663 across the whole SOS region. Lira is estimated to have imported a minimum of 327 T. brucei s.l. infected cattle as a result of legally permitted market trade; Kaberamaido has received at least 212 T.
brucei s.l. infected cattle. Apac district received 119 infected cattle. Dokolo and Amolotar are seen to have received very few though.
6.4. Discussion

With the analysis of potential introduction of *T. b. rhodesiense* as a result of the cattle market trade system it has been indicated that the actions risk the introduction of the parasite to naive areas. This will now be examined further assessing the level of risk this action is generating.

6.4.1. Determination of volume, source and destination of cattle traded

The cattle brought for trade in the sampled markets has been shown as being predominantly sourced from within the markets’ specific district. With 67.9% of cattle entering the markets originating from within the local district, 18.9% originating from districts to the south of the market and just 13.2% coming from districts to the market’s north.

From conversation with cattle traders and veterinary staff it is apparent that the majority of cattle that are moved southwards into the markets are mature and destined for slaughter, whereas the cattle from the local district and cattle originating from the south tend to be younger animals that are taken for restocking after sale.

With reference to the data available from inter-district permit records, it is likely that any estimate of the annual number of cattle moved inter-district from the markets included in the study will be inaccurate. Not only as permit records were widely unavailable for collection but also due to the reportedly high incidence of cattle being moved without the legally necessary permit.

From the data of cattle numbers permitted for inter-district movement the average number of cattle traded was established for each time point. Along with an estimated number of cattle traded at each of the nine markets that have been active throughout the past two years (excluding Apac Adograo) this is shown in Table 6-14.
Table 6-14: Estimation of cattle numbers moved throughout main cattle markets

<table>
<thead>
<tr>
<th>Month</th>
<th>Animals recorded moved inter-district</th>
<th>Markets with records available</th>
<th>Cattle moved per market</th>
<th>Cattle predicted moved through sampled markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun-06</td>
<td>1150</td>
<td>3</td>
<td>383</td>
<td>3450</td>
</tr>
<tr>
<td>Nov-06</td>
<td>1083</td>
<td>3</td>
<td>361</td>
<td>3249</td>
</tr>
<tr>
<td>Feb-07</td>
<td>1332</td>
<td>4</td>
<td>333</td>
<td>2997</td>
</tr>
<tr>
<td>Jun-07</td>
<td>1438</td>
<td>5</td>
<td>288</td>
<td>2588</td>
</tr>
<tr>
<td>Nov-07</td>
<td>2296</td>
<td>6</td>
<td>383</td>
<td>3444</td>
</tr>
<tr>
<td>Feb-08</td>
<td>3001</td>
<td>7</td>
<td>429</td>
<td>3858</td>
</tr>
<tr>
<td>May-08</td>
<td>2967</td>
<td>6</td>
<td>495</td>
<td>4451</td>
</tr>
</tbody>
</table>

Due to the perceived difference seen in the predicted numbers of cattle moved inter-district after sale, an average of the last three sample points is calculated and giving an average number of cattle moved inter-district after market sale, Table 6-15.

Table 6-15: Expanded estimated numbers of cattle moved inter-district

<table>
<thead>
<tr>
<th>Average cattle moved per market per month</th>
<th>Average cattle moved per month in sampled markets</th>
<th>Average cattle moved per year in sampled markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>435</td>
<td>4353</td>
<td>52235</td>
</tr>
</tbody>
</table>

The estimation of cattle numbers permitted for legal inter-district movement after sale in the nine cattle markets included in this study has been found to be 52,235 per year. The overall proportional direction of cattle documented for inter-district trade was 65.8% of cattle were destined to travel north of the market of sale, as such per year 34,371 animals are transported between district north of the market of sale.

As suggested previously the data collected from each of the markets are, at best only indicative of the true numbers moving from the markets. During conversation with both traders and veterinary personnel it became apparent that frequently cattle are taken from
markets without having movement permits in-order to avoid inspection and issuing charges.

From the data on the adjustment in the destination of cattle traded at the markets throughout the seven selected months. It is apparent that the change in direction of cattle after sale correlates with the reduction in fighting between government forces and LRA rebels, and the subsequent withdrawal of the LRA into neighbouring countries. Allowing for stability to return to the northern districts, people to leave the IDP camps and return to rural lifestyles, including cattle rearing. As such the shift in destination is highly likely to be as a result of cattle restocking in response to this return to arable subsistence.

While formal data was unavailable on the origin of cattle brought into the markets, the data collected during sampling indicates that close to 70% of cattle brought into the market system, of the most significant northerly inter-district trading markets, are sourced from the district that the market is located within.

Analysis of the legally permitted movements shows that the cattle are moving distances of approximately 150 miles (240 km) between Bukedea market (Bukedea district) and the destination district of Gulu, this indicates the distances that *T. b. rhodesiense* could progress from the current established foci.

6.4.2. Identification of markets posing risk to SOS treatment area and districts beyond

6.4.2.1. Risk to SOS region

Within the original selection criteria of the study the markets that have been seen to pose the most significant risk to re-introduction of *T. b. rhodesiense* into the region included in the SOS intervention have been identified as the Soroti markets (Arapai, Brookes Corner and Kasilo), Bukedea (Bukedea), Kamuli (Buyende) and Pallisa (Kamuge), Indicated in Figure 6-23. Of these markets two are shown to pose particularly high risk; Pallisa
(Kamuge) and Kamuli (Buyende) which have both returned *Trypanosoma b. rhodesiense* prevalence in excess of 2.0%.

![Figure 6-23: Markets documented selling cattle into SOS intervention region](image)

**Legend**
- Markets not supplying cattle into SOS region
- Markets supplying cattle into SOS region

The two sampled markets within the SOS treatment region, Kaberamaido (Ochero) and Apac (Adograo), were also found with *T. b. rhodesiense* prevalence in excess of 2.0%. Lira (Amach) the third market within the November 2006 SOS treatment region returned a slightly lower *T. b. rhodesiense* prevalence of 1.0%. Uniformly the animals at markets within the SOS region found positive for *T. b. rhodesiense* originate from within the area local to the market site. With reference to the findings of (Fèvre et al., 2006) it is clear that sampling at market sites can give clarity to the status of *T. b. rhodesiense* within the
area surrounding the market site. None of these markets classified as selling into SOS region as vast majority of the cattle originate from within the area.

Each of these markets are located outside of the retreatment area described Figure 3-15, with Kaberamaido (Ochero) being the closest market to the retreatment area.

6.4.2.2. Risk to naive districts

The markets documented as supplying cattle to districts previously unaffected by *T. b. rhodesiense* are indicated in Figure 6-24 as being the Soroti markets (Arapai, Brookes Corner and Kasilo), Bukedea (Bukedea), Kaberamaido (Ochero), Kumi (Ngory) Pallisa (Kamuge) along with Lira (Amach).

![Figure 6-24: Markets documented supplying cattle into districts clear of acute sleeping sickness](image)
It is important to note that veterinary staff and traders indicated that often animals are permitted for movement to northern districts (Amuru and Kitgum) then smuggled across the border into Sudan. While this is illegal traders were often very honest about their intentions, saying the majority of animals taken to Sudan are for slaughter but even so commonly survive for over a month prior to slaughter.

6.4.3. Determination of risk of *T. b. rhodesiense* introduction by infected cattle being moved into clear areas by market trade

With the establishment of the overall prevalence of *T. b. rhodesiense* as 1.5% of cattle taken for sale at market. It is possible to project the number of positive animals that will have been taken into each of the *T. b. rhodesiense* clear districts in accordance to the documented records obtained from the past inter-district movement permits.

This analysis is shown in Figure 6-25, it is worthwhile to bear in mind that Lira had only district wide movement permit data, all of which are included for analysis.

The seven districts documented as supplying cattle to these areas previously clear of *T. b. rhodesiense* are located on the northern shore of Lake Kyoga. However this does not rule out supply of cattle from more southerly districts as conversational information from veterinary officials and cattle traders indicates that cattle are often traded slowly northerly through the market system. This is suggested in the data on cattle origin collected from animals that were sampled.
The projected numbers of cattle likely to be *T. b. rhodesiense* positive that are documented as moved into each of the clear districts from cattle markets within the established *T. b. rhodesiense* region show there is consistent movement of potentially infected cattle, into districts previously clear of the species. Most concerning of which is the movement of cattle into the district Adjumani.
With the analysis of the *T. b. rhodesiense* prevalence of cattle brought for trade it is shown in Figure 6-25 that while the number of potentially infected cattle is not as high as is seen moving into Pader or Amuru as the true numbers moved is much higher than the records indicate. This under-representation is due to two predominant causes; data collected for specified time points is not complete, also the matter of animals being moved illegally without ever being on movement permit records.

Previous work analysing the driver for *T. b. rhodesiense* outbreak in Soroti district shows that importation of 100 cattle from an endemic region over a four year period into a naive district is substantial to give rise to endemicity becoming established within the recipient region (Fevre *et al.*, 2001). Therefore the rate of import shown from areas endemic with the parasite into the districts indicated in Figure 6-25 is substantial for the parasite to become established.

### 6.4.4. Number of cattle imported to SOS treatment region

Analysis of the market trade driven importation into the recently treated SOS intervention region has shown that the SOS area has been receiving cattle from the markets located within the *T. b. rhodesiense* afflicted south east of Uganda.

Previous inter-district movement permits from the markets revealed that of the seven markets that were analysed all but one had documented movements into the SOS intervention region.

Expansion of the monthly average import gives an estimate of the number of cattle that were legally imported as a result of the market trade system into the SOS region during the year directly following the November 2006 intervention.

Analysis of the inter-district permits issued for cattle traded at the markets shows that the distribution of cattle across the SOS region is not even, with certain districts being commercially more available than others. This analysis showed that Lira and
Kaberamaido districts have purchased the major share of cattle during this study period. Kaberamaido has been shown to have bought a high proportion of the cattle that have been imported to the SOS treatment region this movement of animals may be related to the resurgence of *T. b. rhodesiense* within this district. However Dokolo, which also had a defined resurgence of the parasite, is not seen to have received this level of legally documented import from markets. In reference to this observation care must be taken in respect to the identification of Lira as importing a speculated 2107 cattle throughout the year from the markets that were sampled, while the districts of Dokolo and Amolotar both received very few cattle (34 and zero respectively). The districts of Amolotar and Dokolo were counties of Lira district up in till July 2006, when they were reallocated to be their own districts in order to make governance more effective. Although they are known as distinct districts by the local communities, it is reasonable to suspect that the market operatives from other (more distant) districts are likely not to be aware of this change and as such likely to have just put Lira as the destination district and not the newly separated districts.

Importation of cattle to the SOS region that are harbouring *T. brucei* s.l. has been evaluated through the comparison of cattle movement data with molecular analysis of blood samples taken from cattle presented for trade at markets to the south east of the SOS region. The prevalence of *T. brucei* s.l. was established as at least 15.5% throughout this population of cattle. The re-introduction of *T. brucei* s.l. as a direct result of market trade is highly likely to have contributed to the resurgence of *T. brucei* s.l. that was described within Chapter 3. Importation of 663 *T. brucei* s.l. infected cattle is unlikely to have been the sole cause for the cattle within the SOS region becoming re-infected by this parasite to the recorded incidence of 27.44% detected in June 2008, however it cannot be ruled out that importation from these markets will have contributed to the situation.

### 6.4.5. Tsetse presence

Consideration must be given to the fact that for introduced trypanosomes to become stable within the region they have been introduced to it is vital that suitable vector species
of tsetse are present to initiate and maintain the transmission cycle. Assessing the risk of a single infected animal causing further infections of a naive cattle population depends upon the infectivity of the vector (as insects are by no means welcoming hosts to invading pathogens), the feeding frequency of present tsetse and the feeding preference of the tsetse. In the case of cattle being introduced to the SOS region, it is known that the vector competent tsetse are present and feeding frequently upon cattle, what is not so certain (after an extensive literature review as well as asking entomologists working within the region) is that these fly populations are suitably established in the northern region of the country.
6.5. Conclusion

As the conclusions of this chapter apply to differing foci of study they shall be presented individually here to aide clarity.

6.5.1. Spread of \textit{T. b. rhodesiense} to previously clear regions

The inter-district movement permit data that is available for analysis is only an indicator of total numbers being moved. This under-reporting of the true numbers of cattle that have been relocated, resulting in the spatial encroachment of the two forms of sleeping sickness towards each other. From the data that was available it is indicated that overlapping of these two human infective species may have already occurred in Adjumani.

PCR analysis shows that the overall prevalence of \textit{T. b. rhodesiense} is at a minimum of 1.5\% within the cattle bought for trade at the ten markets included in this study. This investigation not only indicates that the markets are indeed playing an important role in the progression of \textit{T. b. rhodesiense} northwards through Ugandan districts. But unless a high proportion of the cattle moved are treated with trypanocides, which from personal observations is exceedingly unlikely, the species of \textit{T. b. rhodesiense} and \textit{T. b. gambiense} are at the risk of having overlapped in Adjumani. Furthermore if the perimeter of \textit{T. b. gambiense} has expanded southerly the problem of the overlapping of the two human diseases is more widespread than this report alone indicates.

6.5.2. Market derived reintroduction of \textit{T. b. rhodesiense} to the SOS region

Markets located in the south east of Uganda have been proven to supply cattle that were imported into the SOS region during the year following the intervention programme. This importation is of direct concern as cattle presented for sale at these markets (shown to supply the SOS region) were found to have an overall prevalence of 1.4\% \textit{T. b. rhodesiense} based upon the results from PCR analysis of the collected samples (this
figure does not include all markets sampled, only those documented as supplying cattle to SOS region). Referring to the focal nature of \textit{T. b. rhodesiense} within the SOS region since the intervention, Dokolo and Kaberamaido have a higher occurrence of the parasite affecting both cattle and humans than the other three districts included in the SOS treatment region. However importation of cattle into these two specific districts cannot be identified as the sole source of this focal burden although it may be seen as a contributing factor.

In conclusion it is undeniable that the market trade system (more specifically the lack of trypanocidal treatment of traded cattle prior to leaving the market sites) has contributed to the resurgence of both \textit{T. brucei} s.l. and \textit{T. b. rhodesiense} within the SOS treatment area.

The impact of pathogen importation through infected cattle will have simply accelerated the increasing prevalence of both species, which was naturally occurring as a result of insufficient coverage by the SOS treatment programme accompanied by the lack of sustained vector control.

The trade of cattle into a treated region is clearly of concern, as this study has shown that a suitable volume of cattle to cause a controlled disease to re-emerge has passed into the SOS treatment region in the year following the intervention. Realistically the only way to combat this re-importation of disease to a controlled area would be to enforce mandatory treatment of all animals entering the controlled area from markets. Through utilising the already present authority enforced animal inspection road blocks. However this would not be necessary in Uganda if the government policy of treating all cattle sold at market with trypanocides was adhered to and enforced, better yet the policy could be revised so the seller is responsible for paying for treatment instead of the buyer.
7. Assessing the potential role of cattle restocking organisations in importing *T. b. rhodesiense* to unaffected regions

7.1. Introduction

The findings of Chapter 6 demonstrated that the districts of the Northern and West Nile regions in Uganda were at risk of importing *T. b. rhodesiense* through infected cattle purchased from markets within the region afflicted by this parasite.

This market driven movement has been investigated through the animal movement records of the ten most active markets in terms of supplying cattle to northern districts. It is imperative to also quantify the numbers of animals being moved into these endangered districts through other non-market associated supply routes.

Restocking of livestock by Governmental Organisations (GOs), as well as Non Governmental Organisations (NGOs) is an established and effective method of poverty elevation in poor rural regions within Sub-Saharan Africa.

Since the mid 1990’s there has been a dramatic increase in the popularity of poverty relief through provision of livestock to communities, or individuals, by charitable organisations and churches. This trend was brought to public popularity within the western charity community by Send-A-Cow; a charitable organisation that started operating in 1988. This was an ambitious scheme that sought to fly cattle from their base in the south-west of England to Uganda, for distribution amongst needy communities. Since inception, their operations have increased with send-a-cow currently offering gifts, such as goats, rabbits, bees, poultry and fruit trees all now included within their mandate in addition to cattle. The donation of a livestock animal, presented to the target community, was bought as a novelty, or ethical, gift with the western recipient given a card telling them of this
donation. With the popularity of this scheme many other charitable organisations fostered similar schemes with near to identical aims and outcomes.

Within Uganda’s post conflict regions there are now numerous initiatives fronted by charities, churches, NGOs and Governmental schemes designed to supplement the restocking of livestock, in particular cattle and goats. These schemes commonly take animals from the south of Uganda and transport them into the north western regions, which have been heavily affected by 20 years of conflict between government troops and the rebel Lord’s Resistance Army (LRA), as discussed in Chapter 5.

7.1.2. Concern about trypanocidal treatment by initiatives

During interviews with a number of District Veterinary Officers (DVO) with in the North and South-Eastern regions of Uganda, concern was commonly expressed about whether these cattle restocking groups were implementing treatment of cattle with trypanocides prior to relocation.

Reportedly, it is common for the groups to acquire cattle for distribution direct from local communities and not through recognized and monitored cattle markets. Also it is the case that many initiatives are not directly responsible for the acquirement and redistribution of cattle. As an example, the Portuguese NGO Veterinaros Sin Fronteros (VSF) indirectly facilitate distribution of cattle within communities through giving funds to outside agencies, for example the Bululu Multi-Cooperative, or Ochero Savings and Credit. These agencies are given funding and are then responsible for obtaining cattle and distributing within the local areas of Bululu and Ochero sub-counties within Kaberamaido district (outside the area of study for this chapter). The scale of such operations will be investigated during the course of this chapter. Conversely the organisation Community Integrated Development Initiative (CIDI) directly employs veterinarians as permanent staff members who are responsible for obtaining and distributing cattle. These veterinarians inevitably have more awareness of animal and zoonotic diseases and the implications of cattle movements than a finance worker.
During the programme of field work conducted for Chapter 6, informal and unrecorded conversations were held with cattle traders, many of whom were bulk buying animals that were then directly loaded onto trucks at the market site. These men generally reported that the animals were destined for the northern districts and often the animals on the truck were bought on behalf of organisations; while working at the markets none of these large scale purchasers were witnessed treating cattle. Operatives of the Ugandan government initiatives were also encountered at the market sites, they always purchased with a veterinarian who was in the employ of the specified organisation and this veterinarian then treated all procured animals with diminazene aceturate prior to transportation.

7.1.3. Distribution of cattle to the north

While many of the initiatives operate on a local level, moving animals within the districts from which they were acquired, there are those which are working to alleviate poverty in the northern districts of Uganda. The majority of people in these northern areas have been existing in densely packed Internally Displaced Persons (IDP) camps for the past 20 years, during fierce fighting between the LRA and government troops. As these people have had little means of income or been able to produce food crops for the past two decades and resultantly are in a severe state of poverty. As a result the residents of IPD camps are prime candidates to receive poverty relief aid from these agencies, as the north west of Uganda has a very low cattle population this means that the livestock for distribution need to be imported from districts in southern Uganda where cattle populations are far more established.

This aid driven migration of cattle has been predominantly from the South Eastern region of Uganda, where a high burden of *T. b. rhodesiense* is known to exist within the resident human and cattle population. As such the transport of cattle, which are not treated with trypanocides, is highly likely to introduce *T. b. rhodesiense* into the Northern region that is already harbouring *T. b. gambiense* and almost certainly competent tsetse vectors for further transmission.
7.1.4. Study design

For this investigation to analyse the impact of NGOs and GOs upon the importation of cattle into northern areas of Uganda it was imperative to first assess the organisations that were known to be active bringing cattle into the area.

The reason that these organisations were selectively targeted for this investigation into the importation of cattle into these Northern and West Nile regions, without attempting to seek out the individuals that have acquired cattle personally within these districts, which would be a monumental task. Targeting of the organisations that will be responsible for the importation of large numbers of cattle in comparison to the numbers imported by the local community, this larger scale of operation implicates restocking organisation as more relevant to the study.

7.1.5. Chapter aims

This chapter will focus upon assessing the potential effect of NGO, and to a lesser extent government, restocking operations within northern Uganda in terms of the risk of introducing *T. b. rhodesiense* into the districts identified in Chapter 6.
7.2. Methods

To accurately gauge the risk of acute sleeping sickness introduction resulting from the importation of cattle potentially affected with *T. b. rhodesiense* into northerly districts of Uganda that were previously clear of the parasite (see Chapter 6). It is vital to assess the activities of restocking organisations in relation to the potential introduction of *T. b. rhodesiense* into this northerly region.

The association of which districts were *T. b. rhodesiense* afflicted and which were deemed to be free from the zoonotic species is founded upon the most recent information upon the spatial segregation of *T. b. gambiense* and *T. b. rhodesiense* (Picozzi *et al.*, 2005b).

Between mid January and late February 2009 District Veterinary Officers (DVOs) from seven districts of the Northern and West Nile regions (shown in Table 7-1) were interviewed about the activities of restocking organisations within their districts.

<table>
<thead>
<tr>
<th>Northern Districts</th>
<th>West Nile Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulu</td>
<td>Nebbi</td>
</tr>
<tr>
<td>Amuru</td>
<td>Arua</td>
</tr>
<tr>
<td>Pader</td>
<td>Adjumani</td>
</tr>
</tbody>
</table>

Table 7-1: Districts included for DVO and NGO questionnaires

Each of the DVOs were questioned about cattle importation into their specific districts, with explicit emphasis upon how many cattle were being imported into their districts during 2008. They were also asked where these animals were originating from and which organisations were involved.

The main restocking organisations active in the importation of cattle were identified during these questionnaires. These organisations were then approached to participate in an additional questionnaire that would focus specifically on assessing their level of involvement with cattle restocking.
7.2.1. DVO questionnaires

Structured interviews with the DVOs in charge of the ‘at risk’ districts were conducted with the primary focus to ascertain which organisations are active within each of the areas. In addition to the primary focus, the interviews also provided an opportunity to assess the proportion of imported cattle being bought in by organisations involved with restocking in comparison to animals imported by private trade. Giving clarity on the impact rate the organisations have in comparison to the private trade sector. Further information was sought, such as the total number of cattle imported to the district and what was the origin district of the imported cattle. Interviews with each of the seven DVOs were conducted during January and February 2009 immediately prior to the secondary interviews carried out with the restocking organisations identified as operating within the district concerned.

For an example of the questionnaires used for DVO interviews see Appendix 2.

7.2.2. Restocking organisation questionnaires

The DVO questionnaires identified the restocking organisations operating within each of the districts, the restocking organisations’ main offices were located and visited to interview the person in-charge of cattle importation.

An example of the questionnaire used for interviews with the operatives from each of the cattle restocking organisations is included within appendix 3. To avoid leading the interviewee to giving answers perceive as ‘correct’ and not necessarily the truth, the principle motivation behind the questionnaires was not discussed prior to interviews. Instead opting to introduce myself as being a PhD student from the University of Edinburgh researching the potential introduction of a disease into the area, going onto say the disease being researched will be discussed fully after the interview if acceptable.
However if there was a particular objection the interviewee was informed that research into the potential spread of diseases was under investigation, taking care not to mention trypanosomiasis unless absolute transparency was insisted by the organisation prior to granting permission for the questionnaire to be conducted.

As well as ascertaining how many cattle each of the identified restocking organisations had imported, heavy emphasis was also placed upon gaining insight to where the animals were procured from, as this is vital information for the assessment of the risk of *T. b. rhodesiense* importation.

The involvement of the organisation in importing cattle that are potentially infected with *T. b. rhodesiense* into northerly districts that are established as clear of the disease was also investigated, as many of the organisations are active in multiple districts. Importantly the restocking organisations being questioned were asked to provide the names of other organisation also conducting cattle restocking operations within their specific district, just in case there were organisations operating without the knowledge of the DVO.

Finally the restocking organisation operatives were also asked a series of questions to assess the awareness of *T. b. rhodesiense* as a zoonosis and the potential gravity of their actions by means of importing the parasite to previously unaffected areas.

### 7.2.3. Analysis of questionnaire data

Besides the initial analysis identifying which organisations are involved with the importation of cattle into, all other analysis was conducted in Edinburgh.
7.3. Results

The presentation of results will first show analysis of responses given by the DVOs, following this analysis of the responses of the restocking organisations will be examined to ascertain the impact of both these restocking organisations and the non-cattle market associated trade of cattle upon the potential introduction of *T. b. rhodesiense* into the districts of the West Nile and Northern Ugandan regions.

7.3.1. DVO questionnaire

The numbers of cattle reportedly moved into each of the northern districts is shown in Figure 7-1 (three of the DVOs were unable to answer, and a further two were unable to give exact numbers). From those DVOs that were able to answer it is clear that there is a large range in the numbers of cattle being imported to the districts of the Northern and West Nile regions.
From the information depicted in Figure 7-1 it is clear that animals are being imported into the districts of the Northern and West Nile regions through the activities of restocking organisations.

From the responses of DVOs depicted in Figure 7-2, it is clear that cattle being imported to the study region are originating from *T. b. rhodesiense* positive districts in southern and south-eastern Uganda along with districts thought to be free from this parasite.
The proportion of cattle movement driven by restocking organisations, in comparison to trade driven, into each district included in the study is shown below in Figure 7-3. While this data is vague in nature it is important to gauge the relative numbers being imported by each aspect of the cattle trade.
Figure 7-3: Proportion of cattle imported to districts during 2008 derived from restocking and private trade

Figure 7-3 shows that the cattle imported to the northern districts are overwhelmingly supplied by restocking organisations. Responses from the four DVOs interviewed showed that two district received in excess of 75% of imported cattle through restocking organisations. Two districts were also receiving between 50 and 75% of imported cattle through restocking organisations. Whereas cattle supplied to the West Nile region are more heavily imported through private trade. One DVO reporting between 50 and 75% imported by private traders, another reporting between 75 and 100% imported by private traders and one DVO being uncertain the proportions of import.
This difference in the cattle supply to the two regions is significant in terms of cattle importation as generally the districts of West Nile region were less affected by both the Karamojong cattle raids and the war between the LRA and UPDF forces which was focal within the Northern region. Also suggested through conversational information with DVOs of the Northern and West Nile regions is that the two regions are dominated by different tribe populations, with differing customs. The population of the West Nile region are not large scale cattle herders whereas, those in the Northern region culturally are.

7.3.1.1. Regional district breakdown

While the combined movements of cattle are important to gain insight into the overall patterns of cattle moving into the districts of the Northern and West Nile regions, it is also important to have insight to the trends of import for the specific regions as there are great differences in the intensity of combat within the two and therefore differing degrees of disruption to the cattle stock levels. Also the two regions are host to differing terrain and tribes which potentially can give rise to altering levels of cattle movement into each of the areas.
Figure 7-4: Districts of Northern and West Nile regions benefiting from restocking organisations during 2008 and the districts supplying cattle indicating supplying districts with confirmed T. b. rhodesiense, as reported by DVOs

Figure 7-4 shows that cattle are being supplied into the Northern region by 12 districts, five of which are known to have T. b. rhodesiense within their borders; these supplying districts are reported to be from across the country from east to west, with two supplying districts in the most south-eastern corner of Uganda.

Cattle are reportedly supplied into the West Nile region from six districts, two of which are established T. b. rhodesiense infected areas. The districts that supply cattle to the West-Nile region are in the Northern and Western regions of Uganda.

It is clear from Figure 7-4 that there are more districts supplying cattle to the Northern region than are supplying the West Nile region, also the districts supplying the Northern region are seen to be more disperse, with cattle originating from the far south of Uganda, along with animals from districts of the South East region. While animal movement into the West Nile region is reportedly from much closer districts.
7.3.1.2. Restocking organisations operating within each district

The results of the DVO based questionnaire showed that each of the districts included in this study were receiving cattle from at least two restocking organisations.

<table>
<thead>
<tr>
<th>Region</th>
<th>District</th>
<th>Restocking organisations</th>
<th>Governmental</th>
<th>Non-Governmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Nile</td>
<td>Adjumani</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Arua</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Nebbi</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Northern</td>
<td>Amuru</td>
<td>9</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Gulu</td>
<td>10</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Kitgum</td>
<td>12</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Pader</td>
<td>11</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 7-2: Numbers of restocking organisations operating in selected districts, based of DVO responses

The responses given by the DVOs during questioning show that there are more restocking organisations operating in the districts of the Northern region than there are in West Nile region as shown in Table 7-2.

The fact that there are far more non-governmental restocking organisations operating within the Northern region than there are in the West-Nile region is attributed to the fact that the districts of West-Nile region have been far less afflicted by LRA rebel activity than the districts of the Northern region as such have not had their cattle population dwindled by the drawn out conflict.

7.3.2. Cattle restocking organisation questionnaire

The interviews with organisations facilitating cattle restocking showed that there were no additional restocking organisations bringing cattle into the districts other than the ones already identified by the DVO. There were differences between the information provided by the restocking organisation and the DVOs, these discrepancies are discussed below.
7.3.2.1. Overview of organisations conducting cattle restocking

The organisations that were identified as being involved with restocking of cattle into the districts and included in the questionnaire based survey are shown within Table 7-3.
<table>
<thead>
<tr>
<th>Designated identification of organisation</th>
<th>Affiliation</th>
<th>Operating cattle restocking within</th>
<th>Reason for district selection</th>
<th>Mode of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Non-government</td>
<td>Gulu and Amuru</td>
<td>Insecurity related food shortages</td>
<td>Draught and breeding</td>
</tr>
<tr>
<td>2</td>
<td>Non-government</td>
<td>Pader, Gulu, Amuru</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>3</td>
<td>Non-government</td>
<td>Pader, Kitgum, Gulu and Amuru</td>
<td>Within Gulu Archdiocese</td>
<td>Draught</td>
</tr>
<tr>
<td>4</td>
<td>Non-government</td>
<td>Gulu and Amuru</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>5</td>
<td>Non-government</td>
<td>Gulu, Amuru, Pader, Kitgum</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>6</td>
<td>Non-government</td>
<td>Pader and Kitgum</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>7</td>
<td>Non-government</td>
<td>Pader only</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>8</td>
<td>Non-government</td>
<td>Gulu and Amuru</td>
<td>Insecurity</td>
<td>Draught and milk</td>
</tr>
<tr>
<td>9</td>
<td>Non-government</td>
<td>Kitgum</td>
<td>No response</td>
<td>Draught</td>
</tr>
<tr>
<td>10</td>
<td>Non-government</td>
<td>Pader, Katakwi, Kitgum, Kampala, Jinja, Arakai</td>
<td>Needy population</td>
<td>Draught</td>
</tr>
<tr>
<td>11</td>
<td>Non-government</td>
<td>Gulu and Amuru</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>12</td>
<td>Non-government</td>
<td>Kitgum, Kotido, Kaabong,</td>
<td>Insecurity</td>
<td>Draught and breeding</td>
</tr>
<tr>
<td>13</td>
<td>Non-government</td>
<td>Gulu, Kitgum, Pader, Lira, Amuru, Oyam</td>
<td>Insecurity</td>
<td>No response</td>
</tr>
<tr>
<td>14</td>
<td>Non-government</td>
<td>Gulu, Kitgum, Pader, Lira, Amuru, Oyam</td>
<td>Insecurity</td>
<td>Draught, milk and breeding</td>
</tr>
<tr>
<td>15</td>
<td>Non-government</td>
<td>Gulu, Kitgum, Pader, Lira, Amuru, Oyam</td>
<td>Insecurity</td>
<td>Draught</td>
</tr>
<tr>
<td>16</td>
<td>Government</td>
<td>All Ugandan districts</td>
<td>Introduce cattle as a technology</td>
<td>Milk</td>
</tr>
<tr>
<td>17</td>
<td>Government</td>
<td>Kitgum, Pader, Oyam, Lira, Apac, Abim</td>
<td>Cattle corridor needs restocking</td>
<td>Restocking</td>
</tr>
<tr>
<td>18</td>
<td>Government</td>
<td>Gulu, Pader, Kitgum, Lira &amp; Papac</td>
<td>No response</td>
<td>Draught, milk and breeding</td>
</tr>
</tbody>
</table>

Table 7-3: Overview of restocking organisations operating in study area
Of the 18 restocking organisations shown in Table 7-3, 15 were non-governmental organisations and three had direct affiliation with the Ugandan government. Twelve of organisations stated that the areas they operated within were selected due to the conflict and associated insecurities; all of these organisations are of non-governmental affiliation.

Only one organisation was found to operate in a single district, with five operating in two districts, two active within three districts, eight operating in four or more districts and one organisation operating in all Ugandan districts. However it should be noted that these organisations that do operate across many districts or even nationally have facilitated a district headquarters in each of their districts of operation, either through the banner of their own organisations or in some cases by combining with another organisation, having an operating official within their offices.

The variation in the number of districts operated by the different restocking organisations, as an example the governmental organisation identification number 16 is active throughout all of Uganda, whereas another governmental organisation identification number 18 is only active within the northern districts. Finally the NGO charity identification number 7 was seen to be active only within the district of Pader. These discrepancies of how many districts each organisation operates in are linked to the objectives of the specific organisation identification number 16 has a national focus, whereas identification number 18 is specifically engaged within the northern districts and finally identification number 7, whilst an international organisation (based in Ireland), is specifically operating cattle restocking within the northern district of Pader.

7.3.2.2. Districts supplying cattle

From questioning the cattle restocking organisations it became apparent that an additional two districts to the north of the established T. b. rhodesiense area are receiving cattle through their activities, namely Kaabong and Kotido districts in the North East region. Additional districts supplying cattle were also identified compared to those listed by DVOs, these districts are shown in Figure 7-5.
It was also identified that for restocking in the Northern region the animals acquired for distribution are generally Zebu breed which are the preferred breed by the specific local community. These animals originate from the *T. b. rhodesiense* affected South-Eastern region. Animals that are imported from the west are generally Friesian - Ankole crossbreeds which are selected for their high milk yields; these animals are from outside the established *T. b. rhodesiense* afflicted region and as such are of no relevance to the importation of the parasite into the Northern region. Whilst these Friesian-Ankole cross breed will be free from *T. b. rhodesiense* upon import, they are far more susceptible to trypanosome infection than the Zebu breed (Magona et al., 2004). The importation of
Friesian-Ankole into a region also populated by *T. b. rhodesiense* infected animals may, in the presence of transmission effective tsetse vector, result in these animals rapidly succumbing to infection.

From the results of questionnaires with restocking organisations, the number of cattle imported into the area shown as green in Figure 7-5 is reported to be 57,821 cattle between late 2006 and the end of 2008. One governmental restocking organisation was unable to put forward a figure and is not included. These governmental organisations were seen to be the more active in terms of animals imported to the Northern and West Nile regions it is highly likely that the true number imported is substantially higher still than the reported 57,821 imported cattle.

From questioning the restocking organisations it is apparent that the vast majority of NGOs outsource the acquisition of cattle to a private contractor, with only one of the fifteen NGOs questioned staffing the purchase of cattle themselves. From work conducted at markets during June 2008 and firsthand experience, it is apparent that these contractors do not treat the cattle they acquire with trypanocides. The costs of administering treatments would impact into the profit margins due to animal cost being commonly set with any treatment expenses included in one overall cost, in order to maximise profits treatment is commonly overlooked by the contractor. NGOs restocking cattle are high risk for importation of *T. b. rhodesiense* into the Northern region.

In contrast the Government affiliated restocking organisation, have in their staff veterinary personnel who are responsible for purchasing cattle from markets for their operations. These veterinary personnel are provided with trypanocides to treat each animal prior to movement from the market sites.

<table>
<thead>
<tr>
<th></th>
<th>Number of cattle moved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Governmental Organisations</td>
<td>4250</td>
</tr>
<tr>
<td>Governmental Organisations</td>
<td>53607</td>
</tr>
</tbody>
</table>

*Table 7-4: Numbers of cattle reportedly imported by the non-governmental and governmental affiliated organisations during 2008*
The numbers of cattle being moved by the organisations that are shown in Table 7-3 are examined within Table 7-4 to exemplify the relationship between which group of affiliation are responsible. Clearly the organisations of governmental affiliation are responsible for the movement of higher numbers of cattle than the NGOs, further when the numbers are split to the average for the 15 NGOs and three GOs it is seen that each GO averages 17,869 cattle imported during 2008 whilst the NGOs average is found to be 283 during the same period.

### 7.3.2.3. Supply mechanism of cattle for restocking

The cattle can potentially be acquired for movement into the districts that are being restocked by a number of means and from a number of potential sources.

<table>
<thead>
<tr>
<th>Who acquires the cattle</th>
<th>Overall</th>
<th>Non-Government</th>
<th>Government</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualified Vet</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Qualified AHO</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Animal handler</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Contractor</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>15</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 7-5: Means of cattle acquisition

Table 7-5 contains the results from questioning the cattle restocking organisations as to who procures the animals they import into the restocked districts. Importantly this table shows that all of the government restocking organisations have their cattle purchased by a qualified vet who is a member of staff. This was also seen by personal observations during the field work for Chapter six. Conversely 14 of the 15 NGOs acquire their cattle through private contractors, which were observed during field sampling to almost certainly result in the animals being left untreated, due to the reduced profit margin that this would incur to the contractor.

As a generalisation the restocking organisations that have qualified veterinary personnel for the acquisition of cattle have more structured and developed cattle restocking programmes.
The source of cattle being imported by restocking organisation was found to be predominantly unknown by the restocking organisations as the animals are brought in by private traders without a specified trade source, other than the district of origin (Table 7-6). All three of the government organisations source their cattle from large markets, with two non-governmental organisations specifying that cattle are procured from large markets. Three non-government organisations answered that they acquired their cattle directly from communities within the specified source district and not from the formal market system. Finally one non-governmental organisation responded that they partially obtained cattle from ranches in the south-west of Uganda, although it was specified that these animals were the Friesian cross breeds being imported specifically for milk production. As such the originating location of the cattle bought by the NGOs is highly likely linked to the purpose that the cattle are being acquired for, this aspect will be examined later within this chapter.

### 7.3.2.3.1. Inspection of cattle

Prior to moving cattle from a point of sale it is required that a visual inspection (at least) of the animal is conducted by a qualified veterinarian assessing the animals health, most importantly in reference to the presence of any communicable diseases which may be spread as a result of the movement of any infected individuals.
Encouragingly the responses to the interviews show that 16 of the 18 restocking organisations report that health inspections are conducted upon their cattle. Where as one organisation reported no health inspection was carried out on their cattle, one organisation was unsure of the inspection status of the cattle. It became apparent that the majority of animals sold at market to the NGOs and private purchasers were poorly assessed. The method by which the animals’ acquired for the restocking organisations health was also assessed during the interviews is investigated below.

<table>
<thead>
<tr>
<th>Cattle inspection</th>
<th>Organisation response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market vet at source district</td>
<td>7</td>
</tr>
<tr>
<td>Private vet employed by organisation</td>
<td>5</td>
</tr>
<tr>
<td>Vet in recipient district</td>
<td>3</td>
</tr>
<tr>
<td>No response</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 7-7: Method of inspection of animal health for all restocking organisations (GO and NGO)

Seven out of the 18 restocking organisations rely upon the veterinary staff at the source market to conduct any inspection of the animals destined for import when combined with the three non-respondents (see Table 7-7). Upon referral to the raw data showed that these three all had their cattle acquired by contractors and as such will have their animals inspected by market vet personnel, taking the total to ten. Five of the organisations having veterinary staff within their personnel, this includes the three government organisations that all have vets as permanent staff members. It is unclear whether the two non-governmental organisations that have been found to have their own veterinary staff are employing the veterinarians on a full-time or part-time basis.

Aside from the poor inspection, the animals that had been inspected were most commonly then not treated with the policy determined treatments.
7.3.2.3.2. Treatment of acquired cattle

Interviewees were questioned about whether the cattle that are procured for their operations were treated to prevent movement of transmissible disease; all of the organisations that were interviewed replied that the cattle they import are treated.

Restocking organisation personnel were then asked what specifically they were treated for; this question was open with no leading prompts. As the government organisations had been witnessed treating all animals with trypanocides, the main focus here will be upon the NGO accounts of treatments.

Four of the 15 organisations stated that trypanosomiasis was treated. Three of the 15 stated that cattle were treated for any specific ailment presenting. One respondent was unable to say what treatments were offered. One of the interviewees stated that all their animals are injected with insecticides, which is most unlikely and an indication of the level of animal handling knowledge and not an indication of what is genuinely occurring.

7.3.2.4. Purpose of cattle for restocking and type of cattle imported

While the purpose of operation stated by the restocking organisations is overwhelmingly for the elevation of poverty, the means by which the cattle are destined to provide poverty elevation to the recipient communities is varied to four predominant approaches.

The 18 organisations interviewed often gave multiple responses as frequently restocking organisations import cattle for more than a single purpose, which is why there are 25 responses in Table 7-8.
The principle method of poverty relief stated by restocking organisations is through the provision of cattle for the purpose of providing draught power, whereby cattle are used to plough plots of land, improving the productivity of arable activities (Table 7-8).

Following draught purposes importation of cattle for breeding or restocking intentions are the second most commonly referenced reason for cattle importation followed by milk production and meat provision respectively.

The breeds of cattle selected for importation by the restocking organisations is also of relevance as, generally the breeds of cattle are spatially distinct. With Zebu predominating from the South-East region of Uganda and Ankole from the Western and South-Western regions, as do the Friesian animals. The differences between what breed of cattle organisations are selecting and the purpose for which they are being imported will be investigated later within this chapter.

Of the breeds imported by the restocking organisations, the majority of organisations selectively acquire Zebu breed cattle for the purpose of restocking: This suggests that the animals being imported by these organisations are highly likely to originate from *T. b. rhodesiense* affected areas because in Uganda Zebu are near to exclusively found in this

<table>
<thead>
<tr>
<th>Purpose of import</th>
<th>Organisations import directive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draught</td>
<td>15</td>
</tr>
<tr>
<td>Milk production</td>
<td>4</td>
</tr>
<tr>
<td>Breeding / Restocking</td>
<td>5</td>
</tr>
<tr>
<td>Meat</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7-8: Justification for cattle importation (responses to more than category are frequent)

<table>
<thead>
<tr>
<th>Breed imported</th>
<th>Organisations import directive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zebu only</td>
<td>13</td>
</tr>
<tr>
<td>Mixed breeds</td>
<td>3</td>
</tr>
<tr>
<td>Community decide</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 7-9: Breeds of cattle selected for import
region, with Ankole (which were not identified as the only breed to be imported by any of the restocking organisations) originating from the western regions, also no restocking organisation identified that they were importing only Friesian breed cattle (Table 7-9).

Furthermore two organisations import the breeds of cattle that are specified by the recipient communities. While working in the region it became apparent that the local population prefer Zebu cattle for the reason that they are hardier than the Ankole and Friesian alternative breeds hence communities are likely to have requested and subsequently imported Zebu cattle. Finally three organisations imported a mixture of breeds, after referring to the raw data these three organisations are found to be importing cattle for multiple purposes and it is likely that Friesian crosses were imported due to their higher milk yield than Zebu, while Ankole will be selected for breeding operations but not for draught power due to their stubborn temperament.

The ages of cattle being imported by the restocking organisations in Table 7-10 shows that adult animals are most commonly selected, which is of interest as the purpose of importation was most frequently stated as being for draught in Table 7-8. If this is the case it would be logical that juvenile cattle would make up the majority of animals imported as these would be more suitable for training into draught animals than an adult (unless purchase is specifically of draught trained animals). This protocol of giving young animals for training has lead to recipient communities referring to these animals as unproductive gifts as such the restocking organisations may likely have altered their strategy to giving adult cattle that can be used to provide draught power straight away after donation.
That juvenile animals make up the second most commonly imported age group of animals, is suggestive that some of the restocking organisations are more aware what is required by the recipient communities than others, with a lower number of restocking organisations bringing suitable animals to their beneficiaries. This view was galvanised during personal conversation with both community members and veterinary personnel who indicated that often old ‘stubborn’ animals are given for draught. Likewise frequently juvenile or even calf aged animals are donated for breeding / restocking purposes, these animals are unable to reproduce for up to two years and are seen as a burden upon the recipient.

With the high occurrence of organisations importing animals for the purpose of providing draught power (shown in Table 7-8) it is expected that they are preferentially importing males, as they are more fitting for draught traction due to being stronger and heavier than female cattle.

The results of the interviews show that 11 of the 18 organisations do acquire only male cattle for their operations, which supports the report that most were distributing cattle for the purpose of traction. With six organisations acquiring cattle of both genders, these organisations were those that indicated involvement in restocking for breeding purposes, and one organisation letting the recipient community decide.

<table>
<thead>
<tr>
<th>Age of cattle imported</th>
<th>Organisations import directive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf</td>
<td>1</td>
</tr>
<tr>
<td>Juvenile</td>
<td>5</td>
</tr>
<tr>
<td>Adult</td>
<td>8</td>
</tr>
<tr>
<td>Community decide</td>
<td>2</td>
</tr>
<tr>
<td>No age stipulated</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 7-10: Ages of cattle imported by restocking organisations
7.3.2.4.1. Breeds and ages of cattle imported for each purpose

The relationship between the reason for import by the organisation and the breed that are brought in for each specific purpose is still unclear. Through analysing the responses from each organisation independently it is entirely possible to assess whether there are specific preferences for animals of a particular breed or age being acquired for a specific purpose.

The graphical representation of the data comparing the breeds of cattle being sought by agencies operating with differing objectives shown in Figure 7-6 shows that there is a definite preference for the Zebu breed to be imported as to provide draught power. Whereas Friesian cattle were imported to provide milk and breeding (to improve the high milk yielding population), Ankole cattle were found to have been imported for both draught and breeding.

The fact that Zebu are so preferred for the purpose of animal traction is relevant in terms of *T. b. rhodesiense* introduction as the Zebu breed is predominantly from Uganda’s South East region. As well over half the restocking programmes are operating to provide draught cattle it follows that Zebu are by far the most commonly imported breed into the *T. b. rhodesiense* naive region of Northern Uganda.
Organisations that brought in cattle for draught most commonly stipulated the acquisition of mature adult animals, with just over twice the number of organisations selecting adults over juvenile cattle (Figure 7-7: Ages of cattle imported for specific purpose by restocking agencies). This is interesting as the selection of juveniles is likely to facilitate the training of the recipients in draught animal management as the animal would first need to be broken into be used for traction. The importation of adults indicates that these organisations are more focused with providing animals for immediate use than enabling the community to prepare and train more animals for draught power. A single organisation selected calf aged cattle for draught projects; this indicated that the initiative was more to enable the community to gain access to further power with their experience raising a draught animal from a very young age.

Animals brought in for milk provision by the three organisations working in this field are split with one importing juveniles, one adults and one allowing the recipients to decide, this is of little surprise as the training for milking is not as intense on either the animal or keeper, so productive older animals are most suitable.
The organisations that were operating to provide animals for breeding purposes all indicated that they only requested adult cattle for their programmes; this is as animals for this purpose require no conditioning and the training for the keepers will consist of little more than basic animal husbandry.

7.3.2.5. Support offered for cattle recipients

The distribution of cattle into recipient communities is unlikely to have been a single point event, with the restocking organisations subsequently being disinterested in the upkeep of the donated cattle.

The results of interviews shows that 16 restocking organisations do offer some level of follow up support to the recipients of their donated cattle, whereas two organisations do not offer any level of support to their recipients.

The nature of the support offered by these organisations can be divided into two main categories: Firstly, livestock management training, which entails training the recipients to be able to effectively manage their animals, improving both the standard of living for the animal and maximising their potential outputs. Secondly, animal health assistance, provision of veterinary services to the distributed cattle, ensuring they remain healthy and productive after allocation.

<table>
<thead>
<tr>
<th>Nature of support</th>
<th>Organisation response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock management training</td>
<td>5</td>
</tr>
<tr>
<td>Animal health assistance</td>
<td>0</td>
</tr>
<tr>
<td>Both</td>
<td>11</td>
</tr>
<tr>
<td>No assistance</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 7-11: Nature of support offered to cattle recipients by restocking organisations

Of the 16 organisations offering follow up support to their recipients all of them give livestock management training to the recipients; this occurs prior to the distribution of the
cattle. Furthermore, 11 of the organisations also give assistance with the maintenance of animal health which is a continued effort to ensure the animals remain productive after distribution. None of the organisations solely rely upon the provision of animal health assistance.

**7.3.2.6. Survival rate of distributed cattle**

The survival rate of distributed cattle is of high relevance, if many cattle are dying after distribution it is indicative either that the animals are being mismanaged by the recipients or they have been imported with existing health problems.

Interviews with the restocking organisation showed that all 18 of the restocking organisations interviewed had some level of data on the survival rate of cattle they had distributed.

As each of the agencies operate independently the follow up rates at three and six months post distribution were requested, with response given to the time point that correlated closest.

Just over half of the interviewed organisations were able to provide a survival rate for the cattle that they had distributed to recipient communities. The responses are represented in graphical form in Figure 7-8.
Figure 7-8: Cattle survival rate as reported by restocking organisations

Figure 7-8 shows that the responses from the restocking organisations, able to give a relevant survival rate, put the survival rate of all imported cattle at between 75% and 100%. In addition to the responses that are shown seven respondents were unsure of the survival rate at three months and eight were unsure of the survival rate at six months. During interviews the interviewees often stressed that losses were often not due to health, with wild fires and conflict being cited as the reason for animal losses.

The number of cattle that were imported by the interviewed restocking organisations was reported to be at least 57,503 during 2008 this equates to the loss of 14,376 with an overall 75% survival rate and 5750 with a 90% overall survival rate.

7.3.2.7. Knowledge of *T. b. rhodesiense* as a zoonosis

Along with assessing the animals that are being imported by the restocking organisations it is also necessary to gauge the awareness of acute sleeping sickness and the causative *T. b. rhodesiense* within the restocking organisation network.
Table 7-12: Interviewees’ awareness of acute sleeping sickness

<table>
<thead>
<tr>
<th>Have you any experience with, or know of acute or Rhodesian sleeping sickness?</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>12</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
</tr>
<tr>
<td>No response</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 7-12 shows that the great majority of organisation operatives answered that they were aware of the disease acute (or Rhodesian) sleeping sickness. However, it is often the case that persons in a position of power do not want to appear foolish by not knowing about a matter when asked, in order to establish whether the subject was really known a series of open ended follow up questions were asked. One of the participants stated that while he was growing up in Iganga during the 1970’s his elder brother had contracted the disease and spent a lengthy time in hospital.

From the questions that were asked the overall proportion of interviewees that were able to give correct, or acceptable, answers uniformly and there for can be considered to truly know acute sleeping sickness and more importantly that cattle from the South Eastern region harbour the parasite is established. Four of the 18 persons questioned were able to answer all questions correctly. Only one interviewee from the NGOs and all three interviewees from the GOs, all of whom were veterinarians, the full analysis of these individual questions are detailed below

Table 7-13: Interviewed member of restocking organisation knowledge of sleeping sickness

<table>
<thead>
<tr>
<th>What is sleeping sickness?</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trypanosomiasis</td>
<td>3</td>
</tr>
<tr>
<td>Human disease</td>
<td>6</td>
</tr>
<tr>
<td>Sleep disruption *</td>
<td>1</td>
</tr>
<tr>
<td>Tsetse transmitted</td>
<td>6</td>
</tr>
<tr>
<td>Animal disease only *</td>
<td>2</td>
</tr>
<tr>
<td>Zoonosis</td>
<td>3</td>
</tr>
<tr>
<td>No response *</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 7-16 shows the summary of the answers given by the personnel of restocking organisations (although the answers were given verbally as prose) answers that indicated that the interviewee had no knowledge of the subject are marked with an asterisk (*), as such interviewees gave seven answers that can be considered incorrect. However three interviewees gave the unprompted response that it was a zoonotic disease, six identified sleeping sickness as a disease effecting humans, six also identified tsetse as the vector, and three termed it, or referenced, trypanosomiasis. These responses showed that about half of the personnel interviewed had a basic knowledge of the disease, as it was a free prose response; the awareness was examined further still through questions requiring more specific answers.

Asking the interviewees about the location where acute sleeping sickness occurs is critical as some may even be aware that they are risking importing diseases to their donor area.

<table>
<thead>
<tr>
<th>Where is acute sleeping sickness endemic in Uganda?</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>1</td>
</tr>
<tr>
<td>South-Eastern</td>
<td>8</td>
</tr>
<tr>
<td>Northern</td>
<td>2</td>
</tr>
<tr>
<td>Southern</td>
<td>0</td>
</tr>
<tr>
<td>Unsure</td>
<td>3</td>
</tr>
<tr>
<td>No response</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 7-14: Locations restocking organisations cited as harbouring acute sleeping sickness

Table 7-14 shows that eight interviewees correctly identified the South-Eastern region as being the location where acute sleeping sickness occurs within Uganda, seven did not respond or stated they were unsure about the answer. Two wrongly identified the northern direction and one stated it was in the Western region, these three incorrect responses could possibly be down to confusion between acute and chronic sleeping sickness, which does have an established foci in West-Nile region.
When asked directly how sleeping sickness is transmitted to humans 13 interviewees gave responses that indicated accurate the knowledge of the tsetse vector transmission mechanism of sleeping sickness. A total of five respondents were unable to give any response to the transmission mechanism, indicating poor knowledge of the disease.

<table>
<thead>
<tr>
<th>Animal reservoir in Uganda</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>7</td>
</tr>
<tr>
<td>Buffalo</td>
<td>3</td>
</tr>
<tr>
<td>Wildlife</td>
<td>1</td>
</tr>
<tr>
<td>No reservoir</td>
<td>1</td>
</tr>
<tr>
<td>Unsure</td>
<td>4</td>
</tr>
<tr>
<td>No response</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 7-15: Knowledge of animal reservoirs of sleeping sickness in Uganda

Table 7-15 shows that when responding to an open question (no prompts offered) seven interviewees correctly identified that cattle are the reservoir of *T. b. rhodesiense* within Uganda. Other than these seven responses all other answers that were given were inaccurate, while buffalo can act as reservoir they are not of significance within the context of Uganda where they are restricted to the west of Uganda which is free from acute sleeping sickness.

Finally the interviewees were asked how sleeping sickness can be prevented; the response to this was again free prose so as to avoid leading the interviewees into guessing answers.
<table>
<thead>
<tr>
<th>How can sleeping sickness be prevented</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsetse trapping</td>
<td>11</td>
</tr>
<tr>
<td>Epidemiology</td>
<td>5</td>
</tr>
<tr>
<td>Habitat destruction</td>
<td>6</td>
</tr>
<tr>
<td>SIT</td>
<td>1</td>
</tr>
<tr>
<td>Vaccination *</td>
<td>1</td>
</tr>
<tr>
<td>Quarantine cases *</td>
<td>2</td>
</tr>
<tr>
<td>Avoid bites</td>
<td>1</td>
</tr>
<tr>
<td>No response *</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 7-16: Interviewees interpretation of how sleeping sickness could be effectively prevented

Table 7-16 shows each of the results given by the interviewees, seven of the responses are indicative that the interviewees had little or no understanding of the disease these are marked with an asterisk (*).

The other responses suggest that the respondents have good knowledge of the way that sleeping sickness can be controlled, one of the interviewees stated that they had themselves been involved in the mass clearance of tsetse habitat from Iganga district during the mid 1970's.
7.4. Discussion

7.4.1. Responses given by DVOs

From the interviews conducted with both DVOs and restocking organisations of Northern and West Nile regions of Uganda it is clear that there is a large scale of cattle movement, specifically into the Northern region as a result of restocking organisations.

Restocking organisations are most active in the districts of Northern Uganda, as West Nile was not as heavily affected by the ongoing and brutal conflict between the rebel LRA forces and the government UPDF troops, so the cattle population was not as heavily depleted.

7.4.2. Responses given by restocking organisations

With the amount of animals being moved into the Northern region there is a high risk of introduction of *T. b. rhodesiense* into this area, especially when combined with the fact that the virtually all animals for NGO programmes are being acquired by private contractors who negate treatment with trypanocides as the cost of treatment will reduce the profit being made.

While it has been seen that the NGO restocking organisation cattle remain untreated and as such highly likely to facilitate the introduction of *T. b. rhodesiense*, the animals that are acquired for governmental restocking are bought by qualified veterinarians who have trypanocides provided for the treatment of purchased cattle.

While the majority of animals are imported to the Northern region by the government affiliated programmes (53607) there is also a high number of animals brought in for NGO operations (4250) which are highly doubtful to receive any form of treatment so the risk of importation of *T. b. rhodesiense* to the region by NGOs is high.
7.4.3. Supply of cattle for distribution

Of the organisations that have been identified as active in cattle restocking to the Northern and West Nile regions all of the three government affiliated restocking organisations acquired their cattle through their own privately employed veterinary staff members. These personnel attend the markets sales and select which animals are procured for their respective organisations. While collecting blood samples from cattle at markets these veterinarians were witnessed treating each animal they had purchased with diminazene aceturate. Conversely of the 15 organisations of non-governmental affiliation 14 acquired their cattle through an external private contractor, some of whom admitted to not treating the cattle they acquired as it impacted upon their profit margins. One of the NGOs indicated that their animals were acquired by a qualified Animal Husbandry Officer (AHO), upon reference to the raw collected data this organisation was shown to have imported 80 cattle during 2008 as such the AHO was most likely not in their direct (permanent) employ but sub-contracted from the district veterinary officer for the purpose of acquiring cattle.

While the contracting of a private party for the purpose of cattle acquisition would not be of concern if the persons contracted were adhering to the government policy (stating that all cattle traded at markets are to be treated with trypanocidal compounds prior to leaving the market site). But as it has been both personally witnessed and freely admitted by these contractors that they are not carrying out these essential treatments at all. As such it is clear that the agencies that are participating in restocking whom are acquiring their cattle through external private contractors are likely responsible for the unwitting import of T. b. rhodesiense into the areas of the communities they are attempting to benefit. Whereas the governmental associated agencies have shown to be operating with perfect policy in terms of minimising the potential introduction of disease through their actions, this is implicitly due to the fact that their fully qualified veterinary staff members inspect each animal prior to purchase. With this achieved it is less likely that the animals that are acquired will be infected with any transmissible disease to start with as the highly skilled veterinarian staff will avoid purchasing animals with clinical manifestations of disease.
Whereas the private contractors do not have this level of training and as such are more likely to acquire cattle that are infected.

7.4.3. Discrepancies between DVO and restocking organisations responses

The numbers of animals being moved into the study area by restocking organisations during 2008 is reported by the DVOs as being in excess of 2767 cattle, this figure was taken from four of the seven districts as three of the DVOs were unable to state how many cattle had been imported into their district by cattle restocking organisations.

From the responses given by the non-governmental restocking organisations in excess of 2767 cattle were imported by these organisations, with the three governmental restocking organisations reporting that 53,607 cattle had been imported into the Northern and West-Nile regions. This shows that the vast majority of cattle that have been imported have been done by government organisations.

7.4.4. Animal treatment facilitated by the United States military

During 2008 and early 2009 the United States of America’s military funded (and accompanied) the treatment of all animals within the heavily conflict effected districts of Gulu and Amuru. This action was publicised as humanitarian providing much needed assistance to the war-torn region’s recovering community.

The three distinct treatment sessions (over seen by Makerere University’s faculty of Veterinary Medicine) did treat all cattle that were presented to them with the trypanocide diminazene aceturate, along with a range of other drugs, although many other drugs were administered upon the diagnosis of specific issues.
The numbers of different animal species treated by the US funded operation as a total sum is shown in Figure 7-9 are the sum of the numbers of animals treated during the treatment time points. As such it has to be considered that at least some of the cattle that make up the figure of 14,415 cattle treated with diminazene aceturate will have effectively been cleared of any trypanosome infection.

When compared to the cattle population, of the same region (Gulu and Amuru), of 18,112 taken from the 2002 census (as discussed in Chapter 5), the treatment rate is found to be 79.6% of the cattle in the area. Which is less than the effective clearance target rate of 86%, as discussed in Chapter 3; resultantly any T. b. rhodesiense which may have existed within the project area will have not been eradicated by this particular campaign.
7.5. Conclusion

Through the analysis of the movement patterns of cattle sold, and permitted for inter-district movement in the previous chapter it is clear that cattle sold at market are being supplied to the northern districts. Investigation into the involvement of organisations operating within the districts of West Nile and Northern Uganda that are active in the field of cattle restocking (of both governmental and non-governmental affiliation) has shown conclusively that these bodies are commonly purchasing cattle from the markets of the South-Eastern region proven in Chapter 6 to have *T. b. rhodesiense* afflicted animals for sale.

It is indicated that there is a difference in social responsibility between the government and non-government aligned organisations, in reference to the fact that all bar one of the interviewed NGOs were acquiring their cattle indirectly though an external privately operating contractor. Whereas the cattle destined for government initiatives were acquired by veterinary personnel who are full time employees of the organisation. Considering that while working at these market sites it was witnessed that the staff of the government organisations were treating all of their purchased animals with the trypanocide diminazene aceturate. By comparison no other buyer was seen doing so; and when approached the private contractors commonly admitted that this practice was overlooked to maximise profit margins. However it is not the case that the NGOs are acting with social negligence, as it is the private contractors who are avoiding treatment, it must be considered that they are unaware of the proper requirements of cattle importation. With proper explanation of the imperative nature of treating the animals they import it is the author’s view that NGOs will actively ensure that their private contractors are operating with compliance of government treatment policy.

What can be taken from this is that a combination of factors (including non-compliance with government policy by both buyers and operators of markets, who are not enforcing treatment prior to granting movement permits) are currently leading to the vast majority of the NGOs being at high risk of inadvertently importing *T. b. rhodesiense* into the
districts that are currently deemed to be clear of this zoonotic parasite, as a result of the private contractors not complying with government policy. In essence through their will to assist the people of the conflict embattled Northern region by providing cattle for both breeding and cultivation purposes (which was what the Zebu breeds from the South East were preferred for) they have greatly endangered their beneficiary community through the potential, but highly likely, importation of this deadly pathogen.

Finally in relation to the treatment of cattle that was headed by the United States Marine Corps within the districts of Amuru and Gulu, this was designed to cover all the animals present within these districts, while those whom were active with the programme are confident the coverage was close to 100% it is the authors belief that this is a great disillusion. This sceptical view is founded upon the treatment operation covering 14,000 heads of cattle (all of which were treated with trypanocides), according to the 2002 census data from the Uganda Bureau of Statistics there were a total of 18112 accounted cattle in the two districts (1686 in Amuru and 16426 in Gulu). Bearing in mind both that the census is a massive under-representation due to fear of cattle taxation and that since 2002 the population of cattle will have increased as fighting in the area has ceased and the civil population have returned to arable and agricultural activities (identical to the discrepancies in cattle population estimates used for SOS activities discussed within this thesis). While the US lead treatment was by no means a failure, at best it must be considered a temporary reduction of trypanosomes in the recipient area, as it is likely that less than 50% of the cattle population were treated and movement of infected animals has continued since.
8. Discussion

This thesis has investigated two predominant aspects of acute sleeping sickness epidemiology within northern Uganda. Firstly the control of sleeping sickness through cattle based intervention and secondly to investigate the potential spread of the disease into new areas of Uganda as a result of cattle movement.

To assist with the clarity of the discussion it shall be split into subsections concerning the results chapters, with overlapping themes discussed where they are relevant.

8.1. Outcomes of SOS programme

The SOS programme is a public private partnership initiated during 2006 in response to increasing numbers of HAT cases in previously clear regions of south-eastern and northern Uganda. The causal agent of these cases was identified as *T. b. rhodesiense* (Picozzi *et al.*, 2005b), a zoonotic parasitic infection that is vectored by the tsetse fly. In November 2006 a large scale intervention programme treated 179,478 cattle with trypanocides across the recently affected area of Uganda.

Resulting from the actions of the SOS intervention programme, a statistically significant reduction in the prevalence of both *Trypanosoma brucei* s.l. (P<0.0001) and *T. b. rhodesiense* (P=0.0018), between the baseline and three month post intervention sampling time points was identified by molecular analysis.

This reduction was reciprocated in the numbers of human African trypanosomiasis (HAT) cases originating from within the SOS treatment region, presenting for treatment at either of the local sleeping sickness treatment centres (namely Lwala hospital in Kaberamaido district and Serere hospital in neighbouring Soroti district) when compared to the year directly prior to the SOS programme, as shown in Figure 8-1.
Figures 8-1: Numbers HAT of cases originating from SOS region prior to and post intervention (SOS intervention time point indicated by red line)

Numbers of diagnosed HAT cases originating from within the SOS region are shown to have increased dramatically from a single case during 2003 (which was the first recorded case from the region) to 136 cases during 2004 with further increase to 164 diagnosed cases in 2005. This great rise was likely assisted in its severity by the rapid increase in public awareness of a fatal disease outbreak within the recently affected area. This awareness was assisted by news agency coverage such as local radio broadcasts and the national newspaper coverage such as the article titled “Sleeping sickness kills 10”, which reported that ‘The district (Kaberamaido) has been declared a disaster zone after 10 people died of sleeping sickness’ (Angonu, 2005, Olwa, 2005). One can imagine the effect that coverage such as this would have upon the awareness within the previously naive community. It is likely that more people sought out testing for sleeping sickness upon illness as a direct result of this heightened public awareness.

Overtime the public perception of a disease alters as public concern dissipates and it is likely that the fall in patients diagnosed with the disease by 2006 is attributable to fewer people presenting for testing. This trend is reciprocated within the UK by the demand for anti-viral drugs generated by public perception of swine flu; during the peak of media attention (mid 2009) 40,000 people a week were accessing treatment. By February 2010
this figure had fallen to just 5,000 (Walsh, 2010), while distribution of the anti-viral drugs was conducted without diagnosis, the relationship between public awareness and attendance for treatment (testing in the case of sleeping sickness) is clear.

The impact of the SOS intervention upon HAT cases is difficult to assess fairly as concurrent to the SOS activities there was also an active sleeping sickness awareness campaign operating within the SOS region. Resulting from this elevated awareness level within the community it is possible that the numbers of HAT cases reporting for treatment would rise despite there being fewer actual cases within the region, this is ratified by the fact that only one of every 12 sleeping sickness cases are reported (Odiit et al., 2004b). As such raising the awareness of the disease within the region could reduce this under-reporting, thus the impact of SOS is greater than these numbers suggest. But as the documented HAT case numbers fell from 70 cases during 2006 to 55 during 2007 (after SOS activities plus three months to account for case development post infection) it can be considered that the human cases were greatly impacted as a result of the SOS cattle treatment activities.

Previous work investigating the action of mass trypanocidal treatment of cattle within two separate areas of Uganda and the occurrence of reported HAT cases suggested that there was a negligible effect created by the intervention upon the rate of reported sleeping sickness cases (Fyfe, 2007). However it was noted that the treatment should by no means be discounted as concurrent LRA – UPDF fighting caused mass migration of civilians into one of the study areas, meanwhile within the other study area the human disease was remitting, both of which could have affected the perceived effect of the intervention.

The SOS intervention has clearly been successful in the short-term at reducing the prevalence of human infective parasites within the cattle reservoir, but assessing the long-term impact of the strategy must be accounted for through assessing the initiatives affectivity and impact upon the *T. b. rhodesiense* burden within the region over a period of 18 months after intervention.
8.2. SOS effectively and sustainability

The SOS treatment of cattle with trypanocide and insecticide during November 2006 was shown to have initially controlled the prevalence of both *T. brucei* s.l. and *T. b. rhodesiense*. As proven by the substantial reduction in prevalence detected by PCR for both of these pathogen species during the three month post intervention sampling results. The subsequent rebound of prevalence in both of these target pathogens by nine month post intervention sampling, to a level with no statistical difference to the pre-intervention baseline sampling findings, indicates hindering factors associated with the post intervention insecticidal spraying operations. Further increase of *T. brucei* s.l. prevalence by 18 month post intervention to double the pre-intervention findings was reported throughout the SOS treatment region.

8.2.1. Main drivers for the return of *T. brucei* s.l. and *T. b. rhodesiense* within the SOS region

While the SOS intervention was successful in terms of reducing the prevalence of both *T. brucei* s.l. and *T. b. rhodesiense* the long term effect was not so successful, due to the return in prevalence of both species.

The main factors which are likely to influence this return of parasitemia are briefly discussed within the following section. It is imperative that these are not thought as the only drivers for return as other (potentially) lesser impacting factors are also discussed later within this section.

Following the HAT epidemic in Soroti (1999-2005) it was noted that within the cattle reservoir the ratio of *T. b. brucei* to *T. b. rhodesiense* was 3:1. This ratio appears to be a common feature where *T. b. rhodesiense* has become endemic within the animal reservoir (Welburn et al., 2001c). The findings from within the SOS region show the percentage of *T. brucei* s.l. infected cattle that were *T. b. rhodesiense* to be 5.18% at the pre-intervention baseline sampling and 1.94% at 18 months post SOS treatment. As such it is clear that although the baseline ratio is not as high as was found in Soroti, the SOS
intervention had an indisputable effect upon the zoonotic parasite despite the return of *T. brucei* s.l. over time after the intervention. Understanding the dynamics of the relationship between these two parasites is beyond the scope of this thesis.

### 8.2.1.1. Treatment coverage rate

In order to reduce the reproduction index of *T. b. rhodesiense* to less than 1 within the region it was the aim of the SOS treatment programme to achieve an insecticide treatment coverage rate of 86% of cattle (Welburn et al., 2006). From cattle population estimates for the SOS region, generated by Makerere partners in the SOS operation, it was indicated that the treatment rate during November 2006 exceeded 100%.

During this investigation it has been shown by interviewing cattle owners that the treatment coverage rate within the sampled population of cattle for SOS intervention analysis was in fact substantially lower at 61%, suggesting that the treatment coverage within the entire SOS region is similarly low. This discrepancy between reported and detected coverage rates is attributable to an underestimation of the regions cattle population during the initial coverage rate calculation. The government census was therefore deemed too inaccurate to generate the population figures for the SOS region.

A comparison between the estimated cattle numbers generated by Makerere veterinary personnel (174,851) is not drastically different to the figure generated for the 2002 census (155,496), this is surprising as it was expected that the government derived figures would greatly under-report as due to fear of taxation of livestock, thus when asked, individuals would state ownership of fewer animals than they genuinely owned. The deviation between these two population figures is not substantial enough to account for the difference between the reported treatment coverage rate of in excess of 100% and the observed treatment rate of 61%. However, with consideration to the direct method by which observed treatment rate were obtained it is the personal opinion of the author of this thesis that the figures from the census and estimates are both much lower than the
actual number of animals, although accurately calculating this cattle population would be highly problematic.

8.2.1.2. Inclusion of swine

Prior to the inception of SOS it is worth noting that members of the public private partnership expressed concerns that SOS activities were to focus only upon cattle and not including domestic pigs within the treatment area. The role of pigs in terms of transmission of *T. b. rhodesiense* to humans is unclear (Schares & Mehlitz, 1996, Kioy & Mattock, 2005) as the role of infected animals is not shown to definitely have epidemiological importance in terms of human infection. However, pigs are shown popular feeding hosts of the tsetse fly, to a similar level as cattle.

Previous analysis of the origins of bloodmeals within captured tsetse flies (*Glossina fuscipipes fuscipies*) caught within south eastern Uganda has previously shown that 35% of flies had fed upon cattle, while 23% had fed upon pigs (Waiswa et al., 2006). Furthermore when these bloodmeals were analysed, 14% of the cattle sourced feeds were found to harbour *T. brucei* s.l. whereas 19% of the pig feeds were harbouring the parasite. This suggests that not only are pigs being fed upon to a comparable level as cattle, but also that these feeds are equally capable of introducing viably infective *T. brucei* s.l. parasites to flies.

If treatment of cattle is conducted, effectively clearing *T. b. rhodesiense* from the bovine population but the pig reservoir is not addressed; it is plausible that the situation could arise where cattle are re-infected by tsetse that have acquired *T. b. rhodesiense* from previously feeding upon pigs (Waiswa et al., 2006).

During the course of my field work the high numbers of pigs, particularly within the sub county of Otuboi in Kaberamaido district, were noted. The data displayed in Table 8-1 has been acquired from the 2002 population and housing census which was conducted by
the Ugandan Bureau of Statistics. While this census does have accuracy issues (as previously discussed within this section), it is appropriate for this comparative purpose as different animals are likely to have been under-estimated to a similar rate.

<table>
<thead>
<tr>
<th>District</th>
<th>Numbers</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cattle</td>
<td>Pig</td>
</tr>
<tr>
<td>Amolotar</td>
<td>38344</td>
<td>9746</td>
</tr>
<tr>
<td>Apac</td>
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<td>4120</td>
</tr>
<tr>
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<td>4158</td>
</tr>
<tr>
<td>Kaberamaido</td>
<td>29338</td>
<td>9860</td>
</tr>
<tr>
<td>Lira</td>
<td>68726</td>
<td>6391</td>
</tr>
</tbody>
</table>

Table 8-1: Cattle and pig population figures throughout the SOS region

From the data shown in Table 8-1 it is clear that the districts of Kaberamaido and Dokolo have a ratio of cattle to pig of 3:1 and 5:1 respectively, both of these districts were identified during the post intervention sampling as continuing to be afflicted by *T. b. rhodesiense*. These two districts were observed to have the highest prevalence of *T. b. rhodesiense* within their cattle populations, as measured by molecular means during the SOS baseline survey. High numbers of HAT cases were also reported from within their borders while the SOS programme did have an initial impact of lowering the cattle borne prevalence of *T. b. rhodesiense* to less than 1/10th of the baseline to 0.08%, within 18 months this figure had returned to 0.82%. The fact that these districts have continued to be afflicted since treatment could be attributed to a large population of domestic pig acting as a reservoir of infection.

Interestingly the ratio within Amolotar is four cattle to each pig. This district was included within the SOS treatment programme due to the fact it has direct boundary with two of the other districts within the remainder of the SOS region.

The district seemingly has no detected *T. b. rhodesiense* during baseline, three month, nine month and 18 month post intervention sampling. Retrospectively this could be due to a lack of sampling sites within Amolotar district, however during the 31 month sampling session (not analysed for this thesis) *T. b. rhodesiense* was indentified in a
single animal within the district. Amolotar is only represented as the home location of a single human trypanosomiasis case (2007), however this must be considered in relation to the district having exceedingly poor access to health centres that are capable of diagnosing or treating sleeping sickness. The sleeping sickness case from Amolotar originated from one of the sites included for cattle sampling, making it likely that the patient was motivated to travel 90 kilometres to Lwala hospital (where diagnosis was made and treatment administered) on the basis of information left by the sampling team.

Although it would be greatly beneficial to incorporate the treatment of swine along with that of cattle within a future SOS control campaign, there are issues accompanying the treatment of pigs alongside the treatment of cattle. Primarily swine are much more susceptible to stress than cattle (Hicks et al., 1998) and the pressure induced by administering treatment may result in losses of livestock, the responsibility for which would be pointed at the treatment activity. Also as pigs have a lot of body fat, ensuring the trypanocides are administered intramuscularly is very difficult. Another problem faced when treating pigs is that they are not generally kept within pens or tethered but rather allowed to range freely with minimal human contact, making the task of getting them to the treatment points difficult. However the comparative size of pigs means that they are much cheaper to apply insecticide to the entire body surface area than is the case with treating cattle.

Assuming pigs are included in the treatment programme. Surveillance of the trypanosome prevalence post intervention would be near to impossible due to the stress induced by the act of blood sampling. Also the fact that pigs have a much shorter life expectancy than cattle becoming viable for slaughter by six months of age; this makes the average life expectancy far shorter in comparison. With this high rate of generation turnover in pigs within rural Uganda the animals that were treated may not be present by the first sampling time point, making monitoring and evaluation of the impact of treatment on this animal population difficult to follow.
Factoring in the issues discussed above it is clear that domestic swine should be considered in future SOS activities; however the matter of stress effectively excludes them from trypanocidal treatment and sampling for evaluation. That is not to say they should be overlooked, as pigs should be included with insecticidal treatment activities aimed at reducing their role as reservoirs of human infective parasites. Highlighting the importance of their inclusion to farmers, who may view these animals as a short term investment, may be problematic.

8.2.1.3. Import of untreated cattle from market trade

SOS treatment occurred at a single intervention within a specific region; as such any cattle to be imported post treatment from areas affected by *T. b. rhodesiense* into the control area endanger reintroducing the species. The impact of this will be fully discussed later in Section 8.2.1.3.1.

Monitoring of cattle importation should be considered during the planning and application of future control programmes as the re-introduction of disease by this route would invariably adversely affect the success of any programme. Monitoring would best be conducted through centralised agreements with DVOs of treatment regions as well as DVOs of the districts known to supply cattle into the proposed treatment region. Accurate numbers of animals being legally imported to treatment areas can be sourced from documents from the supplying markets. Ideally it would be made possible for treatment of recently imported cattle to occur at central trade points, implementing this would undoubtedly have to be left in the management of the regions DVO and their staff. This treatment upon importation is essential due to the widespread non-adherence to the (currently unenforced) government policy that all cattle traded must be treated with trypanocides prior to leaving the trading site.
8.2.1.3.1. Import rate of *T. b. rhodesiense* infected cattle into SOS region

The risk of reintroducing *T. b. rhodesiense* to the SOS region (after the cattle population had been cleared of infection) as a direct result of cattle importation has been assessed through investigation of market trade records from 2007–2008 (the year following the SOS intervention). These records show that at least 4,274 cattle were imported into the SOS districts, from the markets within *T. b. rhodesiense* endemic region. From the PCR analysis of samples collected at the market sites, it is derived that at least 60 of these animals will have been infected with *T. b. rhodesiense* (based upon extrapolation of PCR results showing 1.4% prevalence and documented imports of 4,274 cattle). From personal observations it is realistic to assume that the majority of these cattle were imported with non compliance to the governmental policy that all cattle traded at market are treated with trypanocides, therefore these animals will have relocated while still carrying any pre-existing infections.

To assess the potential impact of this level of importation of infected cattle, the findings of past work into the introduction of *T. b. rhodesiense* suggests that the importation of 100 infected cattle into an area over a period of four years can effectively introduce and establish the parasite (Fevre *et al.*, 2001). Thus the importation of 60 infected cattle per annum into the SOS region has the potential to re-introduce the disease.

With the risk of importation of infection to the SOS region it must be considered that the market trade of cattle from outside of the SOS region has adversely impacted the effectivity of the control programme. This point is reinforced by the fact that at both the nine and 18 month post intervention sampling points 10% of the animals that were found *T. b. rhodesiense* infected had been imported since November 2006. While this is clearly not the only source of infection, it does highlight the involvement of importation as a contributing factor to the return of the species within the SOS control area.
8.2.2. Utilisation of prophylactic or curative trypanocides

The treatment regime deployed during the initial phase of the SOS programme utilised two different trypanocides, namely diminazene aceturate (DIM) which is curative and isometamidium chloride (ISO) which has both a curative and prophylactic period of three months. The areas of treatment were defined according to the perception of the level of challenge, with ISO being given to animals located in those areas most at risk of transmission. Subsequent analysis of samples collected during the SOS campaign confirmed that the high risk areas were accurately identified based on the molecular detection of human infective parasites within the cattle population and a higher incidence of HAT cases.

When compared, there were no significant differences in terms of treatment coverage between the areas receiving these different treatments. This is an encouraging finding when the level of transmission and challenge is taken into account; it is therefore likely that the prophylactic property of ISO in high risk areas does indeed have a positive effect.

8.2.3. Insecticidal treatment post SOS treatment

The SOS campaign was designed to be a single point trypanocidal treatment accompanied by sustained spraying of cattle with residual deltamethrin based insecticide. From questioning owners of the cattle that were sampled it was clear that just 61% of the sampled cattle population had been sprayed with insecticide (mainly by SOS operation of November 2006), of which only 31% of the cattle (during three, nine, and 18 month post intervention sampling sessions) had been sprayed in the period following the November 2006 treatment.

With the indication that just 31% of the cattle population in the SOS region received treatment with deltamethrin spray after the November 2006 intervention; it can be implied that the impact of the planned insecticidal aspect of the SOS intervention upon the tsetse vector was not effective at reducing the population number of the flies within
the region. With the fly population ineffectively suppressed it was possible for *T. brucei* s.l. and *T. b. rhodesiense* to continually be transmitted by an active vector population.

Shortcomings in the spraying component of the SOS programme are mainly attributable to the first scheduled follow-up spraying being designed to empower the communities by encouraging them to organise spraying, this failed predominantly to the low accountability placed upon those entrusted to organise and carry out the spraying operations. Likewise the distribution networks for deltamethrin into the SOS region were not established until later than was originally planned, largely due to problems securing the supply of insecticide into Uganda from Kenya.

**8.2.4. Detected bovine *T. b. rhodesiense* infection and the relation to origin of human cases**

The analysis of cattle sampling since the SOS operation indicated a focus of cattle found to be infected with *T. b. rhodesiense* upon the district boundary of Dokolo and Kaberamaido this area has previously been highlighted for its high pig population. When this area was compared with the information from parishes that provided human sleeping sickness cases, it was apparent that there was a single focus of human and cattle associate *T. b. rhodesiense* located upon the district of boundary of the Kaberamaido and Dokolo. The retreatment of these affected parishes was initiated during April 2008, study of this follow-up work has proven the basis of another PhD thesis currently underway within the same research group.

**8.2.5. Participant perception of SOS treatment activities**

As part of the monitoring and evaluation of the SOS programme opinions of the treatment personnel upon the running implementation and running of the project, as well as the various issues encountered was sought. This provided vital insight to the operation particularly how the programme was received by the local communities.
When asked, the SOS treatment personnel identified that the main logistic problems associated with this campaign related to the mobilisation and sensitisation of the community within the SOS region. A lack of community participation was thought to be due to an absence of information about the purpose and benefits of the SOS treatment. Likewise low dissemination of information concerning when and where the treatment activities were occurring were also believed to have impacted the treatment coverage. The public flow of information could be improved by interactions between the SOS personnel and the local community; visiting communities and leaders of the region, ensuring that accurate information is freely available with reliable point of contact also identified within the programme team.

As the SOS programme ran, this form of information transfer did occur to a limited extent as a result of treatment personnel attending church services on Sundays, where they were formally introduced to the congregation, with the SOS programme being explained directly by them. This form of dissemination was limited to select, accessible churches however in the future it could be easier expanded to incorporate other gatherings of the local population.

Several interviewees identified Kaberamaido as being the location were problems affecting the treatment coverage of cattle were most severe, while other districts were not so frequently recalled as problematic. As Kaberamaido was the first district to receive SOS treatment activities, it was bound to be affected by issues (predominantly due to community distrust of animal health based interventions) that had been resolved when treatment started elsewhere. Accordingly it is possible to predict which regions of future SOS intervention programmes will be most likely to have lowest impact based solely on the order that treatment occurred. In practice there are other considerations that also contribute to the coverage of treatment operations, including; political alignment of treatment areas, the land areas (as swampy areas will have higher tsetse burden, accompanied by the fact that gaining access to the swampy areas was more problematic, impacting treatment coverage within these areas) and the education level within treatment areas to list a few.
Within the setting of Northern Uganda it is likely that the institutional memory that exists within Makerere University will help in the successful establishment of any future work. Along with this, social memory would also have an input if SOS were to be re-initiated either within the area which had previously received treatment or directly neighbouring areas as distrust of the treatment initiative would be reduced, improving social trust of the proposed operations.

Post intervention sampling shows that Kaberamaido and Dokolo continued to be afflicted by *T. b. rhodesiense* (0.8% prevalence with significant difference to the remaining SOS region of P=0.0076). In Kaberamaido the continued *T. b. rhodesiense* presence coincided with the reports from the treatment personnel that this district had poor community sensitisation. Dokolo district which also had continued *T. b. rhodesiense* burden was not regarded, or at least reported, to have had these issues.

### 8.2.6. Limitations of SOS study

In an ideal setting the analysis of *T. b. rhodesiense* within the SOS intervention region would have been carried out as a longitudinal study, ensuring that sampled cattle are traceable throughout the sample points. By doing this the interpretation of the treatment’s effect would be absolute in nature as the information for each animal in relation to its specific infection status over time in relation to the treatment and spraying activities. However implementing such a study within the Ugandan Field environment would have presented many issues which it deems the conducting of a longitudinal study on such scale impractical. Notably for the following reasons: Over the 18 month study period many of the animals would inevitably be traded, slaughtered or die. There may well be unrecorded treatment of the sample cohort which would effectively discount the effort of tracking individuals. Also the factor that responsibility for treating specific cattle within the sample group would fall upon the sampler, especially with consideration of detected zoonotic pathogens. For these compounding reasons it was decided the best option was for the monitoring of disease at the herd level within each of the study sites.
8.3. Import of T. b. rhodesiense into northern region of Uganda

Movement of cattle from areas of Uganda endemic with T. b. rhodesiense into regions of Uganda that were previously unaffected by the species has previously been shown to result in the recipient region becoming afflicted by the parasite (Welburn et al., 2006). If cattle traded at market sites are not treated with trypanocides upon sale, the movement of potentially infected animals put recipient regions in danger. The presence of competent vectors at the destination is vital for the establishment of T. b. rhodesiense within the new location. As such importation alone cannot be considered as proof that a region will now be affected, but should be considered that areas that have imported cattle from T. b. rhodesiense endemic regions are at high risk, in the absence of recent monitoring data looking for the presence of vector competent tsetse within northern Uganda.

Sampling at the main markets within the endemic south east region revealed that 1.5% of the cattle bought for trade are infected with T. b. rhodesiense and as such have the potential to introduce the species.

8.3.1. Drivers for mass relocation of cattle

The main driver for the importation of cattle into the T. b. rhodesiense free northern districts of Uganda has been shown to have been predominantly attributable to the conflict within the region which in turn led to decimation of the cattle population. With estimates of hundreds of thousands of cattle being lost from the Northern region (Westbrook, 2000) as a result of the civilian population being forced into camps during conflict, compounded by effective cattle raiding within the conflict affected region by outside parties. Recently the conflict within the north has dwindled and rebel forces are not currently operating within Uganda, resulting in the civilian population returning to agriculture. Restocking of cattle is being conducted through two main routes:
1. Some animals are being imported as a result of private trade as the inhabitants of
   the north are directly acquiring their own cattle.

2. Other cattle that are imported into the region are brought in by restocking
   organisations for distribution to the local communities.

8.3.2. Proportion and numbers of cattle restocking activities

This thesis has shown that a large body of cattle have been imported to the Northern
region from the *T. b. rhodesiense* endemic south with comparatively few cattle being
imported from other regions of Uganda. It is clear that the import activities of restocking
organisations greatly out scale the importation figures generated by the private trade
sector. Throughout the regions of Northern and West Nile Uganda it was reported that
70% of all cattle imported were as a result of restocking organisations. When the West
Nile region (which was not heavily affected by conflict) is discounted the figure is 87.5%
of all cattle imported into the Northern region are brought in by restocking organisations.
With this movement pattern of restocking activities (if the animals are remaining
untreated) it is almost certain that these activities are introducing the zoonotic species to
areas previously unaffiliated by the pathogen.

8.3.3. Treatment rate by NGOs

Within the restocking organisations operating within northern Uganda there are two sub
groups: Non Governmental Organisations (NGOs) and Governmental Organisations
(GOs) it was shown by investigation that the three GOs operating restocking programmes
within Uganda all operate responsibly and legally by having a full time veterinarian who
acquires their cattle at market sites and personally ensures that these animals are treated
with trypanocides prior to departing from the market site (as was personally witnessed).
NGO operations commonly focus upon outsourcing cattle acquisition to private
contractors who purchase and import the cattle to the NGO’s specification. Contractors
were open about not administering treatment to the cattle they were purchasing and
NGOs frequently stated that treatment was at the discretion of the contractor; as such it is
a fair assessment that the overwhelming majority of cattle imported on behalf of the NGOs will be untreated against trypanosomes.

To address this it is probably sufficient to publicise the lack of treatment by the contractors to the organisations. As the organisations are primarily operating due to humanitarian reasons it would be counter to their purpose to endanger their recipient communities. Likewise however the basic malpractice of not treating cattle at the point of sale must be tackled in order to approach the problem of privately transported cattle being treated also, ideally through providing free, or subsidised, trypanocides for point of sale treatment purposes.

Perhaps the most suitable option to maximise adherence to current treatment legislation would be to shift the responsibility for treatment from the purchaser to the seller. This action would work as the purchaser would then demand that the animal had received treatment, while the seller would simply account for this in the price of the animal.

8.3.4. Areas documented as at risk of having imported T. b. rhodesiense

Analysis of past cattle movements indicates that the markets in the T. b. rhodesiense endemic region of South Eastern Uganda have supplied significant numbers of cattle to regions of the country previously unaffected by the disease; West Nile region and most notably in terms of numbers Northern Uganda, as well as the unaffected districts of Amuria and Katakwi in the North Eastern region.

When combined with the known prevalence of T. b. rhodesiense at the market sites (1.5%), the numbers of cattle that have been legally traded from the sampled markets into districts thought to be free of T. b. rhodesiense (13,094, with the legitimate permits). An extrapolated number of 196 T. b. rhodesiense infected cattle that were traded between 2007 and 2008, from sampled markets and imported directly into areas free from the species. The extrapolated number of T. b. rhodesiense infected cattle that have been
introduced to these previously clear districts (from assessing the past movement permit records) it is clear that the districts of northern Uganda and most of West Nile region will certainly have imported cattle harbouring *T. b. rhodesiense* parasites. As such these areas must be considered to be at risk from the introduction and establishment of this human infective parasite.

It must be stressed that the figure of 196 *T. b. rhodesiense* infected cattle imported to the northern districts was obtained just from the legal market trade and does not account for animals that were obtained direct from communities. This direct movement does occur as shown by three of the 18 restocking organisations acquiring animals direct from communities and not through the formal market system.

The severity of this situation has previously been shown as a result of the disease having been introduced into the district of Soroti resulting from the import of *T. b. rhodesiense* infected cattle from districts of existing endemic infection (Fevre *et al.*, 2001).

### 8.4. Major contributions of this study

This thesis has contributed knowledge concerning the mode of action of future animal based interventions against zoonotic disease. Principally that prior to initiating the intervention full saturation of information concerning the benefits and possible risk of the proposed treatment should be made to the general public, ideally providing demonstration treatments to bolster public confidence.

To ensure proper uptake of any follow up treatments (in this case spraying) it is clear from this study that future interventions should not rely upon local communities to undertake operations, instead opting to appoint personnel responsible with overseeing any follow up programmes. Also shown is that the inclusion of other livestock animal species that could act as reservoir hosts of the target pathogen should be seriously considered, in this specific case possibly for insecticide spraying without trypanocidal treatment.

It has also been shown that despite the instigation of government policy specifically designed to restrict the advance of *T. b. rhodesiense* the treatment of cattle is still rarely
undertaken prior to post sale movement as well as being unenforced. With the cattle sold both harbouring the parasite and being relocated into areas currently deemed free of the disease, in numbers sufficient to cause the establishment of new foci in the recipient regions.

In reference to post conflict regions, the restocking of livestock (principally facilitated through charitable organisations) the potential negative implications of relocating animals is made perfectly clear to the organisations. So that they can ensure that all efforts are made not to import infectious diseases by obtaining guarantees that the contractor or staff member responsible for obtaining cattle has treated the animals prior to movement from an endemic region.

8.5. Areas of future research

Resulting from the work presented within this thesis there are certain areas of further work which are suitable for continued intervention, investigation and research. Firstly resulting from the SOS analysis presented in Chapter 3 it was clear that intervention was required to address the specific region of continued *T. b. rhodesiense* burden. This treatment was carried out in early 2008 and the follow up analysis of the trypanosome prevalence within the cattle population is being conducted by a current PhD student.

From the summary findings of Chapter 6, that cattle harbouring *T. b. rhodesiense* have been moved without treatment with trypanocidal drugs. As such it would be responsible for a proper sampling investigation to be carried out within the areas that have been indicated as at risk of having imported the disease, with the aim of establishing whether the parasite species has become established within the cattle population of these northerly districts.

Also establishing which, if any, tsetse species currently exist within the northern regions of Uganda and whether they are competent vectors of trypanosomes is in great need of being carried out.
8.6. Conclusions

Main conclusions that are drawn from the results of this thesis are:

1- The SOS initiative was successful at reducing the prevalence of both *T. brucei* s.l. and *T. b. rhodesiense* within the control region. Return of both species to previous prevalence (even exceeding in the case of *T. brucei* s.l.) can be attributed to;

   a. Lack of follow-up spraying with deltamethrin allowing tsetse transmission to persist
   b. Continual importation of untreated animals from other regions endemic for the diseases
   c. Treatment rate of cattle that was lower than target, due primarily to sensitisation and mobilisation of general public in the SOS region
   d. Non inclusion of other domestic reservoirs of *T. brucei* s.l. and *T. b. rhodesiense*

2- Recent shifts in the dynamics of cattle movement, associated with restocking livestock numbers within the war affected districts of northern Uganda, has been shown to have lead to large numbers of cattle from the *T. b. rhodesiense* endemic south east into the northern region. Findings of this investigation show that the cattle being traded and moved to the northern districts without trypanocidal treatment may contain human infective trypanosomes. It is therefore likely that the introduction of *T. b. rhodesiense* into recipient areas which have vector competent tsetse may lead to the establishment of endemicity, similar to the situation in Soroti in 2001.

Many cattle of the cattle movements are as a result of charitable bodies whose aim is to empower communities who suffered most during the civil war. Due to the involvement of these well meaning, but improperly operating, NGOs the importation of cattle into these post conflict regions has the potential to introduce *T. b. rhodesiense* to these areas.

Along with addressing these problems with the NGOs, the re-stressing of the importance of market site treatment to the veterinary operators of the markets is
vital in the control of these human infective parasites. Ideally trypanocides would be made freely available or subsidised for the purpose of market treatments. Finally I would recommend that the livestock trade policy stating that animals should be treated by the purchaser, be amended to place legal responsibility for trypanocidal treatment upon the seller in order to optimise the treatment of market traded cattle, as the purchaser are likely to demand treatment prior to exchanging money thus ensuring the implementation of this policy.

8.7. Reflections

With reference to the lessons learnt during the process of this thesis future incarnations of the SOS programme should place more emphasis upon the sensitisation and promotion of the SOS operation within the recipient area. Developing trust within the SOS operation would be best promoted by undertaking insecticide spraying operations prior to the initiation of trypanocidal treatment, which will increase the profile of the SOS team within the communities particularly allowing for questions and concerns from these community to be resolved directly by treatment personnel in turn facilitating a higher rate of treatment coverage.

Inclusion of swine in insecticidal spraying activities should be given consideration as a high proportion of tsetse blood meals are known to originate from swine, further more these blood meals are potentially infective. Due to the size of pigs the use of restricted application is not appropriate; meanwhile trypanocidal treatment of the pigs is not as vital as insecticidal treatment due to associated complications combined with the shorter life expectancy of the pigs in comparison to cattle.

The current policy that purchasers are responsible for treating cattle purchased with trypanocides should be amended so that the seller is responsible for providing treatment, this will optimise adherence with the policy and reduce the risk of importation of *T. b. rhodesiense* into unaffected regions as a result of cattle trade.
Finally the matter of NGOs operating irresponsibly and importing potentially infected cattle can be addressed by the production of an information package focussed upon the purpose of raising awareness of their unintentional effect. This information would best be delivered with the combined backing of the Ugandan Ministry of Agriculture and Ministry of Health.
9. References

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10. Appendix

Appendix 1

Questionnaire for SOS staff and treating personnel

Name: …………………………………………………………………………………………………

Current job title: …………………………………………………………………………………………………

1. What role did you play during the November 2006 SOS programme?
 …………………………………………………………………………………………………
 …………………………………………………………………………………………………

2. How long were you involved with the SOS programme for?
 …………………………………………………………………………………………………

3. Which District or Districts of the SOS region were you working in?
   a. Kaberamaido
   b. Amolotar
   c. Dokolo
   d. Lira
   e. Apac

4. Which Parishes (give districts) did you work in?
 …………………………………………………………………………………………………
 …………………………………………………………………………………………………
 …………………………………………………………………………………………………
 …………………………………………………………………………………………………
 …………………………………………………………………………………………………


5. Did you encounter any problems during the SOS campaign?
   Yes / No
   
a. What was the nature of these problems?
   ...........................................................
   ...........................................................
   ...........................................................
   ...........................................................
   ...........................................................
   ...........................................................
   ...........................................................
   ...........................................................

   i. Poor mobilisation
   ii. Poor response to mobilisation
   iii. Community distrust of SOS treatment
   iv. Inadequate supply of trypanocides
   v. Inadequate supply of deltamethrin
   vi. Inadequate supply of syringes and needles
   vii. Issues with spraying mechanisms
   viii. Difficulties assessing animal weight / correct dosage
   ix. Too few students to treat the number of cattle
   x. Transport to and from treatment sites
   xi. Treatment sites had no crush
   xii. Other (please specify)
b. Can you recall where these problems occurred?
   Yes / No
   i. Which treatment sites (give parishes) were problematic (if possible with which problems)?

6. What proportion of the cattle within the treatment area you were involved with do you think were treated?
   i. < 25%
   ii. 25 – 50%
   iii. 50 – 70%
   iv. 70 – 80%
   v. 80 – 90%
   vi. 90 – 100%

b. How would you improve the coverage
i. More mobilisation
ii. Improved community education
iii. Improved provision of trypanocides
iv. Improved provision of insecticides
v. Improved crush construction
vi. More involvement of local community
vii. Increased community awareness of SOS programme
viii. Other (please specify)

7. How confident are you that the correct dosage of trypanocides was administered to cattle?
   Extremely / Highly / Unsure / Unconfident / Not confident at all

8. Do you think that the local population understood the aims of the SOS programme?
   Yes / No

9. Can you describe the main points of restricted application spraying?
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………

10. Was enough emphasis placed upon giving instruction about restricted application spraying to the local farmers?
Yes / No
Appendix 2

Questionnaire on cattle restocking for DVO

District

Name of interviewee

GPS of office

DVO VO AHO

1. Is this district currently receiving cattle from restocking organisations?
   Yes / No

2. Can you name the organisations that are carrying out these programmes?
   ……………………………………………………………………………………………..
   ……………………………………………………………………………………………..
   ……………………………………………………………………………………………..
   ……………………………………………………………………………………………..
   ……………………………………………………………………………………………..
   ……………………………………………………………………………………………..

3. Do these organisations consult with the DVO office?
   Yes / No

4. Do any request treatment of the cattle that they move?
   Yes / No
   a. How many request treatment?
b. Can you name these organisations?

5. Can you estimate the current cattle population in this district?

6. How many cattle are brought into this district by these programmes in 2008?
   Estimate?

7. Which districts do these animals usually originate from?

8. Do you feel these cattle are treated with trypanocides prior to import?
   Yes / No

9. Can you estimate the proportion of cattle brought into this district by restocking organisation and private trade?
   i. Exclusively restocking organisations
   ii. More than 75% supplied by restocking organisations
   iii. Between 75% and 50% supplied by restocking organisations
   iv. Roughly 50% private trade and restocking organisations
   v. Between 75% and 50% supplied by private trade
vi. More than 75% supplied by private trade
vii. Exclusively supplied by private trade

10. Do you know which sub-counties or parishes have the received restocking animals?

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Appendix 3

Questionnaire for cattle restocking organisations

Organisation name
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Interviewee name
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Job description
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GPS of office

N.............................  E.................................

1. What regions of Uganda are the restocking programmes active in?
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2. What districts of (northern) Uganda receive cattle from the programmes?
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3. On what basis do you target these districts?
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4. Do you consult the DVO (or LC5) of these districts?
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5. What districts of Uganda provide cattle for the programme?
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6. Does this organisation coordinate or collaborate with other restocking programmes (or any other type of aid organisation)

   Yes / No

   a. Which programmes / organisations do you collaborate with?
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   b. What is the nature of this collaboration?
   
   i. Discussing distribution of livestock
   ii. Distributing livestock
   iii. Acquiring livestock
   iv. Development of restocking strategy
   v. Work together under separate banners
   vi. Other (details)
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........................................................................................................................................
7. **How are the cattle used in the restocking programme acquired?**
   
   a. Large cattle market (>100 cattle for sale) Go to Q8
   
   b. Small cattle market (<100 cattle for sale) Go to Q8
   
   c. Bought from communities in same district as restocking Programme (not market) Go to Q9
   
   d. Bought from communities in other district (not market) Go to Q9
   
   e. First born from cattle previously distributed by restocking programme Go to Q9
   
   f. Other (please specify)

8. **What markets supply highest numbers of cattle? (District, Name) and roughly how many cattle have been taken from each in the last year**

9. **What parishes are currently supplying cattle for the restocking (District, Parish) and roughly how many cattle have been taken from each in the last year**
10. How are cattle brought into the restocking area(s)
   a. By Truck
   b. On Hoof
   c. Other (please specify)

11. Is a specific type and purpose of cattle used in the restocking programme?
   Breed
   Age
   Sex
   Purpose...Draught...Milk...Breeding.... Other

12. How many cattle have been moved by this restocking operation over the last year?

13. What is the budget for purchase each animal bought?

14. Are the cattle treated to prevent movement of transmissible disease prior to movement?
   Yes / No
   a. What conditions are the cattle treated for?
b. What is the budget for treatment of each animal?

15. In your experience; what diseases of cattle are endemic in the areas restocked?

16. In your experience; what diseases of cattle are endemic in the areas from which you purchase cattle?

17. Who acquires cattle for restocking programme?
   a. Qualified veterinarian
   b. Qualified animal husbandry officer
   c. Experienced animal handler
   d. Other (please specify)

18. Is the health of cattle assessed prior to procurement?
Yes / No

a. How is it assessed?

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19. Does this programme offer any follow up support?

Yes / No

If yes:

a. Livestock management training
b. Animal health assistance (spray / drugs)
c. Both

20. Is there any follow up on the survival of restocking cattle after distribution?

Yes / No

If yes:

a. What is the overall survival rate at 3 months?
……………………………………………………………………………………………………

b. What is the overall survival rate at 6 months?
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21. Have you any experience with acute or Rhodesian sleeping sickness?

Yes / No

If yes:

a. What is sleeping sickness?
……………………………………………………………………………………………………
……………………………………………………………………………………………………

b. Can you say where it is endemic in Uganda?
c. Can you say how it is transmitted to humans?

d. Can you name the animal reservoir with in Uganda?

e. Do you know how the disease is prevented?