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OPTIMIZATION OF SEMIO-CHEMICALS FOR SAVANNAH TSETSE CONTROL THROUGH 'PUSH', 'PULL' AND 'PUSH-PULL' TACTICS IN KENYA

By

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This thesis is my original work and has not been presented for a degree in any other university or any other award.

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DEDICATION

To my parents, Boaz and Janet Ohaga;

My brothers, the late Humphrey, Colchester, John, Paul and Byllings; and

My sisters, Caren and Lorine; I dedicate this thesis.

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TABLE OF CONTENTS

DECLARATION .... **ii**

DEDICATION .... **iii**

ACKNOWLEDGEMENTS .... **iv**

TABLE OF CONTENTS .... **vi**

LIST OF TABLES .... **xiv**

LIST OF FIGURES .... **xvii**

LIST OF PLATES .... **xix**

ACRONYMS AND ABBREVIATIONS .... **xx**

ABSTRACT .... **xxi**

CHAPTER ONE

GENERAL INTRODUCTION **1**

- 1.1 Background information 1
- 1.2 Statement of the problem 5
- 1.3 Hypotheses 5
- 1.4 Objectives 6
  - 1.4.1 General objective 6
  - 1.4.2 Specific objectives 6
- 1.5 Justification of the study 6

CHAPTER TWO

LITERATURE REVIEW **9**

- 2.1 Tsetse flies systematics 9

2.2 Aetiology and transmission of African trypanosomosis 13

2.3 Epidemiology of African trypanosomosis 14

2.4 Pathogenesis of African trypanosomosis 15

2.5 Diagnosis of African trypanosomosis 17

2.6 Control of African trypanosomosis 18

2.6.1 African trypanosomosis vaccines 18

2.6.2 Trypanocidal drugs 19

2.6.3 Trypanotolerant livestock 19

2.6.4 Sterile insect technique (SIT) 20

2.6.5 Insecticide–treated targets 21

2.6.6 Insecticide treated livestock 22

2.6.7 Baited tsetse traps 22

2.6.8 Tsetse repellents (allomones) 24

2.6.9 Natural waterbuck repellent blend (WRB) 25

2.7 Community participation in African trypanosomosis control 26

2.8 Participatory research in animal health surveys 28

2.9 Integration of synthetic repellent with bait technology 29

CHAPTER THREE

GENERAL MATERIALS AND METHODS 30

3.1 Study area 30

3.2 Study population 30

3.3 Parasitological diagnosis of trypanosomes 31

3.4 Tsetse fly monitoring 32

3.5 Questionnaire administration 33
3.6 Data management and analysis 34

CHAPTER FOUR

LIVESTOCK FARMERS' KNOWLEDGE, ATTITUDES AND PERCEPTIONS AND THE EPIDEMIOLOGY OF BOVINE TRYPANOSOMOSIS IN KWALE DISTRICT, KENYA **35**
4.1 Introduction **35**
4.2 Materials and methods **37**
- 4.2.1 Study area 37
- 4.2.2 Study sites 37
- 4.2.3 Livestock farmers' interviews 38
- 4.2.4 Parasitological diagnosis of trypanosomosis 39
- 4.2.5 Tsetse fly monitoring 39
- 4.2.6 Data management and analysis 39

4.3 Results **40**
- 4.3.1 Household information 40
- 4.3.2 Livestock production constraints 41
- 4.3.3 Knowledge of trypanosomosis clinical diagnoses 42
- 4.3.4 Knowledge of the aetiology of cattle trypanosomosis 43
- 4.3.5 Animal health management practices by farmers 44
- 4.3.6 Provision of animal health care 45
- 4.3.7 Tsetse and trypanosomosis control techniques 46
- 4.3.8 Tsetse fly species distribution and relative densities 48

4.3.9 Prevalence of cattle trypanosomosis 51
4.3.10 Packed cell volume (PCV) 52
4.4 Discussion........ 53

CHAPTER FIVE

EFFICACY OF REPELLENTS AND BAITS IN 'PUSH-PULL' TACTIC FOR TSETSE AND TRYPANOSOMOSIS SUPPRESSION 58
5.1 Introduction 58
5.2 Materials and methods 59
5.2.1 Study area 59
5.2.2 Trial sites 59
5.2.3 Synthetic repellent and dispensers 60
5.2.4 Treatment regimes 63
5.2.5 Cattle sample size determination 64
5.2.6 Parasitological diagnosis of trypanosomosis 65
5.2.7 Monitoring cattle body condition scores 66
5.2.8 Monitoring changes in cattle body weights 66
5.2.9 Monitoring household trypanocidal drug use 67
5.2.10 Monitoring household herd dynamics (cattle population) 67
5.2.11 Deployment of control NG2G traps 68
5.2.12 Monitoring of tsetse fly population 69
5.2.13 Data management and analysis 69
5.3 Results 70
5.3.1 Tsetse fly population 70

5.3.1.1 Percentage reduction in tsetse fly population....71

5.3.2 Trypanosomosis incidence....73

5.3.2.1 Percentage reduction in trypanosomosis incidence....73

5.3.2.2 Risk of trypanosomosis incidence....74

5.3.3 Packed cell volume (PCV)....76

5.3.3.1 Percentage increase in mean PCV....76

5.3.4 Cattle body weights....78

5.3.4.1 Percentage increase in body weight....78

5.3.5 Cattle body condition scores....80

5.3.5.1 Percentage increase in body condition score....80

5.3.6 Household trypanocidal drug expenditures....82

5.3.6.1 Percentage reduction in household trypanocidal drug expenditures....82

5.3.7 Changes in household herd sizes (cattle population)....84

5.4 Discussion....84

CHAPTER SIX

PERCEPTIONS, ATTITUDES AND PREFERENCES OF LIVESTOCK FARMERS ON THE IMPACTS OF 'PUSH-PULL' TACTIC IN RELATION TO TSETSE CHALLENGE AND TRYPANOSOMOSIS RISK....90

6.1 Introduction....90

6.2 Materials and methods....92

6.2.1 Study area....92

6.2.2 Questionnaire administration....92

6.2.3 Data management and analysis....93

6.2.4 Binary logistic regression..93

6.3 Results 95

6.3.1 Socio-demographic characteristics 95

6.3.2 Descriptions on the mode of action of repellents, dispensers and the process of deploying a baited NG2G trap..96

6.3.3 Preferred habitats for deployment of baited NG2G traps 97

6.3.4 Individual versus communal methods of trap deployment 97

6.3.5 Preferred cattle group for protection with repellent dispensers 97

6.3.6 Benefits of repellents and baited NG2G traps for tsetse and trypanosomosis suppression 98

6.3.7 Constraints of repellents and baited traps for tsetse and trypanosomosis suppression 101

6.3.7.1 Constraints of repellents..101

6.3.7.2 Constraints of baited NG2G traps 101

6.3.8 Preference for different tsetse and trypanosomosis control methods 104

6.3.9 Preference for repellents or baited traps for tsetse and trypanosomosis control.....105

6.3.10 Preferred costs for repellents, dispensers and NG2G traps..108

6.3.11 Odds ratios (OR) estimates for significant factors affecting livestock farmers responses to the efficacy of baited NG2G traps..109

6.3.11.1 Correct description of the process of baited NG2G trap deployment...........109

6.3.11.2 Preference for baited NG2G traps or current methods (drugs, pour-ons etc) of tsetse and trypanosomosis control 110

6.3.11.3 Preference for Ksh. 100 as the suitable cost for unbaited NG2G trap 111

6.3.12 Odds ratios (OR) estimates for significant factors affecting farmers responses to the efficacy of repellents 112

6.3.12.1 Preference of oxen for protection with repellents 113

6.3.12.2 Preference for Ksh 100 as the suitable cost for 100 ml bottle of repellents... 114

6.4 Discussion 115

CHAPTER SEVEN

THE OLFACTORY RESPONSES OF *GLOSSINA PALLIDIPES* TO ALDEHYDE BLENDS IN THE FIELD 122

7.1 Introduction 122

7.2 Materials and methods 124

7.2.1 Study area 124

7.2.2 Sampling methods 125

7.2.2.1 Traps 125

7.2.2.2 Targets 126

7.2.3 Odour attractants 126

7.2.4 Dispensing of odours 127

7.2.5 Comparison of the attractiveness of different concentrations of aldehyde blends . 128

7.2.6 Enhancing the attractiveness of cow urine and acetone using aldehyde blends 128

7.2.7 Enhancing the attractiveness of acetone using aldehyde blends 129

7.2.8 Data analysis 129

7.3 Results 130

7.3.1 Comparison of the attractiveness of different concentrations of aldehyde blends . 130

7.3.2 Enhancing the attractiveness of cow urine and acetone using aldehyde blends 131

7.3.3 Enhancing the attractiveness of acetone using aldehyde blends 132

7.3.4 Effect of aldehyde blends on tsetse catches using electric targets 133

7.4 Discussion 135

CHAPTER EIGHT

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS 138

8.1 GENERAL DISCUSSION 138

8.2 CONCLUSIONS 146

8.3 RECOMMENDATIONS 149

REFERENCES 151

APPENDICES 176

Appendix 4.1 Recoissance baseline surveys questionnaire 176

Appendix 5.1 Description of livestock body condition scores 182

Appendix 6.1 Farmers' perceptions on the efficacy of the repellents and baits questionnaire 183

LIST OF TABLES

Table No. Page

4.1 Number of farmers and cattle screened in various sub-locations of Shimba Hills, indicating the distance (± SE) from the SHNR fence 42

4.2 Livestock diseases reported by farmers in various sub-locations of Shimba Hills..... 43

4.3 Clinical signs frequently observed by farmers for cattle diseases perceived to be trypanosomosis in various sub-locations of Shimba Hills 44

4.4 Farmer's perceptions of the aetiology of trypanosomosis in various sub-locations of Shimba Hills 45

4.5 Proportion of farmers who used different drugs to cure cattle illnesses in the various sub-locations of Shimba Hills 46

4.6 Proportion of animal health care providers who administered drugs to cattle in various sub-locations of Shimba Hills 47

4.7 Tsetse and trypanosomosis control techniques frequently used by farmers in various sub-locations of Shimba Hills 47

4.8 Number of tsetse fly species and biting flies caught in various sub-locations of Shimba Hills 49

4.9 Tsetse fly density in various sub-locations of Shimba Hills 50

4.10 Parasitological prevalence of trypanosomosis in cattle sampled in various sub-locations of Shimba Hills 51

4.11 Mean packed cell volume (± SE) of trypanosomosis positive and negative cattle sampled in various sub-locations of Shimba Hills 52

Table No. Page

5.1 Number of cattle sampled monthly in the trial sites at Shimba Hills from November 2004 to September 2005 65

5.2 Risk of transmission of trypanosomosis to cattle between different treatment regimes in the trial sites at Shimba Hills 75

5.3 Monthly mean (± SE) cattle population in the trial sites at Shimba Hills, at the beginning and end of the trials 84

6.1 Description of explanatory variables in the logistic regression model 95

6.2 Livestock farmers' ranking of cattle for protection with repellents 98

6.3a Perceptions of livestock farmers on the benefits of repellents on livestock health and tsetse fly population 99

6.3b Perceptions of livestock farmers on the benefits of baited traps on livestock health and tsetse fly population 100

6.4 Livestock farmers' ranking of components of repellent dispensers in terms of weakness 102

6.5 Perceptions of livestock farmers on the constraints of repellents, dispensers and baited traps for tsetse and trypanosomosis suppression 103

6.6 Livestock farmers preference for repellents, traps or both or other methods of tsetse and trypanosomosis control 104

6.7 Perceptions of livestock farmers for the preference of repellents, baited traps or both over current methods for tsetse and trypanosomosis control 106

6.8 Livestock farmers' suggested costs for a 100 ml bottle of repellents, repellent dispensers and un-baited NG2G trap in Kenya Shillings 108

Table No. Page

6.9 Binary logistic regression model estimation for farmers' correct description of the process of baited NG2G trap deployment 110

6.10 Binary logistic regression model estimation for farmers' preference for baited traps to current methods of tsetse and trypanosomosis control 111

6.11 Binary logistic regression model estimation for farmers' preference of Ksh 100 as the suitable cost for un-baited NG2G trap 112

6.12 Binary logistic regression model estimation for farmers' choice of oxen as the preferred cattle for protection with repellents 113

6.13 Binary logistic regression model estimation for farmers' preference of Ksh 100 as the suitable cost for a 100 ml bottle of repellents 115

7.1 The mean catches and catch indices of *Glossina pallidipes* in NG2G traps baited with different concentrations of aldehyde blends 131

7.2 The mean catches and catch indices of *Glossina pallidipes* in NG2G traps baited with cow urine, acetone, and aldehyde blends 133

7.3 The mean catches and catch indices of *Glossina pallidipes* in NG2G traps baited with acetone, and aldehyde blends 134

7.4 The mean catches and catch indices of *Glossina pallidipes* in electric targets baited with cow urine, acetone and aldehyde blends 135

LIST OF FIGURES

Figure No. Page

2.1 Tsetse fly distribution in Africa (Wint and Rogers, 2001)..9

2.2 Quantification of areas with one or more tsetse fly species (Wint and Rogers, 2001)10

2.3 Tsetse fly distribution in Kenya (KETRI, 1997)..12

2.4 Distribution of *Glossina pallidipes* in Kenya (KETRI, 1997)................................13

2.5 Structure of 2-methoxy-4-methylphenol, the synthetic tsetse repellent....................25

2.6 The 'push-pull' paradigm...29

3.1 Map showing sub-locations neighbouring the Shimba Hills National Reserve (SHNR) of Kwale District, Kenya...31

5.1 Map showing the selected trial sites neighbouring the Shimba Hills National Reserve (SHNR) of Kwale District, Kenya 61

5.2 Schematic diagram of a repellent dispenser...62

5.3 Mean (± SE) monthly relative densities of *Glossina pallidipes* in the trial sites at Shimba Hills from Nov 2004 to Sept 2005..72

5.4 Monthly percentage tsetse population density reduction of *Glossina pallidipes* in the trial sites at Shimba Hills from Nov 2004 to Sept 2005 72

5.5 Mean (± SE) monthly trypanosomal incidence (%) in cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005 74

5.6 Monthly percentage trypanosomal incidence reduction in cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005............................75

5.7 Mean (± SE) monthly packed cell volume (PCV) (%) in cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005............................77

Figure No. Page

5.8 Monthly percentage increase in mean % PCV for cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005 77

5.9 Mean (± SE) monthly body weight (kg) of cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005.. 79

5.10 Monthly percentage body weight gains/loss for cattle in the trial sites at Shimba Hills from November 2004 to September 2005 79

5.11 Mean (± SE) monthly body condition score of cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005 81

5.12 Monthly percentage body condition score gains/loss for cattle in the trial sites at Shimba Hills from November 2004 to September 2005 81

5.13 Mean (± SE) monthly trypanocidal drug expenditure by households in the trial sites at Shimba Hills from Nov 2004 to Sept 2005 83

5.14 Percentage reduction in monthly trypanocidal drug expenditure by households in the trial sites at Shimba Hills from Nov 2004 to Sept 2005 83

7.1 Chemical structures of aldehyde compounds used in the trial................................. 124

7.2 A map showing Nguruman, the study area where field tests were conducted.......... 125

LIST OF PLATES

Plate No. Page

3.1 Screening of cattle blood for the presence of trypanosomes at a site in Shimba Hills, Kenya 32

3.2 A baited NG2G trap used for monitoring savannah tsetse fly populations........ 33

3.3 Administering an open-ended structured questionnaire to one of the livestock keepers in Shimba Hills, Kwale District, Kenya........ 34

4.1 Interviewing a group of livestock owners at Mangawani, Shimba Hills 38

5.1 The repellent dispenser 62

5.2 Position of repellent dispensers on animal body........ 63

5.3 Approximation of cattle body weight using a Ceva© weighing band 66

6.1 A livestock farmer in Tsangatamu, Shimba Hills, presenting his perceptions on the impacts of push-pull on tsetse challenge and trypanosomosis risk........ 93

7.1 The blue-black electric target (screen)........ 127

7.2 NG2G trap baited with aldehydes dispensed from polyethylene sachet........ 128

ACRONYMS AND ABBREVIATIONS

AAT	African Animal Trypanosomosis
AB	Aldehyde Blends
ARPPIS	African Regional Postgraduate Programme in Insect Sciences
CUA	Cow Urine and Acetone
DFID-AHD	Department for International Development-Animal Health Programme
DRIP	Dissertation Research Internship Programme
FAO	Food and Agricultural Organization
FTD	Flies/Trap/Day
GC-EAD	Gas Chromatography-linked Electro-Antennographic Detector
GC-MS	Gas Chromatography-linked Mass Spectrometry
HAT	Human African Trypanosomosis
ICIPE	International Centre of Insect Physiology and Ecology
ISCTRC	International Scientific Council for Trypanosomiasis Research and Control
ITDG	Intermediate Technology Development Group
KETRI	Kenya Trypanosomiasis Research Institute
PCV	Packed Cell Volume
PRA	Participatory Rural Appraisal
SAS	Statistical Analysis Software
SHNR	Shimba Hills National Reserve
TBDs	Tick Borne Diseases
T & T	Tsetse and Trypanosomosis
WRB	Waterbuck Repellent Blend
WHO	World Health Organization

ABSTRACT

A synthetic repellent for savannah tsetse (2-methoxy-4-methylphenol), which is a synthetic analogue of a mild natural repellent (2-methoxyphenol), found in the body odours of tsetse bovid hosts was recently identified. Preliminary field trials indicated that the repellent could provide substantial protection to cattle. The repellent could also be integrated with other tsetse control tactics in a 'push-pull' strategy that uses repellents to 'push' the flies away from their hosts, in conjunction with baited traps/targets, which 'pull' and kill them. This study evaluated the efficacy of the 'push-pull' tactic in enhancing tsetse suppression rates and disease levels using on-host repellents to 'push' and baited traps to 'pull' the flies in Shimba Hills, Kwale District, Kenya. From cross-sectional surveys conducted in the area, livestock farmers considered livestock diseases; trypanosomosis, anaplasmosis, East Coast fever and foot-and-mouth disease to be the major constraints to livestock production in the area. Trypanosomosis was the most important compared to other diseases. Chemotherapy was the most widely used method of controlling the disease. Farmer-based tsetse control strategies were poorly adopted. Most farmers demonstrated awareness about trypanosomosis, its clinical symptoms, aetiology, correct treatment and control measures. Survey of the epidemiology of cattle trypanosomosis in the area indicated that, *Glossina austeni, G. brevipalpis* and *G. pallidipes* were found in the area. *Trypanosoma congolense* and *T. vivax* were diagnosed in cattle with infection prevalences in the animals varying between 0 and 25%. A field trial conducted in the area to evaluate the effectiveness of 'push-pull' tactic for tsetse and trypanosomosis control indicated that the 'push-pull' might be a more effective way of reducing tsetse populations, trypanosomosis disease incidences and trypanocidal drug use and improving herd health and productivity compared to 'push' or 'pull'. 'Push-pull' gave significantly higher reduction (62%) in trypanosomosis incidence compared to 'push' (59%) and 'pull' (53%) ($\chi^2 = 65.4$; df = 2; $p < 0.001$). Risk of transmission of trypanosomosis in the controls was upto three times significantly ($\chi^2 = 43.2$; df = 1; $p < 0.0001$) higher than protected cattle. Body weight, body condition and packed cell volume levels were significantly ($F = 48.9$; df = 1; $p < 0.01$) higher in protected cattle than controls. Percentage reduction in *G. pallidipes* relative density in 'push-pull' was 83% compared to 77% in 'pull' sites. Households with protected cattle recorded significant reduction in trypanocidal drug use ($\chi^2 = 11.8$; df = 1; $p = 0.003$). Following the trial, livestock farmers' perceptions on the impacts of the repellent and traps on tsetse challenge and trypanosomosis risk were assessed. Most farmers considered significant reduction in trypanocidal drug use, disease incidence and tsetse population to be the most important benefits of repellents and traps. Additional benefits included quieter grazing, protection of goats and opening up of previously avoided fields for grazing and crop production. Most farmers preferred repellents or traps or both to current methods of tsetse and trypanosomosis control. All farmers preferred repellents to traps. With a view of increasing the potency of the 'pull' component, trials conducted to evaluate the attractiveness of aldehyde blends showed that the blends when used alone did not significantly increase trap catches ($\chi^2 = 0.61$; df = 1; $p = 0.461$), but when combined with cow urine and/ or acetone, they increased the catches, although this was not statistically significant ($\chi^2 = 0.85$; df = 1; $p = 0.644$). Repellents could be integrated with other tsetse control techniques such as traps in enhancing tsetse and disease suppression.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background information

Tsetse flies (Diptera: Glossinidae: *Glossina*) are haematophagous insects, which infest about 40% (11 million km^2) of tropical Africa, affecting thirty eight countries between 15 ^{0}N and 30 ^{0}S (Ford and Katondo, 1977; Leak, 1998). The flies transmit protozoa, *Trypanosoma* species, which causes trypanosomosis in human and domestic livestock. Trypanosomosis is more important in sub-humid than in wetter parts of the semi-arid zones of Africa (Leak, 1998). Incidence and severity of the disease in different regions are dependent upon local conditions. In some areas virtually no economical livestock development is achievable due to the disease. Budd (1999) estimated total losses to agricultural production alone due to trypanosomosis in Africa at US$ 4.5 billion per year. As a vector of trypanosomosis, tsetse flies impose a constraint on orderly rural development in 7 million km^2 of good agricultural land in Africa (Murray and Gray, 1984; Turner, 1986). Persistence of tsetse flies leads to under exploitation of infested land and over exploitation and degradation of uninfested areas.

Human African Trypanosomosis (HAT) is a major threat to human health in Africa. More than sixty million people, mainly in rural sub-Saharan Africa, are at risk of the disease but only about three million of them are under surveillance (WHO, 2001). It is also a major health risk to tourists coming to tropical Africa (Klaassen *et al.*, 2002; Jelinek *et al.*, 2002). The number of infected persons is estimated at 300,000 to 500,000 (WHO, 2000; Kabayo, 2002; Fairlamb, 2003). Some 45,000 new cases were reported in 1999 but the figure does not reflect the real epidemiological situation since surveillance of the people at risk is poor (WHO, 2001). An effective surveillance programme would cost US$ 35 million a year in addition to the annual budget (US$ 38.5 million) for drugs required for the 300,000 cases with over 20% treatment failure (WHO, 2001).

Drug resistance is increasing and no new drugs are being produced (Mugunieri and Murilla, 2003). Due to the high antigenic variation exhibited by pathogenic trypanosomes, attempts to develop trypanosomosis vaccines have failed (WHO, 2001). Recent epidemics have occurred in Uganda, Democratic Republic of Congo and Angola, causing suffering and death of people in several villages (Fevre *et al.,* 2005; Kioy and Marrock, 2005). Southern Sudan is also facing a major resurgence of the disease with approximately 45% of the people infected in some villages (Fevre *et al.,* 2005). Without prompt treatment all the people infected with sleeping sickness might die (Wainaina and Torfinn, 2004).

The number of human trypanosomosis cases is also likely to increase in several countries due to the current upsurge in both forms of sickness (Fèvre *et al.,* 2005). In Kenya, sleeping sickness caused by *T. b. rhodesiense* is endemic in the Lake Victoria basin, especially along Kenya-Uganda border (Wilett, 1965; Wijers, 1974).

Animal African Trypanosomosis (AAT) is a disease primarily of the wild animals, but whereas domestic animals succumb to infection, wild animals show a high degree of resistance (Jordan, 1986). The wild animals act as reservouirs from which tsetse get infected during feeding (Jordan, 1986). Trypanosomosis has a devastating effect on large numbers of livestock. About fifty million cattle and tens of millions of small ruminants are at risk from the disease (Gilbert *et al.,* 2001). Direct losses in meat production and milk yield and the costs of programmes to control trypanosomosis are estimated at US$ 600 million - $ 1.2 billion annually (Gilbert *et al.,* 2001). It is estimated that 80% of land in Africa is tilled by women using hoes due to lack of draft power since the animals are sick with trypanosomosis (Gilbert *et al.,* 2001). In mixed farming systems where trypanosomosis is severe, it can reduce the average area planted per household by as much as 50% due to constrains on the number of oxen that farmers own (Swallow, 1997; 2000). In susceptible cattle breeds, the disease reduces calving by upto 20% and causes deaths of approximately 20% of young livestock. Meat and milk production is reduced by more than 50% (Swallow, 1997; 2000; Erkelens *et al.,* 2000). The disease also causes a decrease in livestock productivity since it prevents the introduction of improved breeds in infested areas while causing overstocking in uninfested areas (Ford and Katondo, 1977).

Current control of trypanosomosis relies on three principal strategies: use of trypanocidal drugs, rearing of trypanotolerant cattle, and tsetse fly control or eradication. Each of these strategies has advantages and disadvantages, but generally none has proven to be fully satisfactory as a viable, sustainable solution to trypanosomosis. Use of trypanocidal drugs continues to be the primary approach to the control of trypanosomes throughout most of Africa. However, cost, availability and growing drug resistance limit its adoption as a sustainable method to prevent or treat the disease (Aferwerk *et al.,* 2000; Mugunieri and Murilla, 2003). Trypanotolerant cattle are only found in certain areas of West and Central Africa and at the Kenyan coast. Although they retain a certain level of productivity under tsetse challenge they are considered less productive in terms of meat and milk yields. They also succumb to trypanosomosis under high tsetse challenge (D'Ieteren, 1993; D'Ieteren *et al.,* 1998). Tsetse vector control methods relying on large-scale bush clearing and aerial spraying methods have largely been discontinued due to environmental concerns (Leak, 1998). The sterile insect technique (SIT) is very expensive and its use on a continent wide scale with very few, if any ecological islands, and with multiple species present is highly questionable (Hargrove, 2000). The use of baited traps and insecticide-impregnated targets and livestock are currently the most common methods of tsetse control. However, difficulties in initiating and sustaining the necessary collective action at the community level have greatly limited their impact (Barrett and Okali, 1999). The existing control methods should therefore be assessed and integrated with improved technologies for effective trypanosomosis management.

Recent research work has resulted in the identification of two potent repellents for savannah tsetse following two approaches: (i) development of a potent synthetic analogue (2-methoxy-4-methylphenol) of a mild natural repellent (2-methoxyphenol) found in the body odours of tsetse bovid hosts through molecular optimization studies, (Saini and Hassanali, 2007) and (ii) identification of natural repellent blend from un-preferred animals like waterbuck (*Kobus ellipsiprymnus defassa*) (Gikonyo *et al.,* 2002; 2003; Kipchumba, 2007) which despite being common in tsetse habitats are rarely fed on by tsetse. Preliminary field trials indicate that synthetic and natural waterbuck tsetse repellents can be an important component of tsetse control (Saini and Hassanali, 2003). The identified repellents for savannah tsetse provide a basis for developing an integrated strategy for improving trypanosomosis control. Repellents may be used alone to reduce tsetse challenge and disease levels or by communities in areas where cattle are a dominant source of bloodmeals for tsetse to 'push' the flies into areas where they are attracted (pull) by baited traps (push-pull). The challenge now is to evaluate how repellents can be integrated with other existing control techniques such as baited traps and insecticide impregnated-targets to design improved strategies that rely less on drugs. Particularly attractive is the 'push-pull' tactic that uses a combination of repellents (to 'push' the flies) and baited traps ('pull' the flies) to substantially enhance suppression rates. This study evaluated the integrated efficacy of the repellent (2-methoxy-4-methylphenol) and baited traps in 'push-pull' strategies to control tsetse flies and trypanosomosis.

In addition, the study evaluated the attractiveness of aldehyde compounds, which are present in the body odours of buffalo and ox with a view to increasing the potency of the current attractant blend for *G. pallidipes*. Accordingly, they were tested either individually as a blend or in combination with known tsetse attractants in the field as potential sources of additional kairomonal (pull) components.

1.2 Statement of the problem

The current tsetse and trypanosomosis control strategies have proved not to be satisfactory, viable or sustainable. The new tsetse and disease control strategies like use of repellents (push), olfactory and visual baits (pull) and their combination (push-pull) needs to be tested in the field, improved, and their efficacy, adoption rate and impact assessed. This study evaluated the 'push-pull' tactic in enhancing tsetse suppression rates and trypanosomosis disease levels.

1.3 Hypotheses

1. Tsetse-transmitted trypanosomosis is not a major disease constraint to livestock production in Kwale District, Kenya.
2. The 'push-pull' tactic based on repellents (push) on hosts and baited traps (pull) is not more effective in suppressing tsetse and trypanosomosis than 'pull' or 'push' alone.
3. Livestock farmers do not prefer repellents to baited traps, trypanocidal drugs or synthetic pour-ons for trypanosomosis suppression.
4. A blend of aldehydes is not an important component of tsetse kairomone system and their presence do not enhance the attractiveness of breath and urine chemicals.

1.4 Objectives

1.4.1 General objective

To evaluate the efficacy of semio-chemicals through tsetse repellents (push) and baited traps (pull) in 'push-pull' tactic for integrated tsetse and trypanosomosis control.

1.4.2 Specific objectives

1. To evaluate livestock owners' knowledge, attitudes and perceptions and the epidemiology of cattle trypanosomosis in Kwale District, Kenya.
2. To evaluate the efficacy of 'push-pull' tactic in enhancing tsetse suppression rates and trypanosomosis disease levels using on-host repellents to 'push' and baited traps to 'pull' the flies.
3. To assess livestock farmer attitudes, perceptions and preferences on the impacts of baited traps and on-host repellents in relation to tsetse challenge and trypanosomosis risk.
4. To assess the identified aldehydes individually as a blend and in combination with known tsetse kairomones for attractiveness to *Glossina pallidipes* under field conditions.

1.5 Justification of the study

Animal trypanosomosis is a major constraint to agricultural production in areas of Africa that hold the greatest potential for expanded agricultural and livestock production. Previous efforts to control the disease have not been successful. Research work at the International Centre of Insect Physiology and Ecology (ICIPE) offers a promising alternative strategy (repellents) that would expand the arsenal of techniques for trypanosomosis control, potentially reducing dependency on trypanocides. Repellents are ready for field-testing and adoption to the needs and circumstances of livestock farmers and formulation of strategies for their use in integrated vector and disease management.

Integrated control strategies based on repellents would be relevant primarily for pastoralists and agro-pastoralists in arid and semi-arid lands. Livestock is the main asset upon which these communities depend and trypanocides are often their single largest livestock health expenditure item. Control using repellents would be of direct benefit to the pastoralists since it is expected to be more cost-effective than the existing methods. This would reduce livestock production costs, use of trypanocides, risk of drug resistance and threat of losing trypanocides as the only available option for trypanosomosis control. These might lead to improved livestock productivity. Repellents may also be suited for pastoralists who are among the poorest communities that depend on transhumance to maintain their livestock. The animal wears repellent dispensers at all times even during migration to new areas in search of fresh pastures and water.

The development of better odour attractants will enhance the efficiency of traps and targets for suppression and control of tsetse populations in affected areas.

Farmers' knowledge, attitudes, perceptions and preferences of the consequences of new control technologies are essential in determining the assumptions that could be made if the technology is to be adopted on a sustainable basis. Lessons learnt from the assessment may be used when re-designing control options to consolidate the desirable perceptions and to counteract any wrong ones. Moreover, the outcomes may be required to improve future research strategies, plans and management.

It is envisaged that the results of the study will provide a rational basis for farmers to choose between available control options, taking into account the ecological, economic and sociological factors. It is also anticipated that, through farmers adoption of the technologies developed they would realize improved livestock productivity due to a reduction in trypanosomosis incidence. Traditionally, new tsetse and trypanosomosis control techniques are difficult to deliver and are rarely adopted by most farmers. However, repellent technology is a low-cost control option, specifically designed for improving livestock health and production for resource poor pastoralist and agro-pastoralist communities. Given the flexibility of the repellent technology, it could easily be integrated into other control techniques to improve livestock production in sub-Saharan Africa.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tsetse flies systematics

All tsetse species and sub-species are grouped into three sub-genera: *Glossina* (morsitans), *Nemorhina* (palpalis) and *Austenina* (fusca). The classification is based on morphological differences in the structure of the genitalia (Potts, 1970). The groups have characteristic differences in terms of ecological preferences and roles as disease vectors. Currently, thirty eight species and sub-species of tsetse flies have been described in sub-Saharan Africa (Figure 2.1 and 2.2).

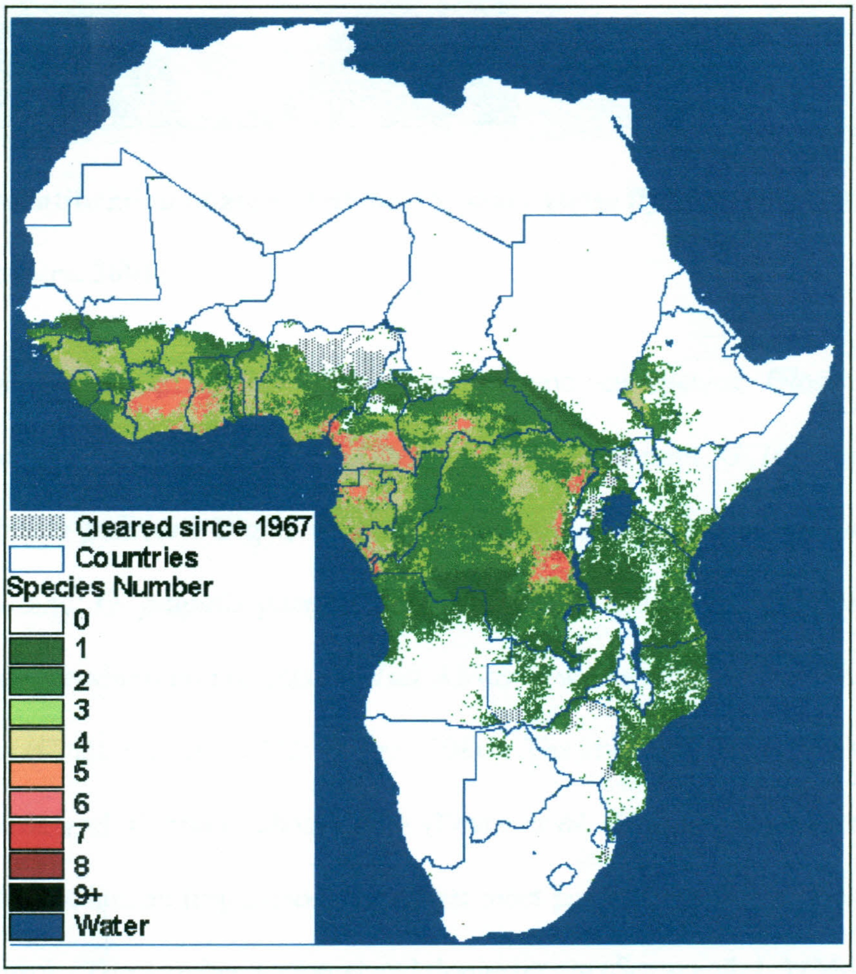


Figure 2.1: Tsetse fly distribution in Africa (Wint and Rogers, 2001)

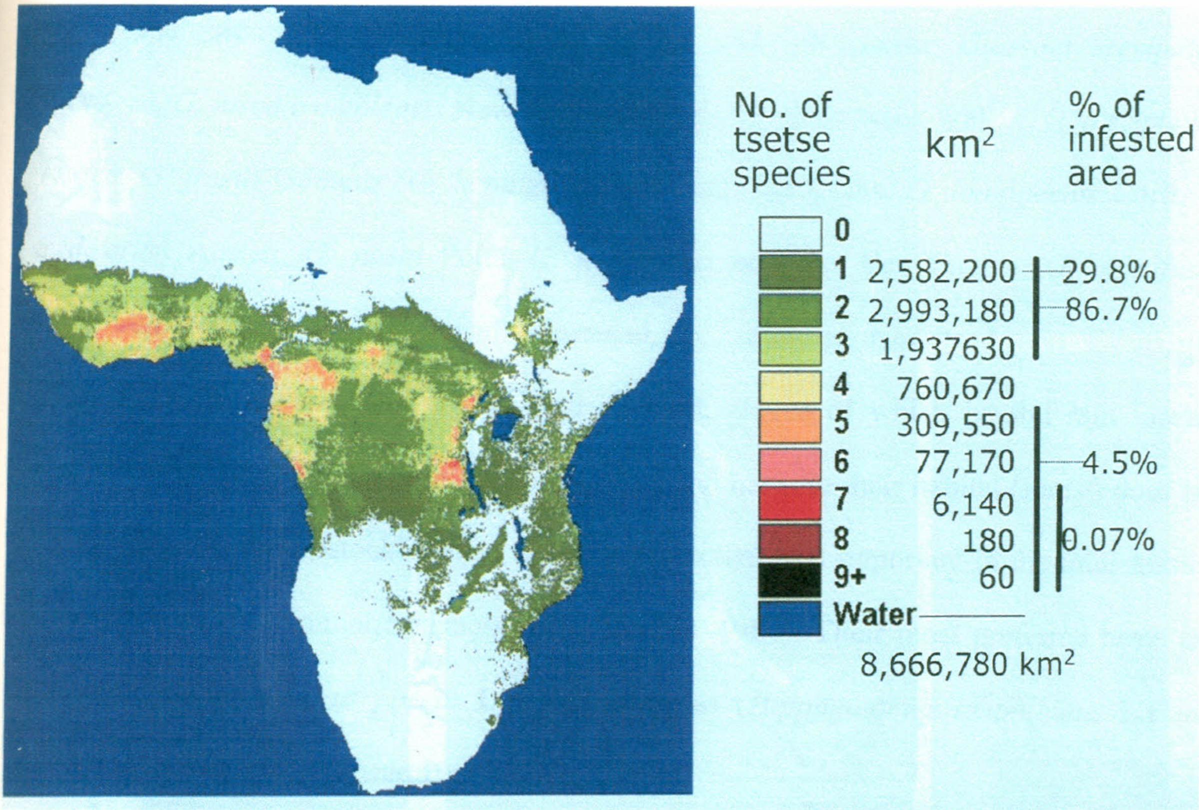


Figure 2.2: Quantification of areas with one or more tsetse fly species (Wint and Rogers, 2001)

The palpalis group consists of nine species and sub-species: *Glossina caliginea* Austen, *G. fuscipes fuscipes* Newstead, *G. fuscipes martinii* Zumpt, *G. fuscipes quanzensis* Pires, *G. pallicera pallicera* Bigot, *G. pallicera newsteadi* Austen, *G. palpalis palpalis* Robineau-Desvoidy, *G. palpalis gambiensis* Vanderplank, and *G. tachinoides* Westwood. They are found in lowland rain forests of West Africa as well as the linear riverine forests of savannah areas (Challier *et al.*, 1977; Jordan, 1986). The riverine species are vectors of *T. brucei gambiense* and *T. brucei rhodesiense* (Fevre *et al.*, 2005). Consequently, they are important vectors of human trypanosomosis. Their most preferred hosts include: man (*Homo sapiens*), bushback (*Tragelaphus scriptus)* and domestic pig (*Sus scrofa* L.) (Moloo, 1993).

The fusca group contains fifteen species and sub-species: *Glossina brevipalpis* Newstead, *G. fusca congolensis* Newstead and Evans, *G. fusca fusca* Walker, *G. fuscipleuris* Austen, *G. frezili* Gouteux, *G. haningtoni* Newstead and Evans, *G. longipennis* Corti, *G. medicorum* Austen, *G. nashi* Potts, *G. nigrofusca hopkinsi* Van Emden, *G. nigrofusca nigrofusca* Newstead, *G. severini* Newstead, *G. schwetzi* Newstead and Evans, *G. tabaniformis* Westwood, and *G. vanhoofi* Henrard, eleven of which inhabit rain forests. Since most of the species do not feed on humans and because their habitat (forest) does not allow extensive fly livestock contact, they are not considered important in the transmission of both human and animal trypanosomosis (Jordan, 1986). Their most preferred hosts are bush pig (*Potomochoerus porcus* L.), hippopotamus (*Hippopotamus amphibious* L.) and buffalo (*Syncerus caffer* Spearman) (Moloo, 1993).

The morsitans group with seven species and sub-species is the most important economically. It comprises: *G. morsitans morsitans* Westwood, *G. morsitans submorsitans* Newstead, *G. morsitans centralis* Machado, *G. swynnertoni* Austen, *G. longipalpis* Wiedeman, *G. pallidipes* Austen, and *G. austeni* Newstead. They occupy the woodland-savanna habitats and are the main vectors of animal trypanosomosis in sub-Saharan Africa. Their most preferred hosts include: warthog (*Phacochoerus aethiopicus* Pallas), cattle (*Bos taurus*) and buffalo (*Syncerus caffer* Spearman) (Moloo, 1993).

In Kenya, tsetse flies are found from 0 - 2000 m above sea level covering 25% (138,000 km^2) of the country, including 60% of the rangeland where beef cattle are concentrated (KETRI, 1997) (Figure 2.3). It is estimated that out of fifteen million cattle in the country, about two million (14%) are at risk of contracting animal trypanosomosis (Wint and Rogers, 2001). At least forty districts, including all those at the border, in seven provinces are infested with tsetse flies. Although there are inland tsetse belts, the coastal belt is the largest, extending from Tanzania to Somalia border (Wint and Rogers, 2001). The country has eight tsetse species transmitting pathogenic trypanosomes. They include: *G. pallidipes* (the most widespread) (Figure 2.4), *G. swynnertoni*, *G. morsitans* and *G. austeni* (restricted to the coastal basin) (KETRI, 1997). *Glossina brevipalpis* and *G. fuscipleuris* are forest species with *G. longipennis* extending into drier zones (KETRI, 1997). *Glossina fuscipes fuscipes* are found along water edge in the Lake Victoria basin (Wijers, 1974).

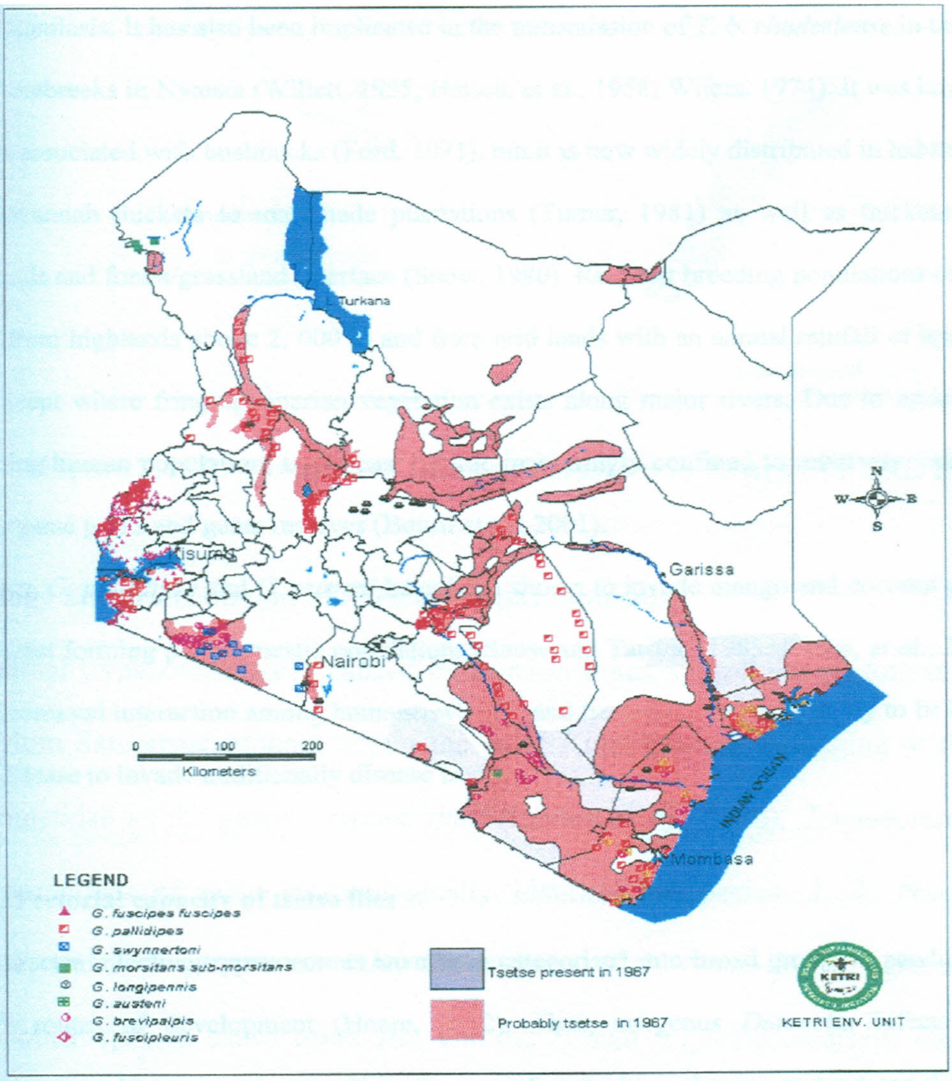


Figure 2.3: Tsetse fly distribution in Kenya (KETRI, 1997)

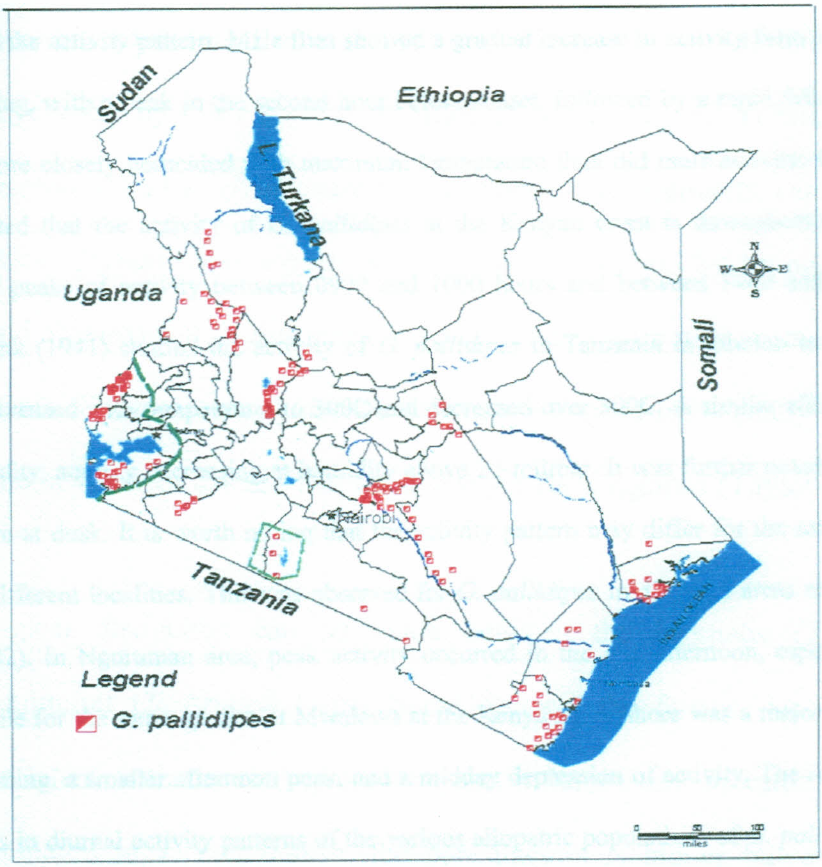


Figure 2.4: Distribution of *Glossina pallidipes* in Kenya (KETRI, 1997)

2.2 Aetiology and transmission of African trypanosomosis

Animal trypanosomosis is caused by trypanosomes, unicellular protozoan parasites of the phylum Sarcomastigophora within the order Kinetoplastida belonging to the family Trypanosomatidae in the genus *Trypanosoma* (Levine *et al.,* 1980). *Trypanosoma brucei* complex comprises of three morphologically identical subspecies: *T. b. brucei*, *T. b. rhodesiense*, and *T. b. gambiense*. Only the ancestral *T. b. brucei* is pathogenic to cattle while the other species cause acute and chronic human trypanosomosis in Eastern and Western Africa, respectively (Fevre *et al.*, 2005).

Trypanosoma congolense is divided into sub-types with different distributions and pathogenicity: savannah type, forest type, Tsavo type, and Kilifi type (Majiwa *et al.,* 1993).

Trypanosoma vivax has been found outside the zone of *Glossina* infestation, where it is transmitted non-cyclically by other species of biting flies (Abebe and Yobre, 1996). The pathogenic *T. congolense* and *T. vivax* cause trypanosomosis in ruminants, camels, equines and swine in Africa. *Trypanosoma evansi* is cyclically transmitted by biting flies of the genus *Tabanus* and *Stomoxys*. It causes surra, a severe disease in horses, camels and dogs, but mild in ruminants. *Trypanosoma equiperdum*, which is transmitted sexually from host to host causes dourine, a venereal disease that exclusively affects equines (Taylor and Authie, 2006).

A pathological distinction can be made between the haematic (*T. vivax*, *T. congolense*) and humoral (*T. brucei*) trypanosome species; the former, associated with anaemia while the latter, with tissue degeneration and inflammation in cattle (Losos and Ikeda, 1972). Compared to *T. congolense*, the parasitaemia is higher but anaemia less profound in *T. vivax* infections. However, it is difficult to clinically distinguish diseases caused by different trypanosome species and mixed infections are common.

2.3 Epidemiology of African trypanosomosis

The epidemiology of animal trypanosomosis in tsetse-infested areas of Africa is determined by four biological factors: trypanosomes, tsetse flies, reservouir hosts and cattle, operating within the physical environment. The severity of the disease depends on the species and strain of trypanosome involved. It is known that *T. vivax* infections predominate in cattle in West Africa and are rapidly fatal while *T. congolense* causes a chronic disease (Taylor and Authie, 2006). In contrast, *T. vivax* may be commonly encountered in East and Central Africa but causes mild disease in cattle in comparison to *T. congolense*. However, the haemorrhagic *T. vivax* infections that occasionally break out in Kenya are rapidly fatal (Stevenson and Okech, 1997; Murilla *et al.,* 1998; Leak, 1998).

The mammalian trypanosomes of the *congolense*, *vivax* and *brucei* species are normally restricted to the humid and sub-humid zones of Africa (15 °N and 25 °S), which coincides with the area of distribution of *Glossina* spp. (Hoare, 1957). Cattle-infective trypanosomes circulate in a variety of wildlife hosts, which generally tolerate infections or have a state of pre-immunity. Small ruminants, equines, pigs, dogs and cats are also susceptible to some species of cattle-infective trypanosomes (Taylor and Authie, 2006). The existence of reservouir and alternative hosts complicate the epidemiology of AAT, making the disease difficult to manage and perhaps impossible to eliminate. The problem is further compounded by the simultaneous occurrence of trypanosomosis and tick borne diseases in most of the tsetse-infested zones in sub-Saharan Africa (Latif and Jongejan, 2002).

2.4 Pathogenesis of African trypanosomosis

Infected tsetse flies inoculate metacyclic trypanosomes into the skin of animals, where they grow for a few days and cause localized swellings (chancres). They enter lymph nodes, then the blood stream, where they divide rapidly by binary fission. In *T. congolense* infections, the organisms attach to endothelial cells and localize in capillaries and small blood vessels. *Trypanosoma brucei* and *T. vivax* invade tissues and result in tissue damage in several organs (Blood *et al.,* 1989). When an animal is infected with trypanosomes, antibodies against the surface coat are produced. However, trypanosomes have multiple genes, which code for different surface proteins allowing organisms with new surface coat glycoproteins to elude the host immune response (Leak, 1998). This process, referred to as antigenic variation, results in the persistence of the organisms. Antigenic variation has prevented the development of a vaccine against trypanosomosis and permits re-infection when animals are exposed to bites of tsetse flies carrying trypanosomes with surface coat glycoproteins of a new antigenic type (Blood *et al.,* 1989). The real cause of death in the infected animal is not fully understood. However, it is believed that the parasite releases toxic substances when it is destroyed within the circulatory system and hence damages the lining of the blood vessels. In some cases, the sudden release of large amounts of such toxins triggers a chain of reactions, which produce a shock-like syndrome (Seifert, 1996).

The disease in cattle varies from hyper-acute to chronic; the latter is more common in endemic areas. Signs are not pathognomonic, but a combination of the following: fever, anaemia, lymphadenopathy, dull and dirty coat, piloerection, change of hair colour, hair loss, weight loss, lacrimation, chancre, fatigue, anorexia, pica, abortion, salivation, nasal discharge, arched back, tucked-up abdomen, laboured respiration and jugular pulse (Maré, 1998). Anaemia appears with progressing parasitaemia and there is lysis of a large number of red blood cells resulting in a drop in packed cell volume (Coetzer *et al.,* 1994). Metabolic disorders are observed in the host due to a trypanosome-induced hypothyroid status (Abebe and Eley, 1992) and pituitary dysfunction during trypanosomosis (Abebe *et al.,* 1993). The ability of trypanosomes to change their surface coat antigen continuously leads to the exhaustion of the antibody production by the host leading to immuno-suppression (Hörchner, 1993). In addition, there is enlargement of lymph nodes and splenomegally associated with plasma cell hyperplasia and hypergammaglobulinaemia (Urquhart *et al.,* 1996). Acute infections associated with high parasitaemia may lead to the death of an animal still in good body condition. However, chronic trypanosomosis is associated with progressive emaciation and eventually, cachexia. This is usually accompanied by low levels of parasitaemia and death in untreated cases (Coetzer *et al.,* 1994).

2.5 Diagnosis of African trypanosomosis

Routine diagnosis of trypanosomosis in the field is undertaken via clinical signs and knowledge of the endemicity of the disease in the area (Blood *et al.,* 1989; Coetzer *et al.,* 1994). The more accurate methods of diagnosis include: parasitology, serology and molecular biology. The parasitological methods currently in use include thin stained blood films (Shute and Maryon, 1966), the buffy-coat dark ground-phase contrast technique (BCT) (Murray *et al.,* 1977), the haematocrit centrifugation technique (HCT) (Woo, 1971) and the miniature-anion exchange centrifugation technique (mAECT) (Lumsden *et al.,* 1977). These methods are confirmatory since they depend on demonstration of trypanosomes. However, they have a limited analytical sensitivity and may lead to under-reporting of the prevalence of disease (Paris *et al.,* 1982).

More sensitive diagnostic methods, including the detection of trypanosome-specific antibodies and antigens have been developed (Nantulya *et al.,* 1992). Nevertheless, the serological tests in current use suffer from lack of well-defined antigens necessary for designing simple and accurate tests that are easily adaptable for field use. In addition, the detection of anti-trypanosomal antibodies in serum cannot distinguish between an active infection and a cured one. This is due to the fact that, in cattle, the length of time taken for antibodies to disappear from the circulation after a successful therapy may extend upto nine months (Voller *et al.,* 1977). Techniques in molecular biology have led to the development of DNA-based assays for detection of trypanosomal DNA. Species-specific DNA probes have been shown to detect simultaneous infection of cattle with *T. vivax, T. b. brucei,* and *T. congolense* when conventional methods revealed only single infections (Nyeko *et al.,* 1990). Polymerase chain reaction (PCR) coupled with DNA probe hybridization may prove to be a highly sensitive tool for the diagnosis and assessment of therapeutic efficacy and disease progress especially in chronic trypanosomosis (Clausen *et al.,* 1999).

2.6 Control of African trypanosomosis

All the available methods of tsetse and trypanosomosis control or eradication has their own specific limitations. Some of the interventions conducted in the past, such as bush clearing (tsetse fly habitat destruction) or the elimination of wild animals (trypanosome reservouir and alternative hosts) have been discarded for ecological and environmental reasons. Limitations are also imposed on the indiscriminate use of insecticides through aerial spraying. Currently, the following interventions are in use: (i) parasite control through use of trypanocidal drugs and promotion of trypanotolerant livestock; (ii) vector control or eradication through use of baited traps, insecticide-treated targets and livestock and the sterile insect technique.

2.6.1 African trypanosomosis vaccines

One important biological feature of the pathogenic trypanosomes is their ability to vary the structure of their external surface coating of variable surface glycoprotein (VSG). This process known as antigenic variation, results in the ability of the parasite to evade the immune response of the mammalian host most effectively (Cross, 1978). The number of variant antigenic types (VATs) of a single strain of trypanosomes is controlled genetically by complex gene switching processes that result in a vast repertoire. There are usually several species, sub-species or types, and strains circulating in any given area, all of which have distinct antigenic repertoires. Consequently, cattle do not develop immunity to trypanosomosis and can undergo repeated infections throughout their lifetime (Blood *et al.,* 1989). In spite of the extraordinary research efforts directed at this problem over the last 30 years, the mechanisms of antigenic variation appear to be effective in thwarting attempts to immunize cattle artificially. Consequently, prospects of developing a vaccine against trypanosomosis are low.

2.6.2 Trypanocidal drugs

The use of trypanocidal drugs is the most widely accepted means of controlling the disease. However, the available drugs are relatively expensive. In some African countries, sales of trypanocides account for more than half of the total sales of veterinary pharmaceuticals (Holmes, 1997). Each diagnosis for animal trypanosomosis costs US$ 4-5, which the African livestock farmer cannot afford. In spite of this, the development of new trypanocides appears to be economically unattractive. As a result, more than 90% of the doses are applied without reliable diagnosis (Holmes, 1997). The widespread, unsupervised and under doses of the few drugs for trypanosomes has led to increased parasite resistance (Murilla *et al.,* 1998; Afewerk *et al.,* 2000; Mugunieri and Murilla, 2003). The overall prospects for the use of trypanocidal drugs against animal trypanosomosis are not bright because of widespread drug resistance (Jordan, 1986). In developing countries, fake drugs with little or no therapeutic effects account for about 60% of trypanocides in the market (Holmes, 1997).

2.6.3 Trypanotolerant livestock

Trypanotolerant livestock have the ability to retain a certain level of productivity under tsetse challenge, control parasitaemia and development of anaemia following a trypanosome infection. They are also known to be tolerant to streptothricosis, ticks and tick borne diseases (TBDs) and to some extent, helminthiasis (D'Ieteren, 1993; D'Ieteren *et al.,* 1998). However, their ability to withstand these diseases is not absolute, and in areas of heavy tsetse challenge they can succumb to infection. Trypanotolerant cattle present a method of control, which is likely to be sustainable. However, factors that mitigate against their adoption include: (i) the limited distribution in West Africa; (ii) their relatively small size; (iii) inherent low calving rate; (iv) low meat and milk production; and (v) unsuitability as draught animals (D'Ieteren *et al.*, 1998).

2.6.4 Sterile insect technique (SIT)

Sterile insect technique (SIT) involves sustained and systemic release of sterile insects among the indigenous target population (Feldman and Hendricks, 2001). Males are sterilized by irradiation and then taken to a target area and released. Following mating with sterile males, the females become infertile for the remainder of their life span. By continually releasing sterile males in large quantities over a time span that is sufficient to cover several generations of target populations, fertile female population is progressively reduced. Eventually, so few fertile insects remain that they cannot sustain the population. For maximum effectiveness, sterile males released must outnumber fertile native males by a considerable margin (Feldman and Hendricks, 2001). Sterile insect technique is the most expensive but environmentally benign control option. It has been successfully deployed to eradicate *G. austeni* in Zanzibar island (600 km^2) (Vreysen *et al.,* 2000). However, its use on a continent-wide scale with very few or no ecological islands and with multiple tsetse species is highly questionable. Re-infestation of the cleared areas is likely to be a major problem with such an approach (Hargrove, 2000). Moreover, sterile insect technique is preceded by initial suppression of target tsetse populations to very low densities for which an effective bait technology is essential (Hargrove, 2000).

2.6.5 Insecticide–treated targets

Targets and electric screens that intercept tsetse flies hovering near and around them were developed in Zimbabwe and West Africa for tsetse sampling and control (Vale, 1974a; Hargrove, 1980). They consist of a central insecticide covered cloth usually about 1 m^2 in area. The face of the cloth is at right angle to the wind direction, presenting maximum visual target for flies approaching from upwind. In addition to the visual component and improvement of target efficacy, insecticide treated mosquito-netting side panels were added to the coloured targets (Green, 1994). Numerous trials have demonstrated that insecticide-impregnated targets, with or without odour attractants, can be efficient and sufficiently specific method for suppressing tsetse populations (Vale, 1993; Vale *et al.*, 1986; 1988a; Dransfield *et al.*, 1990; Bauer *et al.,* 1995; Makumi *et al.,* 2000). Success largely depends on the density and the position of the impregnated attractive devices in the fly habitat (Vale, 1998), the availability of attractants for the target tsetse species (Green, 1994; Torr *et al.,* 1995; 1997), the size of the control area, population dynamics of the tsetse populations in adjacent areas, associated re-invasion pressure (Van den Bossche and Duchateau, 1998; Hargrove *et al.,* 2000), and the tsetse host preference profile (Clausen *et al.,* 1998). These targets have been universally accepted and can reduce tsetse density by over 99%, without unwanted side effects (Dransfield *et al.,* 1990). They are also suited for community ownership and management. However, widespread, unsupervised and insufficiently coordinated use of insecticides on targets risks promoting the development of insecticide resistance including 'behavioural' resistance that is known to occur in other Diptera (Georghiou *et al.,* 1993).

2.6.6 Insecticide treated livestock

There has been high interest in usage of insecticide sprays, dips, and/or pour ons for cattle in tsetse-infested areas. Synthetic pyrethroids are the chemicals of choice. Treatment of cattle with insecticide is likely to be the cheapest method of tsetse control in situations where sufficient cattle and veterinary services are present (Barrett, 1997). Trials in parts of Africa confirm that if enough animals are treated with insecticides in tsetse-infested area, and sufficient flies make contact with treated animals, the method can be extremely effective (Leak *et al.*, 1995; 1996; Bauer *et al.,* 1995; 1999; Warnes *et al.,* 1999). The insecticides also reduce the numbers of biting flies and ticks. However, the technique is too costly for general adoption by poor farmers and concerns about its negative environmental impact have been raised. Furthermore, widespread use of pyrethroids may have adverse impact on invertebrate fauna in dung (Vale *et al.,* 1999; Vale and Grant, 2002; Vale *et al.,* 2004), which play an important role in maintaining soil fertility in mixed crop-livestock farming systems, and exacerbate tick-borne diseases (Eisler *et al.,* 2003). In addition, residues of deltamethrin have also been found in blood and milk samples of insecticide treated cattle (Bourn *et al.,* 2005). Although the development of insecticide resistance in tsetse flies has not been reported so far, the use of insecticides on animals risks promoting insecticide resistance in the vector.

2.6.7 Baited tsetse traps

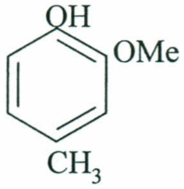
In Africa, transmission of pathogenic trypanosomes prompted the early development of many efficient devices (Cuisance, 1989) and baits (Green, 1994) for sampling and control of tsetse flies. After the refinement of the blue-black biconical trap, similar compact square (F3) or triangular (Epsilon) cloth traps were refined for savannah tsetse in Zimbabwe (Flint, 1985; Hargrove and Langley, 1990). In Kenya, the triangular format was adapted to a more practical, economical design refered to as NGU for use in community based tsetse control programmes (Brightwell *et al.*, 1987; 1991). Parallel improvements were done for riverine tsetse species, with the development of simpler traps (Pyramidal, Vavoua) for large-scale use in vector control (Gouteux and Lancien, 1986; Laveissiere and Grebaut, 1990). Efforts to develop traps for tsetse have continued to date, culminating in occasional new designs for specific tsetse species: M3 (Mhindurwa, 1994), S3 (Ndegwa and Mihok, 1999), H-trap (Kappmeier and Nevill, 2000), and Inzi (Mihok, 2002).

Trials in Ethiopia and Kenya have demonstrated that low density of such traps can achieve tsetse control in cost effective manner (Vale *et al.*, 1986; 1988a; Dransfield *et al.*, 1990; Brightwell *et al.,* 1997). The technique exerts a daily mortality of 2-3% of the tsetse population leading to a 95% annual reduction in the absence of re-invasion (Hargrove, 2000). In view of the low cost of the materials and simple technology, traps combined with odour attractants have been advocated as the most suitable method for community-based tsetse control programmes (Barrett and Okali, 1999). Despite these advantages, there are potential and real difficulties in the implementation of the technology. They require regular supervision to prevent damage, theft, floods and fire. Their effectiveness also varies with species and sub-species of *Glossina* and the geographic location (Hargrove, 2000). The technology has not made sufficient impact in the battle against tsetse flies in the past and may not do so in future if used in isolation. Other techniques must be used to complement the traps. It is for this reason that the promotion of odour-baited traps integrated with repellents to manage tsetse populations and trypanosomosis incidence constituted the principal objective of this study.

2.6.8 Tsetse repellents (allomones)

Insect repellents are meant to prevent host-vector contact or the initiation of feeding process on the host. The search for tsetse repellents started in the 1940s with the testing of several compounds and plant extracts (Holden and Findlay, 1944; Findlay *et al.*, 1946). None of the tested compounds were potent and all suffered from lack of persistence of repellent activity. Early studies showed that chemicals present in human odour reduce the numbers of tsetse flies attracted to a host and also the proportion that subsequently feed (Vale, 1974a). Several other anti-insect compounds such as *N,N*-diethyl-*m*-toluamide (DEET), indalone, citronellal have shown variable repellence to *Glossina* (Schmidt, 1977; Wirtz *et al.*, 1985). However, none is being used commercially due to lack of appropriate dispensing techniques on livestock. Low doses of acetophenone, 2-methoxyphenol, pentanoic and hexanoic acid (repellents of tsetse) reduced the catch of baited traps by 45-85% (Torr *et al.*, 1996), confirming the previous findings (Vale, 1980; Vale *et al.*, 1985). 2-Methoxyphenol was the most potent repellent, reducing trap catches by 85% and its repellent effect was not enhanced by adding pentanoic acid or acetophenone.

Recent research work has identified two potent repellents for savannah tsetse. A single-component synthetic compound (2-methoxy-4-methylphenol) (Figure 2.5), discovered from structure-activity studies of the phenolic constituents of body odours of tsetse bovid hosts and their aged urine (Saini and Hassanali, 2007). The other, a natural multiple-component blend of odour constituents specific to tsetse refractory waterbuck (*Kobus ellipsiprymnus defassa*) (Gikonyo *et al.,* 2002; 2003). Following the identification of the repellents, a series of studies were conducted aimed at: (i) refining the repellents; (ii) developing and optimizing repellent dispensers; (iii) determining an appropriate location on cattle where the dispensers could be placed; and (iv) estimating an optimum proportion of cattle in a herd that should be treated to maximize protection (Saini and Hassanali, 2003).



2-methoxy-4-methylphenol

Figure 2.5: Structure of 2-methoxy-4-methylphenol, the synthetic tsetse repellent

2.6.9 Natural waterbuck repellent blend (WRB)

Studies on chemical volatiles from the skin of preferred hosts (ox and buffalo) and un-preferred host (waterbuck) (*Kobus ellipsiprymnus defassa*) revealed that non-hosts have additional allomonal compounds, which may mask the effect of the common attractant compounds (Gikonyo *et al.,* 2002). Using gas chromatography-linked electro-antennographic detector (GC-EAD) and gas chromatography-linked mass spectrometry (GC-MS) techniques, fourteen of these putative allomonal chemical compounds from waterbuck volatiles were electrophysiologically identified and chemically characterized. These include straight chain carboxylic acid homologues (C_5-C_{10}) (heptanoic, hexanoic, pentanoic, octanoic, nonanoic and decanoic acid); ketone homologues (C_6-C_{13}) (2-octanone, 2-nonanone, 2-decanone, 2-dodecanone and 2-undecanone); phenols [(2-methoxyphenol (guaiacol) and carvacrol)], and δ-octalactone. The waterbuck-specific allomonal compounds were further refined (Kipchumba, 2007). Refining process involved identifying constituents of waterbuck odour blend essential for its repellency. Field studies showed that a blend of four compounds comprising, pentanoic acid, geranylacetone, guaiacol and δ-octalactone were as effective as the original 14-component and were essential for maximum repellency (Kipchumba, 2007). In electric screen experiments, waterbuck repellent blend (WRB) significantly reduced the number of flies coming to an ox (>70%) (long-range repulsion) and the feeding efficiency by more than 90% (short-range repulsion) (Kipchumba, 2007).

Experiments on the comparison of natural waterbuck repellent blends and synthetic repellents indicated that the natural repellent blend was more potent than the synthetic one (Kipchumba, 2007). Underlying rationale for a blend based repellent technology rather than one based on a single synthetic compound is that a blend of different structural types is likely to minimize or eliminate the possibility of the development of behavioural resistance through continued use in the future, which would be expected with a single compound. In addition, the natural repellent blend may enhance and/ or augment the potency of synthetic repellent, or provide a cheaper or more effective alternative. A combination of the two repellents significantly reduced the number of flies caught in baited traps by more than 90%, compared to 80% for natural or synthetic repellents (Kipchumba, 2007).

2.7 Community participation in African trypanosomosis control

Community participation is considered to be one of the most important elements for the control of endemic diseases in poor countries, including prevention and logical surveillance of an epidemic (Catley *et al.,* 2002). Community participation is a social process whereby specific groups with shared values, living in a defined geographical area, actively pursue identification of their needs (Kamuanga, 2003). In cases where a programme is introduced from outside, efforts must be taken to sensitise the community on the issues to enable its members understand the programme and make informed decisions. This reconciles outside objectives with local priorities, and provides an environment for community mobilization to enable active and sustained participation. Bait methods (traps/targets or treated cattle) for tsetse control are particularly suited to community use. Some of the first community projects had the primary objective of controlling human trypanosomosis epidemics in Cote d'Ivoire (Laveissière *et al.,* 1994), Uganda (Okoth *et al*., 1998), Angola (Abel *et al.,* 2004) and Sudan (Joya and Okoli, 2001). These were generally effective in reducing fly numbers and disease incidence, and the community was actively involved in deploying and maintaining traps. However, interest declined with time, and effective control of the programme remained with project staff suggesting low-level participation (WHO, 2004).

Projects with focus on animal health have been described in Kenya, Ethiopia, Uganda, Zambia and Zimbabwe, Botswana and Burkina Faso (Barrett and Okali, 1999; Kamuanga, 2003). The technical results were good but the levels of community participation low, and farmer contribution insufficient to maintain activities without the presence of external support (Brightwell *et al.,* 2001). This was due to the low level of participation and continued domination by administrators and experts. There are intrinsic economic incentives for the failure of community-based control strategies without external support (Barrett and Okali, 1999; Catley and Leyland, 2001). These include the free-rider problem, as vector control is a non-excludable public good so there are incentives to enjoy the benefits without paying the costs (McCarthy *et al.,* 2003); time consistency issues because farmers are less willing to pay when it appears the problem is gone; and equity problems as some benefit more from the control. The World Health Organization (WHO) (2005) recommends that when methods of vector control are included in public health intervention packages, they should be made available at no cost.

2.8 Participatory research in animal health surveys

Workers involved in primary-level veterinary services in Africa have emphasized the importance of participatory analysis and identification of 'best-bet' solutions during the initial stages of community-based animal health projects (Leyland, 1996; Catley and Leyland, 2001). However, in the case of tsetse and trypanosomosis control programmes, accounts of local perceptions on the importance of trypanosomosis relative to other livestock diseases are limited. For community-based tsetse and trypanosomosis control interventions, researchers seemed to overlook control methods that were already being used by livestock keepers, often at individual basis, and assumed that traps or targets would automatically be preferable to other control options (Catley and Leyland, 2001). Similarly, it was often difficult to ascertain whether communities were likely to embark on prolonged collective action to control tsetse flies.

Furthermore, consideration regarding tsetse and trypanosomosis control projects is the ability of livestock keepers to diagnose the disease and determine whether communities and researchers are talking about the same problem (Catley *et al.,* 2002). Veterinary literature from pastoral areas makes frequent reference to pastoralist diagnostic skills although systematic methods for validating local diagnoses versus professional diagnoses are rarely used. By enabling livestock keepers to describe and compare signs, causes and seasonality of different diseases, participatory research methods can assist to understand and validate names of local diseases (Catley *et al.,* 2002). Participatory research techniques that have been previously applied for animal health surveys include semi-structured interviews, visualization, scoring and ranking, focus groups discussions (FGDs), community profile analysis, participatory mapping and social drama (Mwangi *et al.,* 1998).

2.9 Integration of synthetic repellent with bait technology

In the past there has been heavy reliance by African countries on single control techniques for animal trypanosomosis and little attempt at integration of different methods. However, experience from other disease control situations suggests that a combination of different methods may yield far greater benefits than a single method (Holmes, 1997). New technologies especially in vector control are providing new and exciting possibilities for improved control by integrating various control measures. The advantages of combining different vector control techniques certainly merit further study and evaluation. This study evaluated variants of 'push-pull' strategy with respect to the rate and efficiency of tsetse population reduction and disease suppression (Figure 2.6). The 'push' component comprised cattle carrying dispensers with repellents while the 'pull' component was made up of baited NG2G traps deployed in the study area. The 'push-pull' component comprised a combination of both.

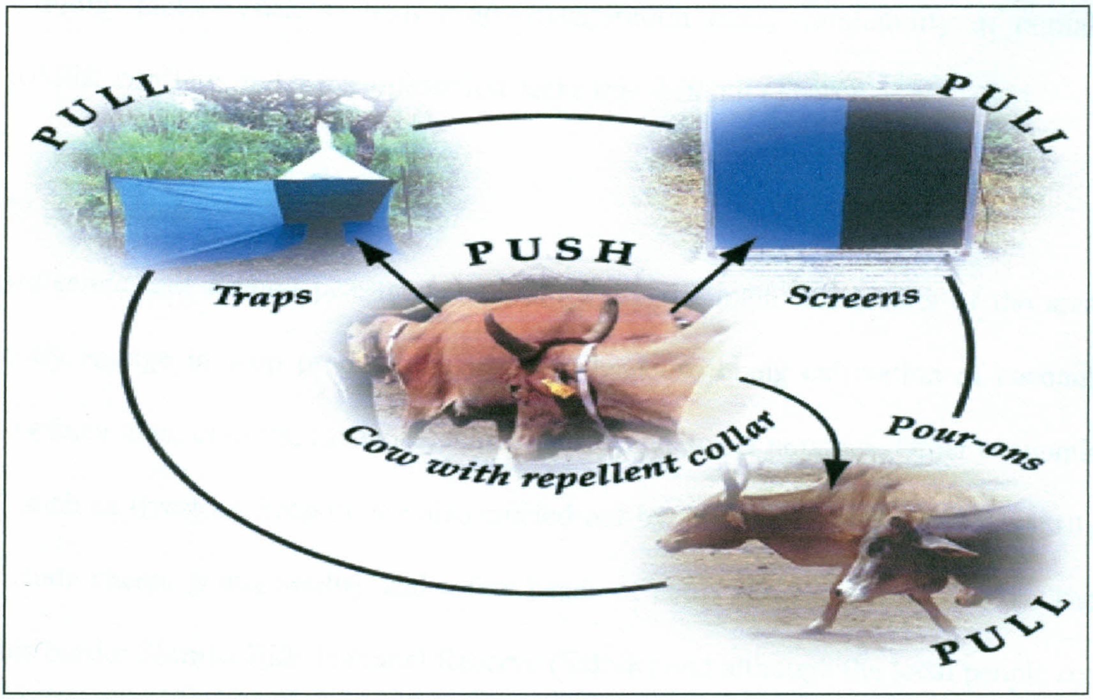


Figure 2.6: The 'push-pull' paradigm

CHAPTER THREE

GENERAL MATERIALS AND METHODS

3.1 Study area

This study was conducted in Shimba Hills, Kwale District, Kenya. Shimba Hills lies between latitude 4^0 20' S and longitude 39^0 31' E in the coastal lowland agro-ecological zones 2-4 (Jaetzold and Schimdt, 1983) (Figure 3.1). Vegetation types in this area range from palm, pine, cashew nuts and mango trees to scattered shrubs and grass. The area receives between 500–900 mm of rainfall in a year, which is poorly distributed and unreliable. Rainfall is weakly bi-modal, with a small peak occurring in October or November and the main rainfall season occurring between April and August. The mean annual minimum and maximum temperatures are 24 and 36 °C, respectively. The area is endowed with a variety of wild game like elephants, buffaloes, warthogs, bush pigs, sable antelopes, waterbucks, leopards and monkeys among others. Though the area is suitable for mixed farming, factors such as high evapo-transpiration rates, unreliability of rainfall, human-wildlife conflicts and tsetse infestation make this difficult (Thorpe *et al.,* 1993).

3.2 Study population

Mijikenda and *Kamba* peasant communities are the main inhabitants of the area. They mostly engage in crop production, the main land use being cultivation of coconut, cassava, cashew nuts, oranges, mangoes, maize, beans and sweet potatoes. Other economic activities such as livestock keeping are also carried out by some farmers. Livestock mostly reared include sheep, goats, poultry and a few heads of cattle (Machila *et al.,* 2003). The households border Shimba Hills National Reserve (SHNR) and although the local people co-exist with wildlife, human-wildlife conflicts are common.

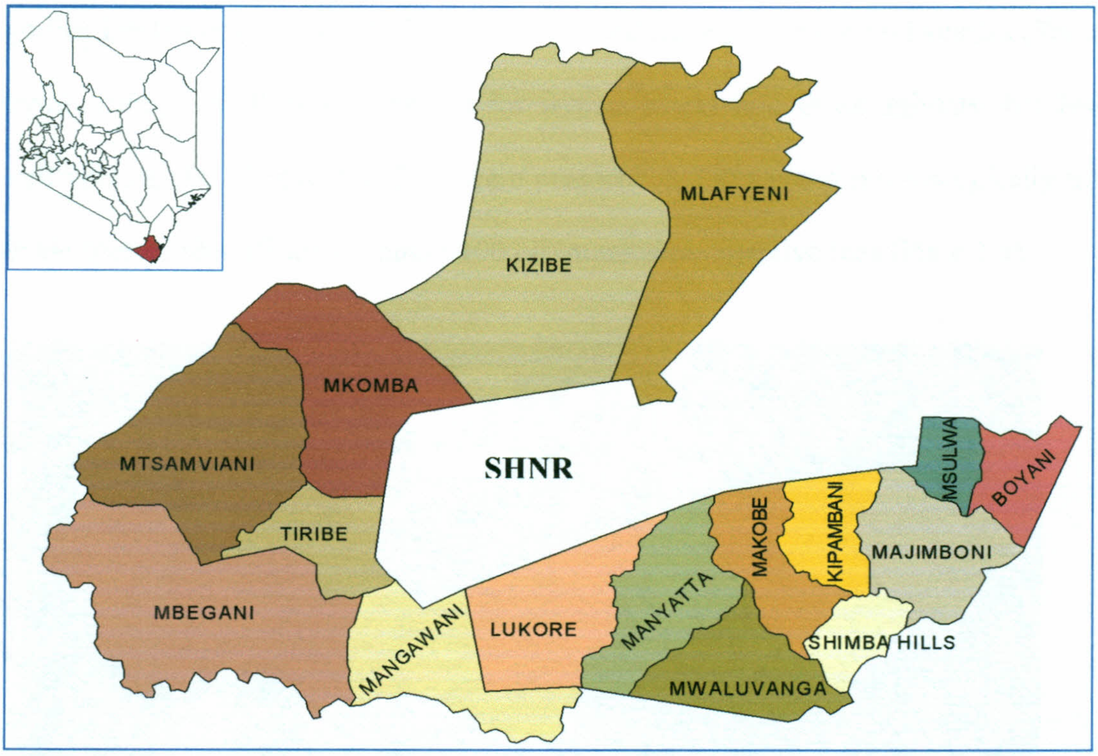


Figure 3.1: Map showing sub-locations neighbouring the Shimba Hills National Reserve (SHNR) of Kwale District, Kenya

3.3 Parasitological diagnosis of trypanosomes

Blood samples collected between 0700 and 1100 hours from a punctured ear vein of each animal was drawn directly into heparinized micro-haematocrit capillary tubes. The tube was sealed at one end with Crystaceal (Hawksley) and then centrifuged at 1200 rpm using micro-haematocrit centrifuge (Haemofuge A) for five minutes. Parasitaemic levels were assessed by packed cell volume (PCV) measured by micro-haematocrit reader (Woo, 1971). The tubes were cut 1 mm below the buffy coat to include the top layer of red cells and blood expressed onto a clean slide including 1 cm of the plasma column. The preparation was covered with a 22 x 22 mm cover slip. Fresh preparations of the buffy coat were examined microscopically under phase-contrast illumination for the presence of live trypanosomes at x40 magnification (Murray *et al.*, 1977). Giemsa stained thick and thin blood smears (Shute and Maryon, 1966) for all slides positive for trypanosomes and those animals that had packed cell volume (PCV) less than 22% were prepared and examined microscopically for trypanosome species identification under x100 oil immersion objective lens (Plate 3.1).

Plate 3.1: Screening of cattle blood for the presence of trypanosomes at a site in Shimba Hills, Kenya

3.4 Tsetse fly monitoring

Tsetse fly populations were monitored using baited NG2G traps (Brightwell *et al.*, 1991) (Plate 3.2). Trap deployment sites in the area were selected based on vegetation to represent all possible habitats that could be related to fly multiplication, behaviour and feeding. Hence, grazing lands, thickets, bushy areas, riverbanks and watering points were purposely included. The co-ordinates of each position were recorded by global positioning system (GPS). Inter-trap distances depended on the vegetation type in the area. The traps were baited with acetone and cow urine dispensed from bottles at release rates of 500 and 1000 mg/h, respectively. The deployed traps were emptied daily for 5 consecutive days and the caught flies sorted according to species, sex and status (teneral and non-teneral). Identification of tsetse species was based on morphological features as outlined in classification keys (Mulligan, 1970). Traps were greased on all support poles to prevent ants from accessing and feeding on the caught flies.

Plate 3.2: A baited NG2G trap used for monitoring savannah tsetse fly populations

3.5 Questionnaire administration

Open-ended structured questionnaires were developed and pre-tested in English. They were revised to clarify specific questions and ensure that the average time taken to interview a respondent was not more than one hour. Questions were posed to the respondents in Swahili, the common local language. Incases where respondents had a problem with the language, village chairmen helped with translation. The questions were asked in open-ended manner. Probing was frequently done by the interviewer in order to get accurate information. The responses were recorded in English and coded before being subjected to statistical analysis. Respondents were household heads or their spouses with responsibility for livestock production and health management (Plate 3.3).

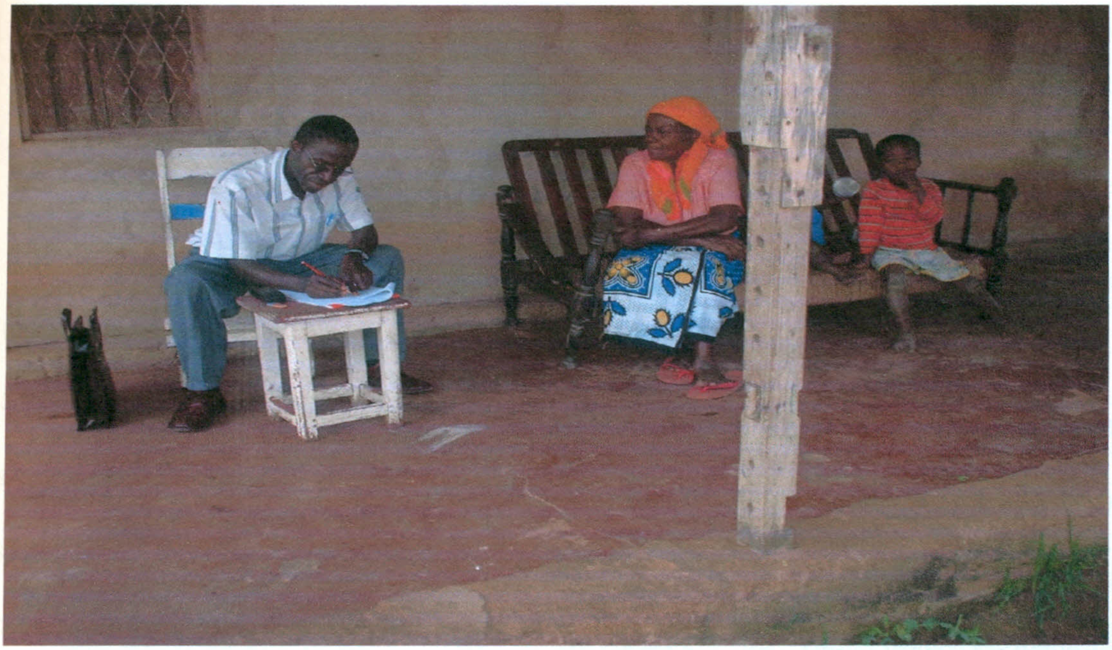


Plate 3.3: Administering an open-ended structured questionnaire to one of the livestock keepers in Shimba Hills, Kwale District, Kenya

3.6 Data management and analysis

All the data obtained were entered in a fully relational database specifically designed for this purpose using Microsoft© Access 2000 (Microsoft Corporation) software. The relational database structure minimizes data entry errors, increases data entry efficiency and maintains a high level of data integrity. Data were verified and files screened for outliers and missing entries and later exported to Statistical Analysis Systems© (SAS, Version 9.1) software for analysis (SAS, 2003). A p-value <0.05 was considered indicative of statistically significant difference.

CHAPTER FOUR

LIVESTOCK FARMERS' KNOWLEDGE, ATTITUDES AND PERCEPTIONS AND THE EPIDEMIOLOGY OF BOVINE TRYPANOSOMOSIS IN KWALE DISTRICT, KENYA

4.1 Introduction

Communities affected by trypanosomosis should be actively involved in the formulation and implementation of tsetse and trypanosomosis (T & T) control strategies (Ssennyonga, 1998). This involvement can only be successful if it is based on sound understanding of the social and cultural settings of the community. Ssennyonga (1998) suggested the collection of four types of baseline information necessary to understand the social and cultural settings of the community that will participate in tsetse and trypanosomosis control. This includes information on indigenous knowledge and management of tsetse and trypanosomosis; demographic profiles; social organization; and local modes of adaptation and spatial dimension of production systems. An important aspect of baseline data is the information on indigenous knowledge and management of tsetse and trypanosomosis from the perspectives of the beneficiaries that can reveal the size of gaps in knowledge. In several parts of Africa, local explanation of trypanosomosis causality is embedded in beliefs in the form of superstitions, magic or witchcraft, myths, taboos and religion (Echessah *et al.*, 1997; Mwangi *et al.*, 1998). Knowledge of the symptoms of trypanosomosis is also an important factor affecting farmer willingness to participate in tsetse and trypanosomosis control activities (Pokou *et al.*, 1999; Kamuanga *et al.*, 1997; 2001). Even in situations where livestock farmers are sufficiently aware of trypanosomosis and its consequences, and or where successful tsetse and trypanosomosis control operations have been carried out, there may still be a need to increase farmers' awareness about control techniques to facilitate their participation in future tsetse and trypanosomosis control activities.

Development of new technologies without involving the stakeholders, and without an adequate understanding of their farming systems and constraints, has been blamed for poor adoption of new improved technologies (Catley *et al.,* 2002). In respect to the current study, previous studies showed that Kwale District, the proposed study area, had high trypanosomosis prevalence rates and was tsetse inhabited (Murilla *et al.,* 1998; Machila *et al*., 2003; Mugunieri and Murilla, 2003; Muraguri *et al*., 2005). However, information on the areas' suitability for field trials and its relevance to current animal health constraints, management practices and the relative importance of trypanosomosis has not been clearly understood. It is therefore imperative to assess livestock owners' knowledge, attitudes on the diagnosis, treatment and control of trypanosomosis, tsetse densities and prevalence of the disease. These estimates are essential in shaping the assumptions that can be made about livestock production if the disease is controlled in the area. This cross-sectional study was conducted to determine the prevalence of trypanosomosis in cattle and tsetse populations in Kwale District. Participatory rural appraisal (PRA) (Chambers, 1992) was used to provide an understanding of local livestock farming systems, disease constraints and farmer decision-making process with respect to current tsetse and trypanosomosis control. The information was used primarily to determine the suitability of the area for the 'push-pull' field trials and the relevance of the strategy for the area. This down-top approach is useful in planning control strategies for the disease and vector considering end user socio-cultural values, practices and expertise.

4.2 Materials and methods

4.2.1 Study area

This study was conducted in Kwale District of Coast Province, Kenya. The study site is described in section 3.1 (Figure 3.1).

4.2.2 Study sites

Out of the six administrative divisions (Kinango, Kubo, Samburu, Matuga, Msambweni and Lunga lunga) of Kwale District, Kubo Division was purposely selected for the survey. The selection of the division was based on the following: the Shimba Hills National Reserve (SHNR) covers approximately 90% of the total land surface area of the division; hence the neighbouring settlements were targeted for the survey. The division is known not to have been subjected to intensive investigations of trypanosomosis that might have sensitized the respondents on the disease problem. It is also an agro-pastoral area. All the five administrative locations (Mangawani, Mwaluphamba, Mkongani, Lukore and Mwaluvanga) in the division were included in the survey. From each location, sub-locations were selected based on the distance between the sub-location and SHNR. All sub-locations less than 5 km from SHNR fence were included in the survey. A list of all livestock keepers within each sub-location was compiled from the area Assistant Chief's office. With the help of area Assistant Chiefs and Village Headmen, each of the listed livestock keeper's homestead was physically visited. During the visit, the position of the homestead was marked by geographical positioning system (GPS) (Garmin GPS 45). The distance between each homestead and SHNR fence was estimated using geographical information system (GIS) analysis software (Arcview) (ESRI, UK). All livestock keepers whose homesteads were less than 5 km from SHNR fence were selected for the survey.

4.2.3 Livestock farmers' interviews

The cross-sectional survey was carried out from February to August 2004. Village Headmen or area Assistant Chiefs were involved in the identification of households within the area that kept livestock. Residents with at least one head of cattle qualified as a livestock farmer. Due to low cattle density in the area, all livestock keepers in each sub-location were interviewed. A participatory rural appraisal (PRA) toolkit comprising of semi-structured questionnaires and interviews was used (Plate 4.1). Interviews focused on: general livestock and crop production; constraints to livestock production; farmer description of the local cattle diseases experienced and the management of herds; treatment given to their animals and reasons for giving them; and the current tsetse and trypanosomosis control methods (Appendix 4.1). Questionnaires were administered to the respondents as described in section 3.5.

Plate 4.1: Interviewing a group of livestock owners at Mangawani, Shimba Hills

4.2.4 Parasitological diagnosis of trypanosomosis

One day after the interview, the animals were screened for trypanosomal infection. On the same day, blood samples were processed at the point of collection by parasitological techniques as described in section 3.3 (Plate 3.1).

4.2.5 Tsetse fly monitoring

Cross-sectional tsetse surveys were conducted simultaneously with animal trypanosomosis surveys. In each sub-location, a total of 15 trap deployment positions were surveyed using five baited NG2G traps as described in section 3.4.

4.2.6 Data management and analysis

Farmers reported cattle diseases using local language and/ or English terms. The equivalent of English terms was used in the analysis. For example, tsetse was reported as *mbungo* in *Swahili*, *mabu* in *Mijikenda* and *matangwa* in *Kamba*, thus *ugonjwa ya matangwa* or *mbungo* or *mabu* was taken to mean trypanosomosis. Farmers' disease diagnoses were accepted when at least half of the clinical signs described were consistent with those given by Radostitis *et al.* (2000). The prevalence rate of trypanosome infection was calculated as the number of parasitologically positive animals examined divided by the total number of animals investigated at that particular time. Percentage mean packed cell volume (PCV) was calculated as an average of the total cattle screened in each sub-location. Tsetse fly relative density was expressed as the total number of flies caught per trap per day.

4.3 Results

4.3.1 Household information

The survey was undertaken in 13 of the 17 administrative sub-locations in Kubo Division that met the inclusion criteria (Table 4.1). Average distances between surveyed sub-locations and SHNR fence ranged between 0.60 - 5.00 km. A total of 132 respondents were interviewed with majority being males (92%). Most of the respondents came from Makobe sub-location. The level of literacy was intermediate with 63% of the respondents having attained up to primary education and beyond.

Crop production was the main economic activity in the area, with almost all respondents cultivating commercially oriented horticultural crops such as citrus fruits (oranges, lemon, grapes and tangerines), mangoes, sweet watermelon, cashew nuts, bixa, coconut and passion. Maize, beans, cassava and sweet potatoes were cultivated mainly for subsistence. Livestock kept were cattle, sheep, goats, bees and poultry. Compared to sheep, goat herd sizes were higher. This was attributed to agro-climatic factors, abundant shrubs, presence of toxic plants that was fatal to sheep, susceptibility of sheep to a fatal diarrhoea condition and higher kidding than lambing rates. Farmers in four sub-locations practiced large-scale production of chicken layers and broilers.

Most respondents kept local livestock breeds except for 4% who owned exotic dairy cattle. The lowest and highest number of cattle kept by farmers was 1 and 23, respectively, while the average cattle herd sizes were 4 per respondent. Most of the cattle were bulls kept for traction. The main grazing system of respondents was tethering, while some employed free range grazing. Kinondo and Kinango sub-locations had the highest (83) and least (56) number of cattle, respectively.

4.3.2 Livestock production constraints

Animal diseases were ranked above other constraints associated with cattle production. This was followed by human-wildlife conflicts, drought, lack of institutional support to control the diseases, poor infrastructure and lack of transport and marketing systems. Out of the fifteen livestock diseases observed by the Kwale District Veterinary Department to be present in the area, the respondents accurately described nine cattle disease episodes (Table 4.2). The respondents were therefore fairly knowledgeable on the clinical symptoms, causes and treatment of the diseases. All diseases described in local terms were assigned to the equivalent English or scientific group. More than 60% of the respondents correctly described at least six disease episodes. Trypanosomosis, followed by tick borne diseases (East Coast fever (ECF) and anasplasmosis) were identified as the most important cattle diseases. Most respondents had problems in recognizing different types of tick borne diseases. Diseases such as pneumonia and rinderpest were cited by 8.3 and 1.5% of respondents, respectively.

Table 4.1: Number of farmers and cattle screened in various sub-locations of Shimba Hills, indicating the distance (± SE) from the SHNR fence

Location	Sub-location	Mean distance from SHNR (km) ± SE	No. of farmers	No. of cattle
Kinondo	Kinondo	0.29 ± 0.08	7	83
Lukore	Lukore 11	0.50 ± 0.14	11	64
Mwaluphamba	Mlafyeni	0.60 ± 0.13	8	73
Mwaluvanga	Kichakasimba	0.80 ± 0.12	13	71
Mangawani	Lukore 1	1.00 ± 0.18	14	65
Majimboni	Makobe	1.00 ± 0.00	16	50
Majimboni	Msulwa	1.18 ± 0.25	13	78
Mwaluphamba	Kizibe	1.66 ± 0.13	10	63
Majimboni	Majimboni	1.62 ± 0.14	11	48
Mangawani	Magwasheni	1.96 ± 0.37	11	78
Mwaluphamba	Kinango	3.42 ± 1.06	6	56
Mkongani	Mkomba	4.80 ± 0.00	7	75
Mkongani	Tiribe	5.00 ± 0.20	5	75
Total			132	879

4.3.3 Knowledge of trypanosomosis clinical diagnoses

For trypanosomosis, a total of 14 clinical signs were recognized by respondents (Table 4.3). These included starring coat, lacrimation, weight loss and swollen lymph nodes. These symptoms named by farmers were largely consistent with the standard twenty three clinical signs of bovine trypanosomosis. More than 68% of the respondents correctly described at least eight standard clinical symptoms and signs of trypanosomosis. Abortion was also cited as a clinical sign by two (1.5%) respondents.

Table 4.2: Livestock diseases reported by farmers in various sub-locations of Shimba Hills

Disease	No. of farmers	% of farmers
Trypanosomosis	110	83.33
Tick-borne diseases (ECF and anaplasmosis)	94	71.21
Helminthosis	43	32.58
Foot and mouth disease	42	31.82
Pneumonia	17	12.88
Anthrax	13	9.85
Heart water	11	8.33
Rinderpest	2	1.52
Abortion	2	1.52

(*n* =132)

4.3.4 Knowledge of the aetiology of cattle trypanosomosis

Seventy-one respondents were aware of the causal association between tsetse flies and trypanosomosis while 22.7% had no idea what caused the disease (Table 4.4). Some associated trypanosomosis with tick bites, worms, weather, grazing hours and watering at certain rivers or streams. Biting flies that also transmit trypanosomes were recognized by 51.5% of the respondents.

Table 4.3: Clinical signs frequently observed by farmers for cattle diseases perceived to be trypanosomosis in various sub-locations of Shimba Hills

Clinical sign	No. of farmers	% of farmers
Eating of soil	109	82.58
Starring coat	101	76.52
Lacrimation	96	72.73
Lack of appetite	91	68.94
Loss of weight	86	65.15
Swollen lymph nodes	84	63.64
General weakness	69	52.27
General dullness	52	39.39
Coughing	26	19.70
Grinding of teeth	17	12.88
Hard stools	13	9.85
Excess salivation	9	6.82
Nasal discharge	7	5.30
Abortions	2	1.52

(*n* =132)

4.3.5 Animal health management practices by farmers

Trypanocides followed by anti-helmintics and antibiotics, were the most commonly administered drugs to perceived cattle illness (Table 4.5). Twenty-one respondents used traditional medicinal plants to treat their animals while some did not use any drug.

Table 4.4: Farmer's perceptions of the aetiology of trypanosomosis in various sub-locations of Shimba Hills

Aetiology	No. of farmers	% of farmers
Tsetse fly bites	71	53.79
Biting flies bites	68	51.52
Tick bites	43	32.58
Worms	31	23.48
Rainy season	29	21.97
Cold weather	26	19.70
Grazing animals next to the national reserve	19	14.39
Grazing animals in bushy areas	17	12.88
Grazing of animals in early mornings (700 – 1000 hours)	9	6.82
Grazing animals in the late evenings (1700 – 1900 hours)	4	3.03
Watering animal at certain streams/rivers	1	0.76
Unknown	30	22.73

(*n* =132)

4.3.6 Provision of animal health care

Cattle owners or fellow farmers and animal health assistants administered 62 and 53% of the drugs, respectively (Table 4.6). Para-veterinary officers (livestock health first aiders) administered 43.2% of the treatments. Supply of drugs to the farmers came mainly from animal health assistants, local agro-veterinary shops, fellow farmers and salesmen based at cattle auction market centres.

Table 4.5: Proportion of farmers who used different drugs to cure cattle illnesses in the various sub-locations of Shimba Hills

Type of drug	No. of farmers	% of farmers
Trypanocides	121	91.67
Antihelmintics	81	61.36
Antibiotics	79	59.85
Multivitamins/boosters	54	40.91
Vaccination	24	18.18
Traditional herbs	21	15.91
Unknown	13	9.85
Non-given	7	5.30

(*n* =132)

4.3.7 Tsetse and trypanosomosis control techniques

Different traditional methods of tsetse fly control were practiced: avoiding grazing in high-risk areas such as woodland and bushes (19%) and burning of bushes/pastures (13.6%) (Table 4.7). Pour-ons (Spot-on®) were the most commonly used (54.6%) ectoparasites treatment. Forty five respondents indicated use of chemicals such as Dominex®, Ectomin® and Decatix®, which are synthetic pyrethroids-based insecticides, used as hand spray wash. Some utilized communal cattle dips to protect their animals. Nine farmers used traps to control tsetse while 8.3% did not use any method for tsetse and trypanosomosis control.

Table 4.6: Proportion of animal health care providers who administered drugs to cattle in various sub-locations of Shimba Hills

Drug administration personnel	No. of farmers	% of farmers
Farmers	82	62.12
Animal health assistants	71	53.79
Para-veterinary officers	57	43.18
Extension officers	41	31.06
Agro-veterinary traders	33	25.00
Herbalists	16	12.12
Unknown	29	21.97

Table 4.7: Tsetse and trypanosomosis control techniques frequently used by farmers in various sub-locations of Shimba Hills

Control technique	No. of farmers	% of farmers
Pour-ons	72	54.55
Insecticide sprays	45	34.09
Dipping	36	27.27
Screens on cattle pens	25	18.94
Smoke near cattle pens	25	18.94
Avoidance of woodland and bushes	19	14.39
Burning of bushes and pastures	18	13.64
Treated targets	13	9.85
Traps	9	6.82
None	11	8.33

4.3.8 Tsetse fly species distribution and relative densities

Three species *Glossina pallidipes*, *G. brevipalpis* and *G. austeni* were caught in traps during the survey (Table 4.8). *Glossina pallidipes* was collected in all sub-locations and was the most abundant. *Glossina brevipalpis* and *G. austeni* were found only in 5 and 7 of the 13 sub-locations, respectively. In all sub-locations, the majority (83.4%) of flies caught were females. A few biting flies, tabanids and *Stomoxys* spp were also collected. Relative tsetse density was calculated as the total number of tsetse caught per trap per day. The relative density of *G. pallidipes* varied between 0 and 147 in Tiribe and Kichakasimba sub-locations, respectively, while that for *G. brevipalpis* varied between 0 and 25 flies/trap/day, respectively (Table 4.9).

Table 4.8: Number of tsetse fly species and biting flies caught in various sub-locations of Shimba Hills

Sub-location	*Glossina brevipalpis*			*Glossina pallidipes*			*Glossina austeni*			Biting flies
	Females	Males	Total	Females	Males	Total	Females	Males	Total	Total
Kinondo	3	0	3	11	2	13	2	6	8	0
Lukore 11	7	0	7	39	11	50	0	0	0	3
Mlafyeni	12	4	16	1048	310	1358	0	0	0	12
Kichakasimba	15	4	19	3302	388	3690	8	0	8	4
Lukore 1	4	2	6	217	151	368	11	6	17	6
Makobe	0	0	0	29	0	29	0	0	0	1
Msulwa	2	3	5	59	31	90	0	0	0	0
Kizibe	0	0	0	33	13	46	0	0	0	6
Majimboni	3	0	3	62	8	70	0	1	1	4
Magwasheni	2	0	2	41	3	44	0	0	0	13
Kinango	24	1	25	85	25	110	3	2	5	7
Mkomba	0	0	0	1	0	1	0	0	0	1
Tiribe	0	0	0	2	1	3	0	0	0	2

Table 4.9: Tsetse fly density in various sub-locations of Shimba Hills

Sub-location	*G. brevipalpis*	*G. pallidipes*	*G. austeni*	Tabanids
Kinondo	0.12	0.52	0.32	0
Lukore 11	0.28	1.56	0	0.12
Mlafyeni	0.64	54.32	0	0.48
Kichakasimba	0.76	147.6	0.32	0.16
Lukore 1	0.24	14.72	0.68	0.24
Makobe	0	1.16	0	0.04
Msulwa	0.20	3.60	0	0
Kizibe	0	1.84	0	0.24
Majimboni	0.12	2.8	0.04	0.16
Magwasheni	0.08	1.76	0	0.52
Kinango	1.00	4.40	0.2	0.28
Mkomba	0	0.12	0	0.04
Tiribe	0	0.04	0	0.08

Fly density = Total catch/trap/day

4.3.9 Prevalence of cattle trypanosomosis

Blood samples from 879 animals consisting of 81% males were sampled using buffy coat phase-contrast technique. Trypanosomal infections were diagnosed in 160 (18.2%) animals (Table 4.10). Majority of infections were due to *T. congolense* (60%, n = 160) and *T. vivax* (40%, n = 160). The highest (25.4%) trypanosomosis prevalence was recorded in Kichakasimba and Mlafyeni sub-locations. In Tiribe, no trypanosomosis was detected.

Table 4.10: Parasitological prevalence of trypanosomosis in cattle sampled in various sub-locations of Shimba Hills

Sub-location	Total No. of cattle screened	Total No. positive	% infections	*T. congolense* infections (%)	*T. vivax* infections (%)
Kinondo	83	05	06.20	2 (40)	3 (60)
Lukore 11	64	15	23.44	2 (13.33)	13 (86.67)
Mlafyeni	73	13	17.81	4 (30.77)	9 (69.23)
Kichakasimba	71	18	25.35	12 (66.67)	6 (33.33)
Lukore 1	65	11	16.92	8 (72.73)	3 (27.27)
Makobe	50	11	22.00	1 (9.09)	10 (90.91)
Msulwa	78	18	23.08	15 (83.33)	3 (16.67)
Kizibe	63	16	25.40	10 (62.5)	6 (37.5)
Majimboni	48	11	22.92	7 (63.64)	4 (36.36)
Magwasheni	78	18	23.08	16 (88.89)	2 (11.11)
Kinango	56	11	19.64	10 (90.91)	1 (9.09)
Mkomba	75	13	17.33	9 (69.23)	4 (30.77)
Tiribe	75	00	0.00	0	0

4.3.10 Packed cell volume (PCV)

Mean % packed cell volume (PCV) varied between 23.0 - 28.9 and 25.5 - 32.7% in trypanosome-positive and negative cattle, respectively (Table 4.11). Average PCV of parasitologically-negative cattle (29.6 ± 0.9%) was significantly higher ($F_{1,18} = 8.61$; $p = 0.009$) than that of positive cattle (25.7 ± 1.6%).

Table 4.11: Mean packed cell volume (± SE) of trypanosomosis positive and negative cattle sampled in various sub-locations of Shimba Hills

Sub-location	Mean PCV ± SE of Positive cattle	Mean PCV ± SE of Negative cattle
Kinondo	23.00 ± 0.09	30.16 ± 1.47
Lukore 11	23.81 ± 0.92	31.81 ± 0.44
Mlafyeni	25.42 ± 1.66	25.54 ± 3.09
Kichakasimba	25.42 ± 1.16	32.67 ± 0.09
Lukore 1	25.55 ± 1.01	26.68 ± 1.11
Makobe	22.33 ± 1.08	29.98 ± 0.84
Msulwa	26.14 ± 4.47	31.43 ± 1.34
Kizibe	25.95 ± 1.93	31.68 ± 1.49
Majimboni	23.96 ± 2.78	25.75 ± 0.01
Magwasheni	29.50 ± 1.74	31.54 ± 0.07
Kinango	28.88 ± 1.12	29.00 ± 1.17
Mkomba	28.16 ± 1.89	28.54 ± 0.14
Tiribe	--	29.78 ± 0.52

4.4 Discussion

In Shimba Hills, trypanosomosis, tick-borne diseases (TBDs) (East Coast fever and anaplasmosis), foot and mouth disease and anthrax were the economically important disease constraints cited by livestock keepers. Assessment of the relative importance of the diseases revealed that trypanosomosis was the most important. The prevalence of trypanosomosis (18%) in the area is supported by earlier research findings (Murilla *et al.,* 1998; Mugunieri and Murilla, 2003; Muraguri *et al.,* 2005). However, earlier reports indicate that the disease is only important to few farmers (11.3%) in Kwale District (Machila *et al.,* 2003). This may be an underestimation as it does not include the 35.2% of the respondents that considered all diseases to be equally important. The high relative importance of trypanosomosis in the current survey may be attributed to several factors. For example, some farmers described the disease as their 'friend' whom they had learnt to 'live' with. It is also possible that respondents ranked trypanosomosis highly because they attribute most deaths indirectly to tsetse flies. In addition, they could have exaggerated the importance of the disease to attract the attention from the research team and Kenya government.

However, low prevalence (less than 1%) has been reported in neighbouring Kilifi District (less than 50 km away) (Maloo *et al.,* 2001). This observation may be attributed to the long distance from SHNR. The variability of distribution of trypanosomosis over very small geographical areas and the importance of the ecological characteristics and farming systems has been recognized (McDermott, 1996). Coastal lowlands of Kwale District have numerous natural forests, rivers and poorly drained lowlands especially in the former sugar-belt of Ramisi which are suitable habitats for tsetse flies. In addition, unoccupied land from the settlement scheme and SHNR also contribute to the high population of tsetse flies. Furthermore, Kilifi District has a more established smallholder dairy production sector than

Kwale District and hence farmers are more experienced in vector-borne disease control strategies (Muraguri *et al.,* 2005). Moreover, they have also been exposed to a lot of epidemiological studies (Gaturaga *et al.,* 1990; Deem *et al.,* 1993).

The development of anaemia is one characteristic sign of trypanosomosis in trypano-susceptible cattle (Murray and Dexter, 1988). The level of anaemia determined from PCV gives a reliable indication of the disease status and productive performance of an infected animal (Trail *et al.,* 1993). Cattle trypanosomosis control aims at reducing the prevalence of infection with concomitant increase in the average PCV of the herd (Bauer *et al.,* 1999). Knowledge of the relationship between prevalence of trypanosomal infections and average PCV of the herd may be a useful tool in preliminary rapid assessment of the expected impact of a control intervention. The significant difference between the PCVs of infected and non-infected cattle observed in the current survey confirms usefulness of the method. The low PCV values of trypanosomosis-positive cattle is in agreement with previous findings, which noted that the disease reduced PCV levels in infected animals (Losos and Ikeda, 1972; Anosa and Obi, 1980). Similarly, cattle with high prevalence of trypanosomosis have low haematocrit levels (Mahama *et al.,* 2004). However, some cattle among *muturu* and *n'dama* breeds may be anaemic, but exhibit no significant difference in mean PCV of infected and non-infected animals (*http://www.isrvma.org/article/55-4-7*). Other observations suggest that mean PCV has no value in predicting the presence of trypanosomosis as would be expected in an area of serious disease challenge where PCV is always low (Otim *et al.,* 2004). Therefore, mean PCV levels in cattle should be used cautiously when interpreting the absence or presence of trypanosomosis in cattle. It has also been observed that average herd PCV values are affected by factors other than trypanosomosis (Connor, 1994). The confounding factors are not easily identifiable but are likely to affect both trypanosomosis-positive and negative animals. A major factor affecting PCV is the plane of nutrition. Poor nutrition is known to result in low PCV (Katunguka-Rwakishaya *et al.,* 1995). This may explain the positive correlation of PCV and trypanosomosis since lack of appetite is a disease symptom. Other causes include fasciolosis or haemonchosis (Zinsstag *et al.,* 1998).

Respondents were found to be fairly knowledgeable on clinical symptoms of different cattle diseases. The symptoms recognized (weight loss, reduced milk production, lacrimation, starring coat and swollen lymph nodes) were highly suggestive of trypanosomosis when occurring in an area of high disease prevalence. However, in earlier studies, respondents were not good at identifying clinical symptoms of the disease (Machila *et al.,* 2003). The unexpectedly good knowledge of clinical symptoms of trypanosomosis by farmers in the current survey could be attributed to lack of government funded extension services due to privatization of veterinary services in the country since the mid 1990s. This has forced most farmers in the area to adopt survival strategies by learning to diagnose and treat their animals. A common observation reported by most respondents in the survey is cattle geo-phagia (soil eating). The phenomenon may be attributed to the destruction of red blood cells and haemoglobin leading to iron deficiency. Geo-phagia previously observed in 40% of calves in the area may be due to anaemia from haemo-parasitic infections (Muraguri *et al.,* 2005).

Although 53% of respondents identified tsetse flies as the cause of trypanosomosis, they did not consider them the sole aetiological factor. Some respondents, including those who cited tsetse flies, considered watering and grazing animals by the river and the rainy season to be associated with trypanosomosis. Grazing near the reserve may have exposed the animals to infective tsetse bites. However, most respondents did not associate grazing near SHNR with trypanosomosis incidence. Some reported grazing time as an aetiological factor. Tsetse flies show pronounced diurnal rhythm of activity that has significant influence on challenge to livestock, with the highest risk at times of peak activity (Brady, 1972). *Glossina morsitans morsitans* is active in the morning and evening. Similarly, *G. pallidipes* restricts the bulk of its activity to early morning and late evening (Brady, 1972). Farmers grazing their cattle when flies are most active might have exposed them to infective bites.

Livestock keepers depended on modern veterinary products although they were not always knowledgeable about their application. Chemotherapy is the most widely used strategy for trypanosomosis control. About 91% of respondents interviewed used trypanocidal drugs to treat sick cattle. However, cases of misdiagnoses and wrong treatment were noted, as evident in large differences observed in frequency of drug use and reported disease prevalence. Tetracycline (antibiotic) and anti-helmintics were used to treat most of the other cattle diseases, with varying degrees of success. Drug resistance has previously been confirmed as a major problem in livestock production in the area indicating overuse and misuse of trypanocidal drugs by farmers (Murilla *et al.,* 1998; Mugunieri and Murilla, 2003). The current pattern could lead to development of multi-drug resistance necessitating farmer based vector control as a viable option. A general problem cited by many respondents is the limited knowledge on the use and specificity of modern drugs. Most farmers blamed privatization of veterinary services in Kenya, leaving drug administration to livestock owners, or extension workers, who are unskilled in disease diagnosis and appropriate drug use.

The main constraint to livestock production in the area surrounding SHNR in Kwale District was trypanosomosis. Most farmers demonstrated awareness about trypanosomosis, its clinical symptoms, aetiology and correct treatment and control measures. The results also provided information on the variation of infection prevalence of trypanosomosis and species of trypanosomes involved in cattle infection across the sub-locations. The presence of various species of tsetse flies in relatively few trap positions indicates that they may be the main epidemiological factor for trypanosomosis. Consequently, these estimates found ‘push-pull’ technique relevant to targeted farmers and the area most suitable for the proposed ‘push-pull’ trials for tsetse and trypanosomosis suppression.

CHAPTER FIVE

EFFICACY OF REPELLENTS AND BAITS IN 'PUSH-PULL' TACTIC FOR TSETSE AND TRYPANOSOMOSIS SUPPRESSION

5.1 Introduction

Efforts to develop new tsetse control arsenals have continued todate with occasional new designs being produced. Recently, research work has identified and developed a potent synthetic analogue of a mild natural repellent (2-methoxyphenol) of savannah tsetse species found in the body odours of tsetse bovid hosts (Saini and Hassanali, 2007).

The synthetic repellent (2-methoxy-4-methylphenol) developed through molecular optimization studies is a phenolic analogue that acts as an olfactory antagonist of key kairomones that tsetse flies use to locate their host for feeding (Saini and Hassanali, 2007). The repellent significantly reduced the number of *G. pallidipes* coming to an ox by 80% (long-range repulsion) and also reduced the feeding efficiency of the flies on cattle by less 80% (short-range repulsion) (Saini and Hassanali, 2003).

A prototype dispenser for on-host use was developed so that constant release rate of the repellent could be maintained for more than a month, while allowing cattle to graze freely with dispensers attached to a waistband. The waistband tied around the animal's neck near the forelegs ensures that dispensers are suspended ventrally (Saini and Hassanali, 2003).

The repellent is a colourless liquid, highly volatile, insoluble in water and has a specific gravity of 1.09-1.10 at 20 ^{0}C. Preliminary results from field trials using pastoralists' livestock in Nguruman, Kenya, indicated that the repellent could effectively protect cattle against the risk of trypanosomosis (Saini and Hassanali, 2003). In addition, all cattle in a herd needed not be treated with the repellent due to its diffusion properties and its volatility as a result of which untreated cattle in proximity to treated ones were also protected (Saini and Hassanali, 2003).

Repellents may enhance tsetse suppression rates and break the disease link by blocking access of vectors to livestock. They could therefore be used to provide protection to cattle against tsetse bites and risk of trypanosomosis. This would reduce reliance on synthetic pyrethroid insecticides and trypanocidal drugs and the associated resistance development. Repellents could also be integrated with other tsetse control tactics in a 'push-pull' strategy that uses repellents to 'push' the flies away from their hosts, in conjunction with baited traps and or targets, which 'pull' and kill them. A variant of this technology might involve the use of a proportion of cattle herds with pour-on insecticides, to act as the 'pull' component. The 'push-pull' strategy, however, needs to be evaluated in the field. Furthermore, it needs to be adapted to the needs and circumstances of the target livestock keepers especially pastoralists. This trial evaluated the efficacy of 'push-pull' tactic in enhancing tsetse flies suppression rates and trypanosomosis disease levels using on-host repellents to 'push' and baited NG2G traps to 'pull' and kill the flies among sedentary livestock farmers.

5.2 Materials and methods

5.2.1 Study area

This study was conducted in Kwale District of Coast Province, Kenya. The area is described in section 3.1.

5.2.2 Trial sites

Based on the results obtained from cross-sectional surveys (Chapter 4), eight trial sites were selected from the area. These included; Mangawani, Mlafyeni, Mauya, Msulwa, Lukore, Kizibe, Katangini and Tsangatamu (Figure 5.1). These sites were selected based on the following criteria: (i) they were 10 km away from the neighbouring identified site; (ii) at least 5 km^2 in size; (iii) easily accessible during the rainy season; (iv) distance between the site and the SHNR was less than 5 km; (v) high tsetse and trypanosomosis challenge; (vi) high cattle population; and (vii) farmers willingness to participate in the trials and committed to provide cattle for at least 12 months. These sites were sufficiently close to present similar habitats and tsetse challenge, but sufficiently far apart that changes in tsetse population in one area did not affect that of the other.

5.2.3 Synthetic repellent and dispensers

The repellent identified by Saini and Hassanali (2007) and supplied by Ecologia e Tecnologia (EMEL T s.r.l), Italy and/or synthesized in Behavioural and Chemical Ecology Department (BCED) laboratories (ICIPE) was used in the trial. The repellent, 2-methoxy-4-methylphenol was administered to cattle using prototype dispensers (Plate 5.1). Dispensers consisted of a repellent reservoir and a diffusion area, which made up the dispensing unit whose top, could be unscrewed for refilling. The upper part was a reservoir tube made of aluminium (diameter 10 mm and length 10 cm), through which no diffusion of the repellent took place. The diffusion area was made from tygon silicone tubing (Cole-Palmer Co, USA) of thickness 3.2 mm and length 2.5 cm. The unit was closed at the top and bottom with a polypropylene screw cap and plug, respectively (Figure 5.2). Each dispenser could hold upto 8 cm^3 of the repellent. Since each unit could constantly dispense only 4.5 mg/h, two dispensers were used per animal. To provide maximum protection, dispensers were tied using a waistband around the animal's neck near the forelegs to allow cattle to graze freely (Plate 5.2). They could be maintained for more than a month without refilling. Upon recruitment of cattle into two treatment groups ('push' and 'push-pull'), they were provided with repellent-filled dispensers. Dispensers were monitored and inspected monthly to record their physical conditions, to replace them and refill the repellent compound.

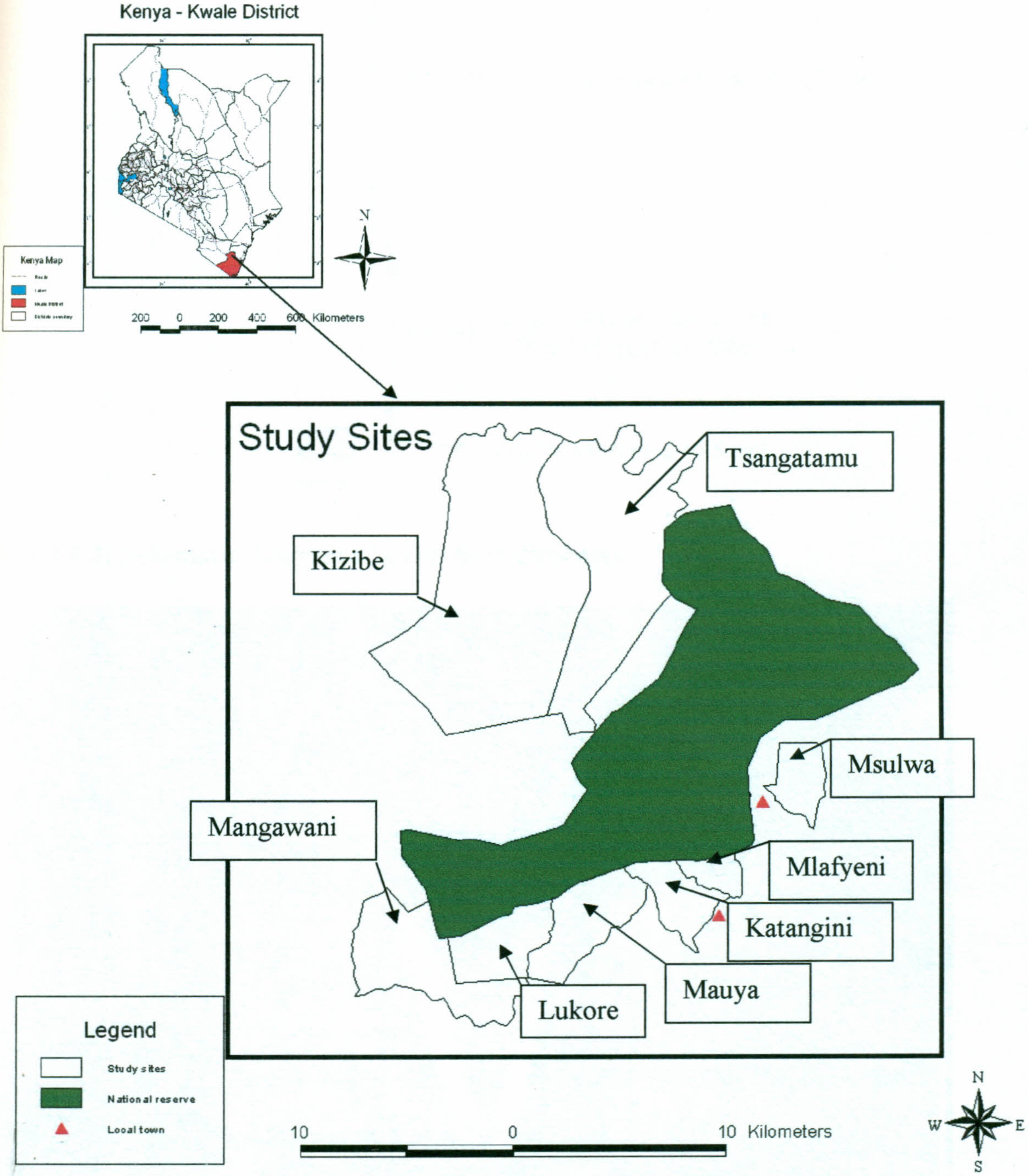


Figure 5.1: Map showing the selected trial sites neighbouring the Shimba Hills National Reserve (SHNR) of Kwale District, Kenya

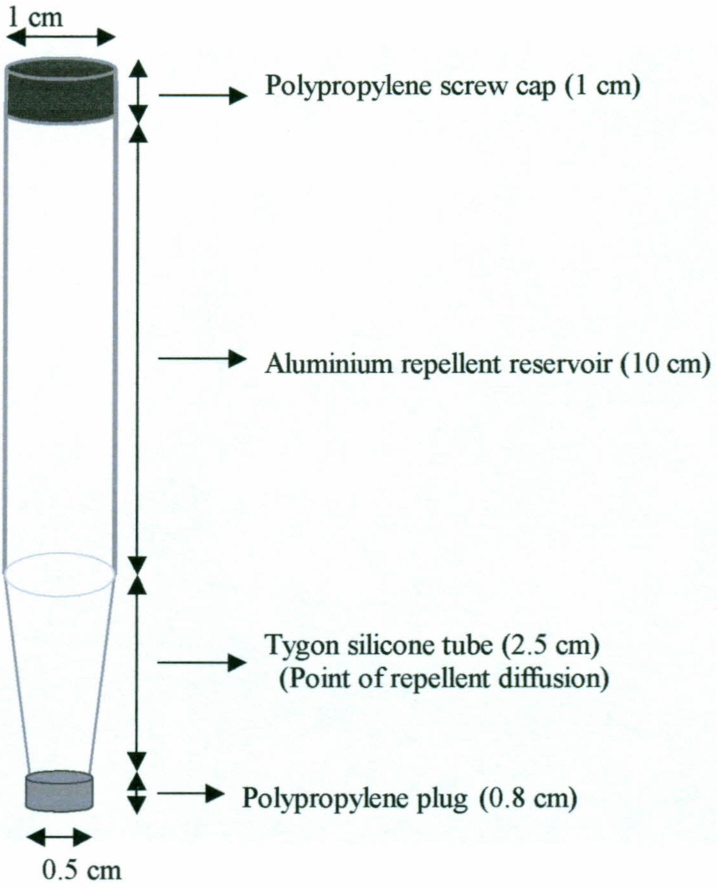


Figure 5.2: Schematic diagram of a repellent dispenser

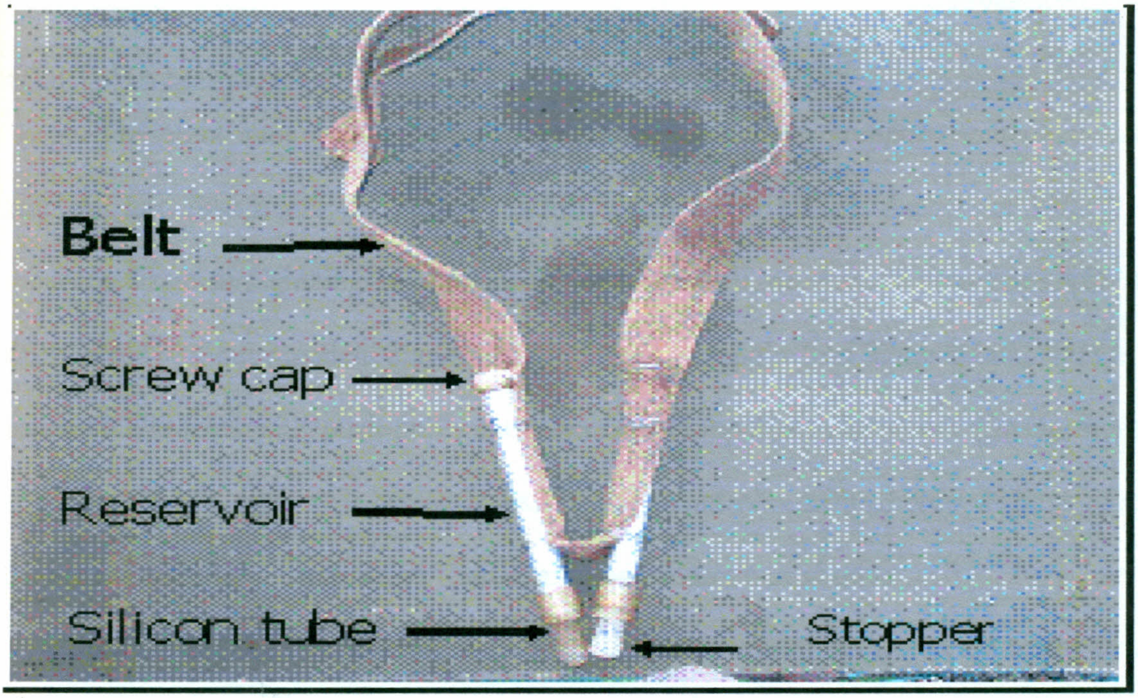


Plate 5.1: The repellent dispenser

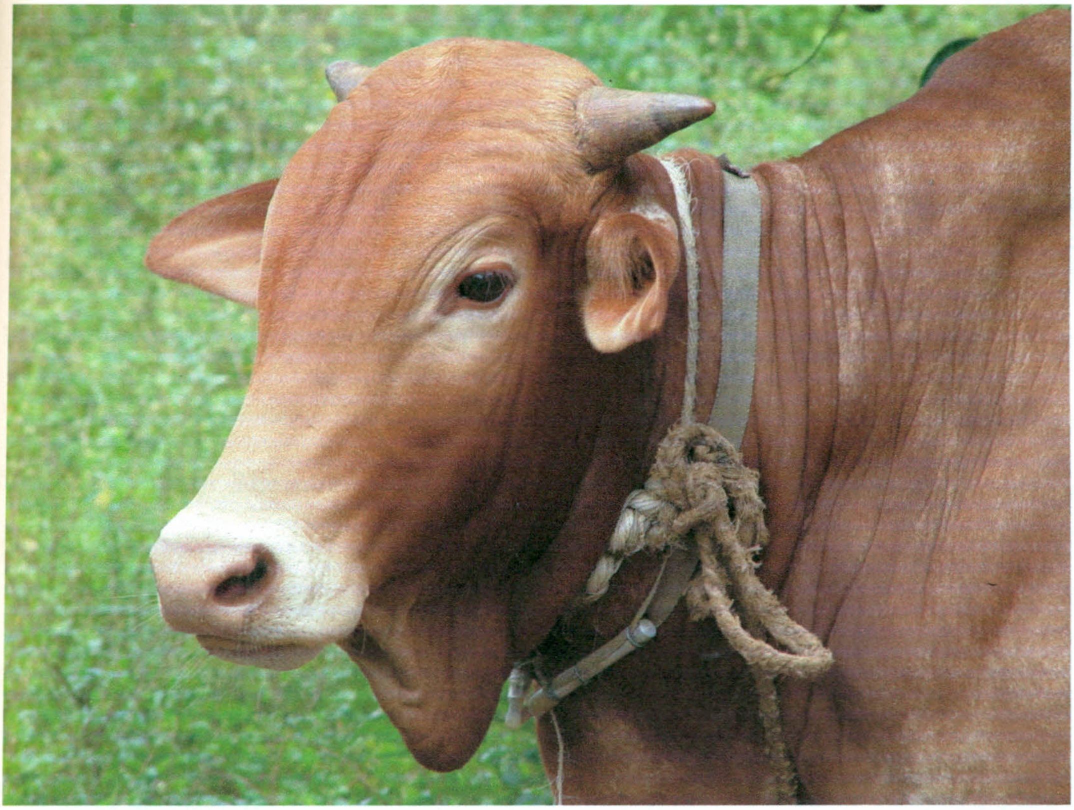


Plate 5.2: Position of repellent dispensers on animal body

5.2.4 Treatment regimes

The eight sites (cattle herds) were randomized using computer-generated random numbers into four treatment regimes as follows (Table 5.1): (1) 'push'- cattle herds with repellent dispensers grazing in Mangawani and Mlafyeni, an area without traps; (2) 'pull'- cattle herds without repellent dispensers grazing in Katangini and Tsangatamu, an area with baited NG2G traps; (3) 'push-pull'- cattle herds with repellent dispensers grazing in Mauya and Msulwa, an area with baited traps; and (4) control - cattle herds without repellent dispensers grazing in Lukore and Kizibe, an area without baited traps.

Cattle in each site came from several livestock keepers and were kept under farmers' management system. Recruited cattle were identified by plastic ear tag (Coopers®). Only animals aged one year and above were recruited into the study, sucking calves being recruited upon reaching the same age. Prior to recruitment into any of the four treatment regimes, all animals were blanket treated with the trypanocide *diminazene diaceturate* (Veriben®) at doses of 3.5 mg/kg, by intramuscular injection, body weight being estimated using weighing bands. This is a curative treatment with no lasting protection against reinfection. All new animals brought into the herd were ear tagged and immediately treated with Veriben® at the same dose. The trial was conducted for ten months (November 2004 to September 2005). The number of cattle sampled monthly for the trial period is shown in Table 5.1.

5.2.5 Cattle sample size determination

Previous surveys on trypanosomosis in cattle in Kwale District found 5% point prevalence in areas without tsetse control (Mugunieri and Murilla, 2003; Muraguri *et al.*, 2005), using the haematocrit centrifugation technique (HCT) (Woo, 1971). The sample size for the present study was calculated from an estimated point prevalence of 5% (*p*) with a 95% *(z)* level of confidence and a desired accuracy (*d*) of 5%. The desired sample size (*n*) was derived according to Kahn and Sempos (1989) as follows:

$$n = \frac{z^2 \text{ x } pq}{d^2} = \frac{1.96^2 \text{ x } 0.05 \text{ x } 0.95}{0.05^2} = \frac{0.1824475}{0.0025} = 72.979$$

Where: n = desired sample size; p = anticipated prevalence (5%); d = desired precision (5%); z = appropriate value from the normal distribution for the desired confidence (1.96) (95%); and q = 1-p.

At least 73 cattle were targeted to be sampled monthly from each site. However, the desired sample size was not achieved in some months and sites due to farmers' failure to present cattle for screening.

Table 5.1: Number of cattle sampled monthly in the trial sites at Shimba Hills from November 2004 to September 2005

		No. of cattle sampled										
Treatment	Sites	Nov 04	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05
Push	Mangawani	74	76	78	79	78	78	90	105	81	109	83
	Mlafyeni	41	52	57	60	63	66	75	74	82	77	62
Pull	Tsangatamu	36	82	81	84	75	88	64	75	59	58	50
	Katangini	77	77	77	71	78	71	85	93	97	86	71
Push-pull	Mauya	54	56	56	62	70	60	73	72	63	76	53
	Msulwa	49	49	57	58	61	60	58	66	56	69	49
Control	Lukore	71	74	55	69	86	85	67	69	58	69	36
	Kizibe	51	49	58	52	62	72	67	75	63	66	62
Total		453	515	519	535	573	580	579	629	559	610	466

5.2.6 Parasitological diagnosis of trypanosomosis

All ear tagged cattle were examined for trypanosome infection once a month. Blood samples were screened for trypanosomes by parasitological techniques as described in section 3.3. Cattle found to be trypanosomes-positive were treated with Veriben® at 3.5 mg/kg. A similar dose was given to cattle which were anaemic (PCV less than 22%) and showed clinical symptoms of trypanosomosis despite the apparent absence of trypanosomes in the blood.

5.2.7 Monitoring cattle body condition scores

Body condition scoring for all animals was carried out every month using 0-9 scoring system developed by Nicholson and Butterworth (1986) (Appendix 5.1). In this method, nine scores were used in which three main conditions - Fat (F), Medium (M) and Lean (L) were subdivided into three categories. The scores were abbreviated as F+, F, F-; M+, M, M-; L+, L and L-; each scoring was given a number from 1 (L-) to 9 (F+). In a borderline case, a half point was added to the lower score so that a cow described as M-/L+ was scored as 3.5.

5.2.8 Monitoring changes in cattle body weights

Body weights measured by weighing bands (CEVA®) for all ear tagged animals were recorded monthly (Plate 5.3). The growth rate was obtained by expressing the mean weight changes as percentages of the original body weight.

Plate 5.3: Approximation of cattle body weight using a Ceva© weighing band

5.2.9 Monitoring household trypanocidal drug use

All livestock keepers whose animals were recruited into the trials were provided with notebooks and biro pens. They were required to record animal numbers and dates when the following took place: when an animal felt sick, when they treated the animal, symptoms treated and the type of drug used for treatment. They were required to keep emptied packets of trypanocides or any other drug administered to be confirmed at the time of sampling. In addition, all local veterinary officers, animal health assistants, community based organization (CBO) salesmen and the para-veterinary officers in the area recorded (on farmers' notebooks) any trypanocidal drug sales and treatment administered to cattle involved in the trials. Illiterate households were assisted by a designated field assistant in each site. Households' records were checked for accuracy during the monthly sampling sessions. It was not possible to register all additional trypanocidal drug purchased from outside sources, but it was suspected, on the basis of information acquired from farmers, that the average monthly rate of non-recorded treatment was about 2 – 3%.

5.2.10 Monitoring household herd dynamics (cattle population)

Animal events that were recorded during the monitoring period were classified as additions or removals. Additions included births, purchases and taken in (as a gift). Removals included sales, deaths, take away (as a gift), emergency and planned slaughter, and missing. Of these variables, the analysis was based on births (calving), purchases, sales and deaths, which were considered important. In each site, field assistants and village chairmen, familiar with livestock owners, helped to authenticate the true owner of the additions. Livestock keepers were also requested to keep records of abortions and stillbirths in their herds.

5.2.11 Deployment of control NG2G traps

In November 2004, 163 NG2G traps (Brightwell *et al*., 1987; 1991) were deployed in four of the eight trial sites. These traps formed the component of 'pull' and 'push-pull' tactics. This trap has been used to control *G. pallidipes* in Kenya (Dransfield *et al.,* 1990; Brightwell *et al*., 1997). Traps were placed at an interval of 250 m (4 per km^2), in lines 1–1.5 km apart. In Msulwa, Mauya, Tsangatamu and Katangini, 39, 41, 41 and 42 traps, respectively, were deployed. Trap-deployment positions were selected based on vegetation to represent all possible habitats that could be related to fly multiplication, behaviour and feeding. Hence, grazing lands, thickets, bushy areas, riverbanks and watering points were purposely included. All trap positions were geo-referenced using global positioning system (GPS). Acetone and cow urine were used as odour baits. Acetone was dispensed from a 500 ml clear glass bottle each with a 2 mm diameter hole perforated through the lid (release rate of approximately 500 mg/h). Aged cow urine collected by local people from their cattle, was dispensed from 1 kg discarded cooking fat tins with the top covered by plastic and a 2 x 4 cm slot cut in the tin just below the rim, giving a release rate of approximately 1000 mg/h. Both dispensers were placed 30 cm behind the traps. Grass and shrubs were cleared within a radius of 3 m of trap posts. Livestock owners were partially involved in the maintenance and provision of side and centre posts for the traps. Traps were inspected every month and torn, stolen or faded cloth materials were replaced, odours replenished and regenerating vegetation around the traps cleared.

5.2.12 Monitoring of tsetse fly population

Tsetse populations were monitored monthly over the trial period. In each site, fifteen trap positions were selected. All the positions were monitored using five baited NG2G traps as described in section 3.4.

5.2.13 Data management and analysis

Relative tsetse density was expressed as the monthly mean number of tsetse caught per trap per day. Monthly incidence of trypanosomosis in cattle was calculated as the number of cattle infected per month as a proportion of the total number examined, less the number infected and treated with Veriben® the previous month, allowing for a prophylactic effect of Veriben® of 7 days (Van Hoeve *et al.,* 1964). Means for each treatment regime were calculated from the monthly values for relative densities of *G. pallidipes*, incidence of trypanosomal infection and mean packed cell volume for 2 sites with similar treatments. Monthly percentage reduction in tsetse relative density, trypanocidal drug use, trypanosomal incidence and percentage increase in cattle body weight, condition score and mean packed cell volume in 'pull', 'push' and 'push-pull' treatments were calculated as a proportion with respect to the monthly values recorded in the control treatment. Monthly trypanosome incidence rates and tsetse relative densities for different treatment groups were compared using Chi-square (χ^2) tests. The test was also used to establish odds ratio (OR) for assessment of the transmission risk of trypanosome infections. Statistical analyses were carried out using General Model Procedures (GENMOD) of SAS (2003). The models included main effects: infection status, study sites, month, animal identification number, trap number and tsetse counts. Cattle body weight and condition score and mean packed cell volume was analyzed using a mixed model.

5.3 Results

5.3.1 Tsetse fly population

Glossina austeni were only caught in some sites; none was sampled in Tsangatamu, while in Msulwa and Mlafyeni, they were only caught in the months of April and February, respectively. Low populations of *G. brevipalpis* (0.04 – 2.24 flies/trap/day) and tabanids (Tabanidae) (2.72 flies/trap/day) were sampled in all sites except in the month of July when none was collected. Monthly relative densities less than 2.24 and 2.16 flies/trap/day (FTD) for *G. brevipalpis* and *G. austeni,* respectively were too low to permit statistical analyses. *Glossina pallidipes* was the most predominant species collected in all sites and in all the months sampled.

Two months following deployment of traps and treatment of cattle with the repellent, there was a sharp decrease in mean relative densities of *G. pallidipes* in 'push-pull' and 'pull' sites. This was followed by further reductions to 1.3±0.2 and 3.5±0.3 FTD, respectively, at the end of the trial (Figure 5.3). There were significant differences in relative densities between 'push-pull' and 'pull' sites ($\chi^2 = 9.21$; df = 1; $p = 0.002$). Controls had the highest mean relative density compared to all treatments. One month after start of the trials, tsetse catches in the control sites declined from 80.2±52.2 to 38.6±26.2 FTD. However, this was followed by a fairly stable population over the trial period. There were fluctuations in relative density in 'push' sites as in controls; however, in the latter they were more pronounced. The difference in the relative density was statistically significant between the two groups ($\chi^2 = 114.01$; df = 1; $p < 0.0001$). In 'push-pull' site, mean relative density significantly differed from 'push' ($\chi^2 = 10.29$; df = 1; $p < 0.001$) and control ($\chi^2 = 169.95$; df = 1; $p < 0.0001$). There was a significantly lower relative density in 'pull' than 'push' sites ($\chi^2 = 6.40$; df = 1; $p = 0.011$).

5.3.1.1 Percentage reduction in tsetse fly population

One month after trap deployment, tsetse catches in ‘push-pull’ and ‘pull’ sites had reduced by 33 and 24.2%, respectively (Figure 5.4). After 4 months, a reduction of 70.4 and 51%, respectively, was recorded. The relative density gradually decreased in the subsequent months, reaching a maximum of 88 and 84%, respectively, at the end of the trials. In ‘push’ sites, following repellent administration, the relative density reduced by less than 2% in the first month. However, after the fourth month, a less drastic reduction in catches was observed, reaching a maximum of 75.5% at the end of the trial. Mean relative density of *G. pallidipes* was significantly affected by time (month) ($\chi^2 = 215.35$; df = 1; $p < 0.0001$) and the type of treatment ($\chi^2 = 10.29$; df = 3; $p < 0.0001$).

Overall, relative to the control, with ‘push-pull’, the percentage reduction in fly density was about 83% compared to 77% with traps alone (‘pull’) while minimal fly reduction was observed with repellents alone (‘push’).

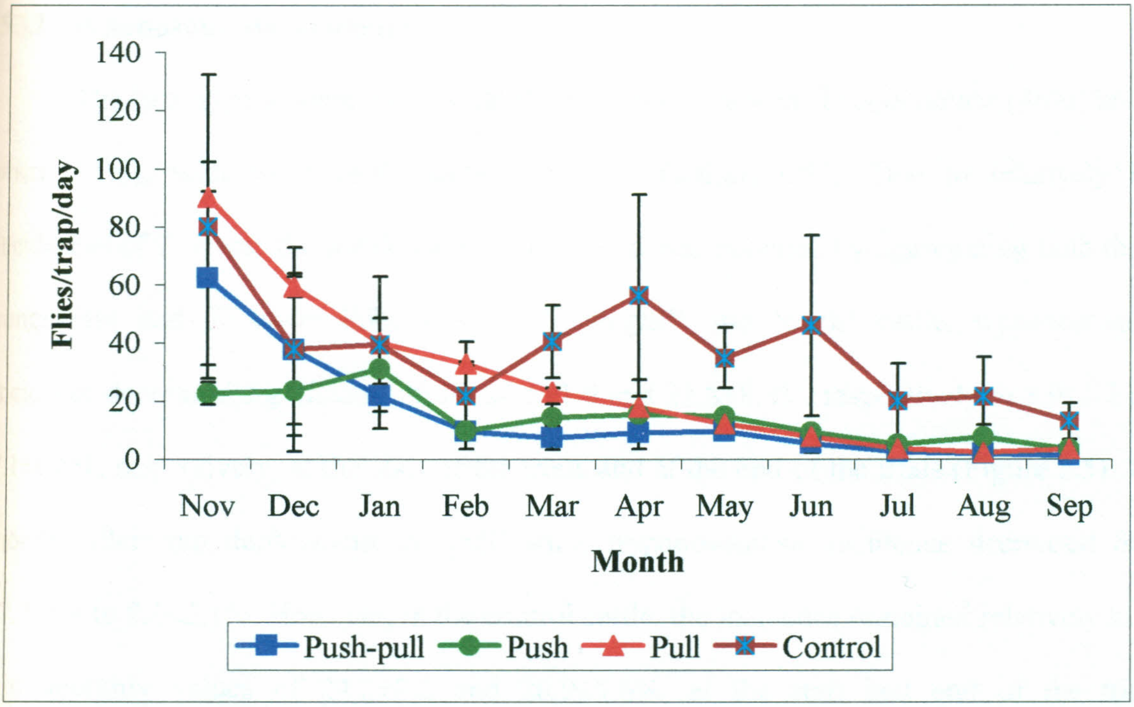


Figure 5.3: Mean (± SE) monthly relative densities of *Glossina pallidipes* in the trial sites at Shimba Hills from Nov 2004 to Sept 2005

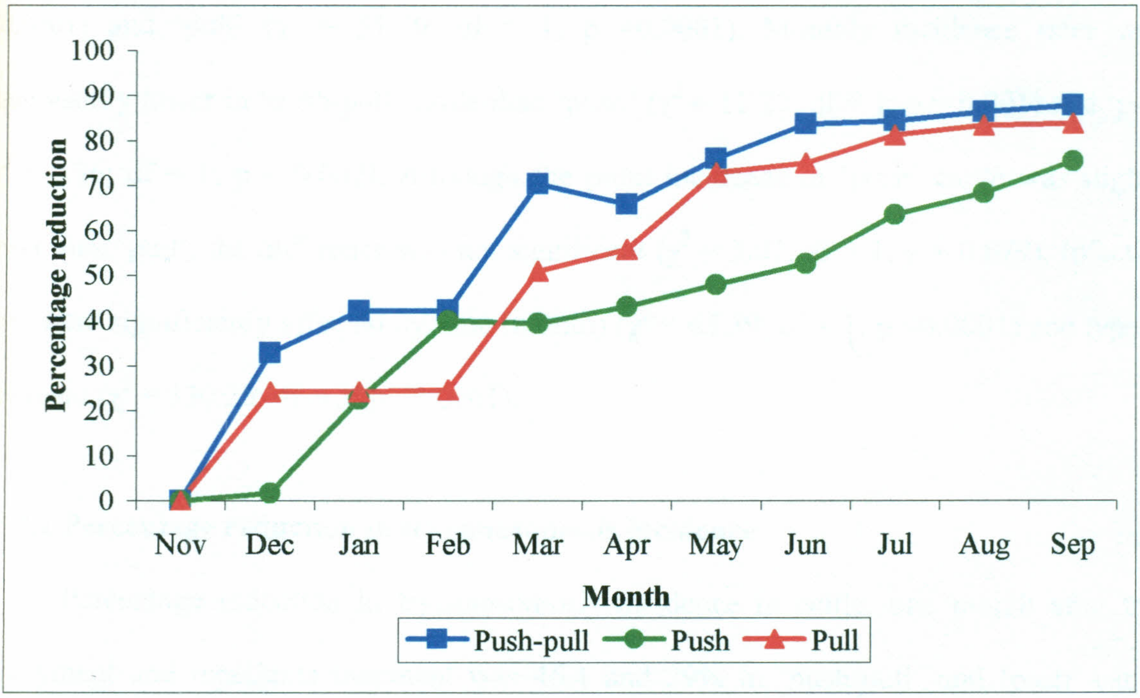


Figure 5.4: Monthly percentage tsetse population density reduction of *Glossina pallidipes* in the trial sites at Shimba Hills from Nov 2004 to Sept 2005

5.3.2 Trypanosomosis incidence

The two trypanosome species identified in the area were *T. congolense* (86%) and *T. vivax* (11%), with some cattle having mixed infections (3%). Due to relatively low incidences of *T. vivax,* the incidence rates indicated was obtained by aggregating both the *T. congolense* and *T. vivax* infections. In 'push-pull' and 'push' cattle, trypanosomosis incidence decreased significantly from 20.5±1.9 and 27.8±8.8%, respectively to 3.9±1.2 and 7.1±0.6%, respectively, at the start of the trials and at the end of the trials (Figure 5.5). Ten months after trap deployment in 'pull' sites, trypanosomosis incidence decreased from 27.7±5.6 to 8.1±2.1%. However, in the control cattle, the incidence remained relatively high, with monthly values of 24.2±8.2 and 20.9±9.6%, at the start and end of the trials, respectively. Monthly trypanosomosis incidence observed in controls was significantly higher than in 'push-pull' (χ^2 = 23.37; df = 1; p <0.0001), 'push' (χ^2 = 43.42; df = 1; p <0.0001) and 'pull' (χ^2 = 51.79; df = 1; p <0.0001). Monthly incidence rates were significantly lower in 'push-pull' cattle than 'push' (χ^2 = 11.20; df = 1; p = 0.001) and 'pull' (χ^2 = 9.36; df = 1; p = 0.002). Although the point incidence in 'push' cattle was slightly lower than 'pull', the difference was not significant (χ^2 = 3.07; df = 1; p = 0.079). Infection rates were significantly affected by time (month) (χ^2 = 65.39; df = 1; p <0.0001) and type of treatment (χ^2 = 130.20; df = 3; p <0.0001).

5.3.2.1 Percentage reduction in trypanosomosis incidence

Percentage reduction in trypanosomosis incidence in cattle, one month after trap deployment and repellents treatment was 46.4 and 29% in 'push-pull' and 'push' cattle, respectively (Figure 5.6). The reduction increased to 82.8 and 66%, respectively after 6 months. By the end of the trial, a maximum reduction of 84.4 and 75.3%, respectively, was recorded. In 'pull' sites, trypanosomosis incidence reduced by 25.1 and 65.2%, one month after start of the trials and 10 months later, respectively. Overall, over the intervention period, relative to the control, the percentage reduction in disease incidence in 'push-pull' cattle was about 62%, compared to that of 'push' (59%) or 'pull' (53%).

5.3.2.2 Risk of trypanosomosis incidence

The overall risk of transmission of cattle trypanosomosis in the controls was 2.6, 3.4 and 3.8 times significantly higher than 'pull', 'push' and 'push-pull' cattle, respectively (p <0.0001) (Table 5.2).

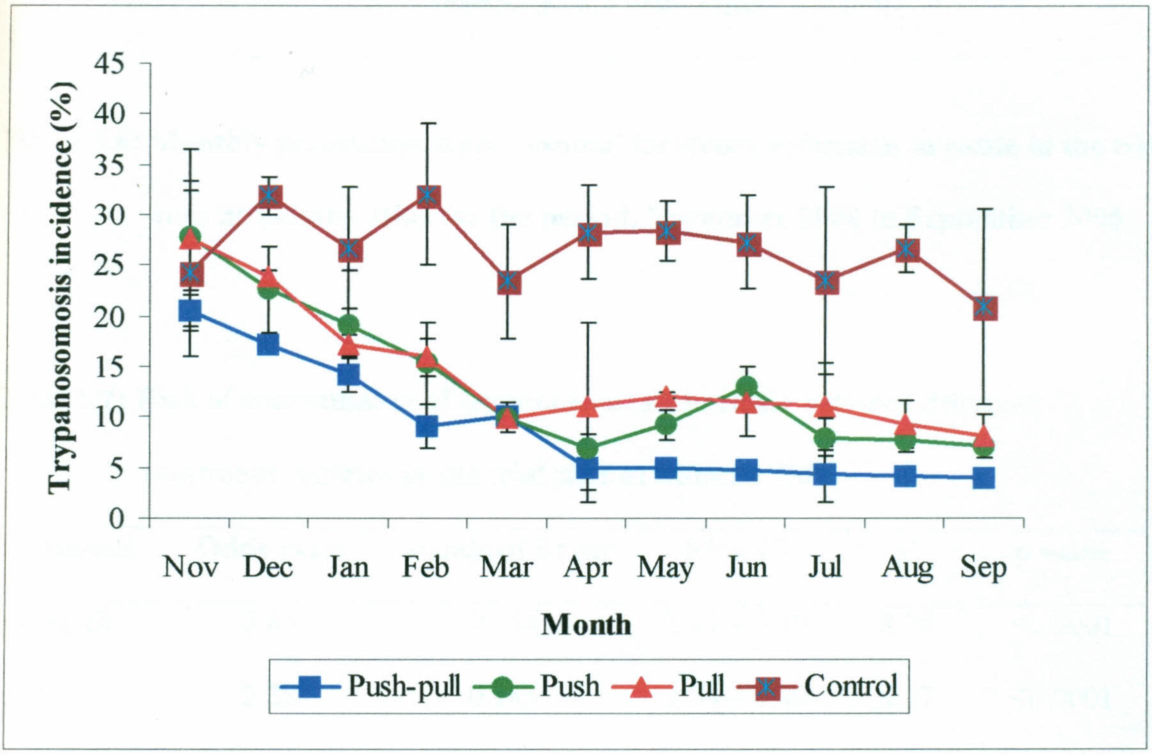


Figure 5.5: Mean (± SE) monthly trypanosomal incidence (%) in cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005

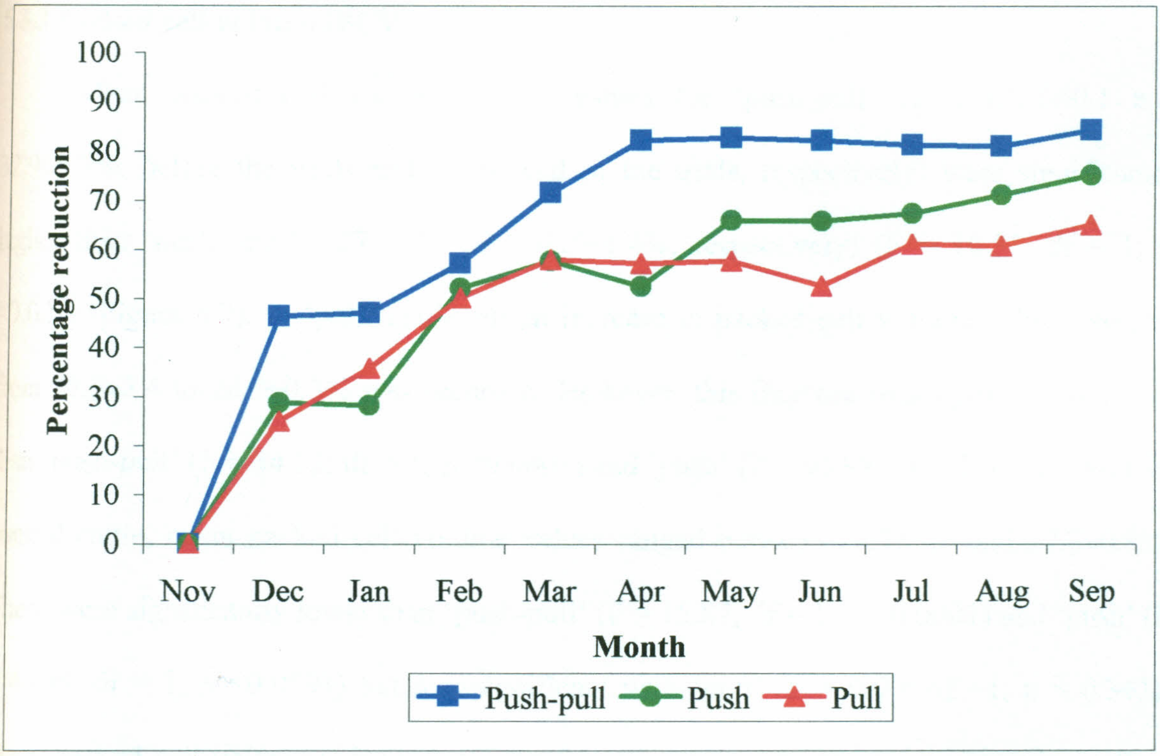


Figure 5.6: Monthly percentage trypanosomal incidence reduction in cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005

Table 5.2: Risk of transmission of trypanosomosis to cattle between different treatment regimes in the trial sites at Shimba Hills

Treatment	Odds ratio	Standard Error	95% CI	χ^2	p value
Push-pull	3.85	0.154	2.85 – 5.19	8.76	<0.0001
Push	3.38	0.145	2.54 – 4.49	8.37	<0.0001
Pull	2.63	0.139	2.00 – 3.46	6.94	<0.0001
Control	0.00	0.000	0	0.00	0

5.3.3 Packed cell volume (PCV)

Mean packed cell volume (PCV) values for 'push-pull' cattle (27.6±0.1 and 32.9±0.3%, before the trials and at the end of the trials, respectively) were significantly higher than 'push' cattle (27.2±2.0 and 31.5±1.4%, respectively) (F = 10.33; df = 1; p <0.001) (Figure 5.7). In 'pull' cattle, slight increase in packed cell volume values ranging from 25.2±2.4 to 28.7±0.3% was recorded. However, this increase was significantly lower than 'push-pull' (F = 34.72; df= 1; p <0.0001) and 'push' (F = 95.98; df= 1; p <0.0001). In control cattle, mean packed cell volume values ranged between 24.7±0.6 and 27.8±0.8%. These were significantly lower than 'push-pull' (F = 15.87; df= 1; p <0.0001) and 'push' (F = 48.59; df = 1; p <0.0001) but non-significant with 'pull' (F = 0.90; df =1; p = 0.343). Mean packed cell volume values were significantly affected by the type of treatment (F = 37.57; df= 3; p <0.0001) and time (month) (F= 23.10; df= 10; p <0.0001).

5.3.3.1 Percentage increase in mean packed cell volume

In the three treatment regimes during the month of December, there was a percentage increase of between 1.4 to 7.2% in mean packed cell volume values (Figure 5.8). In 'push' and 'pull' cattle, the lowest percentage increase in mean packed cell volume was recorded in February (6.6%) and January (1.2%), respectively. By September, the mean packed cell volume values of 'push-pull', push and 'pull' cattle had increased by 30.4, 22.1 and 8.1%, respectively.

Over the intervention period, relative to the control, the overall percentage increase in mean packed cell volume values in 'push-pull' cattle was 19%, compared to 15 and 4% in 'push' and 'pull' cattle, respectively.

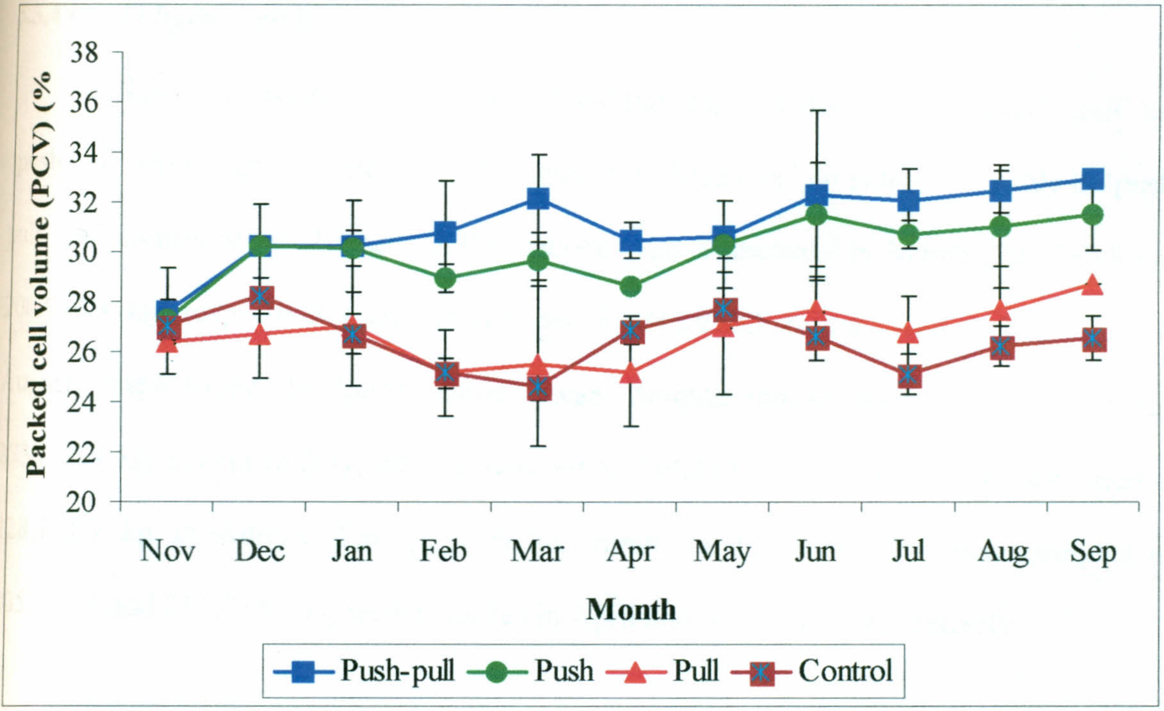


Figure 5.7: Mean (± SE) monthly packed cell volume (PCV) (%) in cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005

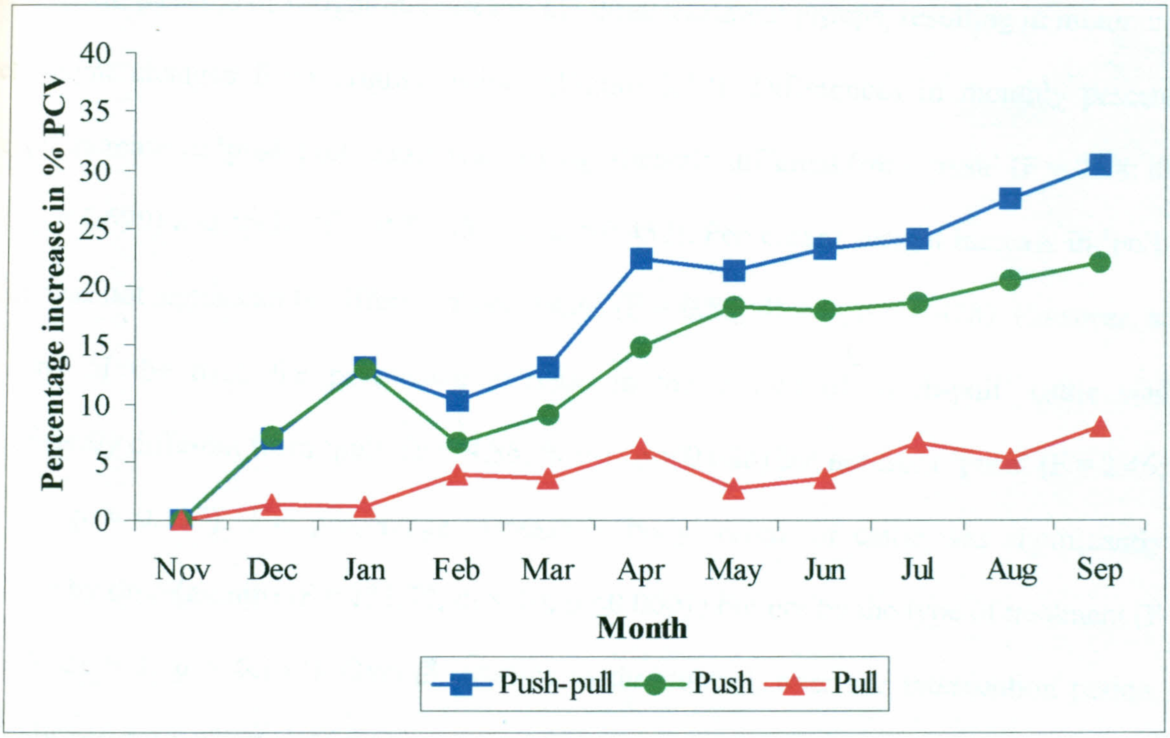


Figure 5.8: Monthly percentage increase in mean % PCV for cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005

5.3.4 Cattle body weights

Following treatments with repellents and trap deployment, cattle in 'push', 'pull' and 'push-pull' sites slightly gained weight (Figure 5.9). Mean weight patterns of cattle in 'push-pull' and control showed seasonal fluctuations with a decrease in March (202.7±0.8 and 206.9±6.4 kg, respectively) and an increase to 212.9±0.7 in June and 225.9±4.8 kg in August, respectively. In 'push' cattle, mean weights ranged between 226.4±3.9 and 233.2±6.4 kg, except in July, when it reduced to 219.3±0.3 kg. However, this increased to 228.1±1.7 kg in August. For 'pull' cattle, minimum and maximum mean weights of 205.8±5.4 and 217.3±6.5 kg were recorded in April and September, respectively.

5.3.4.1 Percentage increase in body weight

Monthly percentage increase in cattle body weight was characterized by periods of inconsistent patterns of weight increases in the three treatment groups, resulting in minimum net weight changes from original values (Figure 5.10). Differences in monthly percent weight increase in 'push-pull' cattle was not significantly different from 'push' (F = 0.28; df = 1; p = 0.599) and 'pull' (F = 0.57; df = 1; p = 0.452). Percentage weight increase in 'pull' cattle was not significantly different from 'push' (F = 0.50; df = 1; p = 0.478). However, at the end of the trial, the percentage increase in the weight of 'push-pull' cattle was significantly different from 'pull' (F = 4.86; df = 1; p = 0.028) but not from 'push' (F = 2.46; df = 1; p = 0.117). The percentage increase in body weight of cattle was significantly affected by time (month) (F = 131.77; df = 10; p <0.0001) but not by the type of treatment (F = 1.85; df = 3; p = 0.137). Overall, relative to the control, over the intervention period, monthly percent body weight increases were 6, 3 and 2.8% in 'push-pull', 'push', and 'pull' cattle, respectively.

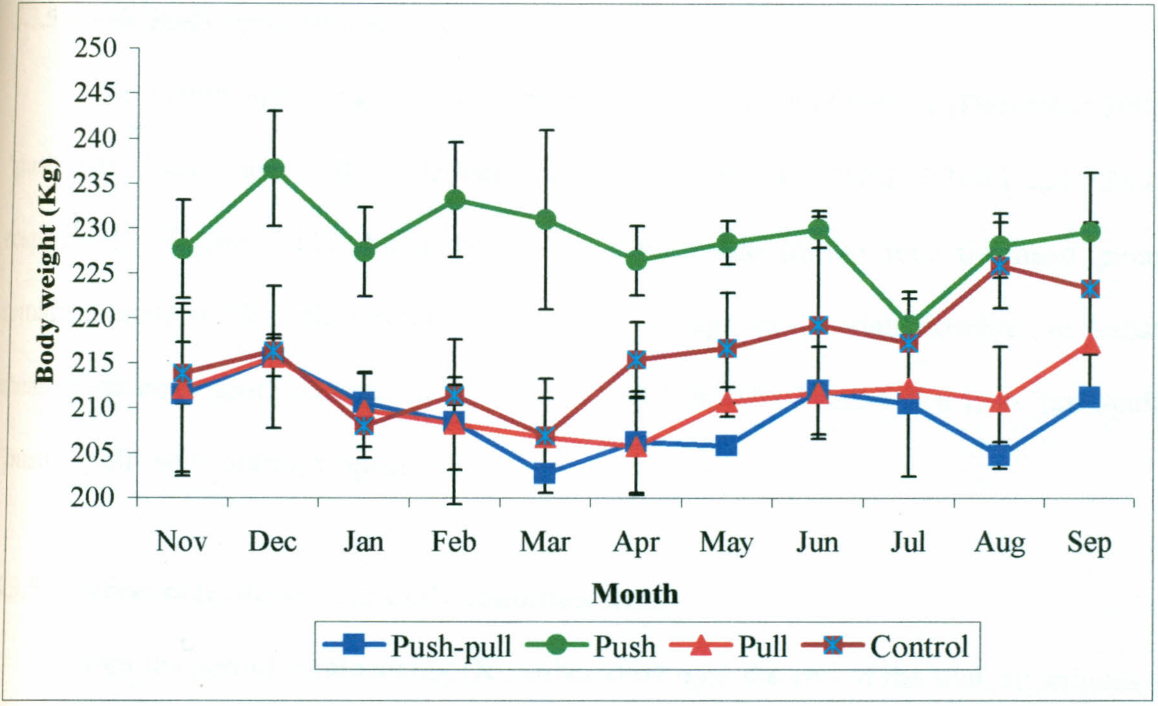


Figure 5.9: Mean (± SE) monthly body weight (kg) of cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005

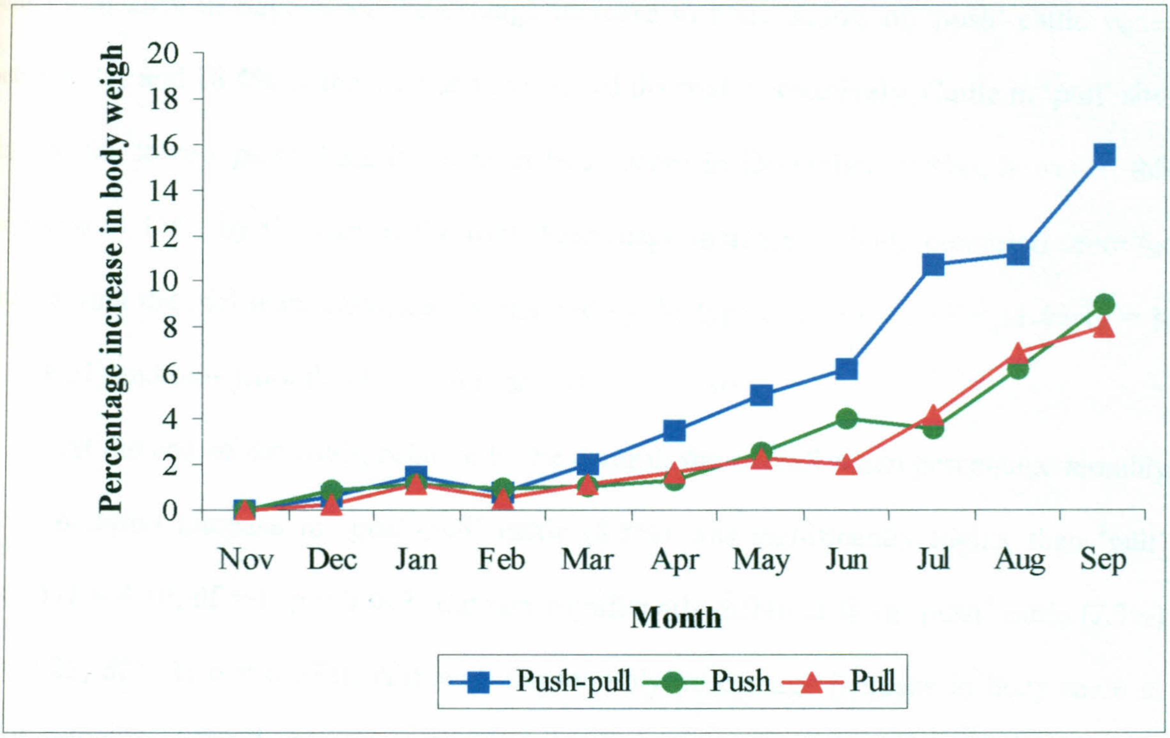


Figure 5.10: Monthly percentage body weight increase for cattle in the trial sites at Shimba Hills from November 2004 to September 2005

5.3.5 Cattle body condition scores

One month following repellents treatment and trap deployment (December 2004), 'push-pull', 'push' and 'pull' cattle had a mean body score of 5.3±0.2, 5.7±0.1 and 5.2±0.1, respectively (Figure 5.11). Mean body scores for cattle in the four treatment groups remained fairly stable with minimum fluctuations throughout the trial. However, in August, mean cattle body score reduced to 5.1±0.01, 5.2±0.1, 4.9±0.02 and 5.2±0.1, in 'push-pull', 'push', 'pull' and control, respectively.

5.3.5.1 Percentage increase in body condition score

From the period commencing December 2004 upto the end of the trial, all animals in 'push-pull', 'push' and 'pull' sites showed slight percent increases in body condition scores (Figure 5.12). In 'push-pull' cattle, percentage increase in body scores ranged from 3% in January to 20% in September. Percentage increase in body scores of 'push' cattle varied between 1.1 and 18.4% at the start and the end of the trial, respectively. Cattle in 'pull' sites showed the lowest percentage increase in body score in December (0.8%), however, this increased to 15%, by the end of the trial. Percentage increase in body condition score for cattle during the trial were significantly affected by the type of treatment ($F = 11.49$; $df = 3$; $p < 0.0001$) and time (month) ($F = 37.44$; $df = 10$; $p < 0.0001$).

At the end of the trials, relative to the control, the overall mean percentage monthly body condition increase in 'push-pull' cattle (8.8%) was significantly higher than 'pull' (6.4%) ($F = 4.10$; $df = 1$; $p = 0.043$) but non-significantly different from 'push' cattle (7.3%) ($F = 3.25$; $df = 1$; $p = 0.072$). Although the monthly percentage increase in body score in 'pull' cattle was slightly lower than that of 'push', the difference was not significant ($F = 0.56$; $df = 1$; $p = 0.454$).

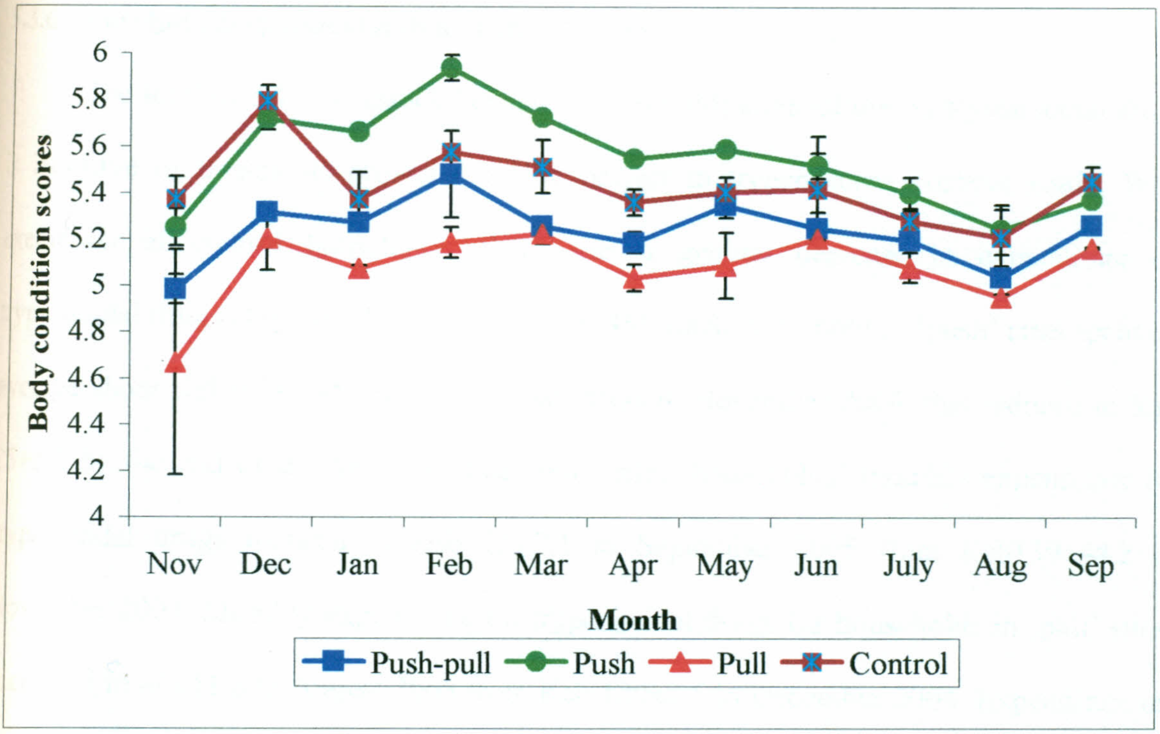


Figure 5.11: Mean (± SE) monthly body condition score of cattle in the trial sites at Shimba Hills for the period, November 2004 to September 2005

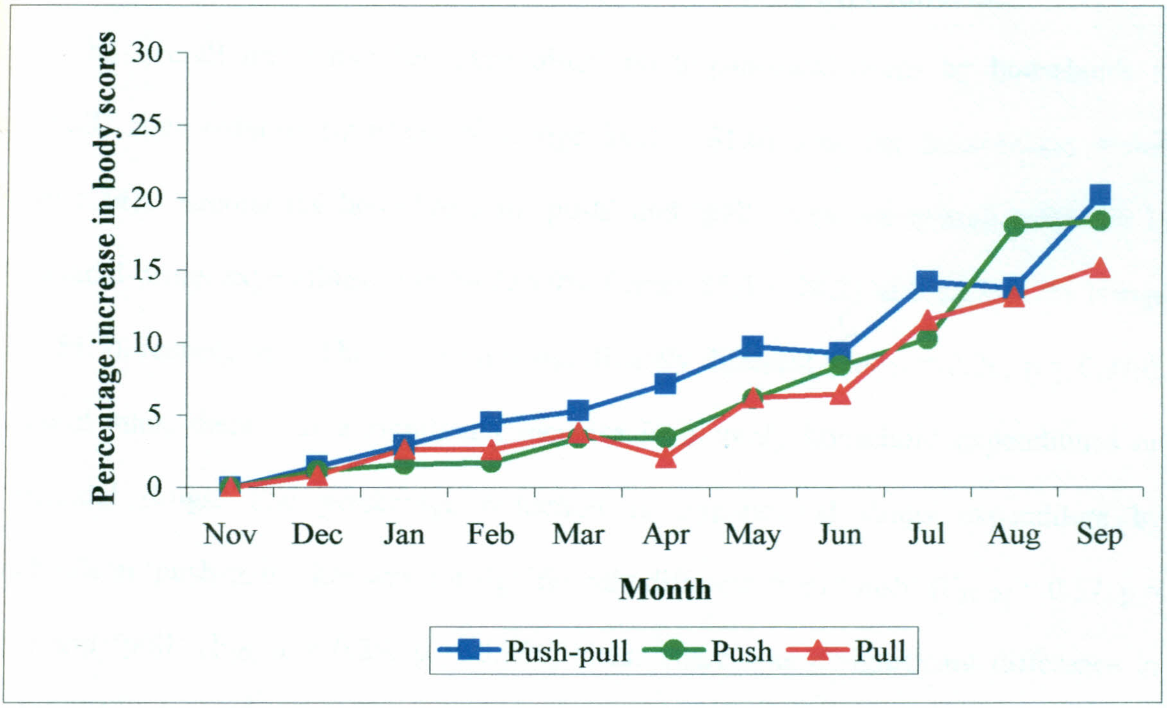


Figure 5.12: Monthly percentage body condition score increase for cattle in the trial sites at Shimba Hills from November 2004 to September 2005

5.3.6 Household trypanocidal drug expenditures

The total monthly livestock keepers' (household) expenditure on trypanocidal drugs is inclusive of treatments provided by the project to trypanosome positive cattle. With exemption of control households, there was a general decrease in expenditure on trypanocidal drugs (Figure 5.13) (Ksh 66 = 1 US$). Each household in 'push' sites spent on average about Ksh103±9.85 on trypanocidal drugs in November 2004, this reduced to Ksh 25±5.9 by the end of the trials. In 'push-pull' sites, households' monthly expenditure on trypanocidal drugs reduced to Ksh 25±7.1 in September 2005 from Ksh139±44.2 in November 2004. Monthly expenditure on trypanocidal drugs for households in 'pull' sites, decreased to 46±11.8 in August 2005 from Ksh 120±2.5 in December 2004. Expenditure on trypanocidal drugs by households in control sites did not change much over the trial period.

5.3.6.1 Percentage reduction in household trypanocidal drug expenditures

The overall mean monthly expenditure on trypanocidal drugs by households in 'push-pull' sites reduced by 61±6.5% (range 14.5 – 81.6) over the intervention period (Figure 5.14). Among the households in 'push' and 'pull' sites, the overall reduction in trypanocidal drugs expenditure was 59.1±6.9% (range 15.4 – 76.2) and 52.3±6.2% (range 10.5 – 81.4), respectively. These were not significantly different ($F_{10, 21} = 0.26$; $p = 0.979$). In control sites, there was a significant increase in monthly household expenditures on trypanocidal drugs. The percentage reduction in trypanocidal drugs expenditure by households in 'push-pull' sites was not significantly different from 'push' ($F_{10, 21} = 0.37$; $p = 0.935$) and 'pull' ($F_{10, 21} = 0.29$; $p = 0.966$) sites. There was a significant difference in monthly expenditures on trypanocidal drugs between control households and 'push-pull', 'push' and 'pull' ($F_{10, 21} = 9.09$; $p < 0.0001$).

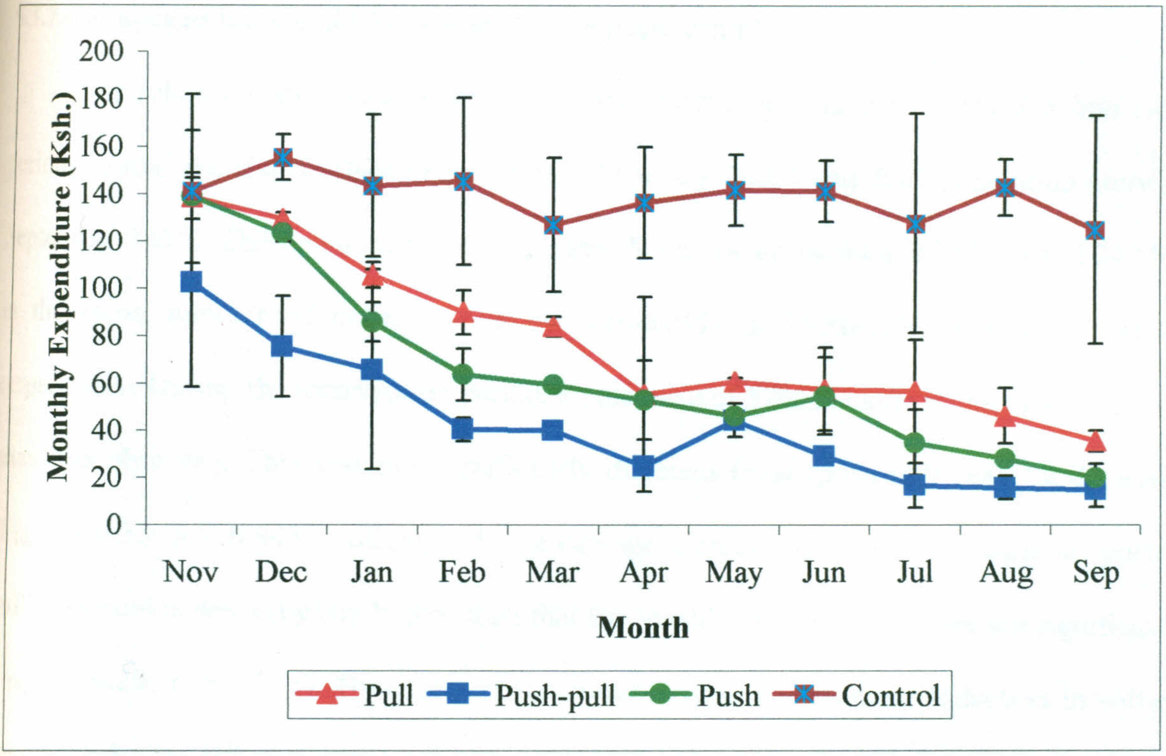


Figure 5.13: Mean (± SE) monthly trypanocidal drug expenditure by households in the trial sites at Shimba Hills from Nov 2004 to Sept 2005

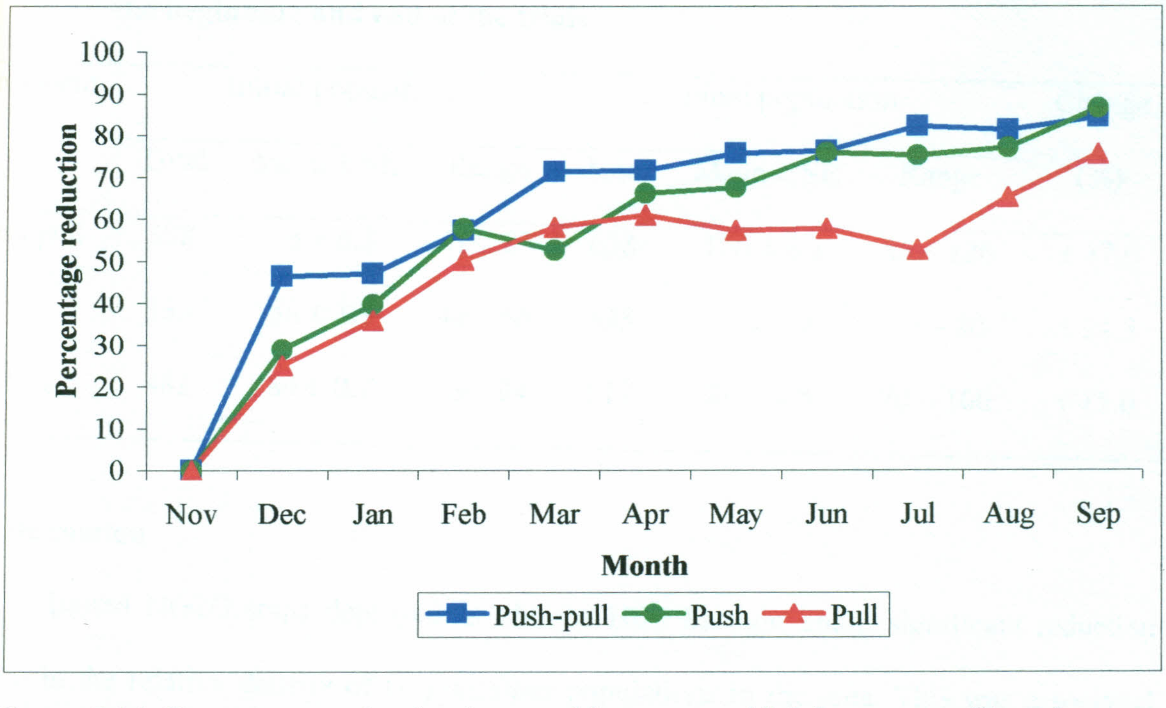


Figure 5.14: Percentage reduction in monthly trypanocidal drug expenditure by households in the trial sites at Shimba Hills from Nov 2004 to Sept 2005

5.3.7 Changes in household herd sizes (cattle population)

For reliable comparison, changes in cattle population have been divided into two periods: initial population (November 2004 – February 2005) and final population (July – September 2005). The results presented in Table 5.3 show an increase of 37.6% and 24.5% in the mean number of cattle owned by households in 'push-pull' and 'push' sites, respectively. During the intervention period, an increase of 17% in cattle population of 'pull' sites was observed. This was not significantly different from 'push-pull' and 'push' sites ($F_{10, 21} = 0.35$; $p = 0.943$). Although the percentage increase in cattle population in 'push-pull' households were slightly higher than that for 'push', the difference was not significant ($F_{10, 21} = 0.29$; $p = 0.731$). However, in the control sites, a significant reduction in cattle population by the end of the trial was observed.

Table 5.3: Monthly mean (± SE) cattle population in the trial sites at Shimba Hills, at the beginning and end of the trials

Treatment	Initial population			Final population			Change
	Total	Mean ± SE	Range	Total	Mean ± SE	Range	(%)
Push-pull	398	66 ± 6.3	41 – 83	638	106 ± 6.1	86 – 126	+ 37.6
Push	333	56 ± 1.9	49 – 66	435	73 ± 1.8	69 – 80	+ 24.5
Pull	481	80 ± 0.7	69 - 94	517	86 ± 6.5	70 – 100	+ 17.0

5.4 Discussion

Baited NG2G traps deployed in Shimba Hills brought about significant reduction (77%) in the relative density of *G. pallidipes* populations in the area. This was associated with significant reduction in trypanosome incidence in cattle and significant improvement in mean PCV values. The results are consistent with the work of others, which demonstrated the efficacy of baited traps and insecticide-impregnated targets for the control of both HAT and AAT (Vale *et al.,* 1988a; Opiyo *et al.,* 1990; Dransfield *et al.,* 1990; Willemse, 1991; Makumi *et al.,* 2000). Extensive studies of traps and targets against *G. pallidipes* and *G. morsitans* have been re-analyzed by Hargrove (2003). In all cases, the results showed a steep decline in tsetse populations, with apparent local elimination being achieved in all except in Nguruman (Brightwell *et al.,* 1997), which was subjected to annual re-invasion.

The reduction in tsetse fly population in the current trial is relatively low compared to those reported in previous similar studies. For example, in one trial, 190 traps were deployed over an area of 100 km^2 resulting in a 98-99% reduction in tsetse population after ten months (Dransfield *et al.,* 1990). In Uganda, tsetse trapping alone was observed to reduce the relative density by 99% in nine months (Lancien *et al.,* 1990). The relatively low performance of traps in the present study could be attributed to loss of trap clothes due to theft, vandalism or fire. Half of the traps had to be replaced due to damage, odours had to be replenished more frequently than expected and the vegetation cleared around traps after heavy rains. The rains also made most of the roads impassable, making servicing of traps impossible. In addition, traps which were in position lost their effectiveness of attracting flies by losing the original attractive blue and black colours. Problems with artificial baits are not new to this study. In Kenya, loss of target clothes due to theft and fires has previously been reported (Opiyo *et al.,* 1990). In Zimbabwe, Vale *et al.* (1988a), reported difficulty of servicing some of the targets due to the rains which aggravated the problem of clearing vegetation that had sprung up near targets in wet season. If traps or targets are to be used for tsetse control, full support of local people is essential in order to minimize losses from damage, vandalism and theft. However, from the point of view of policy makers, major advantages of bait methods are that they are relatively cheap and simple to apply (Barrett, 1997). Trap production and maintenance are labour intensive and would provide employment. Traps can also be seen to be killing tsetse, which evokes considerable local enthusiasm. The initial investment is also minimal since most trap materials are available locally.

Results from this work showed that repellents administered to cattle resulted in a significant reduction (59%) in the incidence of trypanosomal infection in cattle. The reduction was associated with a significant increase in average herd PCV values. Being a repellent, tsetse numbers in the area were less affected, but nonetheless, trypanosome transmission was interrupted. In Kajiado District, Kenya, pastoralists' livestock protected with repellents showed similar significant reduction in trypanosomosis prevalence and an improvement in herd health (Saini and Hassanali, 2003). For disease control, present results suggest that repellents give the best overall most viable option. Using repellents offers numerous advantages over odour-baited traps. Compared to traps, repellent dispensers have the advantages of being closely guarded against theft, vandalism, loss or destruction. They require less labour, avoiding the marked demands of large amounts of labour and transport when traps have to be serviced all year round even in areas that are only used seasonally for grazing.

Repellents are convenient, ready to use formulation requiring no special technical know how and infrastructure; anybody can undertake the application. Previous studies undertaken by Saini and Hassanali (2003) indicated that all cattle in a herd need not to be treated with repellents. This was attributed the repellent diffusion properties and its volatility as a result of which untreated cattle in proximity to treated ones are also protected. Farmers can thus protect the most 'treasured' cattle in a herd e.g. lactating cows and draught bulls.

Due to its low diffusion rate (4.5 mg/h), only a small amount is required. A filled dispenser can last for at least 62 days without refilling. Dispensers can be made to hold enough repellent to last six months or one year, making it even more convenient and cheaper to the farmer. Dispensers and waistbands are simple to use, cheap and made of local materials. Repellents have also been shown to provide protection to cattle against a number of biting flies and hence reducing chances of mechanical transmission of trypanosomosis (Saini and Hassanali, 2003). Repellents are quite safe to protected animals and livestock handlers. Studies undertaken to generate acute toxicity data and assess toxicological effects of repellents on the health of exposed animals indicated that, repellents had no adverse effects on livestock's liver enzymes, haematological parameters, skin, weight and histopathological parameters (Munyua, 2005). Since repellents do not get in contact with the animals' body surface, products from protected cattle can be used for human consumption immediately after repellent treatment (Munyua, 2005). However, the mode of action of repellents in situations where there are alternative sources of bloodmeal especially from wildlife is not well understood. There is still need to carry out field studies to understand the mechanisms by which repellents protect cattle in situations where there are plenty of wildlife hosts.

Statistical analysis revealed that the significant reduction in tsetse population and trypanosomosis incidence in cattle brought about by repellents and baits could be associated with improved herd performance and productivity. There were improvements in animal body weight, PCV, body condition and herd size and significant reduction in trypanocidal drug use. However, it is not possible to compare recorded parameter gains in the present study with those of other studies that have attempted to analyse the impact of tsetse control on livestock productivity (Fox *et al.,* 1993; Rowlands *et al.,* 1996). This is because for all cattle, only 10 months data were collected. In addition, no data was collected before tsetse control was started. Rowlands *et al.* (1996) suggested that when comparing data during an intervention, data collected over several years is required to increase the certainty that statistically significant improvement in productivity is due to the intervention alone. Despite many imperfections in the present data set (comparatively short period of study and small cattle herd size), the differences in productivity parameters of cattle among the treatment regimes with different levels of trypanosomosis suggest a positive impact of repellents and baits on herd performance and productivity.

Introduction of repellent technologies as a component of tsetse management will not only reduce risk of trypanosomosis, but also will significantly reduce dependence on trypanocidal drugs, thus safeguarding the only curative control option by reducing pressure on drug use and the risk of resistance. The expected cost savings and improved effectiveness of disease control will enable livestock herders, especially pastoralist communities, to improve productivity of their existing herds and to maintain optimal herd sizes, thereby contributing to higher income and improved livelihoods. In addition, tsetse removal will open up more land for cultivation with enhanced draft power. A comparison of overall effectiveness of different tsetsc and trypanosomosis control options is complex. For example, it is difficult to compare baited traps and repellents because of their differing nature as 'public' or 'private' goods. Traps are essentially public goods for which individual farmers have difficulty capturing benefits relative to their individual control costs. Repellents while having more private benefits also provide some public benefits to farmers who would not necessarily pay for them. Protecting valuable livestock as a private good with repellents would not only result in productivity increases and lower morbidity and mortality, but would also support trypanosomosis control campaigns, thus achieving a public good. Just like trypanocidal drugs and pour-ons, repellents provide more private benefits and are likely to be more economically attractive for farmers to adopt. In Africa, 'private goods' paid for by farmers are currently the main disease control methods used. If refined, repellent technology is one such control strategy with great potential for adoption and impact. Assuming that repellents are adopted in a similar pattern or even exceed that for trypanocides, adoption is likely to be greatest in the sub-humid zones of West Africa, particularly Mali and Nigeria, Ethiopia and East Africa, which account for less than 45% of the trypanocide market (Sones, 1999).

Protection of cattle with repellents ('push') or baited traps ('pull') or both ('push-pull') resulted in significant reductions in trypanosomosis disease incidence, tsetse population and trypanocidal drug use. The reductions were positively associated with significant improvement in cattle body weight, body condition, mean PCV levels and household herd size. Repellents could be integrated with baited traps or impregnated targets or insecticide-treated cattle to enhance trypanosomosis suppression rates. However, more research coupled with large-scale trials should continue to validate and optimize the repellent technology for eventual commercial production and dissemination to livestock keepers in tsetse-infested areas.

CHAPTER SIX

PERCEPTIONS, ATTITUDES AND PREFERENCES OF LIVESTOCK FARMERS ON THE IMPACTS OF 'PUSH-PULL' TACTIC IN RELATION TO TSETSE CHALLENGE AND TRYPANOSOMOSIS RISK

6.1 Introduction

Perceptions of stakeholders in the delivery of services are critical to the success of any programme. Bembridge (1991) noted that there was lack of consultation and participation of farmers during introduction of technology or programmes and that actual circumstances, needs and aspirations of farmers were rarely considered. The clients (animal owners) have mostly been left out. However, their perceptions are critical since these could either be harnessed to promote the new technology or be a hindrance to its acceptance. Odeyemi (1997) noted that perception describes a process whereby an individual subjects a service to "personal value systems test", during which the service is evaluated according to what the recipient stands to gain compared to other services, commitments and in the context of the prevailing socio-economic circumstances. While the perception of the individual is unique, there is a tendency for it to be similar within related and identifiably distinct social and economic groupings (Odeyemi, 1997).

Despite the apparently low cost or high effectiveness of new control technologies, communities can predict problems with the method if provided with sufficient information (Barrett and Okali, 1999; Budd, 1999). Furthermore, local people can cite rational reasons for investing in alternative interventions or areas of research. It is therefore useful to assess how local characterization of new control methods compares with current methods in use (Catley and Leyland, 2001). Emerging trends in planning, implementing and delivery of tsetse and trypanosomosis control inputs and services are towards a greater involvement of livestock keepers and communities in the programme (Blanc *et al.*, 1991). Farmer perceptions and knowledge of the consequences of new control technologies are essential in shaping the assumptions that can be made about the product if adopted.

Repellent technology is currently being validated in different pastoral and agro-pastoral conditions so that it can be optimized for eventual commercial production and dissemination to livestock owners in tsetse infested areas. Since this is a new technology, factors that will derive its uptake and eventual utilization are unknown. There is lack of information on attributes that livestock keepers will prefer or not prefer. In addition, factors that will influence farmer preferences for different factors are also not known. Knowledge of these factors is important in refining and optimizing the technology in order to improve its rate of adoption. This study undertook an assessment of livestock farmers' attitudes, practices, preferences and perceptions on the impacts of repellents and baited traps in relation to perceived reduction in tsetse challenge and trypanosomosis risk. The study set out to determine the following:

i. The main benefits and constraints of repellents and baited traps for tsetse and trypanosomosis control as perceived by livestock farmers

ii. Livestock farmers perceptions about the efficacy of repellents in relation to other tsetse and trypanosomosis control technologies such as baited traps

iii. Livestock farmers preference between baited traps, repellents or both or the other current tsetse and trypanosomosis control strategies

iv. The relationships between explanatory variables and respondents' outcome responses.

6.2 Materials and methods

6.2.1 Study area

This study was conducted in Kwale District of Coast Province, Kenya. The area is described in section 3.1.

6.2.2 Questionnaire administration

The population targeted for the interview consisted of 102 livestock farmers that were actively involved in the 'push-pull' trials. An interview with all farmers has the advantage of being more representative of the wide differences within the population. Following the testing of questionnaires, interviews (Plate 6.1) were conducted between May and July 2006 to 94 livestock farmers distributed as follows: 'push-pull' (31), 'pull' (28) and 'push' (35).

The questionnaire was divided into six sections which included: (I) demography and farming enterprise; (II) livestock inventory and management; (III) livestock health; (IV) comparison of various tsetse and trypanosomosis control options; (V) efficacy of repellents; and (VI) efficacy of baited traps. All farmers answered questions in section I – IV. Sections V and VI were only answered by farmers from 'push-pull and push' and 'push-pull and pull' sites, respectively. Specific questions were asked on: (a) socio-economic characteristics such as age, sex, educational status and family size of farmers; (b) current expenditure on veterinary products; (c) mode of action of repellents and baited NG2G traps, trap deployment and repellents administration; (d) benefits and constraints (with possible remedies) of repellents and baited traps for tsetse and trypanosomosis control; (e) preference for repellents, traps or both or current methods of tsetse and trypanosomosis control; (f) preferred market prices for repellents and traps; (g) general comments on repellents and traps technologies (Appendix 6.1). The questionnaires were administered as described in section 3.5.

6.2.3 Data management and analysis

Data analysis involved descriptive statistics and calculation of percentages of respondents with similar responses to each question. Chi-square (χ^2) tests, where appropriate, were used to compare the percentages and score ranks of respondents with respect to selected variables. In some cases, respondents indicated more than one option, thereby resulting in total percentages exceeding 100% in some tables.

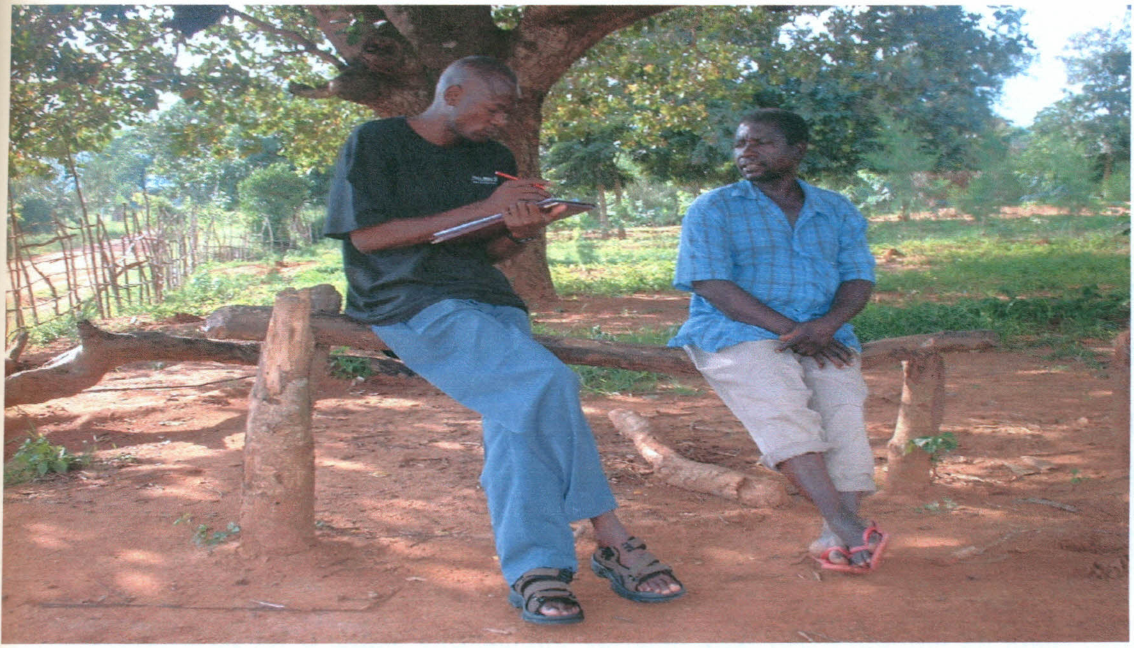


Plate 6.1: A livestock farmer in Tsangatamu, Shimba Hills, presenting his perceptions on the impacts of 'push-pull' on tsetse challenge and trypanosomosis risk

6.2.4 Binary logistic regression

Univariable analysis using binary logistic regression models was used to screen the relationship between explanatory variables and outcome binary response variables (Hosmer and Lemeshow, 2000). Explanatory variables screened were: age, ethnicity, cattle keeping period, gender, education, occupation, herd size, caretaker, farm size and treatment. The variables are outlined in Table 6.1. Outcome binary response variables included: (a) farmers correct description of the mode of action of repellents, dispensers and baited traps; (b) correct administration of repellent dispensers on cattle; (c) correct deployment of a baited NG2G trap in the field; (d) preference for individual or communal method of trap deployment; (e) preference for repellents, traps or both or the other current methods of T & T control; (f) choice of oxen as the preferred cattle for repellent protection; (g) choice of Ksh. 100 as the suitable cost for un-baited NG2G trap or 100 ml bottle of repellents.

Each binary response variable was coded as either yes (y = 1) or no (y = 0).

Thus the logit model was written as:

$$Prob\,(y=1) = \frac{e^{x\beta}}{1 + e^{x\beta}} = f\,(x\beta)$$

Where: *Prob* (y =1) is the probability of 1; e is the base of the natural logarithm; $f(x\beta)$ is the standard logistic distribution function; and x is the explanatory variable vector.

The odds ratios (OR) for all of the explanatory variables were calculated considering the following formula:

$$Odds = P/\,(1-P)$$

It indicates, for a single explanatory variable, that when holding all other variables constant, for each binary response variable, a respondent is more likely to choose one outcome than the other.

Analyses were performed using Proc Logistic of SAS, with class effects as categorical explanatory variables (ethnicity, gender, education, occupation, caretaker and treatment). The model effects included a single binary response variable and all explanatory variables. The model was also used to fit the odds ratios (OR) and their confidence intervals.

Table 6.1: Description of explanatory variables in the logistic regression model

Variable name	Description
Age	Number of years from date of birth
Tribe	Ethnic background of the farmer (1 = *Kamba*; 2 = *Mijikenda*)
Cattle keeping period	Number of years the farmer has been rearing cattle
Gender	Sex of the farmer (1 = male; 2 = female)
Education	Level of education of the farmer (1 = no formal schooling; 2 = primary school and above)
Occupation	Daily activity of the farmer for a source of income (1 = formal or self-employed; 2 = peasant farmer)
Herd size	Total number of cattle owned by household
Caretaker	The person responsible for looking after cattle (1 = owner; 2 = others)
Farm size	Total acreage of land owned by household
Treatment	Type of treatment regime administered in the site (1 = push-pull; 2 = push) (1 = push-pull; 2 = pull)

6.3 Results

6.3.1 Socio-demographic characteristics

Majority of farmers (78%) interviewed were males. Mean age of the farmers was 46.9±2.5 years (range 20 – 86). Most farmers had stayed in the area for at least 28.1±3.2 years (range 1 – 80), with an experience of 27.3±1.4 years (range 1 – 51) in keeping livestock. Level of literacy was intermediate with about 71% of farmers having attained up to primary level and beyond. Farmers were of two ethnic groups, *Kamba* (54%) and *Mijikenda* (46%). Peasant farming was the main occupation for most farmers (77%). Farmers owned average land sizes of 12±1.8 acres (range 2 – 46). Each household reared on average 6 heads of cattle (range 1 – 30). On average, every household spent approximately Ksh 3900 (range Ksh 500 – 15000 (1 US$ = 66 Ksh.) annually on veterinary inputs, of which trypanocidal drugs accounted for over 60%. Most farmers (80%) attended to livestock themselves or with the help of children or spouse. Those having permanent employment hired herdsmen. Cattle were the main source of draught power and transport.

6.3.2 Descriptions on the mode of action of repellents, dispensers and the process of deploying a baited NG2G trap

Most farmers (88%) correctly described the mode of action of repellents and dispensers. The process of baited trap deployment was correctly described by 76% of farmers. There were significant differences between farmers who made correct descriptions and those that did not, for repellents ($\chi^2 = 8.33$; df = 1; p = 0.006) and traps ($\chi^2 = 8.02$; p = 0.003). Farmers' descriptions were scored on a scale of 1 – 7 (1 – very poor; 7 – excellent). Average scores for the 58 farmers who correctly described the mode of action of repellents and dispensers ranged between poor and excellent. However, there were no significant differences between the scores ($\chi^2 = 2.06$; df = 6; p = 0.724). On the process of trap deployment, average scores for the 45 farmers ranged from average to excellent. However, there were no significant differences between the scores ($\chi^2 = 4.12$; df = 4; p = 0.39). Farmers who could not make correct descriptions attributed this to: lack of training on the technologies, not directly involved in handling animals and putting up of traps and old age (above 75 years).

6.3.3 Preferred habitats for deployment of baited NG2G traps

Bushes/thickets/shrubland and livestock grazing fields were the preferred habitats for deployment of baited traps by 42 and 39% of farmers, respectively. The least preferred habitats were open grasslands, water point source, cattle sheds and homesteads (2, 2, 5 and 10%, respectively). There were no significant differences in the choice of bushes/thickets/shrubland and cattle grazing fields ($\chi^2 = 2.62$; df = 5; p = 0.76). However, these were significantly different from other habitats ($\chi^2 = 16.89$; df = 4; p <0.0001). Major reasons for the choice of these habitats included: high infestation with tsetse; cattle grazing and tethering points; provision of good security against theft, vandalism and destruction by wildlife; and availability of fresh and green pastures.

6.3.4 Individual versus communal methods of trap deployment

Majority of farmers (75%) preferred individual methods of trap deployment. There were significant differences between farmers who preferred individual and those that preferred communal trap deployment method ($\chi^2 = 8.54$; df = 1; p = 0.003). Reasons for the choice of individual method included: individual traps are easy to maintain, service and repair; individuals will also be in a position to provide good security against theft, wildlife destruction and vandalism. Moreover, each farmer grazes in his/her own farm. Proponents of communal method cited co-operation in the maintenance and deployment of traps as the most attractive factor. In addition, grazing fields are communally shared and it also facilitates spread of many traps over a wide area.

6.3.5 Preferred cattle group for protection with repellent dispensers

Farmers ranked oxen followed by lactating and expectant cows, respectively, as the most important cattle groups for protection with repellents (Table 6.2). There was no significant difference in the choice of the three cattle groups ($\chi^2 = 0.33$; df = 2; p = 0.331). Choice of oxen was influenced by: oxen are the most important source of draught power and transport; oxen plough in fields/farms heavily infested with tsetse; and due to the yoke, oxen are unable to wade off flies.

Table 6.2: Livestock farmers' ranking of cattle for protection with repellents

Cattle group	Number of farmers (%)		
	Most important	Moderately important	Important
Oxen	31 (47)	26 (39.4)	9 (13.6)
Lactating cows	19 (28.8)	19 (28.8)	30 (45.5)
Expectant cows	16 (24.2)	21 (31.8)	27 (40.9)

n = 66

6.3.6 Benefits of repellents and baited NG2G traps for tsetse and trypanosomosis suppression

All farmers considered the significant reduction in trypanocidal drug use to be the most important benefit of repellents (Table 6.3a). This was followed by repulsion of flies from livestock and reduction in disease incidence, respectively. Additional benefits included: protection of goats, improvement in cattle body condition and cattle grazing peacefully undisturbed by tsetse and other biting flies. Significant reduction in tsetse population, trypanocidal drug use and livestock morbidity, respectively were the most important benefits of baited traps observed by farmers (Table 6.3b). In addition, 46% of farmers reported increased income from sale of livestock products.

Table 6.3a: Perceptions of livestock farmers on the benefits of repellents on livestock health and tsetse fly population

Perceived benefits	No. of farmers	% of farmers
Reduction in trypanocidal drug use	66	100
Repulsion of tsetse flies from cattle	54	81.3
Reduction in disease incidence in cattle	53	80.3
Cattle grazing in the field more peaceful, calm and undisturbed	36	54.5
Reduction in disease incidence in goats	33	50
Oxen able to plough in previously avoided farms due to high tsetse populations	29	43.9
Increased income from sale of livestock products	29	43.9
Cattle able to graze in previously avoided fields heavily infested with tsetse	17	25.8
Improved cattle body conditions	16	24.2
Repulsion of biting and nuisance flies from cattle	10	15.2
Increased cattle body weights	9	13.6
Individualistic, do not require community participation	5	7.6
Reduction in smoke use at night in cattle *bomas*	5	7.6
Other benefits	13	19.7

n = 66

Table 6.3b: Perceptions of livestock farmers on the benefits of baited traps on livestock health and tsetse fly population

Perceived benefits	No. of farmers	% of farmers
Reduction in tsetse populations	56	94.9
Caught flies can be physically seen and counted	47	79.7
Reduction in trypanocidal drug use	45	76.3
Reduction in disease incidence in cattle	44	74.6
Increased income from sale of livestock products	27	45.8
Cattle grazing in the field more peaceful, calm and undisturbed	14	23.8
Oxen able to plough in previously avoided farms due to high tsetse populations	14	23.8
Cattle able to graze in previously avoided fields heavily infested with tsetse	11	18.6
Improved cattle body conditions	2	3.9
Increased cattle body weights	2	3.9
Other benefits	9	15.3
No opinion	1	1.7

n = 59

6.3.7 Constraints of repellents and baited traps for tsetse and trypanosomosis suppression

6.3.7.1 Constraints of repellents

Repellent dispensers were ranked in terms of their component's stability into three categories: 'most weak', 'moderately weak' and 'weak' (Table 6.4). Most farmers (83.3%) ranked stoppers as the most 'weak' component of prototype dispensers. Silicon tubing and belts were ranked 'moderately weak' by 25.8 and 21.2% of farmers, respectively. There was significant difference between 'most weak' and 'weak' component for stoppers, silicon tubing and belts ($\chi^2 = 9.22$; df = 1; $p < 0.001$). Stoppers, silicon tubing and belts were not significantly different in the 'most weak', 'moderately weak' and 'weak' categories ($\chi^2 = 0.92$; df = 2; p = 0.631). Thus, the perceived predominant constraint with repellent technology was the frequent loss of dispenser stoppers (Table 6.5). Additional problems included: frequent cutting of silicon tubing at the point joining it to the aluminium reservouir, unfastening of belts and small size of belts for the large bulls. Some farmers (42%) did not observe any problems with repellent technology.

6.3.7.2 Constraints of baited NG2G traps

Of the 59 farmers who had baited traps deployed on or next to their fields, only 48.8% reported the availability of these traps at the end of the trials. There was no significant difference between the group that lost their traps and those that did not ($\chi^2 = 0.38$; df = 1; p = 0.539). Weak netting material and vulnerability to theft, vandalism, wind and destruction by wildlife and or livestock were considered the predominant trap problems (Table 6.5). Additional problems included: weak support posts, quick fading of blue and black clothing and the need for constant maintenance and servicing. Thirty percent of farmers did not observe any problems with baited traps.

Table 6.4: Livestock farmers' ranking of components of repellent dispensers in terms of weakness

Dispenser component	Number of farmers (%)		
	Most 'weak'	Moderately 'weak'	'Weak'
Stoppers	55 (83.3) Aa	7 (10.6) Bb	4 (6.1) Bb
Silicon tubing	45 (68.2) Aa	17 (25.8) Bb	4 (6.1) Bc
Belts	45 (68.2) Aa	14 (21.2) Bb	7 (10.6) Bb

Values followed by same small letters in rows and capital letters in columns are not significantly different ($p < 0.05$; LSD test), $n = 66$.

Table 6.5: Perceptions of livestock farmers on the constraints of repellents, dispensers and baited traps for tsetse and trypanosomosis suppression

Perceived constraints	No. of farmers	%
Repellents		
Frequent loss of dispenser stoppers	26	39.4
Unfastening of dispenser belts at the joints	5	7.6
Cutting of silicon tubing at the point joining it with aluminium case	4	6.1
Some belts too short for large traction bulls	3	4.5
Low repellent potency	3	4.5
Other constraints	6	9.1
No shortcomings	28	42.4
Baited NG2G traps		
Weak netting material	18	30.5
Vulnerability to theft, vandalism, wind blow and wildlife destruction	11	18.6
Quick fading of blue and black clothing	9	15.3
Weak support posts	7	11.9
Costs, expensive to buy and maintain	7	11.9
Need for constant maintenance and servicing	6	10.2
Quick rusting of cone ring	4	6.8
Blue clothing 'attractive' for use in school uniforms	4	6.8
High evaporation rate for acetone	3	5.1
Other constraints	4	6.8

n = 66 for repellents; *n* = 59 for baited NG2G traps

6.3.8 Preference for different tsetse and trypanosomosis control methods

Overall, when presented with a choice, most farmers (79%) preferred repellents or traps or both to the other current methods (pour-ons, drugs etc) of tsetse and trypanosomosis control (Table 6.6). Major reasons for the choice of repellents and traps included significant reductions in trypanocidal drug use, disease incidences and tsetse population (Table 6.7). Additional benefits were opening up of previously avoided fields due to tsetse infestation; repulsion of flies from cattle; improved body condition; protection of goats and increase in draught power.

Table 6.6: Livestock farmers preference for repellents, traps or both or other methods of tsetse and trypanosomosis control

Control method	No. of farmers	%	p value
a) Repellents	52	78.8	<0.0001
Current methods (drugs, pour-ons)	14	21.2	
b) Baited traps	42	71.2	<0.0001
Current methods (drugs, pour-ons)	17	28.8	
c) Both repellents and traps	27	87.1	<0.0001
Current methods (drugs, pour-ons)	4	12.9	

n = 66 for repellents; *n* = 59 for baited NG2G traps; *n* = 31 for both repellents and traps

For all farmers who preferred the current tsetse and trypanosomosis control methods (drugs, pour-ons etc), major reasons for their choice were: pour-ons are broad spectrum (i.e. effective against both ticks and tsetse) while drugs are curative in nature. Moreover, unlike traps, pour-ons and drugs are individual farmer based and are not prone to vandalism, theft or destruction. Prophylactics also provide security against re-infections when cattle move to areas without traps.

6.3.9 Preference for repellents or baited traps for tsetse and trypanosomosis control

All farmers who received both repellents and traps preferred the former. The most attractive attribute of repellents was its simplicity and mobility (cattle moves with repellent dispensers, they are protected at all times, even in areas without traps). In addition, repellent dispensers are simple to use and do not require professional knowledge and skills; they offer protection to goats and humans against tsetse bites; and they might be affordable to poor farmers. Furthermore, repellents are more of individual rather than community oriented.

Table 6.7: Perceptions of livestock farmers for the preference of repellents, baited traps or both over current methods for tsetse and trypanosomosis control

Perceptions	Repellents		Baited traps		Both	
	No. of farmers	%	No. of farmers	%	No. of farmers	%
Reduction in trypanocidal drug use	47	90.4	36	85.7	24	88.9
Mobile, moves with the animal wherever it goes	41	78.8	–	–	12	44.4
Simple, do not require professional knowledge and skills	40	76.9	14	33.3	8	29.6
Repulsion of tsetse flies from cattle	32	61.5	–	–	12	44.4
Increase in draught power	26	50	–	–	16	59.3
Cattle grazing in the field more peaceful, calm and undisturbed	23	44.2	–	–	3	11.1
Oxen able to plough in previously abandoned farms due to high tsetse populations	15	28.8	17	40.5	8	29.6
Reduction in disease incidence in cattle	15	28.8	24	57.1	18	66.7
Protection of goats against tsetse bites	6	11.5	–	–	11	40.7
Costs, might be affordable to poor farmers	5	9.6	14	33.3	7	25.9

Table 6.7 Continued

Perceptions	Repellents		Baited traps		Both	
	No. of farmers	%	No. of farmers	%	No. of farmers	%
Sustainability, longer protection period against tsetse	1	1.9	4	9.5	3	11.1
Increased milk yields	2	3.8	–	–	–	–
Protection of humans against tsetse bites	2	3.8	–	–	–	–
Lack of side effects (e.g. under or over drug dose)	1	1.9	–	–	–	–
Alternative to traditional tsetse control methods	1	1.9	3	7.1	–	–
Reduction in tsetse populations	–	–	38	90.5	5	18.5
Caught flies can be physically seen and counted	–	–	28	66.7	–	–
Encourages co-operation among livestock owners	–	–	16	38.1	–	–
Deployment in heavily tsetse infested thickets	–	–	11	26.2	–	–
Provision of protection to trypanocides resistant cattle	–	–	7	16.7	–	–
Increase in cattle herd sizes	–	–	–	–	7	25.9
Protection of cattle against biting and nuisance flies	–	–	–	–	1	3.7

n = 52 for repellents; *n* = 42 for baited NG2G traps; *n* = 27 for both repellents and traps

6.3.10 Preferred costs for repellents, dispensers and NG2G traps

Most farmers suggested Ksh. 100 (US$ 1.5) as the suitable cost for a 100 ml bottle of repellents or un-baited NG2G trap (Table 6.8). Fifty shillings (US$ 0.7) was the preferred cost for an empty dispenser. However, some farmers could not cost the items. There were no significant differences among suggested costs for 100 ml bottle of repellents ($\chi^2 = 4.524$; p = 0.865), repellent dispenser ($\chi^2 = 0.291$; p = 0.865) or un-baited trap ($\chi^2 = 4.124$; p = 0.39).

Table 6.8: Livestock farmers' suggested costs for a 100 ml bottle of repellents, repellent dispensers and un-baited NG2G trap in Kenya Shillings

	Number of farmers (%)					
	Kenya Shillings					
Item	50	100	150	200	300	No opinion
100 ml of repellents	13 (19.7)	16 (24.2)	8 (12.1)	12 (18.2)	11 (16.7)	6 (9.1)
Empty repellent dispenser	27 (40.9)	7 (10.6)	12 (18.2)	–	–	20 (30.3)
Un-baited NG2G trap	5 (8.5)	23 (39)	9 (15.3)	7 (11.9)	9 (15.3)	6 (10.2)

n = 66 for repellents; *n* = 59 for baited NG2G traps

6.3.11 Odds ratios (OR) estimates for significant factors affecting livestock farmers responses to the efficacy of baited NG2G traps

The binary logistic regression models estimation of the nine different binary response variables are presented in Tables 6.9 to 6.13. Each table includes: the explanatory variable, degrees of freedom (DF), coefficient estimates, standard error, the Wald Chi-square (χ^2), p-values and the Likelihood Ratio. Different explanatory variables had significant effects on different binary response variables at $p < 0.05$. The significant variables had both positive and negative signs.

6.3.11.1 Correct description of the process of baited NG2G trap deployment

The Odds ratios (OR) (95% Wald Confidence Limits) for the significant variables can be interpreted as the following. Holding all other variables constant, farmers from *Kamba* ethnic group were 3.2 (0.91 – 12.1) times more likely to correctly describe the process of baited NG2G trap deployment than the *Mijikenda* (Table 6.9). Farmers with long periods keeping of cattle were 14% (0.98 – 1.33) more likely to correctly describe the process of baited NG2G trap deployment than those with short periods ($p < 0.05$). Male farmers were 5.1 (1.69 – 38.51) times more likely to correctly describe the process of baited NG2G trap deployment than the females ($p < 0.05$). Farmers who received both repellents and traps (push-pull) were 3.6 (0.88 – 3.91) times more likely to prefer individual method of trap deployment than those who only received baited traps (pull) ($p < 0.05$).

Table 6.9: Binary logistic regression model estimation for farmers' correct description of the process of baited NG2G trap deployment

Explanatory variable	DF	Estimated coefficient	Standard error	Wald Chi-square	p value
Age	1	-0.043	0.043	0.981	0.322
Tribe	1	1.175	0.626	3.523	0.040*
Cattle keeping period	1	0.132	0.078	2.912	0.038*
Gender	1	1.622	0.693	5.48	0.019*
Education	1	-1.3406	0.837	2.568	0.019*
Occupation	1	-1.086	0.749	2.104	0.147
Herd size	1	0.127	0.101	1.569	0.210
Caretaker	1	-0.365	0.570	0.411	0.521
Farm size	1	-0.059	0.048	1.488	0.223
Treatment	1	-0.116	0.473	0.060	0.806

* = Significant explanatory variables; Likelihood Ratio χ^2 (10) = 29.98, p < 0.0001

6.3.11.2 Preference for baited NG2G traps or current methods (drugs, pour-ons etc) of tsetse and trypanosomosis control

Farmers with long periods of cattle keeping were 0.9 (0.79 – 1.00) times less likely to prefer baited traps to current methods (drugs, pour-ons) of T & T control than those with short periods (Table 6.10). Farmers who looked after their cattle were 2.3 (0.88 – 3.4) times more likely to prefer baited traps to current methods (drugs, pour-ons) of T & T control than the ones that did not. The larger the farm size, the less likely (0.8 times) (0.74 – 0.93) that a farmer would prefer a baited trap to current methods of T & T control (p <0.01).

Table 6.10: Binary logistic regression model estimation for farmers' preference for baited traps to current methods of tsetse and trypanosomosis control

Explanatory variable	DF	Estimated coefficient	Standard error	Wald Chi-square	p value
Age	1	0.056	0.003	2.587	0.108
Tribe	1	0.600	0.562	1.141	0.285
Cattle keeping period	1	-0.120	0.062	3.798	0.041*
Gender	1	0.254	0.477	0.283	0.595
Education	1	-1.051	0.685	2.354	0.125
Occupation	1	-0.781	0.494	2.503	0.114
Herd size	1	0.107	0.069	2.451	0.117
Caretaker	1	0.849	0.467	3.300	0.043*
Farm size	1	-0.183	0.059	9.693	0.002*
Treatment	1	-0.466	0.445	1.094	0.296

* = Significant explanatory variables; Likelihood Ratio χ^2 (10) = 24.39; p = 0.007

6.3.11.3 Preference for Ksh. 100 as the suitable cost for unbaited NG2G trap

Farmers from *Kamba* ethnic group were 0.36 (0.02 – 0.74) times less likely to prefer Ksh. 100 as a cost for un-baited trap than the *Mijikenda* ($p < 0.05$) (Table 6.11). Male farmers were 0.5 (0.04 – 1.48) times less likely to prefer Ksh. 100 as a cost for un-baited trap than the females ($p < 0.05$). Farmers with large herd size were 2 (0.74 – 21.51) times more likely to prefer Ksh. 100 as a cost for un-baited trap than those with small herd size ($p < 0.05$). Farmers with large farm size were 78% (0.88 – 11.48) more likely to prefer Ksh. 100 as a cost for un-baited trap than the ones with small farm size ($p < 0.05$).

Table 6.11: Binary logistic regression model estimation for farmers' preference of Ksh 100 as the suitable cost for un-baited NG2G trap

Explanatory variable	DF	Estimated coefficient	Standard error	Wald Chi-square	p value
Age	1	-0.005	0.023	0.005	0.982
Tribe	1	-1.022	0.443	5.309	0.021*
Cattle keeping period	1	0.031	0.053	0.336	0.562
Gender	1	-0.693	0.453	2.340	0.013*
Education	1	0.189	0.422	0.200	0.654
Occupation	1	0.210	0.376	0.312	0.577
Herd size	1	0.692	0.430	2.591	0.011*
Caretaker	1	0.313	0.124	6.356	0.012*
Farm size	1	0.578	0.328	3.108	0.047*
Treatment	1	-0.003	0.038	0.007	0.932

* = Significant explanatory variables; Likelihood Ratio χ^2 (10) = 17.76; p = 0.059

6.3.12 Odds ratios (OR) estimates for significant factors affecting farmers responses to the efficacy of repellents

Holding all other variables constant, farmers with long periods of keeping cattle were 5.1 (0.96 – 26.8) times more likely to correctly describe the mode of action of repellents than those with short periods ($p < 0.05$). Male farmers were 11.1 (1.78 – 92.28) times more likely to correctly administer repellent filled dispensers to cattle than females ($p < 0.01$). The *Kamba* ethnic group were 0.4 (0.03 – 0.99) times more likely to prefer repellents for tsetse and trypanosomosis control than the *Mijikenda*.

6.3.12.1 Preference of oxen for protection with repellents

Farmers of *Kamba* ethnic group were 53% (0.56 – 9.71) more likely to prefer oxen for protection with repellents than the *Mijikenda* (Table 6.12). Farmers with long periods of keeping cattle were 20% (0.96 – 1.48) more likely to prefer oxen for protection with repellents than those with short period ($p < 0.05$). Peasant farmers were 76% (0.67 – 4.32) more likely to prefer oxen for protection with repellents than self or formally employed ones ($p < 0.05$). Farmers with large farm size were 2.6 (1.87 – 23.54) times more likely to prefer oxen for protection with repellents than the ones with small herd size ($p < 0.01$).

Table 6.12: Binary logistic regression model estimation for farmers' choice of oxen as the preferred cattle for protection with repellents

Explanatory variable	DF	Estimated coefficient	Standard error	Wald Chi-square	p value
Age	1	0.007	0.023	0.088	0.766
Tribe	1	0.424	0.364	1.357	0.024*
Cattle keeping period	1	0.179	0.109	2.729	0.045*
Gender	1	0.126	0.413	0.093	0.760
Education	1	-0.157	0.421	0.139	0.709
Occupation	1	0.564	0.391	2.075	0.015*
Herd size	1	-0.275	0.369	0.554	0.046*
Caretaker	1	-0.027	0.078	0.122	0.727
Farm size	1	0.946	0.323	8.59	0.003*
Treatment	1	0.017	0.038	0.193	0.660

* = Significant explanatory variables; Likelihood Ratio χ^2 (10) = 16.26, p = 0.092.

6.3.12.2 Preference for Ksh 100 as the suitable cost for 100 ml bottle of repellents

Older farmers were 8% (1.02 – 1.16) more likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than the young ones (p <0.05) (Table 6.13). *Kamba* ethnic group farmers were 0.8 (0.14 – 2.53) times less likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than the *Mijikenda* (p <0.05). Farmers with long periods of keeping cattle were 0.9 (0.88 – 1.02) times less likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than those with short periods (p <0.05). Farmers without formal education were 0.2 (0.004 – 0.57) times less likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than those with formal education (p <0.05). Farmers with large herd size were 0.7 (0.15 – 1.82) times less likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than those with small herd size (p <0.05). Farmers who looked after cattle were 11% (0.98 – 1.25) more likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than those that did not (p <0.05). Farmers with large farm size were 47% (0.59 – 7.82) more likely to prefer Ksh. 100 as the suitable cost for a 100 ml bottle of repellents than the ones with small farm size (p <0.05).

Table 6.13: Binary logistic regression model estimation for farmers' preference of Ksh 100 as the suitable cost for a 100 ml bottle of repellents

Explanatory variable	DF	Estimated coefficient	Standard error	Wald Chi-square	p value
Age	1	0.081	0.034	5.842	0.016*
Tribe	1	-0.268	0.374	0.515	0.047*
Cattle keeping period	1	-0.058	0.038	2.376	0.012*
Gender	1	-0.107	0.389	0.076	0.783
Education	1	-1.510	0.627	5.794	0.016*
Occupation	1	0.019	0.381	0.003	0.959
Herd size	1	-0.326	0.319	1.04	0.031*
Caretaker	1	0.105	0.062	2.878	0.044*
Farm size	1	0.382	0.330	1.344	0.025*
Treatment	1	0.017	0.030	0.315	0.575

* = Significant explanatory variables; Likelihood Ratio χ^2 (10) = 13.19; p = 0.213

6.4 Discussion

When selecting cattle for protection with repellents, livestock owners in Shimba Hills gave priority to their bulls (draught oxen). Similarly, farmers in Ethiopia gave priority to oxen for treatment with insecticide pour-ons (Swallow *et al.,* 1995). Previous studies had indicated that trypanosomosis has direct impact on draught animals (Doran, 2000). In

Draught oxen are the most important source of farm labour, transport and household income. These animals are more susceptible to trypanosomes infection due to the stress of traction. The oxen are relatively more exposed to tsetse bites in the course of ploughing in or next to tsetse-infested fields. Most farmers also use draft power either early in the morning or late in the evening, when *G. pallidipes* are most active (Brady, 1972). Larger and or older hosts are bitten more by tsetse than smaller/younger ones (Torr *et al.,* 2006). Draft oxen being generally larger may be more attractive to tsetse; moreover, bulls produce more carbon dioxide, a known tsetse attractant (Green, 1994). Higher rates of defensive behaviour by younger cattle have been shown to prevent tsetse from feeding (Torr *et al.,* 2006). However, with oxen, due to the yoke, they display poor defensive behaviour during ploughing and hence are unable to deter tsetse from feeding. Households that are most likely to invest and protect their animals with repellents are those with high proportions of oxen in their herds.

One of the major perceived benefits of repellents by livestock keepers is the expanded use of draft power. This they attributed directly to the improvement of animal health that accompanied T & T control. Animal traction still remains the most economical form of draft for many smallholder farmers in Africa (Ellis-Jones and Whitmore, 2004). The expanded use of animal traction will translate into opening-up more land and increased land for cultivation. These perceptions are consistent with those of Ethiopian farmers who observed that, following treatment of cattle with insecticide pour-ons, there was an increase in draught power (Swallow *et al.,* 1995). The anticipated improved use of draft power, in addition to leading to increased cropped area will lead to reduced bush coverage and consequently, clearing of the favourable habitats for tsetse. Increased yields will lead to additional income generation, which in turn will impact on hunger, food security and poverty in sub-Saharan Africa.

Some livestock farmers preferred to deploy baited traps in their homesteads, cattle sheds or water point sources. This is similar with the findings of the Intermediate Technology Development Group (ITDG) (2003) in which farmers in Machakos District, Kenya, preferred to deploy traps next to cattle sheds or homesteads. This suggests that most farmers do not understand the principles of trap deployment and there is need to spend more time and resources on training and community education on T & T control by baits. To have any effect, traps have to be sited within the main tsetse habitat so that they reduce the source of infestation (Green, 1994). Trying to intercept tsetse entering cattle shed or homesteads do not reduce the infection rate as tsetse flies will still get through and cattle will continue to be bitten when they are out grazing. Nevertheless, water point sources and cattle sheds are suitable for trap deployment in cases where the aim is to reduce the biting activity of tabanids on livestock (Wilson, 1968). It is also pointless for a farmer or few farmers in a tsetse infested area to deploy traps, as reinvasion pressure is immense and will not lead to reduction in trypanosomosis.

Analysis of the preferred method of trap deployment by livestock owners suggests that farmers in Shimba Hills are more individual-based rather than community-oriented. This is a direct contrast to farmers in Machakos District, Kenya, who showed a high level of commitment to community-based vector control. Traps were well maintained with tsetse in cages and odour baits present, no theft or vandalism was reported (ITDG, 2003). Similarly, in the Gambia, farmers preferred a communal participatory T & T control strategy (Somda *et al.,* 2006). Some of the reasons advanced by livestock farmers for the preference of individual-based methods have previously been discussed by Brightwell *et al.* (2001). The problem with services such as tsetse control by traps or targets is that they are regarded as "public goods" in that benefits spill over to other members of the community. In such a situation, it is difficult to get someone to take the initiative and commit for the service, as everyone wants to wait and be a "free rider". Therefore, for successful tsetse control by traps there is need to promote communal action among farmers.

Few livestock farmers regarded the use of trypanocidal drugs, insecticide pour-ons and hand-wash sprays as more effective and acceptable than repellents or baits. The major justification for the choice of trypanocidal drugs is that they are curative in nature. Analysis of T & T control methods in most tsetse-affected areas indicated that farmers tend to favour using drugs since they are cheaper, easier to administer, cause less stress to the animal and can also cure the TBD, babesiosis (Morton, 2002). Hence, many individual livestock owners choose the private, immediate and obvious benefits of using trypanocides rather than the more expensive, public and long-term benefits of controlling tsetse. However, with the current trend of multiple-drug resistance in Kwale District (Mugunieri and Murilla, 2003), trypanocides must be used cautiously. Compared to repellents, pour-on treatments and hand-wash sprays provide an extra benefit; nuisance and biting flies and ticks may also be controlled (Leak, 1998). This is supported by perceptions of farmers in Ethiopia who observed that animals treated with pour-ons were at less risk of contracting trypanosomosis and TBDs. In addition, there were fewer problems with ticks, biting and nuisance flies and tsetse, animals were calm when grazing and during milking and improved body condition were observed (Swallow *et al.,* 1995). According to Bauer and Snow (1999), use of pour-ons on cattle is inherently more sustainable on the premise that it provides for both individual farmer and community benefit. However, effective tsetse control using pour-ons still require the participation of many livestock farmers if it is to be successful (Somda *et al.,* 2006). Livestock farmers in Shimba Hills, typically own 1–4 bulls for traction. The relatively low density of cattle, their static grazing regime and the patchy distribution of farmers in the area means that use of insecticide treated cattle may not control tsetse effectively. Provision of repellents to protect animals directly from tsetse would be the most suitable strategy and may encourage a sustained commitment by farmers who are responsible for the health and productivity of their herds.

Perceptions of livestock farmers in 'push-pull' sites clearly indicate that the biological efficacy of repellents in the control of trypanosomosis is not contentious. When provided with a choice between repellents and traps, all farmers preferred the former. This was also the view of most pastoralists in Nguruman and Narok, Kenya, who had an experience with repellents (Saini and Hassanali, 2003). They indicated that repellents reduced morbidity and mortality from trypanosomosis. Given the non-cooperation in the deployment and/ or maintenance, vandalism, theft and destruction of traps by fires, floods or wildlife in most tsetse infested areas, the repellent technology is expected to be more attractive. In comparison with current methods of tsetse and trypanosomosis control, it is generally likely that repellents present no risk to environmental contamination. The major advantages of repellents are that they are mobile (an animal moves with it wherever it goes) and may be relatively cheap to apply once mass-produced. Moreover, they do not have the technical and logistic operational difficulties associated with other techniques. They could therefore in principle, be carried out and paid for by farmers themselves. These together with their relative simplicity have made the technology popular with livestock keepers (Saini and Hassanali, 2003). Repellents may also be used as components of integrated control. Disease control by repellents may open up a new dimension of benefits derived from introducing upgraded livestock breeds and crossbreeds and changing to more productive agricultural practices.

The overall impression of regression data indicates that the explanatory variables, tribe and cattle keeping period have significant relationships with most outcome responses. Other variables such as age, education, occupation and treatment did not seem to play a role in the preference for the technologies. It is a common perception that farmers with more experience in livestock rearing are more likely to prefer and eventually adopt new control technologies (Wekesa *et al.,* 2003). The present data is therefore consistent with the observation, since out of the nine outcome responses, five were either negatively or positively correlated with the duration a farmer has been rearing livestock. As observed by Wekesa *et al.* (2003) farmers with more experience in agricultural husbandry have high abilities to process information and assess the potential net gains or loss from adoption of new technologies. Furthermore, they are more likely to be innovative in their choice of control options and to take risks.

Though the *Mijikenda* are the majority (>80%) in Kwale District, the regression model indicates that the preference for repellent and bait technologies are likely to be higher among farmers from the *Kamba* than the *Mijikenda* ethnic group. There may be a number of possible reasons for this observation. The *Kamba* are more agriculturally and commercially oriented and rely heavily on oxen for draught power, transport and household income (Mwanzia, 1999). The *Kamba* being migrants from other regions might have been exposed to the benefits of other improved or new control technologies. On the other hand, the *Digos* (the most common *Mijikenda* sub-tribe in the district) in their culture and traditions attach little or no value to livestock rearing. Most *Mijikenda* farmers are squatters or own land in communal holdings. The land is also characterized with poor soils and has the lowest potential for agricultural use (Waaijenberg, 1994). Livestock production is therefore an uncertain undertaking, hence they rely on off-farm employment. The less preference and less likelihood of adoption of repellents and traps among the *Mijikenda* indicates that there is still a group of livestock farmers whose needs may have not been met by the new technologies.

The most important perceived benefits of repellents and baits were the significant reduction in trypanocidal drug use, disease incidence and tsetse population. Additional benefits included: increase in the use of draught power, cattle ability to penetrate or plough or graze in previously avoided fields and improved body condition of cattle. When provided with a choice between repellents and traps, all farmers preferred repellents. Most farmers preferred repellents, traps or both to other current methods of tsetse and trypanosomosis control. Preference for repellents and bait technologies were likely to be higher among the *Kamba* ethnic group and farmers with more experience in livestock rearing.

Livestock farmers' perceptions confirm results obtained from the longitudinal study that, the use of repellents and baits resulted in significant reduction in trypanosomosis disease incidence, tsetse population and trypanocidal drug use. The reduction was associated with significant increase in mean PCV, improved cattle body weight, condition score and household herd size. Thus repellent technology is a promising farmer based control strategy, either as an alternative or component of integrated vector and disease management.

CHAPTER SEVEN

THE OLFACTORY RESPONSES OF *GLOSSINA PALLIDIPES* TO ALDEHYDE BLENDS IN THE FIELD

7.1 Introduction

The identification of components of odours that attract tsetse flies has been made possible through improved techniques of analysis including electroantennogram (EAG) recordings of column chromatographic effluents of odour passed over the antenna (GC-EAD) (Hall *et al*., 1984). Components of ox breath that are attractants to tsetse are carbon dioxide (CO_2), acetone and 1-octen-3-ol (octenol). Carbon dioxide induces alighting responses of tsetse flies (Vale, 1983; Vale e*t al*., 1985) and in the presence of acetone triggers upwind anemotaxis. Trap catches of *G. morsitans morsitans* and *G. pallidipes* were increased by upto three times when octenol was dispensed 1m upwind of the traps. However, when dispensed in front, catches were reduced (Bursell, 1984).

The attractiveness of buffalo or ox urine to tsetse flies was shown to be due to phenols in urine (Hassanali *et al*., 1986). A chromatographic fraction of the urine extract containing six simple phenols; 3-methylphenol, 4-methylphenol, 3-ethylphenol, 4-ethylphenol, 3-*n*-propylphenol and 4-*n*-propylphenol increased field catches of *G. pallidipes* by up to seven folds when dispensed in biconical traps. Of these phenols, 4-methylphenol and 3-*n*-propylphenol (acting synergistically) were shown to be the most important for attractiveness of the urine (Owaga *et al*., 1988). Using chemical methods of fractionating cattle urine, Bursell *et al*. (1988) found similar phenols in the phenolic fraction. A minor component of the cattle urine, 2-methoxyphenol was found to be a repellent to both *G. morsitans morsitans* and *G. pallidipes* in the field in Zimbabwe (Bursell *et al*., 1988; Vale *et al*., 1988b).

Although combinations of these kairomones have been used successfully as baits with traps and targets for *G. pallidipes* and *G. morsitans morsitans* control, they are still less than 50% as attractive as the natural cattle odour (Vale *et al*., 1988b; Brightwell *et al*., 1991; Willemse, 1991). This implies that there are other unidentified attractive components of the host odour (Vale, 1981; Willemse and Takken, 1994; Hargrove *et al*., 1995; Torr *et al*., 1995; 2006). Vale (1980) suggested that aldehydes, which were suspected to be present in ox body odour, were likely to contribute to its attractiveness to tsetse flies.

Analysis of volatiles collected from waterbuck, ox and buffalo using gas chromatography-linked electro-antennographic detector (GC-EAD) and gas chromatography-linked mass spectrometry (GC-MS) techniques indicated that these volatiles are made up of a series of homologous aldehydes (Gikonyo *et al*., 2000; 2002). Out of the identified aldehydes, six (2-*E*-heptenal, octanal, decanal, undecanal, dodecanal and nonanal) (Figure 7.1) that elicited strong electrophysiological responses were further characterized (Gikonyo *et al*., 2003). In the wind tunnel experiments, these compounds elicited activation and upwind flight of *G. morsitans morsitans* and *G. pallidipes*. Thus, the aldehyde blend elicited more or less the same behaviour as the known tsetse attractant blends. The occurrence of different combinations of electroantennogram active compounds in these animals suggested that they may play a role in host detection (Gikonyo *et al*., 2003). The blend of aldehydes may be a hitherto unidentified part of the attractant system for these insects. Thus, opportunity exists for further optimization of the odour baits. This study undertook field-based evaluation of aldehyde blends individually and in combination with known savannah tsetse kairomones (acetone and cow urine) using *G. pallidipes* populations. Evaluation of these aldehydes may contribute in understanding their role in attracting tsetse, augmenting known tsetse attractants and improving trap catches.

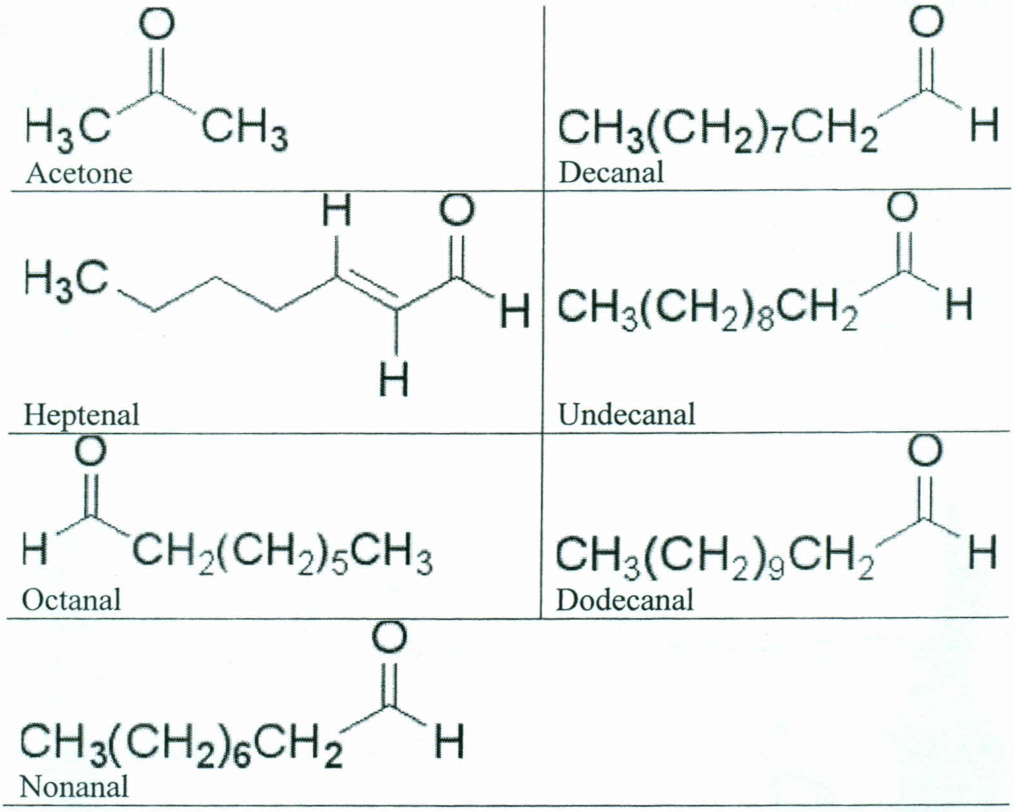


Figure 7.1: Chemical structures of aldehyde compounds used in the trial

7.2 Materials and methods

7.2.1 Study area

These experiments were conducted in Nguruman, Kajiado District, Kenya. Nguruman (Figure 7.2), lies in Southern Kenya, 600–800 m above sea level between the Nguruman escarpment to the West and Lake Magadi to the East at latitude 1^{o} 50' S and longitude 36^{o} 05' E on the floor of the Rift Valley (Dransfield *et al.*, 1986). The area has a mean annual rainfall and temperature of 550 mm and 28 °C, respectively. The vegetation comprises of *Acacia* woodland and bush grassland with thickets along streambeds. It is an area within a typical semi-arid pastoral ecosystem and infested all year round with *G. longipennis* and *G. pallidipes,* the latter being dominant. There are large numbers of wild ungulates such as bushbuck, warthog, bushpig, elephant, eland, waterbuck, buffalo and many antelopes.

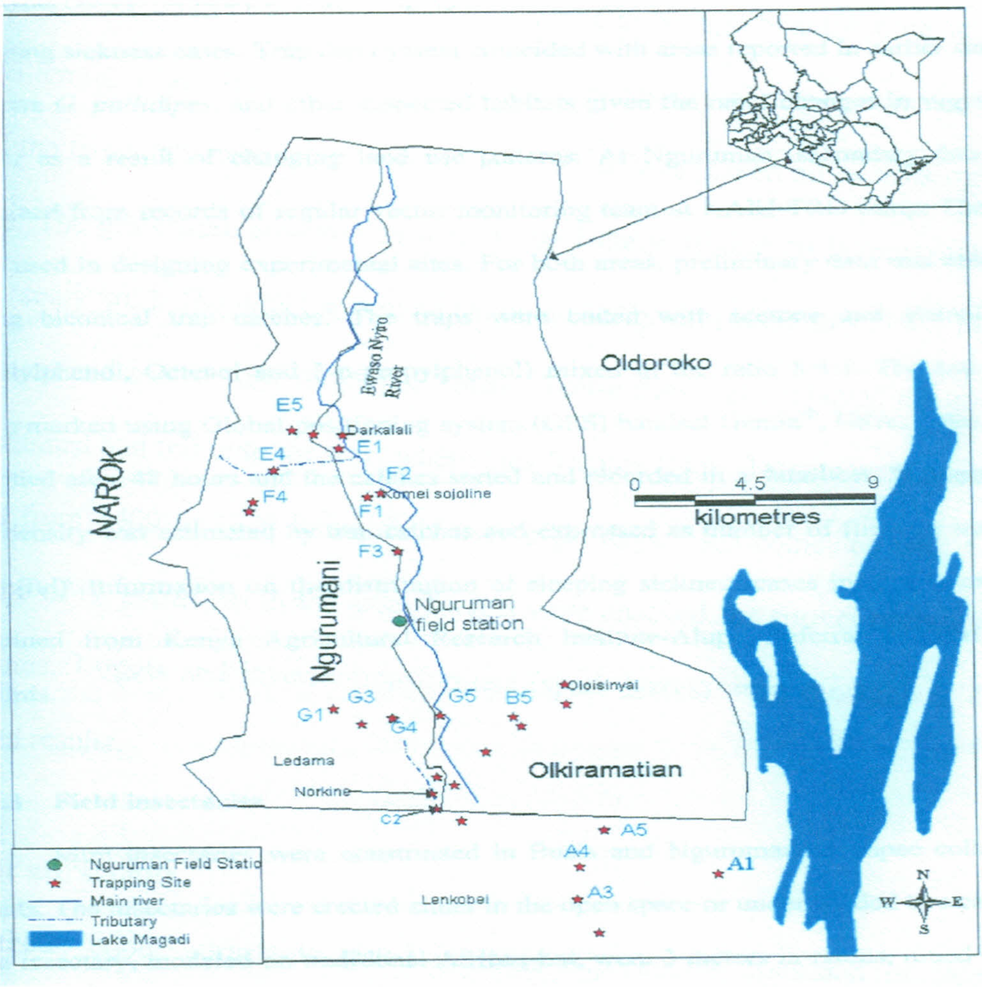


Figure 7.2: A map showing Nguruman, the study area where field tests were conducted

7.2.2 Sampling methods

7.2.2.1 Traps

Sampling traps consisted of the NG2G (Brightwell *et al.*, 1991) (Plate 3.2). Trap sites were located 200 m apart and were changed after every 24 hours. Traps were emptied after 24 hours to record the species, sex and number of teneral and non-teneral flies caught.

7.2.2.2 Targets

Targets consisted of a panel of vertically oriented half pthalogen-blue/half black double-dyed cotton cloth (1 x 1 m), which had proved to be significantly more attractive to tsetse (Willemse, 1991) (Plate 7.1). To estimate the number of tsetse attracted and that contacted the target, an electrocuting grid (Vale, 1974b) was placed all over its surfaces on both sides. The grids were powered by a 12 V car battery driving an inverter-transformer oscillator (spark box). The target was mounted on a corrugated plastic tray (1 x 1 m) placed on the ground and coated with sticky polybutene. Tsetse flies that contacted the grids were killed or stunned and fell onto the tray, where they became stuck. Targets were operated for four hours from 1400 to 1800 hours daily over eight days. This coincided with the peak activity time of *G. pallidipes* in the area. Targets were checked for correct operation every thirty minutes. Targets and inverter-transformers (spark boxes) were randomized daily to avoid biased results.

7.2.3 Odour attractants

Synthetic odour attractants tested in these experiments consisted of aldehydes identified by Gikonyo *et al.* (2002; 2003) from buffalo, ox and waterbuck volatiles. These included: heptenal, octanal, nonanal, decanal, undecanal and dodecanal. Mixtures of 4 ml of the six compounds were combined in proportions 1:9:20:11:7: and 8, respectively to make a single blend (henceforth termed 'the aldehyde blend') for bioassay (Gikonyo *et al.*, 2003). An antioxidant, butylated hydroxytoluene (BHT) (2, 6-di-tert-butyl-4-methylphenol), was added to each compound. Known tsetse attractants consisted of cow urine and acetone.

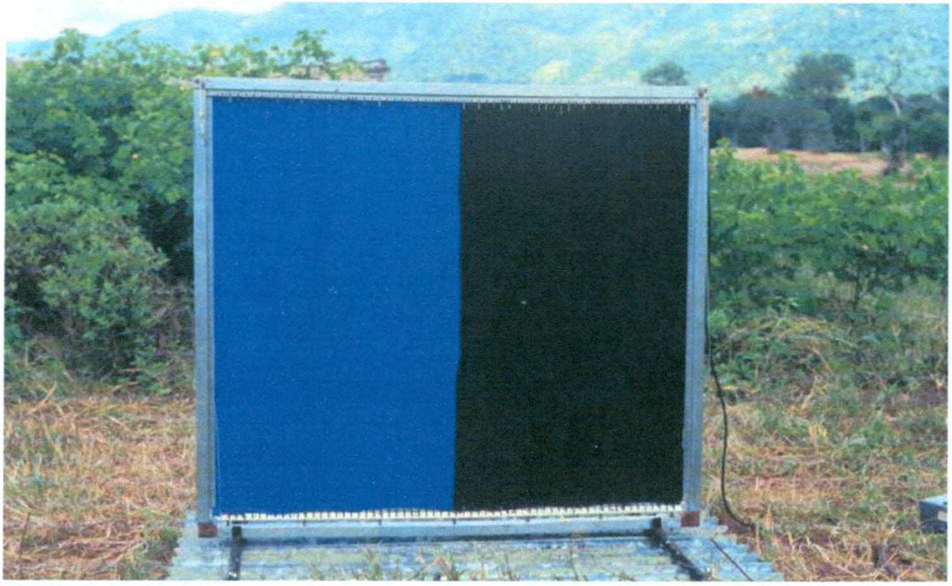


Plate 7.1: The blue-black electric target (screen)

7.2.4 Dispensing of odours

The blends were dispensed from a 5 x 5 cm heat-sealed thin walled polythene sachets constructed from polyethylene layflat tubing with 50 μm thick walls and a surface area of 25 cm^2 folded into a tetrahedron (Plate 7.2). Odour sachets were suspended 30 cm from the ground, down wind of traps or targets. Release rates for the blends were measured in the field by weighing method. It involved measuring weight loss of 4 ml of odour samples in polyethylene sachet kept outdoors before and after every 24 hours for seven consecutive days. The average release rates for 0.4, 2, 10, 50 and 100% concentration of the blends were 0.47, 0.74, 1.66, 2.04, and 4.81 mg/hr, respectively. Acetone was dispensed from glass bottles with a 2 mm diameter aperture perforated through the lid (release rate approximately 500 mg/h). Aged cow urine (4 weeks) was dispensed from covered plastic containers with a 2 x 4 cm slot cut in the tin just below the rim, giving a release rate of about 1000 mg/h. Odour dispensers were placed on the ground, 30 cm downwind of traps or targets.

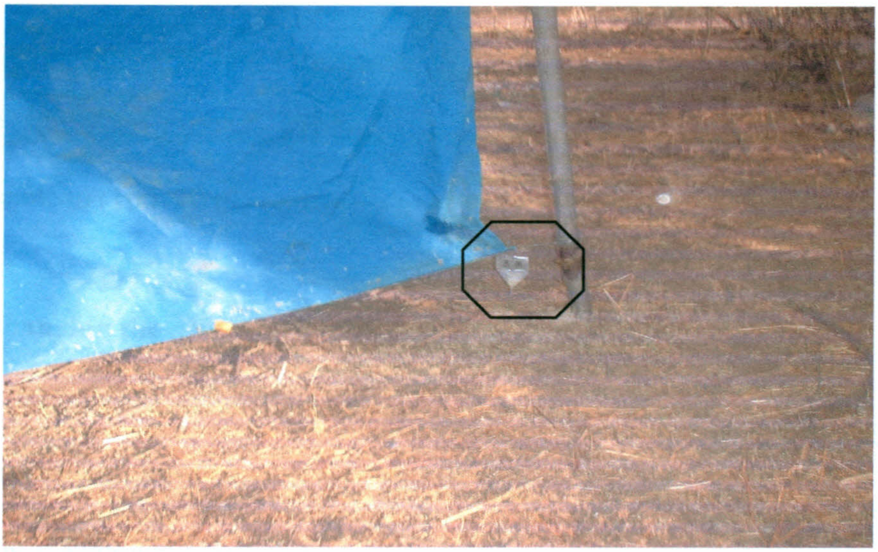


Plate 7.2: NG2G trap baited with aldehydes dispensed from polyethylene sachet

7.2.5 Comparison of the attractiveness of different concentrations of aldehyde blends

Tsetse responses to four concentrations of the blends were investigated through a 6 x 6 Latin square experiment, replicated thrice. Concentrations of the blends used were: 0.4, 2, 10 and 50%, diluted in paraffin oil. The 6 traps were treated as follows: (1) aldehyde blend (0.4% concentration); (2) aldehyde blend (2%); (3) aldehyde blend (10%); (4) aldehyde blend (50%); (5) cow urine and acetone; and (6) unbaited trap (control). A 2 x 2 Latin square experiment, replicated four times was also conducted with two targets treated as follows: (1) aldehyde blend (100%); (2) un-baited target.

7.2.6 Enhancing the attractiveness of cow urine and acetone using aldehyde blends

To investigate possible enhancement of cow urine and acetone attractiveness by the blends, a 5 x 5 Latin square experiment, replicated 3 times was conducted. The five traps were treated as follows: (1) cow urine + acetone + aldehyde blend (100% concentration); (2) cow urine + acetone + aldehyde blend (50%); (3) aldehyde blend (100%); (4) aldehyde blend (50%); and (5) cow urine + acetone (control). Two separate 2 x 2 Latin square experiments, replicated four times were also carried out with targets treated as follows. First, (1) aldehyde blend (100%); (2) cow urine + acetone. Second, (1) cow urine + acetone + aldehyde blend (100%); (2) cow urine + acetone.

7.2.7 Enhancing the attractiveness of acetone using aldehyde blends

Effects of the aldehyde blends on acetone were investigated through a 5 x 5 Latin square experiment, replicated thrice. The treatments comprised of NG2G traps baited with: (1) acetone + aldehyde blend (100% concentration); (2) acetone + aldehyde blend (50%); (3) aldehyde blend (100%); (4) aldehyde blend (50%); and (5) acetone (control).

7.2.8 Data analysis

Daily tsetse catches (*n*) were subjected to normalization using $\log_{10}(n + 1)$ transformation prior to statistical analyses. Catches of males and females were analyzed separately. When the effect of treatment and sites were significant, differences among means were examined by Student-Newman-Keuls (SNK) test. For presentation, detransformed means have been reported, accompanied by their transformed means and standard errors. Mean catch with the test odour was expressed as a proportion of the detransformed mean control catch, to give an index of the effect of the test odour – referred as the 'catch index'. Statistical analyses were carried out using Procedure General Model (GENMOD) of SAS. The class effects included day, site and treatment, while model effects included total catches, females and males.

7.3 Results

In all experiments, greater numbers of female than male *G. pallidipes* were caught in both un-baited and baited NG2G traps and targets. However, the index of catch between the sexes was not significantly different. Owing to the low numbers of *G. longipennis*, *Tabanid* and *Stomoxys* spp, differences in their trap catch size were not subjected to statistical analysis. For reporting, cow urine and acetone has been termed 'CUA' while aldehyde blends as 'AB' followed by the respective concentration.

7.3.1 Comparison of the attractiveness of different concentrations of aldehyde blends

Aldehyde blends at 0.4 to 50% concentrations enhanced detransformed mean trap catches of both male and female *G. pallidipes* (Table 7.1). At 50% concentration, mean male and female *G. pallidipes* daily catches of 7.15 and 10.82, respectively, compared to 7.19 and 9.38, respectively for 10% were recorded. The difference was not significant ($\chi^2 = 0.66$; df = 1; p = 0.416). Male and female catches of 5.93 and 9.27, respectively recorded at 2% concentration were not significantly different from 5.78 and 8.79, respectively, recorded at 0.4% ($\chi^2 = 0.32$; df = 1; p = 0.569). Relative to the control, there were slight improvements of 3, 14, and 34% in total trap catches for *G. pallidipes* at 2%, 10% and 50% concentrations, respectively. There were no significant differences in trap catches between the four concentrations ($\chi^2 = 0.58$; df = 1; p = 0.446). Thus, there was no clear evidence that the highest concentration (50%) was more effective than the lowest (0.4%).

For both male and female *G. pallidipes*, the four concentrations, did not perform significantly better than the control, with no odour ($\chi^2 = 2.37$; df = 1; p = 0.124). However, CUA caught significantly more flies (2.7 times) than the control ($\chi^2 = 30.59$; df = 1; p <0.0001) or the blends ($\chi^2 = 48.79$; df = 1; p <0.0001).

Table 7.1: The mean catches and catch indices of *Glossina pallidipes* in NG2G traps baited with different concentrations of aldehyde blends

Treatment	Males ($n = 18$)		Females ($n = 18$)		Total catch ($n = 18$)	
	Mean	Catch index	Mean	Catch index	Mean	Catch index
AB (50%)	7.15a (0.85±1.37)	1.24	10.82a (1.03±1.41)	1.20	17.13a (1.23±1.40)	1.34
AB (10%)	7.19a (0.86±1.37)	1.24	9.38a (0.97±1.46)	1.04	14.59a (1.16±1.47)	1.14
AB (2%)	5.93a (0.77±1.36)	1.03	9.27a (0.97±1.41)	1.03	13.29a (1.12±1.45)	1.03
AB (0.4%)	5.78a (0.76±1.36)	1.00	8.79a (0.94±1.42)	0.98	12.85a (1.11±1.44)	1.00
Cow urine + acetone	16.05b (1.21±1.33)	2.79	19.34b (1.29±1.40)	2.15	34.19b (1.53±1.39)	2.67
Unbaited trap	5.76a (0.76±1.40)	1.00	8.98a (0.95±1.47)	1.00	12.81a (1.11±1.49)	1.00

AB – Aldehyde blends (concentration)

The catch index is the detransformed mean catch of tsetse expressed as the proportion of the catch from un-baited electric targets (control); Means in each column followed by the same letter are NOT significantly different from unity ($P > 0.05$; SNK test); Numbers in parentheses show transformed means ± standard error (SE); n = sample size.

7.3.2 Enhancing the attractiveness of cow urine and acetone using aldehyde blends

To determine whether the combination of CUA and AB would produce a greater enhancement in catches, CUA was combined with AB 100% or AB 50%. For both male and female *G. pallidipes*, the highest detransformed total mean catches (140.62) were recorded with the combination of CUA with AB 100% (Table 7.2). However, these catches were not significantly higher than those from CUA with AB 50% (115.54) ($\chi^2 = 2.22$; df = 1; p = 0.136) or the control (114.91) ($\chi^2 = 3.96$; df = 1; p = 0.065). Total catches with AB 100% (46.08) were not significantly greater than AB 50% (43.88) ($\chi^2 = 0.24$; df = 1; p = 0.624). However, these catches were significantly lower than CUA with AB 100% ($\chi^2 = 35.54$; df = 1; p <0.0001), CUA with AB 50% ($\chi^2 = 22.04$; df = 1; p <0.0001) or the control ($\chi^2 = 16.91$; df = 1; p <0.0001).

Relative to the control, for CUA with AB 100%, an increase of 11 and 25%, in trap catches was observed for male and female *G. pallidipes*, respectively. This translated to an increase of 22% in total fly catches. While for CUA with AB 50%, total fly catches increased by 1%. Both concentrations (100 and 50%) of the blends when dispensed alone had indices (0.38 and 0.40), respectively, less than the control.

7.3.3 Enhancing the attractiveness of acetone using aldehyde blends

To determine whether the combination of acetone and AB would record increased catches, acetone was combined with AB 100% or 50%. There was little effect of AB (both 100 and 50%) either on its own, or in combination with acetone. For both male and female *G. pallidipes*, the combination of acetone with AB 100% recorded total catches of 76.32 (Table 7.3). This was not significantly higher than the control (71.88) ($\chi^2 = 1.47$; df = 1; p = 0.225) or acetone with AB 50% (70.34) ($\chi^2 = 1.45$; df = 1; p = 0.229). However, these catches were significantly greater than those of AB 100% (34.46) ($\chi^2 = 33.62$; df = 1; p <0.0001) or AB 50% (22.72) ($\chi^2 = 22.47$; df = 1; p <0.0001). Total catches were not significantly different between AB 100% and AB 50% ($\chi^2 = 1.21$; df = 1; p = 0.271).

Table 7.2: The mean catches and catch indices of *Glossina pallidipes* in NG2G traps baited with cow urine, acetone, and aldehyde blends

Treatment	Males ($n = 15$)		Females ($n = 15$)		Total catch ($n = 15$)	
	Mean	Catch index	Mean	Catch index	Mean	Catch index
CUA + AB (100%)	30.11a	1.11	109.05a	1.25	140.62a	1.22
	(1.48±1.25)		(2.04±1.21)		(2.15±1.21)	
CUA + AB (50%)	19.84a	0.73	92.17a	1.06	115.54a	1.01
	(1.30±1.36)		(1.96±1.26)		(2.06±1.26)	
AB (100%)	8.55b	0.31	38.52b	0.44	46.08b	0.40
	(0.93±1.28)		(1.59±1.26)		(1.66±1.27)	
AB (50%)	8.64b	0.32	37.20b	0.43	43.88b	0.38
	(0.94±1.36)		(1.57±1.40)		(1.64±1.42)	
Cow urine + acetone	27.18a	1.00	87.03a	1.00	114.91a	1.00
	(1.43±1.18)		(1.94±1.17)		2.06 ± 1.16	

CUA – Cow urine and acetone; AB – Aldehyde blends (concentration)

The catch index is the detransformed mean catch of tsetse expressed as the proportion of the catch from un-baited electric targets (control); Means in each column followed by the same letter are NOT significantly different from unity (P >0.05; SNK test); Numbers in parentheses show transformed means ± standard error (SE); *n* = sample size.

7.3.4 Effect of aldehyde blends on tsetse catches using electric targets

Baiting blue-black electric targets with aldehyde blends (50% concentration) did not increase the *G. pallidipes* catch significantly. Electric targets baited with the blends had a detransformed total mean catch of 126.14 compared with 116.18 for an un-baited target (Table 7.4). These were not significantly different (χ^2 = 0.21; df = 1; p = 0.649). Detransformed total mean catch for the blends combined with cow urine and acetone

(532.88) were not significantly higher than cow urine and acetone alone (487.59) ($\chi^2 = 0.60$; df = 1; p = 0.438). Dispensing the blends alone increased total catches by 9%, but when dispensed with cow urine and acetone the catch increased by 4.6 times. However, this was not significantly different from cow urine and acetone alone (4.2x) (p >0.05).

Table 7.3: The mean catches and catch indices of *Glossina pallidipes* in NG2G traps baited with acetone, and aldehyde blends

	Males ($n = 15$)		Females ($n = 15$)		Total catch ($n = 15$)	
Treatment	Mean	Catch index	Mean	Catch index	Mean	Catch index
Acetone+ AB (100%)	21.19a (1.33±1.27)	1.07	54.22a (1.73±1.23)	1.05	76.32a (1.88±1.23)	1.06
Acetone + AB (50%)	19.01a (1.28±1.25)	0.96	50.65a (1.70±1.20)	0.98	70.34a (1.85±1.21)	0.98
AB (100%)	7.59b (0.88±1.32)	0.38	25.97b (1.41±1.32)	0.50	32.46b (1.51±1.33)	0.45
AB (50%)	4.45b (0.65±1.24)	0.22	18.70b (1.27±1.28)	0.36	22.72b (1.36±1.27)	0.32
Acetone	19.80a (1.30±1.24)	1.00	51.43a (1.71±1.21)	1.00	71.88a (1.86±1.21)	1.00

AB – Aldehyde blends (concentration)

The catch index is the detransformed mean catch of tsetse expressed as the proportion of the catch from un-baited electric targets (control); Means in each column followed by the same letter are NOT significantly different from unity (P >0.05; SNK test); Numbers in parentheses show transformed means ± standard error (SE); n = sample size.

Table 7.4: The mean catches and catch indices of *Glossina pallidipes* in electric targets baited with cow urine, acetone and aldehyde blends

Treatment	Males ($n = 8$)		Females ($n = 8$)		Total catch ($n = 8$)	
	Mean	Catch index	Mean	Catch index	Mean	Catch index
Un-baited target	45.17a	1.00	69.81a	1.00	116.18a	1.00
	(1.65±1.26)		(1.84±1.15)		(2.07±1.18)	
AB (50%)	59.40a	1.31	65.81a	0.94	126.14a	1.09
	(1.77±1.14)		(1.82±1.12)		(2.10±1.10)	
CUA + AB (50%)	235.04b	5.20	292.06b	4.18	532.88b	4.59
	(2.37±1.16)		(2.47±1.17)		(2.73±1.15)	
Cow urine + acetone	217.66b	4.82	265.66b	3.81	487.59b	4.20
	2.34±1.17		2.42±1.16		2.69±1.15	

CUA – Cow urine and acetone; AB – Aldehyde blends (concentration)

The catch index is the detransformed mean catch of tsetse expressed as the proportion of the catch from un-baited electric targets (control); Means in each column followed by the same letter are NOT significantly different from unity (P >0.05; SNK test); Numbers in parentheses show transformed means ± standard error (SE); *n* = sample size.

7.4 Discussion

Aldehyde blends failed to demonstrate statistically significant field activity following positive indications from the laboratory. Lack of close correspondence between EAG responses and field activity has previously been observed in behavioural studies. Studies by Den Otter *et al.* (1988) found that *G. morsitans morsitans*, *G. austeni*, *G. tachinoides* and *G. fuscipes fuscipes* all gave strong EAG responses to octenol and acetone. However, *G. tachinoides* showed little if any response to acetone in the field (Kupper *et al.*, 1991) and *G.*

fuscipes fuscipes was unresponsive to both substances. Bursell *et al.* (1988), Mwangelwa *et al.* (1991) and Green (1993) also observed positive responses in the laboratory to 2-methoxyphenol that was later confirmed to be a mild tsetse repellent in the field (Torr *et al.*, 1996). The conflicting results may reflect the fact that laboratory assays focus on a single element of behaviour, whereas trap or target catches depend on several interacting responses (Vale, 1982). The anemotactic flight induced by the aldehydes in the field might have been offset by response inhibitions once flies arrived near traps or targets. The failure to demonstrate field activity following positive indications from the laboratory could justify suspicions that field tests are not directed at the appropriate response of the fly or not performed against the right background of stimulation (Bursell *et al.*, 1988). For field experiments with odours, an appropriate way of measuring fly response must be used.

In the laboratory, the EAG and wind tunnel bioassay experiments were conducted using *G. morsitans morsitans* (Gikonyo *et al.*, 2002; 2003). However, the present field trials were carried out using *G. pallidipes*. Though both species are closely related savannah species (morsitans group), previous studies have indicated that they can at times respond differently to the same set of odour components (Green, 1994). The combinations of attractive odours to a visual target in Zimbabwe increased catches of *G. morsitans morsitans* by five times and *G. pallidipes* by 20 times (Vale *et al.*, 1988b). The selective effect of the repellency of humans is stronger with *G. pallidipes* than *G. morsitans morsitans* (Green, 1994). It might be possible that aldehyde blends are also less attractive to *G. pallidipes* but highly attractive to *G. morsitans morsitans.* However, it is difficult to explain why *G. pallidipes* is not attracted to a component of bovid odour (aldehydes) that is powerfully attractive to *G. morsitans morsitans* since bovids form an important part of the diet of both species (Glasgow, 1963). The innate olfactory uniqueness of each species might partly account for the observed failure of the aldehydes to induce attraction to *G. pallidipes*. For instance, although both species responded to heptenal, nonanal and decanal, *G. morsitans morsitans* and *G. pallidipes,* responded only to undecanal and nonenal, respectively (Gikonyo *et al.,* 2002).

Aldehyde blends either on their own or in combination with acetone and cow urine or acetone alone slightly increased *G. pallidipes* trap catches, although not significantly. This suggests that there is a small but positive effect on trap catches of this tsetse species. However, there is need to assess the aldehyde blends individually and in combination with known tsetse kairomones for attractiveness to *G. morsitans morsitans* and other savannah species (*G. austeni* and *G. swynnertoni*) under field conditions. Positive responses from other savannah tsetse to aldehydes might assist in improving control technologies, especially given the importance of odour baits in tsetse control.

CHAPTER EIGHT

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

8.1 GENERAL DISCUSSION

The present study evaluated the efficacy of synthetic repellent in protecting cattle against trypanosomosis, especially when integrated with baited traps in a 'push-pull' strategy. The results clearly demonstrated that protecting cattle with the tsetse repellent leads to significant reduction in trypanosomosis disease incidence and subsequently reduces trypanocidal drug use among households. This clearly confirms preliminary results of trials in Nguruman that synthetic repellent can provide substantial protection to cattle against trypanosomosis (Saini and Hassanali, 2003). The results also indicate that the repellent technology can be integrated with other existing tsetse control options such as baited traps in 'push-pull' strategies to enhance tsetse suppression rates and disease levels substantially. The current study also showed that livestock farmers preferred the easy to use repellent dispensers compared to other tsetse and trypanosomosis control options. The perceived benefits of repellents by farmers confirm results of the trial that showed that the repellent could provide substantial protection to cattle against trypanosomosis and also significantly reduce trypanocidal drug use within a herd.

Repellents, however, are not silver bullets for trypanosomosis control by the farmer. The advantage is that they can be integrated with other tsetse and trypanosomosis control technologies. In addition, its properties, as perceived by most livestock keepers, make it very attractive to the farmer. The repellent being a ready to use formulation is rather convenient to use by livestock owners. Unlike synthetic insecticides and some pour-ons, the repellent does not require a plentiful and guaranteed supply of water, spray equipment and dip tanks. Synthetic repellent is also a 'private' good (an item a farmer can buy to repel flies from his/her cattle). Furthermore, repellents do not require collective communal action as a farmer can decide to use the technology alone. Thus, repellent technology is more of an individual responsibility unlike baited traps, which require the participation of other livestock keepers. Similar to trypanocidal drugs, farmers could eventually buy the repellent from local shops and use them to protect animals in an area-wide control approach. Livestock keepers also showed their willingness to pay for the repellent and hence its commercial viability and sustainability would be guaranteed, as there will be sufficient incentive to ensure that the private sector continues to invest, produce and supply it.

The repellent is most suited for pastoralist communities often among the poorest that depend on transhumance to maintain their livestock, since most being mobile, the animal carries repellent dispensers wherever it goes and is protected at all times. Once commercially available, the repellent can be packaged in minute quantities and made available in the smallest and most remote local shops and sold as an over the counter (OTC) product. They can also be promoted as a marketable synthetic compound that can be locally produced and serve as a business enterprise for local farmers. The repellent is environmentally safe and unlike some pour-ons, would not have undesirable effects on non-target insects such as the dung fauna (Vale *et al.,* 1999; Vale and Grant, 2002; Vale *et al.,* 2004). Unlike topical insecticides applied to host animals to reduce incidences of insect bites, efficacy of the repellent cannot be greatly reduced by exposure to water or rainfall after an application or by cattle moving through vegetation that brushes off the chemical. The repellent may also be effective against other groups of biting flies such as the Tabanidae and *Stomoxys* spp, which mechanically transmit trypanosomes (Saini and Hassanali, 2003).

The use of synthetic repellent for trypanosomosis control is expected to substantially reduce trypanocidal drug use by farmers in the area. The advantages of reduced use of trypanocides are numerous, including lower production costs at farm level. In addition, it could decrease the danger of drug-resistant trypanosome strains from developing (Geerts and Holmes, 1998) and the threat of losing trypanocides as the only available treatment option for trypanosomosis. Kwale District is reportedly one of the areas in Kenya with the highest trypanocidal drug resistance (Mugunieri and Murilla, 2003). Results from the cross-sectional survey in Kwale District confirmed that trypanocidal drugs were readily available in the area. Farmers had adopted a curative and protective treatment strategy and applied trypanocides to animals that were clinically ill, usually without confirmed diagnosis. In view of the widespread and indiscriminate use of trypanocides, it may only be a matter of time before multi-chemo-resistance makes it impossible to control animal trypanosomosis in the area. In the presence of multi-drug resistance in the area, it would not be possible to eliminate all infections; a possible approach to alleviate the problem would be to reduce tsetse challenge. Tsetse control by repellents would become an integral part of a campaign against animal trypanosomosis if the frequency of trypanocidal treatments were to be reduced.

Synthetic repellent can be dispensed by the easy to use and portable repellent collars made of local materials. However, during the trial, it was observed that most of the prototype repellent dispensers were prone to abrasions and tensions, especially at the point of diffusion. Most of the damage recorded involved loss of silicon tygon tube, stoppers and at times loss of the whole dispenser. Overall, approximately 20% of the cattle were not adequately protected with repellents due to the foregoing encountered problems with the prototype dispensers. Farmers also perceived leakage and loss of dispensers as the major constraint to the repellent technology.

The present results indicate that over the intervention period, 'push-pull' is slightly better than 'push' or 'pull'. This contrasts with previous trials to control tsetse and trypanosomosis in Africa using integrated techniques, which clearly demonstrated that combining different methods might yield greater benefits than a single method (Kamuanga, 2003). For example, integrated control of tsetse and trypanosomosis by treating cattle with insecticides, in addition to deployment of insecticide-impregnated targets proved successful in two previous campaigns in Burkina Faso (Bauer *et al.,* 1999; Kamuanga *et al.,* 2001). The efficacy of this method has also been confirmed in Uganda, where in addition to insecticide-treated pyramidal traps, deltamethrin pour-on was applied to cattle (Magona *et al.,* 2000). Reasons for the low performance of repellents when integrated with baited traps in the present trial could be manifold. For instance, this could be attributed to nearly 50% of the traps not working properly due to theft, vandalism or destruction by wildlife, fire or livestock and to the rapid fading of blue and black colours of the cloth material. There may have been pockets of *G. pallidipes* not caught as a result of lower density of traps in some areas. The numerous problems encountered with baited traps in the area could be reinforced by observations that farmers in Kwale District generally do not prefer baited traps for tsetse and trypanosomosis control. This could be attributed to some of the constraints of trapping technology as discussed by Allsopp (1999). For example, traps are generally labour intensive and also require constant monitoring, maintenance and servicing. Furthermore, they are prone to theft, vandalism and destruction by natural calamities or wildlife. Since individual farmers own different numbers of livestock, they will expect varying levels of benefit from their input on trapping. Tsetse control would also not affect other livestock diseases; consequently it would be difficult to maintain farmers' co-operation. As observed by Leonard (1993), most individual farmers are also not interested in contributing towards a 'public' good such as traps. Baited traps could however, rapidly reduce animal trypanosomosis as long as their use is ensured by external financial resources or continuously subsidized. The difficulty of detecting low populations of *G. austeni* and *G. breviplapis* due to lack of appropriate and efficient monitoring traps hinders the objective interpretation of entomological results. For efficient tsetse monitoring an appropriate standard sampling tool must be used (Green, 1994). The recently developed H-trap (Kappmeier and Nevill, 2000) could be used to monitor and control *G. austeni* and *G. breviplapis* in the area. Since some parts of Kwale District are typically semi-arid, hence, during the dry season, some cattle herds moved to tsetse infested areas outside the site with baited traps in search of fresh pasture and water and this was not easy to solve.

Another problem was mixing of herds when cattle protected with synthetic repellent came in contact with other unprotected livestock complicating the interpretation of changes in trypanosomosis incidence. In view of the high level of trypanosomal drug resistance and the relapse of infections, cattle in the area could remain infected despite treatment. Synthetic repellent so far has been shown to work only for the savannah tsetse species *G. pallidipes* and *G. morsitans.* However, its efficacy against *G. austeni,* a species with the highest vectorial capacity in the coastal region of East Africa (Moloo, 1993) is not well known. Further trials are required to test synthetic repellent against other important savannah tsetse species (*G. austeni* and *G. swynnertoni*) and in different ecological regions. The repellent also needs to be evaluated and optimized for riverine tsetse (*G. fuscipes fuscipes* and other *palpalis* species) to provide new arsenal for protection of humans and vectors of human sleeping sickness. It is envisaged that repellents could enhance suppression rates and will break the disease link, blocking access of vectors to humans. Regardless of these limitations, the use of the repellent integrated with traps could still achieve significant reduction in tsetse population and trypanosomosis incidence to a negligible level if the problems associated with baited traps and prototype repellent dispensers could be minimized. A part from using the baited traps, there is also need to evaluate a variant of the 'push-pull' technology, which involves the use of baited insecticide treated targets or a proportion of cattle herds treated with insecticide pour-ons to act as the 'pull' component.

The synthetic repellent used in the present study is a laboratory product and the synthetic compounds are currently available only in small quantities. One litre of the repellent costs about US $ 250, while a prototype dispenser costs US $ 5 per cow. It is envisaged that in partnership with the private sector, large-scale production could reduce the costs of both the repellent and dispensers to sufficiently low price that can compete effectively with insecticides, pour-ons or trypanocides. As observed by the Department for International Development-Animal Health Programme (DFID-AHP) (2004) for the cost of synthetic pour-ons, the cost of repellents can also be reduced to a level that makes it affordable to poor livestock farmers. Even 1-octen-3-ol, a tsetse attractant, was very expensive initially. However, following large-scale production, its cost reduced drastically to a level where it could be used effectively and economically as olfactory bait in tsetse control programmes (DFID-AHP, 2004).

One of the possible ways of reducing the costs of repellents use within a herd is to only protect portion of a herd. This is due to the diffusion properties of the volatile repellents as a result of which untreated cattle in proximity to treated ones are also protected. Livestock farmers can therefore choose to only protect those animals that are more attractive to tsetse bites. However, this will depend on what the farmer wants to achieve and the magnitude of infection within a herd. The general trend has shown that tsetse tend to feed on larger and/ or older animals (Torr *et al.,* 2006; 2007), so young livestock can be left unprotected. Provided the largest animals, on which the majority of tsetse will feed, are protected with repellents, the cost of effective tsetse control can be reduced while maintaining overall protection of the herd. During the household surveys, livestock farmers ranked oxen, lactating and expectant cows as the most important cattle groups for protection with repellents. Protecting these groups within a herd by repellents might reduce the overall cost of repellent treatment. In Zimbabwe, it was observed that restricted application of insecticides to some 'parts' (mostly belly and legs) of an animal could offer the same level of protection as 'whole' body treatments (Torr *et al.,* 2006). This reduced the cost of insecticide treatments from 50 cents a cow to 5 cents or less. Both commercial and small-scale livestock farmers seemed to be quite comfortable with the approach (DFID-AHP, 2004). Based on this approach, further reduction in both costs and usage of synthetic repellent can also be achieved by only protecting selected 'parts' (mostly the most 'treasured' or preferred cattle groups) of the 'whole' herd.

Although synthetic repellent significantly reduces tsetse challenge and feeding efficiency on cattle by more than 80% (Saini and Hassanali, 2007), experiments on the comparison of natural waterbuck repellent blend (WRB) and synthetic repellents indicated that the natural repellent blend was more potent than the synthetic one (Kipchumba, 2007). Underlying rationale for a blend based repellent technology rather than one based on a single synthetic component is that a blend is likely to minimize or eliminate the possibility of the development of resistance through continued use, which would be expected with a single component compound. The natural repellent blend may therefore enhance and/ or augment the potency of the synthetic repellent, or provide a more effective alternative as a component of 'push'. The natural repellent blend compounds being relatively cheap and easily available than synthetic repellent might make the blend more accessible and affordable to really poor livestock farmers, following large-scale production. However, the optimization of the WRB for trypanosomosis control in the field has been hindered by lack of an effective dispensing unit. There is need to continue conducting more experiments aimed at improving the potency of both synthetic repellent and the natural repellent blend. Further studies should also be carried out to identify additional and more potent tsetse allomones from unpreferred tsetse hosts or any other potential sources. These would enhance substantially the efficiency of the 'push' component.

Trials to increase the potency of the current tsetse attractant blends (pull component), indicated that aldehyde blends alone or in combination with acetone and cow urine or acetone alone slightly increased trap catches of *G. pallidipes*, although not significantly. Since the aldehydes seemingly are unlikely to improve the effectiveness of the 'pull' component, more studies should focus in identifying additional attractants from preferred savannah tsetse hosts. These could then be checked either individually or as blends in combination with known tsetse kairomones. Development of additional attractants will allow for enhancing substantially the efficiency of the 'pull' component (traps or targets) and open up the possibility of dramatic reduction of the tsetse population.

8.2 CONCLUSIONS

1. During the cross-sectional survey, livestock keepers in Kwale District considered livestock diseases; trypanososis, anaplasmosis, East Coast fever and foot-and-mouth disease to be the major constraints to livestock production in the area. Trypanosomosis was the most important compared to other diseases. Chemotherapy was the most widely used method of controlling the disease. Farmer-based tsetse and trypanosomosis control strategies were poorly adopted. Most farmers demonstrated awareness about trypanosomosis, its clinical symptoms, aetiology and correct treatment and control measures.

2. Survey of the epidemiology of cattle trypanosomosis in Kwale District indicated that, three tsetse species, *Glossina austeni*, *G. brevipalpis* and *G. pallidipes* were present, the latter being the most common. Two trypanosome species, *Trypanosoma congolense* and *T. vivax* were found in cattle, with the former being more prevalent. Infection prevalences in cattle varied between 0 and 25% (mean: 18%).

3. Cattle protected with repellents and grazing in an area with baited traps (push-pull) showed significant reduction in trypanosomosis disease incidences, compared to cattle protected with repellents only (push) or those grazing in areas with traps only (pull). This clearly confirms that repellents can provide substantial protection to cattle against trypanosomosis.

4. In sites with repellents (push) or baited traps (pull) or both (push-pull), there was significant reduction in tsetse population and trypanocidal drug use within households.

In addition, there were significant improvements in cattle body weight, body condition, mean packed cell volume levels and household's herd size compared to the controls.

5. Cattle protected with repellents (push) or grazing in areas with baited traps (pull) or both (push-pull) were upto three times less likely to be infected with trypanosomes than unprotected cattle (control).

6. 'Push-pull' tactic might be a more effective way of reducing tsetse populations, trypanosomosis disease incidences and trypanocidal drug use and improving herd health, productivity and performance compared to 'push' or 'pull'.

7. Most livestock farmers considered significant reductions in trypanocidal drug use, disease incidence and tsetse population to be the most important benefits of repellents and traps. Additional benefits included: quieter grazing, protection of goats, improved body condition; increased draught power and opening up of previously avoided fields for grazing and crop production. The most attractive attribute of repellents was its individualistic nature, simplicity and mobility (cattle move with repellent dispensers wherever they go).

8. All livestock farmers preferred repellents to traps for tsetse and trypanosomosis control. Majority of livestock farmers preferred repellents or traps or both to the other current methods (pour-ons, drugs etc.) of tsetse and trypanosomosis control.

9. Predominant challenges with repellent technology were the loss of dispenser stoppers, cutting of silicon tubing and unfastening of waistbands from cattle necks. Major

problems with traps were weak netting material, rapid fading of cloth material, theft and vandalism.

10. The acceptance and adoption of repellents and baited traps is likely to be higher among the *Kamba* ethnic group and livestock farmers with more experience in rearing livestock.

11. The results obtained from the repellent trials and household questionnaires clearly indicated that repellents and baited traps could significantly reduce drug use, disease incidence and tsetse population culminating in improved herd health and productivity. This clearly confirmed the strong findings on major positive impacts of repellents or baited traps or both for tsetse and trypanosomosis control.

12. Aldehyde blends when combined with cow urine and/or acetone had a slight but positive effect on the trap catches of *Glossina pallidipes* in the field.

8.3 RECOMMENDATIONS

1. The efficacy of repellent technology and the 'push-pull' strategy need to be further refined and optimized especially through large-scale field trials. Long-term studies are also needed to quantify the impact of repellent technology on livestock productivity that would result from adoption of the strategy by pastoralists, agro-pastoralists and ranchers in tsetse infested areas of Africa.

2. The repellent prototype dispenser needs to be refined, modified and optimized to make it more durable and stable for long-term use in the field.

3. The efficacy of the repellent needs to be investigated on the other economically important savannah (*G. morsitans, G. austeni* and *G. swynnertoni*), riverine (*G. fuscipes fuscipes*) tsetse species and the biting flies (tabanids and *Stomoxys* spp).

4. There is need to conduct further studies to elucidate the mechanisms by which repellents would protect livestock in areas with plenty of wildlife hosts, in scenarios where tsetse population is relatively high and in areas with different herder conditions (pastoral, agro-pastoral and ranches).

5. Training the community on disease diagnosis, trypanocidal drug use, trapping and repellent technology and community involvement need to be strengthened. This would reduce misuse of trypanocidal drugs and also reduce trap theft, destruction or vandalism.

6. The synthetic repellent and the natural waterbuck repellent blend should be further modified to provide protection to humans against tsetse fly bites.

7. There is need to determine the efficacy of the natural waterbuck repellent blends in reducing tsetse challenge, trypanocidal drug use and trypanosomosis prevalence and incidence.

8. Studies are needed to assess the aldehydes individually and as blends in combination with known tsetse kairomones for attractancy to other savannah tsetse (*G. morsitans, G. austeni* and *G. swynnertoni)* under field conditions. More work is also needed to identify better attractive baits for enhanced attractiveness of the 'pull' component.

REFERENCES

Abebe, G. and Eley, R.M. (1992). Trypanosome-induced hypothyroidism in cattle. *Br. Vet.* J. **148**, 63-70.

Abebe, G. and Jobre, Y. (1996). Trypanosomosis: A threat to cattle production in Ethiopia. *Rev. Med. Vet.* **147**, 897-902.

Abebe, G., Shaw, M.K. and Eley, R.M. (1993). *Trypanosoma congolense* in the microvasculature of the pituitary gland of experimentally infected Boran cattle (*Bos indicus*). *Vet. Pathol.* **30**, 401-409.

Abel, P.M., Kiala, G., Loa, V., Behrend, M., Musolf, J., Fleischmann, H., Theophile, J., Krishna, S. and Stich, A. (2004). Retaking sleeping sickness control in Angola. *Trop. Med. Int. Health.* **9**,141-148.

Afewerk, Y., Clausen, P.H., Abebe, G., Tilaum, G. and Mehlit, D. (2000). Multiple drug resistant *Trypanosoma congolense* populations in village cattle of Metekel District, north-west Ethiopia. *Acta Trop.* **76**, 231-238.

Allsopp, R. (1999). The implementation of odour bait techniques for the control of tsetse flies in eastern and southern Africa. *Proceedings of the 24th Meeting of the International Scientific Council for Trypanosomosis Research and Control (ISCTRC),* Maputo, Mozambique, 1997. **119**, 411- 426.

Anosa, V.O. and Obi, T.U. (1980). Haematological studies on domestic animals in Nigeria. The effects of age, breed and haemoglobin type on bovine haematology and anaemia. *Vet. Med.* **27**, 773-788.

Barrett, J.C. (1997). Economic issues in trypanosomiasis control. NRI Bulletin 75. Chatham, UK, National Resources Institute.

Barrett, K. and Okali, C. (1999). Partnership for tsetse control – community participation and other options. *Proceedings of the 24th Meeting of the ISCTRC,* Maputo, Mozambique, 1997. **119**, 451-461.

Bauer, B. and Snow, W.F. (1999). Sustainable integrated disease management for the control of African animal trypanosomosis: Experiences in West Africa. *Programme Against African Trypanosomiasis (PAAT) Technical and Scientific Series*. Food and Agricultural Organization of the United Nations (FAO). Rome, Italy.

Bauer, B., Amsle-Delafosse, S., Clausen, P-H. and Petrich-Bauer, J. (1995). Successful application of deltamethrin pour-on to cattle in campaign against tsetse flies in the pastoral zone of Burkina Faso. *Trop. Med. Parasitol*. **46,** 183-189.

Bauer, B., Amsler-Delafosse, S., Kabore, I. and Kamuanga, M. (1999). Improvement of cattle productivity through rapid alleviation of African animal trypanosomosis by integrated disease management practices in the agro pastoral zone of Yale, Burkina Faso. *Trop. Anim. Health Prod.* **31**, 89-102.

Bembridge, T.J. (1991). The Practice of Agricultural Extension – A Training Manual. Development Bank of South Africa, Halfway House. 195 – 225.

Blanc, F., Gouteux, J.P., Cuisance, D., Le Masson, A., N_dokoue, F., Mainguet, M., D_Amico, F. and Le Gall, F. (1991). La lutte par pi´egeage contre *Glossina fuscipes* pour la protection de l_ ´elevage en RCA. III. Vulgarisation en milieu Mbororo. *R´evue d'Elevage et de M´edecine V´et´erinaire des Pays Tropicaux*. **44**, 301–307.

Blood, D.C., Radostits, O M. and Henderson, J.A. (1989). Diseases caused by protozoa. A textbook of the diseases of cattle, goats and horses. 7th Edition. Oxford ELBS, United Kingdom.

Bourn, D., Maitima, J., Motsamai, B., Blake, R., Nicholson, C. and Sundstol, F. (2005). Livestock and environment. Chapter 9. In: *Livestock and Wealth Creation: Improving the Husbandry of Animals Kept by Resource-Poor People in Developing Countries*. Nottingham University Press.

Brady, J. (1972). Spontaneous circadian components of tsetse fly activity. *J. Insect Physiol.* **18**, 471-484.

Brightwell, R., Dransfield, R.D. and Kyorku, C. (1991). Development of a low-cost trap and odour baits for *Glossina pallidipes* and *Glossina longipennis* in Kenya. *Med. Vet. Entomol.* **5**, 153-164.

Brightwell, R., Dransfield, R.D., Kyorku, C., Golder, T.K., Tarimo, S.A. and Mungai, D. (1987). A new trap for *Glossina pallidipes*. *Trop. Pest Management.* **33**, 151-159.

Brightwell, R., Dransfield, R.D., Maudlin, I., Stevenson, P. and Shaw, A. (2001). Reality vs. rhetoric – a survey and evaluation of tsetse control in East Africa. *Agric. Human Values.* **18**, 219-233.

Brightwell, R., Dransfield, R.D., Stevenson, P. and Williams, B. (1997). Changes over twelve years in populations of *Glossina pallidipes* and *Glossina longipennis* (Diptera: Glossinidae) subject to varying trapping pressure at Nguruman, south-west Kenya. *Bull. Entomol. Res.* **87**, 349–370.

Budd, L. (1999). "Volume 2: economic analysis". In: *DFID-funded Tsetse and Trypanosome Research and Development since 1980*. Chatham: Department for International Development (DFID): Livestock Production, Animal Health and Natural Resources Systems Programmes.

Bursell, E. (1984). Observations on the orientation of tsetse *Glossina pallidipes* to wind borne odours. *Physiol. Entomol.* **9**, 133-139.

Bursell, E., Gough, A.J.E., Beevor, P.S., Cork, A., Hall, D.R. and Vale, G.A. (1988). Identification of components of cattle urine attractive to tsetse flies, *Glossina* spp. (Diptera: Glossinidae). *Bull. Entomol. Res.* **78**, 281-291.

Catley, A., Irungu, P., Simiyu, K., Dadye, J., Mwakio, W., Kiragu, J. and Nyamwaro, S.O. (2002). Participatory investigations of bovine trypanosomosis in Tana River District, Kenya. *Med. Vet. Entomol.* **16**, 55-66.

Catley, A and Leyland, T. (2001). Community participation and the delivery of veterinary services in Africa. *Prev. Vet. Med.* **49,** 95-113.

Chambers, R. (1992). *Rural Appraisal: Rapid, Relaxed, and Participatory*. Institute of Development Studies Discussion Paper 311. Sussex: HELP.

Challier, A., Eyraud, M., Lafaye, A. and Laveissière, C. (1977). Amélioration du rendement du piège biconique pour glossines (Diptera, Glossinidae): par l'emploi d'un cône inférieur bleu. *Cahiers ORSTOM, séries Entomologie médicale et Parasitologie*. **15,** 283-286.

Clausen, P.H., Adeyemi, I., Baver, B., Breloeer. M., Salchow, F. and Staak, C. (1998). Host preferences of tsetse flies (Diptera: Glossinidae) based on bloodmeal identifications. *Med. Vet. Entomol.* **12**, 169-180.

Clausen, P.-H., Waiswa, C., Katunguka-Rwakishaya, E., Schares, G., Steuber, S. and **Mehlitz, D.** (1999). Polymerase chain reaction and DNA probe hybridization to assess the efficacy of diminazene treatment in *Trypanosoma brucei*-infected cattle. *Parasitol. Res.* **85,** 206-211.

Coetzer, J.A.W., Thomson, G.R. and Tustin, R.C. (1994). Infectious diseases of the livestock. Cape Town: Clyson press, Maitland, South Africa.

Connor, R.J. (1994). African Animal Trypanosomosis. In; Coetzer, J.A.W., Thomson, G.R. and Tustin, R.C (Eds.), *Infectious Diseases of Livestock with Special Reference to Southern Africa*, Oxford University Press, Cape Town. 166-203.

Cross, G.A.M. (1978). Antigenic variation in trypanosomes. *Proceedings of the Royal Society of London* (B). **202**, 55-72.

Cuisance, D. (1989). Le piegeage des tsetse. *Etudes et Syntheses de lIEMVT,* 32, IEMVT, Paris, 172 pp.

Deem, S.L., Perry, B.D., Katende, J.M., McDermott, J.J., Mahan, S.M., Maloo, S.H., Morzaria, S.P., Musoke, A.J. and Rowlands, G.J. (1993). Variations in prevalence rates of tick-borne diseases in zebu cattle by agro-ecological zone: Implications of East Coast fever immunization. *Prev. Vet. Med.* **16**, 171-187.

Den Otter, C.J., Tchicaya, T., and Van den Berg, M.J. (1988). Olfactory sensitivity of five species of tsetse (*Glossina* spp.) to 1-octen-3-ol, 4-heptanone, 3-nonanone and acetone . *Insect Sci. Appl.* **9**, 213 218.

Department for International Development-Animal Health Programme (DFID-AHP). (2004). Recent advances in livestock keeper-based tsetse control: the way forward. Report of a workshop organized by the DFID Animal Health Programme, held in Nairobi, Kenya, October 2003. 68 pp.

D'Ieteren, G.D.M. (1993). Trypanotolerant livestock, a sustainable option for increasing livestock production in tsetse affected areas. In. *Towards Increasing Use of Trypanotolerance, Current Research and Future Directions*. Proceedings of a workshop organized by The International Laboratory for Research on Animal Diseases (ILRAD) and International Livestock Centre for Africa (ILCA). Nairobi, Kenya, pp 3-11.

D'Ieteren, G.D.M., Authié, E., Wissocq, N. and Murray, M. (1998). Trypanotolerance, an option for sustainable livestock production in areas at risk from trypanosomosis. *Revue Scientifique et Technique*. **17**, 154-175.

Doran, M. (2000). Socio-economics of trypanosomosis. Implications for control strategies within the common fly-belt of Malawi, Mozambique, Zambia and Zimbabwe. Bovine trypanosomosis in Southern Africa. Vol. 3. Harare, Zimbabwe, Regional tsetse and trypanosomosis control project for Southern Africa. 156 pp.

Dransfield, R.D., Brightwell, R., Chaudhury, M.F., Golder, T.K. and Tarimo, S.A.R. (1986). The use of odour attractants for sampling *Glossina pallidipes* Austen (Diptera: Glossinidae) at Nguruman, Kenya. *Bull. Entomol. Res.* **76**, 607-619.

Dransfield, R.D., Williamson, B.G. and Brightwell, R. (1990). Control of tsetse fly (Diptera: Glossinidae) population using traps at Nguruman, south-west Kenya. *Bull. Entomol. Res*. **80**, 265-276.

Echessah, P.N., Swallow, B.M., Kamara, D.W. and Curry, J.J. (1997). Willingness to Contribute labour and money to tsetse control: application of contingent valuation in Busia District, Kenya. *World Development*. **25**, 239-253.

Eisler, M.G., Torr, S.J., Coleman, P.G., Machila, N. and Morton, J.F. (2003). Integrated control of vector-borne diseases of livestock-pyrethroids: panacea or poison. *Trend. Parasit*. **19**, 341-345.

Ellis-Jones, J and Whitmore, A. (2004). Animal power for crop production: new tillage or no tillage Benefits and challenges in sub Saharan Africa. World Association for Transport Animal Welfare Studies (TAWS), Silsoe Research Institute, UK. pp 1-5.

Erkelens, A.M., R.H. Dwinger, Bedane, B., Wint, W. and Slingenbergh, J.W. (2000). Selection of priority areas for tsetse control in Africa; A decision tool using global information systems (GIS) in Didesa Valley, Ethiopia as a pilot study. In: *Animal Trypanosomosis Diagnosis and Epidemiology*. Backhuys publisher, Netherlands.

Fairlamb, A.H. (2003). Chemotherapy of human African trypanosomosis: current and future prospects. *Trend. Parasit.* **19**, 488-494.

Feldman, U and Hendricks, J. (2001). Integrating the sterile insect technique as a component of area wide tsetse and trypanosomosis intervention. *PAAT Technical and Scientific Series*. FAO, Rome, Italy.

Fèvre, E.M., Picozzi, K., Fyfe, J., Waiswa, C., Odiit, M., Coleman, P.G. and Welburn, S.C. (2005). A burgeoning epidemic of sleeping sickness in Uganda. *The lancet.* **366**, 745-747.

Findlay, G.M., Hardwicke, J. and Phelps, R.J. (1946). Tsetse fly repellents. *Trans. Royal Soc. Trop. Med. Hyg.* **40**, 341-344.

Flint, S. (1985). A comparison of various traps for *Glossina* spp. (Glossinidae) and other Diptera. *Bull. Entomol. Res.* **5**, 529-534.

Ford, J. and Katondo, K.M. (1977). Maps of tsetse fly *Glossina* distribution in Africa, 1973 according to sub-generic groups on scale of 1:5,000,000. *Bull. Anim. Health Prod. Africa.* **15,** 188-194.

Fox, R.G.R., Mmbando, S.O., Fox, M.S. and Wilson, A. (1993). Effect on herd health and productivity of controlling tsetse and trypanosomosis by applying deltamethrin to cattle. *Trop. Anim. Health Prod.* **25**, 203-214.

Gilbert, M., Jenner, C., Pender, J., Rogers, D., Slingenbergh, J. and Wint, W. (2001). The development and use of the Programme Against African Trypanosomosis Information System (PAAT-IS). Newsletter on Integrated Control of Pathogenic Trypanosomes and their Vectors (ICPTV). No. 3. pp 10-12.

Gaturaga, I.M., Maloo, S.H. and Lohr, K.F. (1990). Monitoring for trypanosomosis on dairy farm under apparent low tsetse challenge at the Kenyan Coast. *Proceedings of the 20th Meeting of the ISCTRC,* Mombasa, Kenya, 1994. **115**, 297-300.

Geerts, S. and Holmes, P.H. (1998). Drug management and parasite resistance in bovine trypanosomosis in Africa. *PAAT Technical and Scientific Series 1*, FAO, Rome, Italy.

Georghiou, G.P., Denholm, I., Heckel, D.G., Hemingway, J. and Mouchès, C. (1993). The potential for tsetse flies to develop resistance to insecticides. *Consultants Report*. Vienna, FAO/International Atomic Energy Agency (IAEA), 14 pp.

Gikonyo, N.K., Hassanali, A., Njagi, G.N.P. and Saini, R.K. (2000). Behaviour of *Glossina morsitans morsitans* Westwood (Diptera: Glossinadae) on waterbuck *Kobus defassa* Ruppel and feeding membranes smeared with waterbuck sebum indicates the presence of allomones. *Acta Trop.* **77,** 295-303.

Gikonyo, S.K., Hassanali, A., Njagi, P.G.P., Gitu, P.M. and Midiwo, J.O. (2002). Odour composition of preferred (buffalo and ox) and non-preferred (waterbuck) hosts of some savanna tsetse flies. *J. Chem. Ecol.* **28**, 969-981.

Gikonyo, N. K., Hassanali, A., Njagi, G.N.P. and Saini, R.K. (2003). Responses of *Glossina morsitans morsitans* to blends of electro-antennographically active compounds in the odours of its preferred (buffalo and ox) and non-preferred (waterbuck) hosts. *J. Chem. Ecol.* **29**, 2331-2345.

Glasgow, J.P. (1963). The distribution and abundance of tsetse. Pergamon Press, London. 241 pp.

Gouteux, J.P. and Lancien, J. (1986). Le piege pyramidal a tsetse (Diptera: Glossinidae) pour la capture et la lutte: Essais comparatives et description de mouveaux systemes de capture. *Trop. Med. Parasitol.* **37**, 61-66.

Green, C.H. (1993). The effects of odours and target colour on landing responses of *G. m. morsitans* and *G. pallidipes* (Diptera: Glossinidae). *Bull. Entomol. Res.* **83**, 553-562.

Green, C.H. (1994). Bait methods for tsetse fly control. *Adv. Parasitol.* **34,** 229-291.

Hall, D.R., Beevor, P.S., Cork, A., Nesbitt, B.F. and Vale, G.A. (1984). 1-octen-3-ol: A potent olfactory stimulant and attractant for tsetse isolated from cattle odours. *Insect Sci. Appl.* **5**, 335-339.

Hargrove, J.W. (1980). The effect of model size and ox odour on the alighting responses of *Glossina morsitans* Westwood and *Glossina pallidipes* Austen (Diptera: Glossinidae). *Bull. Entomol. Res.* **70**, 229-234.

Hargrove, J.W. (2000). A theoretical study of the invasion of cleared areas by tsetse flies (Diptera: Glossinidae). *Bull. Entomol. Res.* **90,** 201-209.

Hargrove, J.W. (2003). Optimized simulation of the control of tsetse flies *Glossina pallidipes* and *Glossina morsitans morsitans* (Diptera: Glossinidae) using odour-baited targets in Zimbabwe. *Bull. Entomol. Res.* **93,** 19-29.

Hargrove, J.W., Holloway, M.T.P., Vale, G.A. and Hall, D.R. (1995). Catches of tsetse flies (*Glossina* spp.) (Diptera: Glossinidae) from traps and targets baited with large doses of natural and synthetic host odour. *Bull. Entomol. Res.* **85**, 215-227.

Hargrove, J.W. and Langley, P.A. (1990). Sterilizing tsetse (Diptera: Glossinidae) in the field: a successful trial. *Bull. Entomol. Res.* **80**, 397-403.

Hargrove, J.W., Omolo, S., Msalilwa, J.S.I. and Fox, B. (2000). Insecticide treated cattle for tsetse control: The power and problems. A theoretical study of the invasion of cleared areas by tsetse flies (Diptera: Glossinidae). *Med. Vet. Entomol.* **14**, 123-130.

Hassanali, A., McDowell, P.G., Owaga, M.L.A. and Saini, R.K. (1986). Identification of tsetse attractants from excretory products of a wild host animal, *Syncerus caffer*. *Insect Sci. Appl.* **7**, 5-9.

Hoare, C.A. (1957). The spread of African trypanosomes beyond their natural range (essay on historical zoogeography of the host-parasite system). *Tropen. Med. Parasitol.* **8**, 151-161.

Holden, J.R. and Findlay, G.M. (1944). Pyrethrum as a tsetse fly repellent: Human experiments. *Trans. Royal Soc. Trop. Med. Hyg.* **37**, 33-40.

Holmes, P.H. (1997). New approaches to the integrated control of trypanosomosis. *Vet. Parasitol.* **71**, 121-135.

Hörchner, F. (1993). Neue Erkenntnisse über Pathogenese und Bekämpfung der Trypanosomiasis der Haustiere. Die Blauen Hefte. **67**, 329-333.

Hosmer, D.W. and Lemeshow, S. (2000). Applied Logistic Regression. John Wiley & Sons Inc. New York, USA.

Intermediate Technology Development Group (ITDG). (2003). Community based tsetse fly management. Annual Report 2002/2003.

Jaetzold, R. and Schimdt, H. (1983). Farm Management handbook of Kenya, vol. 2 (Eastern and Coast Provinces). Ministry of Agriculture, Nairobi. pp 325-366.

Jelinek, T., Bisolfi, Z., Bonazzi, L., Van Theil, P., Bronne, U., De Frey, A., Gundersen, S.G., McWhinney, P. and Ripamonti, D. (2002). Cluster of African trypanosomosis in travelers in Tanzania national parks. *Emerg. Inf. Dis.* **8**, 634-635.

Jordan, A.M. (1986). Trypanosomosis Control and African Rural Development. Longman, London and New York, 357 pp.

Joya, L.L. and Okoli, U.A. (2001). Trapping the vector: community action to curb sleeping sickness in southern Sudan. *Am. J. Public Health.* **91**, 1583-1585.

Kabayo, **J.P.** (2002). Aiming to eliminate tsetse from Africa. *Trend. Parasit.* **18,** 473-475.

Kahn, A.H. and Sempos, C.T. (1989). Statistical Methods in Epidemiology, Oxford University Press, Oxford, 24-26.

Kamuanga, M. (2003). Socio-economic and cultural factors in the research and control of trypanosomosis. *PAAT Technical and Scientific Series 4*. FAO, Rome, Italy.

Kamuanga, M., Kaboré, I., Swallow, B.M., Amsler-Delafosse, S. and Bauer, B. (1997). Evaluating factors affecting implementation of community-based tsetse control using insecticide-impregnated targets in southern Burkina Faso. *Proceedings of the 23rd Meeting of the ISCTRC,* Banjul, the Gambia, 1995. **118**, 318-330.

Kamuanga, M., Sigue, H., Bauer, B. and d'Ieteren, G. (2001). Farmers' perceptions of the impacts of tsetse and trypanosomosis control on livestock production: evidence from southern Burkina Faso. *Trop. Anim. Health Prod.* **33**, 141-53.

Kappmeier, K. and Nevill, E.M. (2000). A newly developed odour-baited "H-trap" for the live collection of *Glossina brevipalpis* and *Glossina austeni* (Diptera: Glossinidae) in South Africa. *Onderstepoort J. Vet. Res.* **67**, 15-16.

Katunguka-Rwakishaya, E., Parkins, J.J., Fishwick, G., Murray, M. and Holmes, P.H. (1995). The influence of energy intake of the pathophysiology of *Trypanosoma congolense* infection in Scottish blackface sheep. *Vet. Parasitol.* **59**, 207-218.

Kenya Trypanosomiasis Research Institute (KETRI). (1997). Proceedings of the national workshop to revise the tsetse distribution map of Kenya. KETRI, Muguga, 17-18 April 1996.

Kioy, D and Marrock, N. (2005). Control of sleeping sickness—time to integrate approaches. *The Lancet.* **366**, 695-696.

Kipchumba, B.M. (2007). Optimization of the waterbuck-specific repellents through field studies. PhD Thesis, Moi University, Kenya.

Klaassen, J.M., Wyrick-Glatzel, J.M., Neyrinck, N. and Belair, P.A. (2002). African sleeping sickness in a young American tourist. *Lab. Med.* **33**, 783-788.

Küpper, W., Spath, J and Krober, T. (1991). Attractiveness of chemicals to *Glossina tachinoides* Westwood (Diptera: Glossinidae) in Cote d'Voire. Trop. Pest Manage. 37: 436-438.

Lancien, J., Muguwa, J., Lannes, C. and Bouvier, J.R. (1990). Tsetse and human trypanosomosis challenge in southeastern Uganda. *Insect Sci. Applic.* **11,** 411-416.

Laveissière, C. and Grébaut, P. (1990). Recherches sur les pièges a *Glossines* (Diptera: Glossinidae). Mise au point d'un modele economique: Le piège "Vavoua". *Trop. Med. Parasitol.* **41**, 185-192.

Laveissière, C., Grebaut, P., Lemasson, J.J., Meda, A.H., Couret, D., Doua, F., Brou, N. and Cattan, P. (1994). Les Communautés rurales et la lutte contre la maladie du sommeil en forêt de Côte d'Ivoire. WHO, Geneva, Switzerland.

Latif, A. and Jongejan, F. (2002). The wide-use of acaricides for the control of livestock diseases in Africa. Proceedings of the joint ICTTD-2/ICPTV workshop on integrated vector control, use of drugs and bait technologies for the control of trypanosomosis and tick-borne diseases. Institute of Tropical Medicine, Antwerp, Belgium.

Leak, S.G.A. (1998). Tsetse biology and ecology: Their role in the Epidemiology and Control of Trypanosomosis. CABI publishing. 567 pp.

Leak, S.G.A., Peregrine, A.S., Rowlands, G.J., and Mulatu, W. (1996). Use of impregnated targets for the control of tsetse flies (*Glossina* spp) and trypanosomosis occurring in cattle in an area of southwest Africa with high prevalence of drug resistant trypanosomes. *Trop. Med. Int. Health.* **1**, 599-609.

Leak, S.G.A., Rowlands, G.J., and Mulatu, W. (1995). A trial of cypermethrin pour-on insecticide to control *Glossina pallidipes* and *Glossina morsitans submorsitans* in south west Ethiopia. *Bull. Entomol. Res.* **85**, 241-251.

Leonard, D.K. (1993). Structural reform of the veterinary profession in Africa and the new institutional economics. *Economic Development and Cultural Change*. **24**, 227-267.

Levine, N.D., Corliss, J.O., Cox, F.E., Deroux, G., Grain, J., Honigberg, B.M., Leedale G.F., Loeblich, A.R., Lom, J., Lynn, D.H., Merinfield, E.G., Page, F.C., Poljansky, G., Sprague, V., Vavra, J. and Wallace, F.G. (1980). A newly revised classification of the protozoa. *J. Protozool.* **27**, 37-38.

Leyland, T. (1996). The case for a community-based approach with reference to southern Sudan. The World Without Rinderpest. FAO Animal Health and Production Paper 129, pp. 109-120.

Losos, G.J. and Ikeda, I. (1972). Review of the disease in domestic and laboratory animals caused by *Trypanosoma congolense, Trypanosoma vivax, Trypanosoma brucei, Trypanosoma rhodesiense* and *Trypanosoma gambiense*. *Vet. Pathol.* **9**, 1-17.

Lumsden, W.H.R., Kimber, C.D. and Strange, M. (1977). *Trypanosoma brucei:* detection of low parasitaemias in mice by a miniature anion-exchange/centrifugation technique. *Trans. Royal Soc. Trop. Med. Hyg.* **71**, 421-424.

Machila, N., Wanyangu, S.W., McDermott, J., Welburn, S.C., Maudlin, I. and Eisler, M.C. (2003). Cattle owners' perceptions of African bovine trypanosomosis and its control in Busia and Kwale Districts of Kenya. *Acta Trop.* **86**, 25-34.

Magona, J.W., Greiner, M. and Mehlitz, D. (2000). Impact of tsetse control on the age-specific prevalence of trypanosomosis in village cattle in southeast Uganda. *Trop. Anim. Health Prod.* **32**, 87-89.

Mahama, C.I., Desquesnes, M.I., Losson, R., Dedeken. and Geerts, S. (2004). A cross-sectional epidemiological survey of bovine trypanosomosis and its vectors in the Sevalugu and west Mamprusi districts of northern Ghana. *Vet. Parasitol.* **122**, 1-13.

Majiwa, P.A.O., Maina, M., Waitumbi, J.N., Mihok, S. and Zweygarth, E. (1993). *Trypanosoma (Nannomonas) congolense*: molecular characterization of a new genotype from Tsavo, Kenya. *Parasitology*. **106**, 151-162.

Makumi, J.N., Stevenson, P. and Green, C.H. (2000). Control of *Glossina longipennis* (Diptera: Glossinidae) by insecticide-treated targets at Galana Ranch, Kenya, and confirmation of the role of *Glossina longipennis* as a vector of cattle trypanosomosis. *Bull. Entomol. Res.* **90**, 397-406.

Maloo, S.H., Thorpe, W., Kiio, G., Ngumi, P., Rowlands, G.J. and Perry, B.D. (2001). Seroprevalences of vector transmitted infections of smallholder dairy cattle in coastal Kenya. *Prev. Vet. Med.* **52**, 1-16.

Maré, C.J. (1998). Trypananosomiasis. In: *Foreign Animal Diseases*. Committee on Foreign Animal Diseases of the United States Animal Health Association. Pat Campbell and Associates and Carter Printing Company, Richmond, Virginia, USA.

McCarthy, N., McDermott, J. and Coleman, P. (2003). Animal health and the role of communities: An example of trypanosomosis control options in Uganda, Environment and Production Technology Division (EPTD) *Discussion Paper No. 103*. International Food Policy and Research Institute (IFPRI), Washington, USA.

McDermott, J. (1996). Requirements for diagnostic tests to improve field investigations into the epidemiology and control of trypanosomosis. In: Morzaria, S., Rowlands, J., Musoke, T. (Eds.), *Antigen Elisas for Trypanosomes*. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Mhindurwa, A. (1994). Field observations of tsetse flies *Glossina* spp. with new odour-baited trapping devices. *Bull. Entomol. Res.* **84**, 529-532.

Mihok, S. (2002). The development of a multi-purpose trap (the NZI) for tsetse and other biting flies. *Bull. Entomol. Res.* **92**, 385-403.

Moloo, S.K. (1993). The distribution of *Glossina* species in Africa and their natural hosts. *Insect Sci. Appl.* **14**, 511-527.

Morton, J. (2002). Livestock management and socio-economic factors affecting the feasibility of trypanosomosis and malaria control in Konso special woreda, Ethiopia: report of a preliminary survey. Natural Resources Institute (NRI), United Kingdom.

Mugunieri, G.L. and Murilla, G.A. (2003). Resistance to trypanocidal drugs-suggestions from field survey on drug use in Kwale District, Kenya. *Onderstepoort J. Vet. Res.* **70,** 29-36.

Mulligan, J.W. (1970). The African Trypanosomosis. Ministry of Overseas Development and George Allen & Unwind, London, 950 pp.

Munyua, P.M. (2005). Toxicological assessment of a tsetse repellent developed for smallholder indigenous communities of sub-Saharan Africa, on the health of exposed animals. Msc. Thesis, University of Nairobi, Kenya.

Muraguri, G.R., McLeod, A., McDermott, J.J. and Taylor, N. (2005). The incidence of calf morbidity and mortality due to vector-borne infections in smallholder dairy farms in Kwale District, Kenya. *Vet. Parasitol.* **130**, 305-315.

Murilla, G.A., Mdachi, R.E., Okech, G.O. and Ndungu, J.M. (1998). Novel approaches to the epidemiology of resistance to drugs used in the control of bovine trypanosomosis in East Africa. Annual Report 1997/1998, European Union Project.

Murray, M. and Dexter, T.M. (1988). Anaemia in bovine African trypanosomosis: a review. *Acta Trop.* **45**, 389-432.

Murray, M. and Gray, A.R. (1984). The current situation on animal trypanosomosis in Africa. *Prev. Vet. Med.* **2**, 23-30.

Murray, M., Murray, P.K. and McIntyre, W.I.M. (1977). An improved parasitological technique for the diagnosis of African trypanosomosis. *Trans. Royal Soc. Trop. Med. Hyg.* **71**, 325-326.

Mwangelwa, M.I., Dransfield, R.D. and Otieno, L.H. (1991). The response of *Glossina fuscipes fuscipes* Newstead to odour baits and trap types on Rusinga Island, Kenya. *Proceedings of the 20th Meeting of the ISCTRC.* Mombasa, Kenya, 1989.

Mwangi, D.K., Swallow, B. and Roderick, S. (1998). *The socio-economic and cultural impacts of trypanosomiasis and its control*. Working document No. 7. Meeting of the Panel of the PAAT Advisory Group Co-ordinators, Harare, Zimbabwe.

Mwanzia, R.M. (1999). Possible use of wild animals in provision of draught power in the 21st Century. http://www.atnesa.org.

Nantulya, V.M., Lindqvist, K.J., Stevenson, P. and Mwangi, E.K. (1992). Application of a monoclonal antibody-based antigen detection enzyme-linked immunosorbent assay (antigen ELISA) for field diagnosis of bovine trypanosomosis at Nguruman, Kenya. *Ann. Trop. Med. Parasitol.* **86**, 225-230.

Ndegwa, P.N. and Mihok, S. (1999). Development of odour-baited traps for *Glossina swynnertoni* Austen (Diptera: Glossindae). *Bull. Entomol. Res.* **89**, 255-261.

Nicholson, M.J. and Butterworth, M.H. (1986). A guide to condition scoring of Zebu cattle. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.

Nyeko, J.H.P., Ole-Moi yoi, O.K., Otieno, L.H. and Ociba, P.M. (1990). Characterization of trypanosome isolates from cattle in Uganda using species-specific DNA probes reveals predominance of mixed infections. *Insect Sci. Applic.* **11**, 271-280.

Odeyemi, I.A.O. (1997). Understanding privatization of animal health delivery systems in Africa: concepts, impacts and approaches. *FAO Electronic Conference for Principles for Rational Delivery of Public and Private Veterinary Services*, 1997.

Okoth, J.O., Omare-Okuru, A. and Eboyu, F. (1998). The use of theatre to mobilize and sensitize rural communities to participate in tsetse control in Bugiri district, Uganda: a case study. *Ann. Trop. Med. Parasitol.* **92**, 127-128.

Opiyo, E.A., Njogu, A.R. and Omuse, J.K. (1990). Use of impregnated targets for control of *Glossina pallidipes* in Kenya. *Insect Sci. Applic.* **11**, 417-425.

Otim, C.P., Ocaido, N.M., Okuna, J., Erume, J., Ssekitto, R.Z.O., Wafula, D., Kakaire, J., Okello, A., Mugisha, A. and Monrad, J. (2004). Disease and vector constraints affecting cattle production in pastoral communities of Ssembaule District, Uganda. *Liv. Res. Rural Dev.* **16**, 5-11.

Owaga, M.L.A., Hassanali, A. and McDowell, P.G. (1988). The role of 4-cresol and 3-*n*-propylphenol in the attraction of tsetse flies to buffalo urine. *Insect Sci. Appl.* **9**, 95-100.

Paris, J., Murray, M. and McOdimba, F. (1982). A comparative evaluation of the parasitological techniques currently available for the diagnosis of African trypanosomosis in cattle. *Acta Trop*. **39**, 307-316.

Pokou, K., Kamuanga, M., Swallow, B.M. and N'gbo, A.G.M. (1999). *Analyse contingente de la contribution des éleveurs à la lutte contre la trypanosomose animale en Afrique de l'Ouest: le cas de la Côte d'Ivoire*. Working paper No. 2. Abidjan, Cooperative Institute for Research in Environmental Sciences/University of Abidjan-Cocody. 28 pp.

Potts, W.H. (1970). Miscellaneous techniques used in study of *Glossina*. In: *The African Trypanosomosis*. (Mulligan, H.W. Potts, W.H, Eds) Overseas Development Association (ODA), George Allen & Unwin, London.

Radostitis, O.M., Blood, D.C., Gay, C.C. and Hinchcliff, K.W. (2000). Veterinary Medicine: A textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, ninth ed. W.B. Saunders Company Ltd, London, pp 1877.

Rowlands G.J., d'Ieteren G.D.M., Coulibaly L., Hecker P.A., Leak S.G.A. and Nagda S.M. (1996). Assessment of the effect of tsetse control on livestock productivity - a case study in northern Côte d'Ivoire. *Prev. Vet. Med.* **28**, 17-32.

Saini R.K. and Hassanali, A. (2003). Diffusion of new tsetse control technologies for improved livestock health and productivity in smallholder indigenous communities of sub-Saharan Africa. *ICIPE, Annual Report,* 2002/2003, pp 97-101.

Saini, R.K. and Hassanali A. (2007). A 4-Alkyl-substituted analogue of guaiacol shows greater repellency to savannah tsetse (*Glossina* spp.). *J. Chem. Ecol*. **33**, 985-995.

Schmidt, M.L. (1977). Relative effectiveness of repellents against *Simulium damsosum* (Diptera: Simuliidae) and *Glossina morsitans* (Diptera: Glossinidae) in Ethiopia. *J. Med. Entomol.* **14**, 276-278.

Seifert, H.S.H. (1996). Tropical animal health. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Shute, P.G. and Maryon, M.E. (1966). Laboratory technique for the study of malaria. 2nd edition. London, J. and A. Churchill.

Somda, J., Kamuanga, M. and Tollens, E. (2006). Prospective analysis for community participation in trypanosomosis control in The Gambia. *Trop. Anim. Health Prod.* **38**, 103–111.

Sones, K. (1999). Pharmaceutical companies: partners or enemies. 2nd Integrated Control of Pathogenic Trypanosomes and their Vectors (ICPTV) Workshop on Drug Delivery in the context of integrated disease management, Nairobi, Kenya.

Ssennyonga, J.W. (1998). *Incorporating socio-cultural factors into the research and control of trypanosomosis*. Working document No. 8. Meeting of the Panel of the PAAT Advisory Group Co-ordinators, Harare, Zimbabwe, 1998.

Statistical Analysis Software (SAS) (2003). *SAS User Guide for Personal Computers,* Statistical Programme, Release 8.01 Windows Version 4.10.22. (SAS Institute Inc., Cary. NC).

Stevenson, P. and Okech, G. (1997). Haemorrhagic *Trypanosoma vivax* on Galana Ranch in Kenya. *Proceedings of the 24th meeting of the ISCTRC.* Maputo, Mozambique. **119**, 296-298.

Swallow, B.M. (1997). Impacts of trypanosomosis on African agriculture. *Proceedings of the 24th Meeting of the ISCTRC.* Maputo, Mozambique, **119**, 515-537.

Swallow, B.M. (2000). Impacts of Trypanosomosis on African Agriculture. *PAAT Technical and Scientific Series 2,* FAO, Rome, Italy 52 pp.

Swallow, B.M., Mulatu, W. and Leak, S.G.A. (1995). Potential demand for a mixed public-private animal health input: evaluation of a pour-on insecticide for controlling tsetse-transmitted trypanosomosis in Ethiopia. *Prev. Vet. Med.* **24**, 265-275.

Taylor, K and Authie, E.M.L. (2006). Pathogenesis of animal trypanosomosis. *The Trypanosomiases* (ed. by I. Maudlin, P.H. Holmes and M.A. Miles), pp. 331-353. CABI, Wallingford.

Thorpe, W., Chabari, F., Maloo, S., Muinga, R., Mukhebi, A., Mullins, G., Mureithi, J., Mussukuya, E., Nyambaka, R., ole Make, M., Otieno, L., Perry, B., Rugema, E. and Wekesa E. (1993). Smallholder dairy cattle production in coastal Kenya: Resource base assessment and constraint identification. In: *Animal Production in Developing Countries,* Proceedings of the meeting held at Ashford, UK. BSAP (British Society of Animal Production), Penicuik, Scotland, UK. pp 167–168.

Torr, S.J., Hall, D.R. and Smith, J.L. (1995). Responses of tsetse flies (Diptera: Glossinidae) to natural and synthetic ox odour. *Bull. Entomol. Res.* **85**, 157-166.

Torr, S.J., Hall, D.R., Phelps, R.J. and Vale, G.A. (1997). Methods for dispensing odour attractants for tsetse flies (Diptera: Glossinidae) *Bull. Entomol. Res.* **87**, 299-304.

Torr, S.J., Mangwiro, T.N.C. and Hall, D.R. (1996). Responses of *Glossina pallidipes* (Glossinidae) to synthetic repellents in the field. *Bull. Entomol. Res.* **86**, 609-616.

Torr, S.J., Mangwiro, T.N.C. and Hall, D.R. (2006). The effects of host physiology on the attraction of tsetse (Diptera: Glossinidae) and *Stomoxys* (Diptera: Muscidae) to cattle. *Bull. Entomol. Res.* **96**, 71-84.

Torr, S.J., Maudlin, I. and Vale, G.A. (2007). Less is more: restricted application of insecticide to cattle to improve the cost and efficacy of tsetse control. *Med. Vet. Entomol.* **21**, 53–64.

Trail, J.C.M., D'Ieteren., G.D.M., Murray, M., Ordner, G., Yangari, G., Maille, J.C., Viviani, P., Colardelle, C. and Sauveroche, B. (1993). Measurements of trypanotolerance criteria and their effect on reproductive performance of N'Dama cattle. *Vet. Parasitol*. **45**, 241-255.

Turner, D.A. (1986). Tsetse and trypanosomosis in the Lambwe Valley, Kenya. *Trans. Royal Soc. Trop. Med. Hyg.* **80**, 592-595.

Urquhart, G.M., Armour, J., Dunn, A.M. and Jennings, F.W. (1996). Veterinary Parasitology. 2nd edition. Blackwell Science Ltd., Osney Mead, London, U.K.

Vale, G.A. (1974a). The responses of tsetse flies (Diptera: Glossinidae) to mobile and stationary baits. *Bull. Entomol. Res.* **64**, 545-588.

Vale, G.A. (1974b). New field methods for studying the response of tsetse flies (Diptera: Glossinidae) to baits. *Bull. Entomol. Res.* **64**, 199-208.

Vale, G.A. (1980). Field studies of the response of tsetse flies and other Diptera to carbon dioxide, acetone and other chemicals. *Bull. Entomol. Res.* **70**, 563-570.

Vale, G.A. (1981). An effect of host diet on the attraction of tsetse flies (Diptera: Glossinidae) to host odour. *Bull. Entomol. Res*. **71**, 259-265.

Vale, G.A. (1982). The trap-orientated behaviour of tsetse flies (Diptera: Glossinidae) and other Diptera. *Bull. Entomol. Res.* **72**, 71-93.

Vale, G.A. (1983). The effects of odours, wind direction and wind speed on the distribution of *Glossina* (Diptera: Glossinidae) and other insects near stationary targets. *Bull. Entomol. Res.* **73**, 53-64.

Van Hoeve, K., Cunningham, M.P. and Grainge, E.B. (1964). Some observations on the treatment of cattle with Berenil. *Proceedings of the 10th Meeting of the ISCTRC.* Kampala, Uganda.

Vreysen, M.J.B., Saleh, K.M., Ali, M.Y., Abdulla, A.M., Zhu, Z.R., Juma, K.G., Dyck, V.A., Msangi, A.R., Mkonyi, P.M. and Feldmann, H.U. (2000). The use of the sterile insect technique (SIT) for the eradication of the tsetse fly *G. austeni* (Diptera: Glossinidae) on the island of Unguja (Zanzibar). *J. Econ. Entomol.* **93**, 177-184.

Voller, A., Bidwell, D.E., Bartlett, A. and Edwards. R. (1977). A comparison of isotopic and enzyme-immunoassays for tropical parasitic diseases. *Trans. Royal Soc. Trop. Med. Hyg.* **71**, 431-437.

Waaijenberg, H. (1994). Mijikenda agriculture in Coast Province of Kenya: Peasants in between tradition, ecology and policy. PhD Thesis, Wageningen Agricultural University. Wageningen, The Netherlands.

Wainaina, V. and Torfinn, S. (2004). Beyond the River Yei . Life in the land where sleeping is a disease. UNON press. 97 pp.

Warnes, M.L., Van den Bossche, P., Robinson, T.P., Shereni, W. and Chadenga, V. (1999). Evaluation of insecticide-treated cattle as a barrier to re-invasion of tsetse to cleared areas in northeastern Zimbabwe. *Med. Vet. Entomol.* **13**, 177-184.

Wekesa, E., Mwangi, W., Danda, K. and De Groote, H. (2003). Adoption of maize production technologies in the coastal lowlands of Kenya. KARI-CYMMIT Report.

World Health Organization (WHO). (2000). Communicable diseases surveillance and response (CSR), disease and impact of African trypanosomosis. www.who.int/emc/disease/ tryp/trpanodis.html.

World Health Organization (WHO). (2001). About WHO disease eradication/ elimination goals. www.who.int/aboutwho/en/disease_er.htm.

World Health Organization (WHO). (2004). Strategic review of traps and targets for tsetse and African trypanosomosis control. Special Programme for Research and Training in Tropical Diseases. WHO, Geneva, Switzerland.

World Health Organization (WHO). (2005). Strategic and technical meeting on intensified control of tropical diseases Berlin, 18-20 April 2005: Main conclusions. WHO, Geneva, Switzerland.

Wijers, D.B.J. (1974). The complexity epidemiology of Rhodesian sleeping sickness in Kenya and Uganda. IV. Alego and the other *fuscipes* areas north of the endemic. *Trop. Geog. Med.* **26**, 341-351.

Wilett, K.C. (1965). Some observations in the recent epidemiology of sleeping sickness in Nyanza region, Kenya and its relation to the general epidemiology of Gambian and Rhodesian sleeping sickness in Africa. *Trans. Royal Soc. Trop. Med. Hyg.* **59**, 374-386.

Willemse, L. (1991). A trial of odour baited targets to control the tsetse fly *Glossina morsitans morsitans* Machado (Diptera: Glossinidae) in west Zambia. *Bull. Entomol. Res.* **81**, 351-357.

Willemse, L.P.M. and Takken, W. (1994). Odour-induced host location in tsetse flies (Diptera: Glossinidae). *J. Med. Entomol.* **31**, 775-794.

Wilson, B. H. (1968). Reduction of Tabanid populations on cattle with sticky traps baited with dry ice. *J. Econ. Entomol.* **61**, 827-829.

Wint, W. and Rogers, D. (2001). Predicted distributions of tsetse in Africa. *Consultants Report*. FAO, Rome, Italy.

Wirtz, R.A., Roberts, L.W., Hallam, J.A., Macken, L.M., Roberts, D.R., Buescher, M.D. and Rutledge, L.C. (1985). Laboratory testing of repellents against the tsetse fly *Glossina morsitans*. *J. Med. Entomol.* **22**, 271-275.

Woo, P.T.K. (1971). Evaluation of the haematocrit centrifuge and other techniques for the field diagnosis of human trypanosomosis and filariasis. *Acta Trop*. **28**, 293-303.

Zinsstag, J., Ankers, P., Ndao, M., Bonfoh. and Pfister, K. (1998). Multiparasitism, production and economics in domestic animals in sub-Saharan West Africa. *Parasit. Today*. **14**, 46-49.

APPENDICES

Appendix 4.1 Recoissance baseline surveys questionnaire

RECOISSANCE SURVEY IN SHIMBA HILLS QUESTIONNAIRE

SECTION A: FARMER'S BACKGROUND

1. Farmer Identification

Full Names --

Age -------------------------------- Date ---

Division -- Location -------------------------------------

Sub-location ---Village ---------------------------------

GPS reading --

Average distance from SHNR fence ---

2. Gender Male Female

3. Level of education

No formal Education Primary High School (Form 1-6)

Tertiary (middle level colleges) University and above

4. Family size

Husband ------------- Wife(s) ----------- Children -------------- Other relatives ------------

5. Main occupation

Formal Employment Self Employed Commercial farmer Peasant farmer None

Others (specify) ---

6. Do you own livestock? ---

7. Who takes care of the livestock? ---

8. Total size of the farm in acres ---

9. Types of crops and acreage cultivated

Type of crop	**Average acreage**

SECTION B: GENERAL LIVESTOCK PRODUCTION

10. Type and number of livestock on the farm

Type of Livestock	Number

11. Current size, composition and structure of cattle herds

Age-sex cohort	Number
Male calves	
Female calves	
Young Males	
Young Females	
Adult Males	
Adult Females	
Expectant cows	
Lactating cows	
Draught oxen	
Crossbreeds	

12. In order of priority, what do you generally use livestock for?

SECTION C: LIVESTOCK DISEASES AND OTHER CONSTRAINTS

13. What are your major problems with livestock rearing? (List in order of importance).

Problem	Coping strategies

14. List in order of importance the diseases that affect your animals

Disease	Symptoms

15. What are your coping mechanisms with these diseases?

Disease	Coping mechanisms

SECTION D: TSETSE AND TRYPANOSOMSIS

16. Have you ever heard of tsetse fly? YES ----------------------- NO ----------------------

17. Have your farm plots ever been infested with tsetse fly? YES ------------ NO ------

18. Have your animals ever suffered from trypanosomosis? YES ------------ NO ------

19. If, YES, How did you know it was trypanosomosis? (List symptoms mentioned below)

----

20. What are the main causes of trypanosomosis?

----

21. How long ago did your animal(s) last suffer from trypanosomosis (months)? -----

22. How much money approximately did you spend over the last one-year to;

Prevent trypanosomosis? --- (KES)

Treat trypanosomosis? -- (KES)

23. Have you ever attempted to prevent your animal against trypanosomosis over last one year? YES ---------------------- NO ---------------------

24. If YES, **which methods did you use?**

----

25. Do you use trypanocides to treat or prevent trypanosomosis among your livestock?

YES ------------------------ NO -----------------------

26. If YES, **complete the table below**

Name of trypanocides used	**Source**	**Cost per dose (KES)**

27. Who administered the trypanocides?

----

28. Do you know of any indigenous methods of tsetse and trypanosomosis control?

YES ------------------------ NO -----------------------

29. If YES**, please describe the methods and how they were used.**

----

30. Do you get any assistance from the government or any NGOs for livestock production? YES ------------------------ NO ----------------------

If NO**, give reasons**

----

31. If YES**, mention the type of assistance and reasons for its provision**

----

32. What type(s) of assistance would you recommend to improve on livestock production?

Appendix 5.1 Description of livestock body condition scores

DESCRIPTION OF LIVESTOCK BODY CONDITION SCORES

Score	Condition	Features
1	**L-**	Marked emaciation (animal would be condemned at ante-mortem examination).
2	**L**	Transverse processes project prominently, neural spines appear sharply.
3	**L+**	Individual dorsal spines are pointed to the touch; hips, pins, tail-head and ribs are prominent. Transverse processes visible, usually individually.
4	**M-**	Ribs, hips and pins clearly visible. Muscle mass between hooks and pins slightly concave. Slightly more flesh above the transverse processes than L+.
5	**M**	Ribs usually visible, little fat cover, dorsal spines barely visible.
6	**M+**	Animal smooth and well covered; dorsal spines cannot be seen, but are easily felt.
7	**F-**	Animal smooth and well covered, but fat deposits are not marked. Dorsal spines can be felt with firm pressure, but feel rounded rather than sharp.
8	**F**	Fat cover in critical areas can be easily seen and felt; transverse processes cannot be seen or felt.
9	**F+**	Heavy deposits of fat clearly visible on tail-head, brisket and cod; dorsal spines, ribs, hooks and pins fully covered and cannot be felt even with firm pressure.

Source: Nicholson and Butterworth (1986)

Appendix 6.1 Farmers' perceptions on the efficacy of the repellents and baits questionnaire

SHIMBA HILLS FARMERS' PERCEPTIONS ON REPELLENTS AND BAITS QUESTIONNAIRE

Interviewer Name -- No. -------------------

Place --- Time -----------------------------------

PART 1: FARMER'S BACKGROUND (Push-pull, Push, Pull)

1. Farmer Identification

Full Names --

Relationship to household head --

Age -------------------------------- Date ---

Division -- Location --------------------------------------

Sub-location -- Village ---------------------------------

Treatment ------------------------------ GPS reading --

Duration of cattle keeping --------------------- Duration of stay in the area -------------------

2. Gender Male Female

3. Level of education

No formal Education Primary High School (Form 1-6)

Tertiary (middle level colleges) University and above

4. Formal training in agriculture YES NO

5. Family size

Husband ------------- Wife(s) ----------- Children -------------- Other relatives ------------

Widower ------------------------ Widow ------------------------ Single ------------------------

6. Main occupation

Formal Employment Self Employed Commercial farmer Peasant farmer None

Others (specify) ---

----

7. Total size of the farm in acres --

8. Major enterprises on the farm (acreage)

Enterprise	2004	2005

9. Types of crops, acreage cultivated today and in the past

Type of crop	2004	2005

10. Total monthly sources of income

Sources	2004	2005
Total		

11. Total monthly expenditure on income

Expenditure	2004	2005
Total		

PART 2: GENERAL LIVESTOCK PRODUCTION (Push-pull, Push, Pull)

12. Type and number of livestock on the farm

Type	2004	2005

13. Who takes care of livestock? --

14. Describe the size and structure of cattle herds (Numbers)

Age-sex cohort	2004	2005	Order of preference
Male calves (0-1 year)			
Female calves (0-1 year)			
Young Males (1-2 years)			
Young Females (1-2 years)			
Males (2-3 years)			
Females (2-3 years)			
Adult Males (>3 years)			
Adult Females (>3 years)			
Expectant cows			
Lactating cows			
Draught oxen			
Total			

15. In order of priority, what do you use livestock for?

----

16. In order of importance, what are your major problems in livestock rearing?

PART 3: LIVESTOCK HEALTH (Push-pull, Push, Pull)

17. Current tsetse and trypanosomosis control methods (in order or priority)(tick)

Method	2004	2005

18. Monthly livestock sickness and treatments

Animals Number	2004	2005
Sick animals in the herd		
Sick animals in the herd suspected to have trypanosomosis		
Sick animals in the herd treated		
Sick animals in the herd treated for trypanosomosis		
Times a single animal got sick		
Times a single animal got sick with trypanosomosis		
Times a single animal was treated		
Times a single animal was treated for trypanosomosis		

19. Monthly livestock drugs expenditure

Type of Drug	Prices	2004	2005
Veriben			
Samorin			
Novidium			
Anti-biotics			
Anti-helmintics			
Multi-vitamins			
Vaccination			
Anti-theilerials (TBDs)			
Traditional			
Unknown			

PART 4: EFFICACY OF THE SYNTHETIC REPELLENT (Push-pull and Push)

22. Was your cattle protected with the repellent collars/dispensers?

YES (If YES, How many? ----------------) NO

23. Did you understand how the tsetse repellent and dispenser works?

YES NO

24. If YES, Describe briefly how they work. (Score farmer's explanation as follows):

Very Poor Poor Average Above Average Good

Very Good Excellent

24. If NO, Give reasons

----

25. Which Points in the repellent dispenser do you consider weakest (order 3)

Screwcap Aluminium case Silicon tubing Supporter

Stopper Collar

26. Reasons for the choice

----

27. When provided with a dispenser filled with repellent can you successfully install it on your animals?

YES NO

28. If NO, Give reasons

----

29. For protection, what proportions of the herd would you treat with the repellent?

100% 75% 50% 25%

30. Reasons for choosing ALL

----

31. Reasons for choosing a FRACTION

----

32. Provided with a dispenser filled with repellent, on which animal would you give a priority for it (mark according to priority 3)

Calves males Calves females Young males Young females

Mature males Mature females Expectant cows Lactating cows Oxen

33. Reasons for the choice

----

34. In your own opinion what do you consider as strengths of the repellent technology?

----

35. In your own opinion what are the shortcomings of the repellent technology?

----

36. Suggestions on how to overcome these shortcomings:

----

37. How much would you like to buy a bottle of 100 ml of the repellent ----------------

dispenser with collar --

PART 5: EFFICACY OF BAITED NG2G TRAPS (Push-pull and Pull)

38. Did you have a baited tsetse trap deployed in or next to your farm household?

YES (If YES, How many? -------------) NO

39. Do you understand how a baited tsetse trap works?

YES NO

40. If YES, Describe briefly how they work. (Score farmer's explanation as follows):

Very Poor Poor Average Above Average Good

Very Good Excellent

41. If NO, Give reasons

----

42. Status of the deployed baited trap at the end the trials

Available (Number ---------------) NOT Available

43. If Available, Describe it/their condition in terms of, availability of:

Baits Blue and Black Cloths Centre Posts Side posts

Cage Netting Visibility

44. If NOT Available, Give possible reasons

----

45. Where would you deploy a trap when provided with one?

Location --

46. Reasons for choice

----

47. How should the traps be deployed?

Individually Communally

48. Give reasons for choice

----

49. In your own opinion what do you consider as strengths of baited traps

----

----

50. In your own opinion what are the shortcomings of baited traps

----

----

51. Suggestions on how to overcome these shortcomings:

----

52. How much would you like to buy one tsetse trap? ------------------------------------

PART 6: EFFECTS OF REPELLENTS AND TRAPS ON CATTLE/ LAND

(Push-pull, Push, Pull)

53. Describe the physical behaviour of the protected cattle while grazing in the field or tethered or at the boma (use adjectives)

----

54. Farmer's description of the animals health status before and after trials

2004 ---

2005 ---

----

56. Examples of not previously utilized land --

Land in acres	**2004**	**2005**
Not utilized		
Open for Crop cultivation		
Open for Livestock grazing		
Open for Human settlement		

57. Possible reasons for not utilization

----

58. Possible reasons for opening up

PART 7: COMPARISON BETWEEN VARIOUS CONTROL OPTIONS

(Push-pull, Push, Pull)

59. Between repellents and farmer's control methods, which one would he/she prefer?

Farmer's

Reasons

Repellents

Reasons

----

60. Between traps and farmer's control methods, which one would he/she prefer?

Farmer's

Reasons

Traps

Reasons

----

61. Between a combination of both repellents and traps and farmer's control methods, which one would he/she prefer?

Farmer's

Reasons

Both

Reasons

----

63. Between repellents and traps or both, which one would he/she prefer?

Repellents

Reasons

Traps

Reasons

Both

Reasons

64. In your opinion, do you feel that the <u>repellents</u> or <u>traps</u> or <u>both</u> worked?

(Mark appropriately according to the treatment)

YES NO

If YES, Give reasons

If NO, Give reasons

65. What are your GENERAL comments on the repellent/trap/both technology?