FINAL TECHNICAL REPORT

DECISION SUPPORT FOR RISK MANAGEMENT STRATEGIES OF TICK-BORNE DISEASES WITHIN SUSTAINABLE PASTORAL SYSTEMS

Project R8208

Animal Health Programme

April 2002 – September 2003

EXECUTIVE SUMMARY

The project purpose was to provide new knowledge to policy makers, animal health workers and pastoralists to help them (1) better understand factors associated with variations in tickborne diseases (TBD) and ECF risk; (2) better assess and target ECF control measures, particularly vaccination; and (3) place their TBD and ECF control decisions in a broader pastoral risk management and pastoral livelihoods framework. This latter aspect is of great importance as disease control decisions are increasingly made under constrained access to grazing areas.

Field studies were conducted at two sites, one considered to have year-round transmission (Elang'ata Dapash) and one with a more seasonal transmission (Mairowa). Longitudinal studies were conducted to collect data on tick population dynamics, infection prevalence and intensity of *Theileria parva* in ticks and morbidity, mortality and seroprevalence of various tickborne diseases. Data obtained from these studies were used to further improve infection dynamics models of *T. parva* developed earlier.

Household and focus group studies of livelihoods and pastoral risk management were also conducted. Studies were based on previous experience among the Maasai and attempted to link with pastoralists' producer associations, NGOs and public and private veterinary providers.

The project targeted activities in poor-pastoral communities of northern Tanzania that rely on cattle for their livelihoods. Many of these pastoralists have had their livestock numbers reduced because of calf mortality due to ECF.

The first output is information for policy makers to enable them to target TBD control, particularly ECF immunisation, in pastoral areas. There were three main components to this output, namely: field information on TBD and ECF risk, transmission and impact of ITM in two different ecological settings; an infection dynamics model incorporating this field information to predict risk and control impacts and information from household and focus group studies on livelihood impacts and the implication of ECF immunisation within a broader pastoral risk management strategy.

The second output is the development of media and formats for transferring knowledge from the first output. Key messages appropriate for policy makers, pastoralists, extension staff private sector and donor agencies were prepared based on the results of the study. The messages have been disseminated by various forms to different stakeholders.

These outputs contribute to AHP purposes. Improved epidemiological and socio-economic knowledge will allow policy makers and other stakeholders to target and implement appropriate and cost-effective strategies to control ECF. The knowledge gained from household and focus group studies will contribute to making ECF control appropriate in a broader pastoral livelihoods context.

The project addresses priorities in the DFID-supported National Development Plan and links to previous DFID-ESCOR projects (R6828 and R7638). Field studies have been complimentary with the recently funded AHP project on cerebral theileriosis in Tanzania (R8022). The project will also have links and gain from the experience of AHP projects R7360 to improve targeting and appropriate use of drugs for trypanosomosis and (R7596) on decision support systems for trypanosomosis control in south-eastern Uganda. Information from this project will greatly benefit the targeting and use of new vaccines for ECF being developed at ILRI with DFID funding.

BACKGROUND:
East Coast Fever (ECF) is an important endemic disease of cattle in 11 countries of eastern and southern Africa. In Tanzania, the focus of this project, ECF is ranked (with contagious bovine pleuropneumonia) as one of the two top priority diseases and is estimated to account for over 40% of cattle mortality due to disease[1]. ECF is a key constraint in smallholder, agro-pastoral and pastoral systems but understanding of its impacts and control is less well developed in agro-pastoral and pastoral systems. In indigenous pastoralist systems, calf mortality of 40-80 % has been reported with ECF thought to be responsible for approximately 75% of these deaths. This high level of calf mortality severely limits the livestock management options of pastoralists, and demands further attention. In addition to high average risks, there is variability in the risks of ECF and other tick-borne diseases (TBD) both spatially and temporally (seasonally and between years), largely due to variations in climatic suitability for the vectors. Vaccination by the infection and treatment method (ITM) has been a promising tool for 30 years, but its wide spread adoption has been hampered by a lack of information on its impact at a system level. However, in recent years, both smallholders and pastoralists in Tanzania (including cross-border migrants from Kenya) have adopted a modified ITM with over 60,000 calves vaccinated to date at full cost-recovery prices.

Without understanding the complex epidemiological situation it is impossible to support decisions on control strategies. Infection dynamic models [2,3], based on field data, produce quantitative information on control strategy impact, and should be the basis of rational vaccination programme design. Thus, a key component of this research was to collect data from carefully designed field studies to assess factors associated with the variability of ECF and the impact of different control options. This would allow:

(1) determination of the impacts of ECF on livelihoods of poor farmers;
(2) estimation of the impacts of vaccination in different pastoral settings;
(3) prediction of how vaccination can be better applied to maximize benefits;
(4) place decisions about the control of ECF and its impact on herd dynamics in a broader pastoral risk management settings to provide policy makers, technical staff and pastoralists with better decision making information.

Many national institutions were involved in detailed discussions leading to the development of the proposal. ILRI and the Tanzanian collaborators (ITTBDC, Ministry of Water and Livestock Development, Sokoine University of Agriculture) met in March 1999 to develop plans within an East African wide initiative on the assessment of ITM impact. Further to that, subsequent discussions were held in Arusha in March 2001, including visits to potential study sites. University College London has developed complementary interests in the impact of ITM on pastoralists' livelihoods in collaboration with ERETO, a civil society organization representing pastoralists in the Ngorongoro Conservation area and operating a major livestock-restocking project for poor households. This history and the ITTBD provide strong links to pastoral groups. Subsequently a subset of the collaborators met in Arusha in August 2001 to draft the concept note and after its acceptance, field visits and meetings with all NARS and some local organizations and animal health assistants to develop the full

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[1] Kambarage, D.M., (1995). East Coast fever as a continued constraint to livestock improvement in Tanzania: a case study. *Trop. Anim. Hlth. Prod.* 27: 145-149.
[2] Medley, G.F., Perry, B.D. & Young, A.S. (1993). Preliminary analysis of the transmission dynamics of *Theileria parva* in eastern Africa. *Parasitology*, 106: 251-264.
[3] O'Callaghan, C.J., Medley, G.F., Peter, T.F., Mahan, S.M. & Perry, B.D. (1999) Predicting the effect of vaccination on the transmission dynamics of heartwater (*Cowdria ruminantium* infection). *Preventive Veterinary Medicine* 42: 17-38.

proposal were held in northern Tanzania form December 9-14. Thus the proposal development process already involved livestock keepers, animal health workers, ITTBDC project staff, Sokoine University researchers, Ministry of Water and Livestock development staff as well as researchers of the UCL and ILRI.

PROJECT PURPOSE:
The purpose of the project was to provide new knowledge to policy makers, animal health workers and pastoralists to help them (1) better understand factors associated with variations in TBD and ECF risk in order to target their control activities; (2) better assess and target ECF control measures, particularly vaccination; and (3) place TBD and ECF control decisions in a broader pastoral risk management and pastoral livelihoods framework.

RESEARCH ACTIVITIES:
Longitudinal field studies of TBD infection dynamics
H.K.Kiara, G.Di Giulio, G.Lynen, C.J. O'Callaghan, J.J. McDermott, Medley, G

Objectives
The objectives of the field studies were:
i. To characterise the epidemiological states of tick borne diseases in two contrasting agroecological zones
ii. To estimate the *T.parva* infection dynamics parameters
iii. To determine the indicators of the stability of the different states over time

Materials and Methods

Selection of study Sites
Two sites were chosen purposively to represent contrasting levels of vector challenge and disease risk. Elang'ata Dapash is considered to have year-round transmission while Mairowa has a more seasonal transmission (Figure 1).

Selection of farms/herds
Four herds were selected in Mairowa while 25 farms were selected in E/Dapash. This was based on the logistical requirements of the study, the herd sizes and willingness of the farmers to participate in the study. A total of 102 and 101 calves of comparable age were selected in Elang'ata Dapash and Mairowa respectively, in February 2002 (the beginning of the calving season). Calves were identified using ear-tags.

Data collection
i. Clinical diseases
Field assistants in collaboration with the community animal health worker and the herd owners observed experimental calves daily for any signs of ill health. Scientists from the ITTBD Project in Arusha closely supervised them. Any calf suspected to be ill was examined and the clinical findings recorded on prescribed forms. A thin blood and lymph node smear were made from these calves, fixed in methanol and examined microscopically for haemoparasites. The calf was then treated as appropriate. If it was not possible to examine the slides immediately they were stored in slide boxes and later taken to Arusha for examination.

ii. *Disease monitoring of other farm animals*

In addition to the experimental calves, other farm animals in the monitoring herds were also observed for diseases. Initially these animals were identified by their names but this proved difficult and was later ear-tagged to ease monitoring.

iii. *Antibody prevalence*

Sera were collected every month from the experimental calves to assess the prevalence of *T.parva, A.marginale,* and *B.bigemina*.

iv. T.parva *parasite prevalence*

EDTA blood was collected every month from all experimental calves to assess the prevalence of carrier animals.

v. *Tick Attachment Rate (TAR)*

A sample of 12 calves in each site was randomly selected for tick assessment. Yje method of assessing attachment rates of *R.appendiculatus* adults on the calves has been described[4]. Assessment of numbers of adults and nymphs of other species of ticks on the 12 calves was also carried out by counting all observable ticks on the whole body of the calf every second day. Results were recorded on prescribed forms.

vi. *Assessment* T. parva *infection in ticks*

Several methods were used to collect ticks of different physiological states for assessment of infection prevalence and intensity.

a) Flagging using a towelling material was used to collect ticks from pasture.
b) Unfed adults and nymphs were collected from a non-experimental cattle in the monitoring herds.
c) Partially fed adults were collected from calves that were monitored for tick attachment rate at the end of the marking of new ticks (day 13).
d) Engorged larvae and nymphs were collected from cattle in the monitoring herds (assessed as unfed nymphs and adults respectively) after moulting.

After collection tick were kept in glass tick tubes, stored in moist sand until they were sent to the laboratory for identification and analysis.

Tick infections were assessed by Feulgen's stain method[5].

vii. *Immunisation*

In Mairowa all calves in two of the monitoring herds were immunised against ECF by ITM in June 2002. The other two herds were left as the non-immunised controls. To continue the monitoring of infection and disease status in calves, an additional 20 recently born calves, were recruited at the time of immunisation. The additional calves were also monitored for serology, EDTA blood and diseases. Immunised herds continued to be monitored as previously.

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[4] Kiara, H.K., McDermott, J.J., O'Callaghan, C.J., Randolph, T.F and Perry, B.D. 2003. Estimating biological parameters for modelling the transmission dynamics of *Theileria parva* infection. In Proceedings of the 10th International Symposium for Veterinary Epidemiology and Economics, Vina del Mar, Chile, 17-21, November 2003.

[5] Buscher, G. and Otim, B.1986. Quantitative studies on *T. parva* in the salivary glands of *R. appendiculatus* adults: quantitation of and prediction of infection. *International Journal for Parasitology*, **16**: 93-100.

In E/Dapash all animals that were still seronegative were immunised in June 2002 to assess the impact of immunisation on transmission dynamics in the population. As in Mairowa an additional 20 calves were recruited during immunisation in the same herds. The additional calves were monitored for serology, EDTA blood and disease. The monitoring of the immunised calves continued as previously.

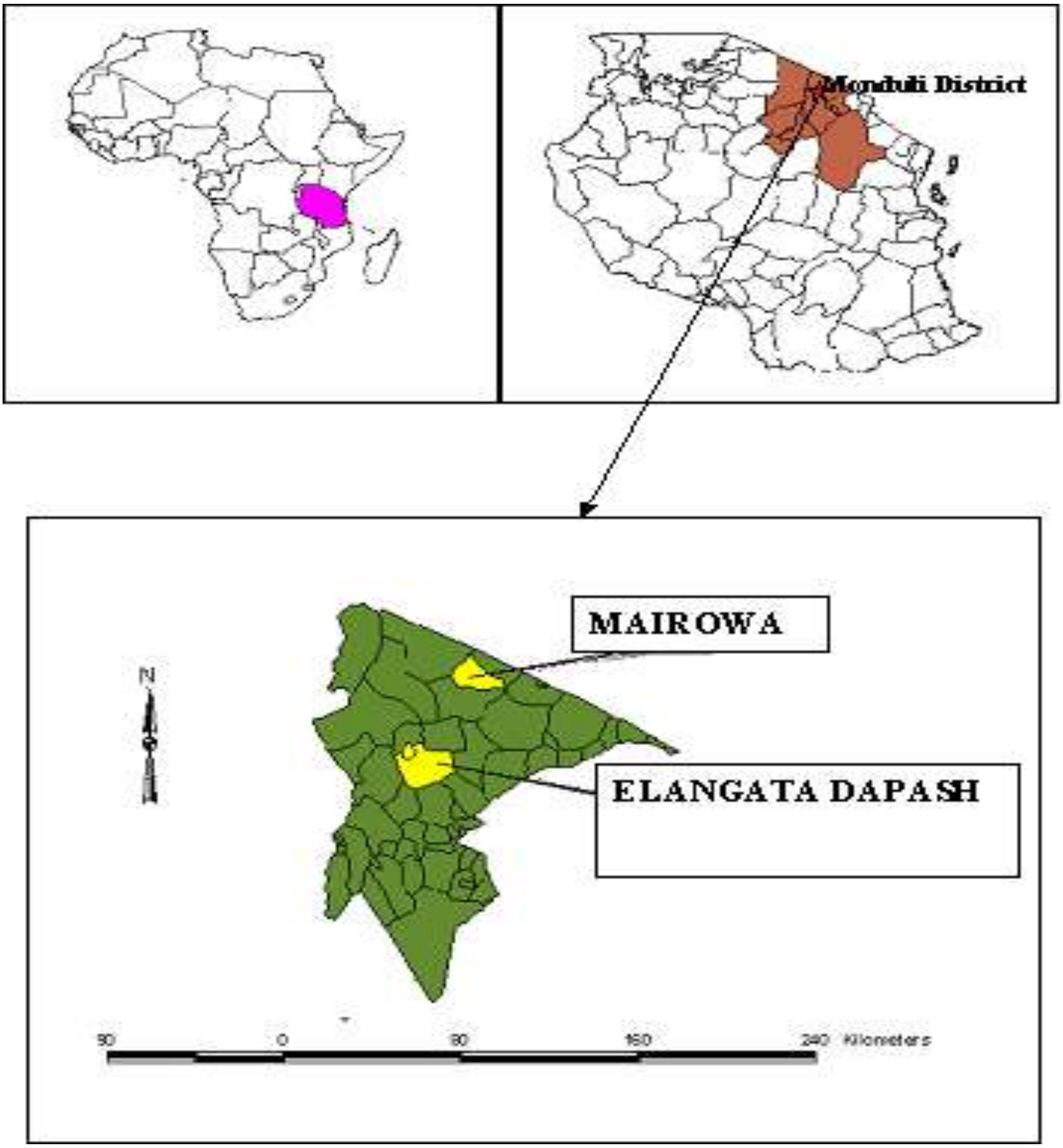

Figure 1. Map of Tanzania showing the location of the study sites

PASTORAL DISEASE RISK MANAGEMENT
Household and focus group studies of livelihoods and pastoral risk management

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Aims and objectives
The aim of this component was to evaluate the impacts of ECF immunisation on poor pastoralists' livestock production and on their livelihoods, within an overall pastoral risk decision-making framework. This has been achieved through documenting (and where possible, quantifying) impacts of the ITM programme on:

- herd performance,
- household economy,
- grazing patterns and land use,
- cross investment in complementary income earning/ livelihood activities,
- experience of and views on ITM.

Study areas and methods
These dimensions have been studied through:

- pilot PRA/focus group meetings and key informant interviews,
- a multi-round prospective survey of births, deaths, disease and transfers for a register of individual livestock. For each of 72 households across two main study sites, we established and monitored a register of individually identified immunised or control animals. We established a list of named cows being milked by individual wives and then asked those women about the birth histories for the individual cattle for which they personally cared. Follow up visits for these animals and their individually identified offspring allowed evaluation of immunisation impacts on herd dynamics through systematic recording for a total of approximately 1,528 animals of: fertility, mortality, offtake for gift, sale or exchange, TBD impacts and changes in grazing patterns.
- multi-round prospective survey of household economic activity (72 households), including: proportional contribution of pastoral, crop and other produce, income from livestock/pastoral produce, expenditure (animal health, food, education etc.), and cross-investment (cultivation, trade etc.).

The methods used for these multi-round surveys have been established and tested in the course of previous work in the overall study area, as well as for a variety of sites with different environmental and economic circumstances in the study regions[1].

Sampling and data collection schedule
Studies were directed by KH, and carried out by KH together with UCL postgraduates (EB, RF) and other research colleagues (EC, ES, SO'C), working with local assistants who were present in the field throughout the research period. Data were collected through semi-

[1] Retrospective analysis of veterinary records for calves immunised and followed up in Ngorongoro Conservation Area since 1999 was originally envisaged. It was hoped that veterinary record analysis would give retrospective estimates of survivorship and also of births/exchanges/transfers in a sample of over 3000 immunised calves for a period of approximately 30 months in an area with year round ECF transmission. As flagged in the original application, though, these records proved insufficiently complete and accurate to allow the proposed analysis given the time and resources (future work could carry this out given resources to follow up and cross check data through extended field visits).

structured interview, key informants, and multi-round household surveys monitoring livestock dynamics and household economy, as well as through group meetings. Study sites, sample households, and fine tuning of survey approaches were finalised in consultation with regional and local government, public and private veterinary providers. The analysis has been carried out in conjunction with Dr S Randall and Dr P Trench (see summary and conclusion)

Date	Researchers	Method	Study sites	Sample
May- June 2002	KH + MSc student (EB)	Household survey: wealth ranked by livestock holdings	Mairowa (Engare naibor: 49 households) and Sokon (Elang'ata Dapash: 23 hh)	Initial household survey (n=72) and livestock register (1528 cattle)
June 2002	RF (MSc student) working with Dr Bakuname	Focus group and semi structured interview Wealth ranking by cattle numbers	Mairowa (Engare naibor) and Simanjiro	Factors influencing vaccine adoption 74 interviews in Mairowa 22 in Simanjiro 2 focus groups
August-Sept 2002	KH + EC, ES	Follow up on household survey	Mairowa (Engare naibor) and Sokon (Elang'ata Dapash)	2nd round: livestock performance and household economy, 72 hh
December 2002	KH + SO'C	Follow up on household survey	Mairowa (Engare naibor) and Sokon (Elang'ata Dapash)	3rd round: livestock performance and household economy, 72 hh

DEVELOPMENT OF DECISION SUPPORT SYSTEMS

The original proposal set out the following categories of decision support guidelines expected from the project

LIVESTOCK OWNERS LOCAL LEADERS	1. ITM IMPACTS 2. ECF TRANSMISSION
PRIVATE SECTOR	1. MARKET DEMAND 2. DELIVERY
PUBLIC SECTOR	OPTIMAL LOCAL VACCINATION STRATEGY
DONORS	DIFFERENTIAL IMPACTS ON POOR

At the conclusion of the field studies and preliminary analysis of the data the research team met in May 2003 to prepare decision support tools for the various categories of stakeholders. The team agreed on the decision support guidelines and dissemination messages for each of the user groups and the issues to focus on. It was agreed the messages would be passed to the user groups by means of participatory meetings, one-page briefs in Swahili and Maasai and through the local radio and other media.

OUTPUTS

LONGITUDINAL FIELD STUDIES OF TBD INFECTION DYNAMICS

Tick Population dynamics

The following tick species were collected from the two sites *Rhipicephalus appendiculatus, R.pulchellus, R.simus, R.praetextatus, R.evertsi, R.tricuspis, Amblyomma variegatum, Amblyomma spp., Boophilus decoloratus, Hyalomma marginatun rufipes,* *H.trancatum*, *Haemaphysalis*, and *Ixodes*. The range and number of different species found at the two sites were markedly different (Figure 2). Elang'ata Dapash had predominantly *R.appendiculatus* (95%) whereas Mairowa had a much wider range of ticks.

Total ticks collected and their sources

	Host		Pasture		Source not identified		Total
	Dead	Alive	Dead	Alive	Dead	Alive	
E/Dapash	2990	1964	341	638	147	6	6086
Mairowa	1494	1420	318	1127	402	166	4927

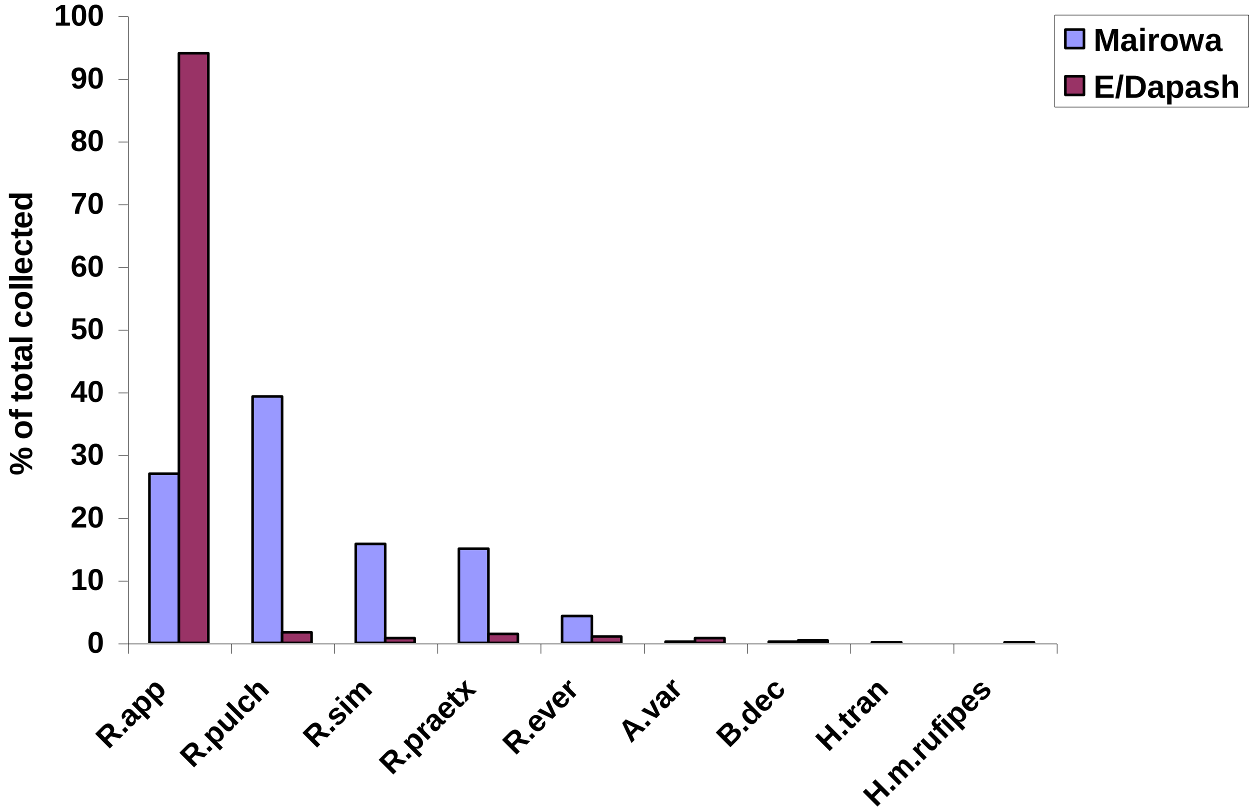


Figure 2: Various tick species collected as a percentage of total collection

Table1 summarises the mean TAR per animal per day and the feeding duration per attaching tick. Both parameters were significantly different ($p<0.001$) at the two sites. There was seasonal variation with a peak between December and April at both sites (figure)

Table 1. Daily attachment rate and feeding duration of *R.appendiculatus* (TAR)

Parameter	E/ Dapash	Mairowa
Number of animals	12	12
TAR (mean + se)	7.97 $\pm$ 0.28	3.08 $\pm$ 0.07
Range		
Feeding duration + se)	2.51 $\pm$ 0.02	3.47 $\pm$ 0.02
Range	2.19-3.31	2.19-4.14

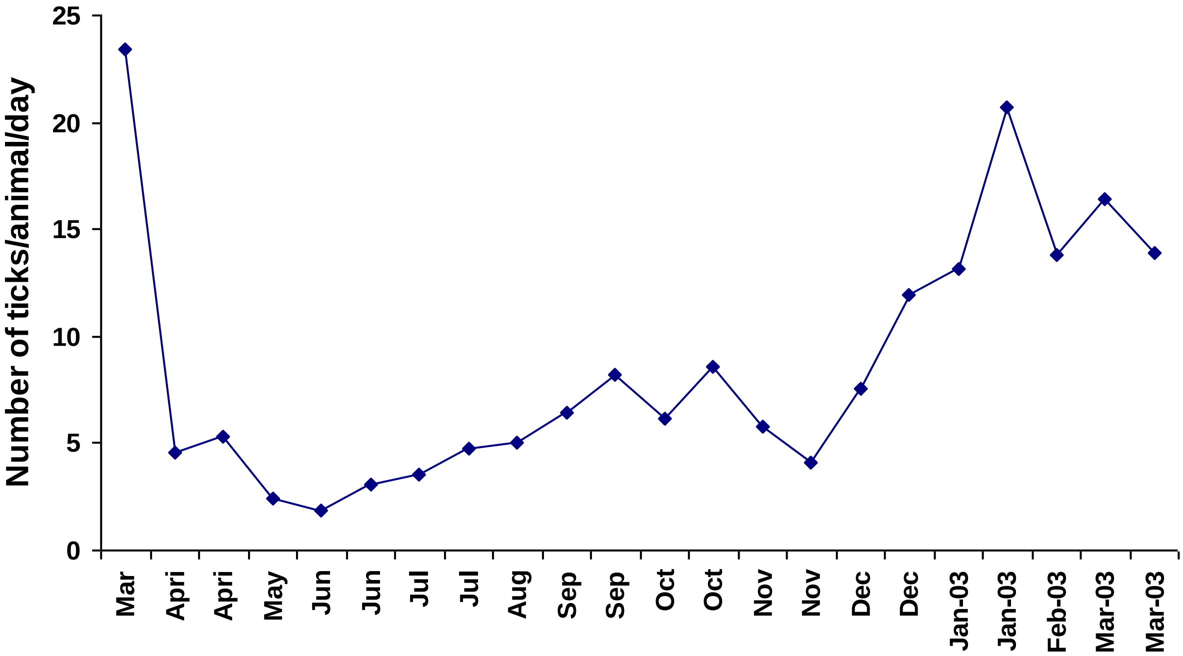
Tick infections with *T.parva* parasites

Table 2 is a summary of the infection of ticks with Theileria parasites. The infection prevalence was similar at both sites about (0.6 %) and all infections were found in adult ticks. A surprising finding in both sites was that males had higher intensity of infection than females.

Table 2. Infection prevalence and intensity in *R.appendiculatus* ticks

Study Site	Sex	#Assessed	#Infected	Total acini	Prevalence	Intensity
Elang'ata	Adults	1811	12	51	0.66	4.3
	Nymphs	289	0	0	0	-
	Female	925	6	7	0.67	1.2
	Male	886	6	44	0.68	7.3
Mairowa	Adults	581	3	10	0.52	3.3
	Nymphs	172	0	-	0	-
	Female	289	1	1	0.36	1.0
	Male	292	2	9	0.68	4.5

a) Elangata Dapash



b) Mairowa

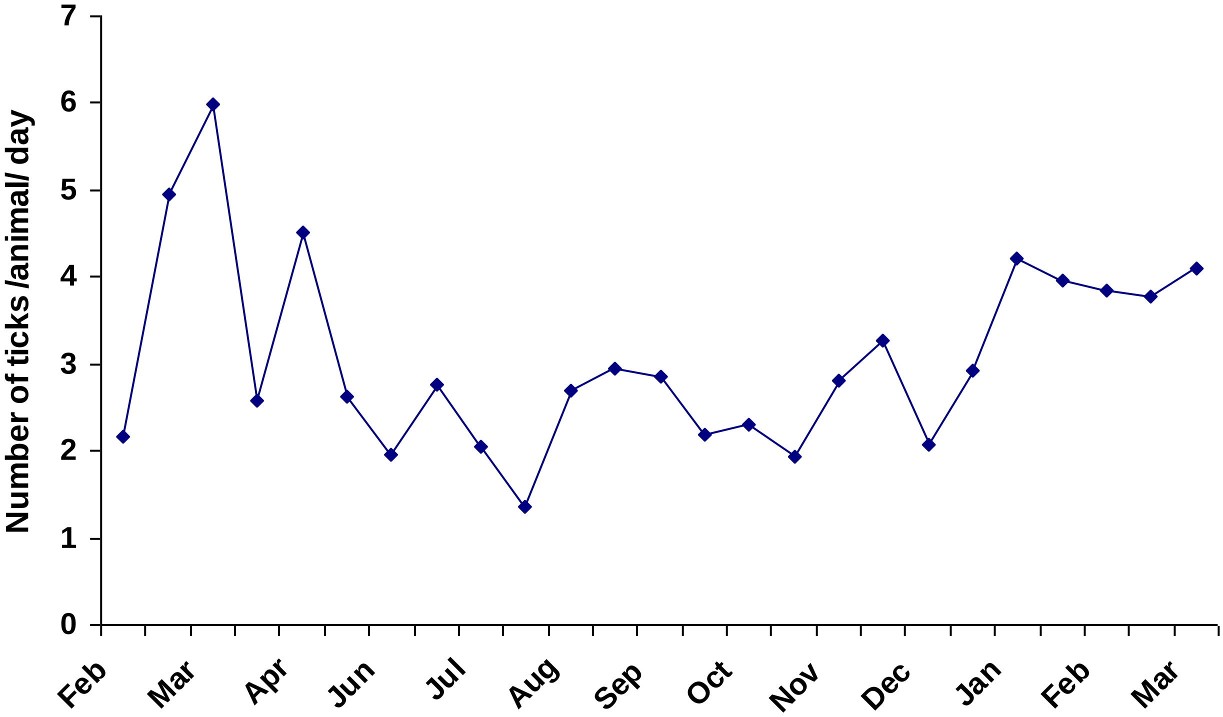
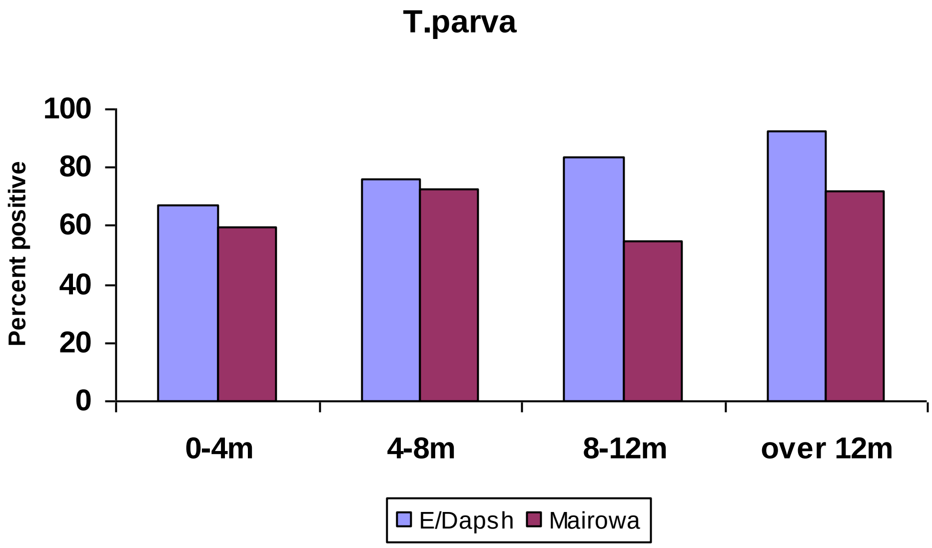


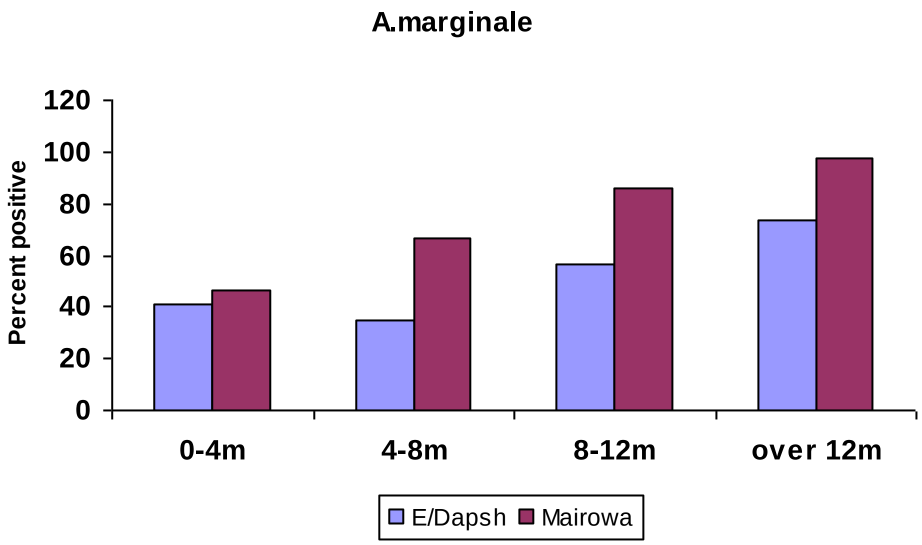
Figure Seasonal variation in TAR at the two study sites

Antibody prevalence

Prevalences of *T.parva*, *A.marginale* and *B.bigemina* antibodies are shown on Figure 3. In the 4–8 month age group (the most vulnerable age group) only 76 % and 72% had seroconverted to *T.parva* in Elang'ata Dapash and Mairowa, respectively. These levels rose to 92 % and remained at 72% in Elang'ata Dapash and Mairowa, respectively.

Seroprevalence to *A.marginale* was much lower in both sites but more so in Mairowa. At 4–8 months only 38% and 22% were seropositive in Mairowa and Elang'ata respectively. The situation was reversed with regard to *A.marginale*. At 4–8 months 66 % and 35 % of the calves were seropositive in Mairowa and Elang'ata, respectively. The levels rose to 97 % and 74%, respectively after one year. In summary except for *T.parva* in Elang'ata Dapash and *A.marginale* in Mairowa calves were susceptible to the three tick-borne diseases for up to one year and beyond at both sites.





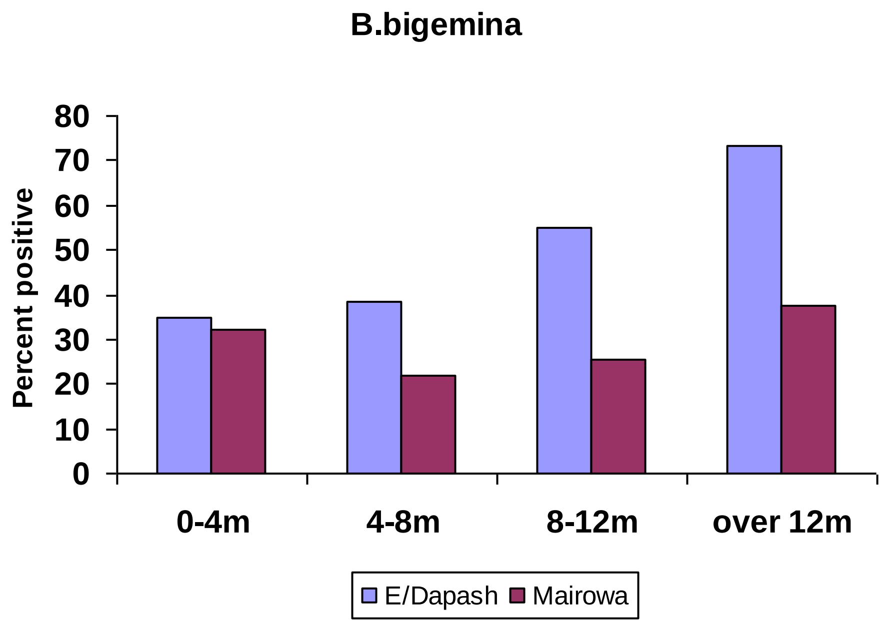


Figure: Seroprevalence of different tickborne diseases at the two study sites

Diseases

The main cattle diseases recorded at the two sites are listed in table 3. In both sites ECF including cerebral theileriosis syndrome known locally as ormilo was by far the most important disease. The incidence of the disease was slightly higher in Elang'ata Dapash than in Mairowa. It is probable that the large number of non-specific infections (cases whose diagnoses could not be confirmed by laboratory analysis of samples) were also mild cases of ECF. Calculation of the different rates of ECF (incidence, case fatality etc) is currently underway.

Immunisation

Preliminary results indicate that all the immunised cattle were protected against ECF. Calculations of the actual protection levels are underway.

Table 3. Morbidity of cattle diseases at the two study sites

	Number of cases and percent of total	
Disease	**Elang'ata Dapash**	**Mairowa**
East Coast fever	41 (61.2)	31 (31.6)
Endoparasites/enteritis	5 (7.5)	1 (1.0)
Non-specific infections	8 (11.9)	59 (60.2)
Ormilo	11 (16.4)	0 (0)
Pneumonia	1 (1.5)	2 (2.0)
Others	1 (1.5)	5 (5.1)

Discussion and Conclusions

The study attempted to characterise the epidemiological states of tick-borne diseases at two contrasting pastoral areas. Contrary to earlier expectations, both sites were found to have a seasonal transmission although the seasonality is more pronounced in Elang'ata Dapash. It was concluded that both sites are clearly in an endemically unstable[6] state with regard to the three tick-borne diseases investigated. East Coast fever is clearly a major constraint to livestock production at the two sites accounting for 60 % and 31% of all cases in Elang'ata Dapash and Mairowa respectively. (This could be up 90% in both sites if the non specific infections were included).

The other tick-borne diseases; anaplasmosis, babesiosis and heartwater were not recorded during the study, although the vectors of these disease were present albeit in low numbers. This fact is also demonstrated by the low seroprevalence of antibodies to *B.bigemina* in both sites (38% and 22% in the 4–8 month old calves). The relatively higher seroprevalence of antibodies to *A.marginale* is due to fact that *A.marginale* parasites can be transmitted mechanically by biting flies. Serology of heartwater was not carried out.

The reasons for the endemic instability at the two sites are probably the low number of vector ticks. The area is near the margin of the distribution of the *R.appendiculatus* and the environment is unsuitable for large populations of the tick. Instability might also be due to the lower than expected prevalence of infection in ticks. The 0.6%prevalence of infection is lower than that reported for field ticks in other studies [4,7,8]. The reasons for this are not clear. The higher infection intensity is probably due to the high prevalence of clinically sick animals.

Immunisation against ECF would appear to be the only option for reducing the impacts of the disease. Immunisation reduces clinical diseases and consequently mortality due to the disease.

Immunisation might have greater impact if it was timed to take place around one month before the start of the peak tick abundance rather than during it (when farmers are more likely to demand for the vaccine because of calf mortality). This would ensure calves are immune during the time of maximum challenge and more importantly that the few immunisation reactors that might occur do not result in higher infections in ticks.

There should be concern for the other tickborne diseases, especially babesiosis. Although these diseases are not a problem, at the moment, cattle are largely susceptible and the vectors are present. In the event of a change of climatic conditions, such as a succession of wetter than normal years, there could be an outbreak of some of these diseases.

Can immunisation permanently alter the epidemiological state of ECF in these sites to the point that there would be no need for continued immunisation? This question might be answered through a modelling approach. But one could speculate that in Elang'ata Dapash this might happen. Since the vectors are more abundant and if clinical diseases were reduced through immunisation, subsequent tick infections would be from carrier cattle thus leading to lower tick infections, and consequently to the development of endemic stability. This is less likely in Mairowa because of the much lower vector abundance. This should however be taken with a great deal of caution as it is purely speculative.

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[6] Perry, B.D. and Young, A.S. 1995. The past and future roles of epidemiology and economics in the control of tick-borne diseases of livestock in Africa.: the case of theileriosis. *Preventive Veterinary Medicine*, 25, 107-120.

[7] Ochanda, H., Young, A.S., Medley, G.F. and Perry, B.D. 1998. Vector competence of seven rhipicephalid tick stocks in transmitting two *T. parva* parasite stocks from Kenya and Zimbabwe. Parasitology, 116: 539-545.

[8] Leitch BL and Young AS 1986. Theileria infections in *Rhipicephalus appendiculatus* ticks collected in the field. In: Advances in the control of theilerios. A.D. Irvin , M.P. Cunningham and A.S.Young (eds). Martinus Nijhoff , The Hague, pp63-65.

PREVALENCE OF *T.PARVA* CARRIER STATE IN CATTLE AT THE TWO STUDY SITES

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Blood was collected every month from all the experimental calves to determine the prevalence of *T. parva* carrier state in immunised versus non-immunised herds. Blood from the field was transported in cool boxes and stored frozen in VIC Arusha, until transportation to SUA, Morogoro. In the SUA laboratory, the prevalence of *T. parva* was determined using a specific p104 PCR described by Skilton *et al*., (2002). A total of 1,100 and 987 blood samples from Mairowa and Elangata Dapash, respectively, were screened for *T. parva* prevalence between February 2002 to May 2003. All samples were analysed using standard and optimised experimental procedures. Only 2 out of the 987 (0.2%) cattle from Mairowa and 7 out of 1,100 (0.63%) cattle from Elangata Dapash were detected as carriers of the *T. parva* p104 gene by nested PCR.

The estimated prevalence of carriers are lower than expected of carrier state in pastoral herds, where it is usually expected that all adult cattle remain carriers following recovery after natural infection (Matovelo *et al*., 2003), or after artificial immunisation. Possible reasons for such a low prevalence of carriers in the herds may be:

- (i) short time interval from immunisation to sampling
- (ii) low concentration of *T. parva* parasites in blood circulation
- (iii) low sensitivity of the PCR to detect vaccine-derived *T. parva*
- (iv) incompetence of vaccine strains to create PCR-detectable carriers.

These results are however supported by our hypothesis of endemic instability of these herds, which is also supported by the low prevalence of infection in ticks. Low infection rates in ticks with *T. parva* was also previously reported when a 2.6% prevalence was obtained in unfed adult *R. appendiculatus* collected from field sites in Tanzania (Ogden *et al*., 2002).

The reasons for the lower than expected prevalence of *T. parva* in ticks and in carriers are not entirely clear. Efforts are underway to elaborate the sensitivity of the p104 PCR on field blood samples, and other procedures that might have led to these results. This activity is expected to be completed by April 2004.

Skilton R.A., Bishop R.P., Katende J.M., Mwaura S. and Morzaria S.P.,. The persistence of *Theileria parva* infection in cattle immunised using two stocks which differ in their ability to induce a carrier state: analysis using a novel blood spot PCR assay. *Parasitology* (2002), 124, 265-276.

Ogden N.H., P. Gwakisa, E. Swai, N.P. French, J. Fitzpatrick, D. Kambarage, M. Bryant (2003). Evaluation of PCR to detect *Theileria parva* in field-collected tick and bovine samples in Tanzania. *Veterinary Parasitology,* 112 (2003) 177–183.

Matovelo J. A., P. S. Gwakisa, M. Gwamaka, J. Chilongola, R. S. Silayo, K. Mtenga, M. Maselle and D. M. Kambarage (2003). Induction of Acquired Immunity in Pastoral Zebu Cattle Against East Coast Fever After Natural Infection by Early Diagnosis and Early Treatment. *Journal of Applied Research in Veterinary Medicine,* v1, No. 2.

PASTORAL DISEASE RISK MANAGEMENT

The results are presented as follows for village-, household- and animal-level comparisons

- Study sites and samples
- Herd management and performance
- Impacts of vaccination
- Implications of vaccination for livestock numbers and spread of farming
- Factors influencing vaccination uptake

Study sites and samples

	Mairowa (Engare Naibor)	**Sokon (Elang'ata Dapash)**	**Total/ Sig.diff?**
Altitude			
Population size			
Facilities	Several nursery schools Primary school Secondary school planned Dispensary Weekly market 10-20 shops Government offices Police post planned All weather road: <1hr to regional centre	Nursery school Primary school Dispensary Weekly market Shop Dry weather road: 3hrs to regional centre	
Total households surveyed	49	23	72
Total cattle on register	1038	490	1528
Olmarei (household) size	20.1	17.3	NS
Dependency ratio	1.27	1.33	NS
AE (Adult equivalents)	16.6	13.9	NS
Mean yrs education	1.5	1.6	NS
Proportion households taking up cultivating in this site post-1990	<1/3	>1/2	Differs
Nos. fields	90% <2	74% <2; 26% 3-4	Pearson chi square 11.04 df=4, P<0.03
Acreage/hh			
Acreage /AE	0.73	0.70	NS
Self-sufficiency: Mean months harvest lasted	9	8	NS
hoping to increase area cultivated	75%	75%	NS
Material score	50% hh have torch 25% have bicycle 8% have car	75% have torch none none	Pearson Chi square 23.8 N=70 P<.001
Livelihoods score	31% agropastoral + no alternative income 55% have regular income and 14% have high level regular salary or business income	87% agropastoral + no alternative income 13% have regular income as official or teacher	Pearson chi Square 28.9 N=72 P<.001
Mean total cattle/hh	134.5	43.2	P<0.01
Mean total small stock	129.6	161.1	NS
Mean total TLU/hh	117.5	58.0	NS

Lowland, semi-arid Mairowa is the larger settlement, less remote, with better facilities compared to the highland, subhumid Sokon site. There are no significant differences in mean household size, dependency ratio or years of education, but Mairowa has larger numbers and proportions of relatively better-off people with higher material and livelihoods scores. Mairowa households have significantly larger mean cattle holdings. On average Sokon has larger small stock holdings, and Mairowa larger numbers of tropical livestock units per household, but the variation is so great in both sites that neither difference is significant. Acreages cultivated (per household and per adult equivalent) are not significantly different between the two sites, though unlike Mairowa one-quarter of Sokon households have more than 2 fields, perhaps reflecting the mountain terrain and its narrow altitudinal zoning of agroecological potential (from fertile, subhumid forest edge to semi arid rocky slopes lower down). In both sites, the grain harvested lasts on average 8–9 months, and three-quarters of households are keen to extend their area of cultivation.

Herd management and performance

Herd management differs between the two areas. One-third of households in Mairowa share herding, as opposed to one-quarter in Sokon: however, this difference is not statistically significant. There is a significant difference in patterns of transhumance, with two- thirds of Sokon herdowners moving their livestock to different bomas in the course of the year, as opposed to one-third of Mairowa herdowners ($p<0.02$). Other than the expected (and low level) seasonal variation, preliminary analysis indicates no recent or progressive change in grazing patterns that could be related to vaccination uptake as yet.

Mairowa livestock production is significantly more commercial than in Sokon. Total numbers of cattle sold, total TLU sold and the proportion of total TLU sold are all significantly greater in Mairowa (though small stock sales are not). If the wealthiest five households are excluded, proportions of total TLU sold (but not other measures) are still significantly higher in Mairowa.

	Mairowa	**Sokon**	
Mean Total no.cows sold	8.3	2.7	F=7.052,p=.01
Mean total SS sold	10.8	8.9	NS
Mean total TLU sold	7.7	3.4	F=4.029, p<.05
Proportion TLU sold	.03	.02	F=5.422, p<.03

Survivorship (life table) analysis shows these significant differences in levels of livestock trade graphically (Figures 1 and 2). The analysis is focused on immatures and young animals on the register (up to an upper limit of 72 months, thus concentrating on those most susceptible to ECF mortality and also those most likely to be sold in a commercial livestock system). The analysis is carried out using 18-month age periods to minimise the effect of age attribution problems. Sokon animals show a significantly higher 'survival' (=lower probability of offtake through being sold/given) than Mairowa cattle ($p<.001$).

There are significant differences between the mortality patterns for the two areas for unvaccinated animals (but not for vaccinated – see below). Mortality analyses made use of only the 1,389 animals whose exact status was known (alive/dead, omitting those which had been sold or given away). Of these 1,012 had not been vaccinated. In Mairowa 28% unvaccinated animals had died, significantly fewer than the 41% in Sokon ($p<<0.001$). Cattle fertility is difficult to interpret because of the way cattle are recruited onto the register and because the nine months during which by our three visits took place spanned a seasonal pulse of births. During the study, 75/80 cows >54 months calved in Mairowa, and 21/28.5 in Sokon.

Impacts of vaccination

Vaccination makes a highly significant difference to survival in cattle in both areas. Taking the full 1,528 records on the livestock register, which includes all the past offspring of cows currently being milked by sample households, 30% unvaccinated animals had died, as opposed to 2% vaccinated (Pearson chi square 128.4, df=1, p<.001). These data reach back beyond the period of the survey itself. For all 650 immatures in the sample (<3yrs) 33% unvaccinated animals died, as opposed to 2% vaccinated (Pearson chi 102.59, p<.001). These figures do include large numbers of animals that were unvaccinated and dead but for whom exact ages at death were not known. Using only immature animals under three years old and of known age/age at death, 16% of unvaccinated animals died as opposed to 2% of vaccinated animals (n=456, p<0.001). Taking all immatures, including some for whom ages were not known, 25% of unvaccinated animals were reported as having died of ECF *vs* 1% vaccinated (n=610, p<.001). Life table analysis shows vaccinated animals are highly significantly more likely to survive (p<.001: Figure 1).

Implications of vaccination for livestock numbers and spread of farming

The extent to which vaccination is related to household involvement in livestock sales and/or cultivation has implications for changing trends in land use and household economy across the region, and for environmental outcomes.

There are clear links between vaccination and livestock trade. Households with at least one vaccinated animal sell on average double the numbers compared to households with no vaccinated animals, though the variance is so great that this difference is not significant, whether sales are measured as absolute numbers of cattle, sheep or TLU, or as proportions of TLU sold. Multiple regression shows, however, that the level of TLUs traded by the household is a significant determinant of the proportion of immatures vaccinated (F=6.613, n=72, p<.01). Other variables such as numbers of cattle or of small stock sold, or proportions of total TLU sold, all drop out of the analysis. Overall, it is the absolute volume of livestock trade (itself strongly linked to wealth) that determines vaccination, rather than the proportional value, or total number of cattle or of small stock. At the level of individual animals, the 'survival' function is significantly different for vaccinated animals, which show a significantly higher probability of offtake for sale/slaughter/ gift up to the age of 72 months leaving the non-vaccinated animals a higher 'survival' (p<.05). This interaction with trading emerges as the main determinant of vaccination. Of the 72 households in the sample, those with the highest absolute turnover are the wealthiest in TLUs and are the main vaccinators; many of the differences lose significance if the five wealthiest households are excluded from the analysis.

By contrast to the clear link with livestock trading, no significant interactions could be found between vaccination and farming, which suggests that to date there is little either in the way of cross investment nor of direct tradeoffs forcing 'either/or' decisions between livestock and farming enterprises. There is no significant difference between Mairowa and Sokon in acreages/household, acreage/reference adult, number of acres harvested nor months the harvest lasts. These measures do not correlate with either the presence of at least one vaccinated animal in the herd or with the proportion of animals in the herd that have been vaccinated. People who are richer in livestock hire more farm labour (the number of tasks for which labour is hired – clear/till/ plant/weed/ harvest) – correlates with the total household

TLU (Pearson correlation 0.239, n=69, p<.05). However, there is no link between levels of labour hire and presence of vaccinated animals in the herd.

Factors influencing vaccination uptake

We investigated patterns of vaccination by site, by category of animal, by household wealth, and education. In addition to the results from the livestock register and household survey, work by Richard Felstead used focus group and semi-structured interview in Mairowa and Simanjiro to investigate factors influencing vaccination uptake.

There is no difference between the proportion of Mairowa and Sokon households with at least one vaccinated animal (>80% in each case). However, proportions of all cattle vaccinated are significantly greater in Mairowa (31% *vs* 20%, p<.01) as are proportions of immatures (55% vs 37%, p<.02). If the five wealthiest households are excluded from the sample, proportions of immatures vaccinated are no longer significantly different though proportions of all cattle vaccinated remain significantly different.

Significantly more male animals are vaccinated than female (34% males *vs* 22% females in a total of 1454 animals). Among 619 immatures, 53% males were vaccinated as opposed to 44% females (Pearson 5.379, p=0.02). These data crosscheck well against the summary herd data (collected independently from male household heads, as opposed to livestock register data gathered primarily from women responsible for milking and caring for particular cows and their offspring). The summary data give 50% immatures and 27% all cattle as vaccinated. Paired sample tests on summary data confirm that significantly more males (t=2.403, df=71, p=.02), a significantly higher proportion of males (t=6.46, df=71, p<.001), and significantly more immatures (t= 10.07, df=71, p<.001) are vaccinated.

Household wealth is an important determinant of vaccination uptake. The total number of TLUs and the TLUs per reference adult are both strongly associated with presence of at least one vaccinated animal in the herd. Herds with one or more vaccinated animals are significantly larger – double or more the mean holdings for non-vaccinators (mean total herd of vaccinators =110 TLU *vs* non vaccinators 43 TLU; F=4.896, p<.03 ; mean TLU/AE = 7.0 for vaccinators *vs* 3.4 for non vaccinators, F= 5.013, p<.03). However, if the wealthiest households are excluded there is no significant difference between the total TLUs (or TLU/AE) of vaccinators (with at least one vaccinated animal present in the herd) and non vaccinators. Multiple regression shows the proportions of immatures vaccinated depend on the total TLUs (F=11.83, p<0.001), not on the total numbers of cattle, on village or on household size. If the wealthiest households are excluded, the proportion of immatures vaccinated remains significantly related to the total number of cattle owned by the household (F=4.318, p<.05), though other variables such as total TLU, TLU/adult equivalent, village and household size all drop out of the analysis.

This variation in patterns of vaccination with socio-economic status is confirmed by analysis with respect to livelihoods score. This is based on number and type of occupations, from households that engage in agropastoralism only, through to those with government jobs and private business interests alongside herding and farming. The livelihoods score includes a major component of reliability of income. Proportions of animals vaccinated show a significant increase with increasing livelihoods score (from 33% male animals in subsistence agropastoralist herds to 96% in herds belonging to men with administrative posts: F=4.935, p<.002 and from 19% to 61% for female animals, F= 2.478, p=.05).

The livestock register and survey data show no associations between uptake of vaccination (at least one animal in herd vaccinated) and any measure of education (head of household educated/ proportion of household members under 18yrs educated/overall proportion of people in household educated/mean number of years in education for all household members).

Of the 74 Mairowa interviewees in Richard Felstead’s MSc. study, the 3/5 who were vaccinating were more likely to have alternative livelihoods and sources of income (trade, property rental etc) than the 2/3 who were not vaccinating. Similar patterns were seen in the smaller Simanjiro sample According to RF’s wealth ranking, around 50% poor and middling-wealth farmers in Mairowa had vaccinated, while around 90% of wealthy farmers had done so. RF’s Simanjiro wealth ranking was problematic and his breakdown of vaccination by wealth for Simanjiro is not discussed here. RF found 80% Mairowa farmers vaccinated after seeing others do so, and seeing their animals do well. In Simanjiro, most adopted the vaccine as soon as it became available, having already heard about it from users elsewhere. Herd-owners in both areas perceived the vaccine as very effective with respect to ECF and as having a positive effect with respect to survival overall, general health and the risk of other diseases. However, a majority saw no difference in growth rate, final size or fertility as a result of vaccination against ECF.

Both the main study, and RF’s data showed that many households perceive a problem with availability and with cost of the vaccine. RF found over 50% of Mairowa men who had not vaccinated, or who had vaccinated only part of the herd, cited lack of cash, and problems accessing the vaccine, as barriers to use. Most herd-owners (whether or not they were vaccinating) saw cost as the main problem with the vaccine (77% Mairowa; 50% Simanjiro interviewees; in both cases a higher proportion of non adopters cited this as the main problem –90% non adopters in Mairowa, 57% in Simanjiro). Availability was the next most commonly cited problem (54% Mairowa, 18% Simanjiro); few other problems were cited, with 15–18% herd-owners reporting no problems at all. A substantial number of households find it hard to access the benefits of the vaccine for two reasons. First, the cost exceeds the means of the poor households and represents a difficult choice for households of medium wealth. Second, the vaccine is provided in straws which are diluted in the field to 32–35 doses. In this extensive pastoralist system with isolated homesteads scattered over a wide area, poor transport and communications, and erratic veterinary attendance, only large scale operators can gather the necessary numbers of calves for vaccination at one place and time. It is difficult for smaller producers to coordinate enough individual herd-owners with a few calves each to achieve this but they cannot afford to vaccinate less than the 32 minimum.

SUMMARY AND CONCLUSION:

IMPACTS OF ECF VACCINE ON MAASAI LIVESTOCK AND HOUSEHOLDS

(this also represents the abstract for paper accepted for International Symposium for Veterinary Epidemiology and Economics (ISVEE), Chile, November 2003 by K.Homewood, S.Randall , P. Trench and L.Lynen)

Tick-borne East Coast fever is the major cause of calf deaths among East African indigenous cattle, with mortality rates of 50%–80% in unvaccinated immatures. This 9-month study measured the impacts of an Infect and Treat vaccine on livestock survival and its relation to household economy for Maasai households of different socioeconomic status. Using a multiround survey of 72 households and a register of 1,528 cattle in two study areas of different epidemiology, livestock mortality, fertility, sale, slaughter and exchange were measured.

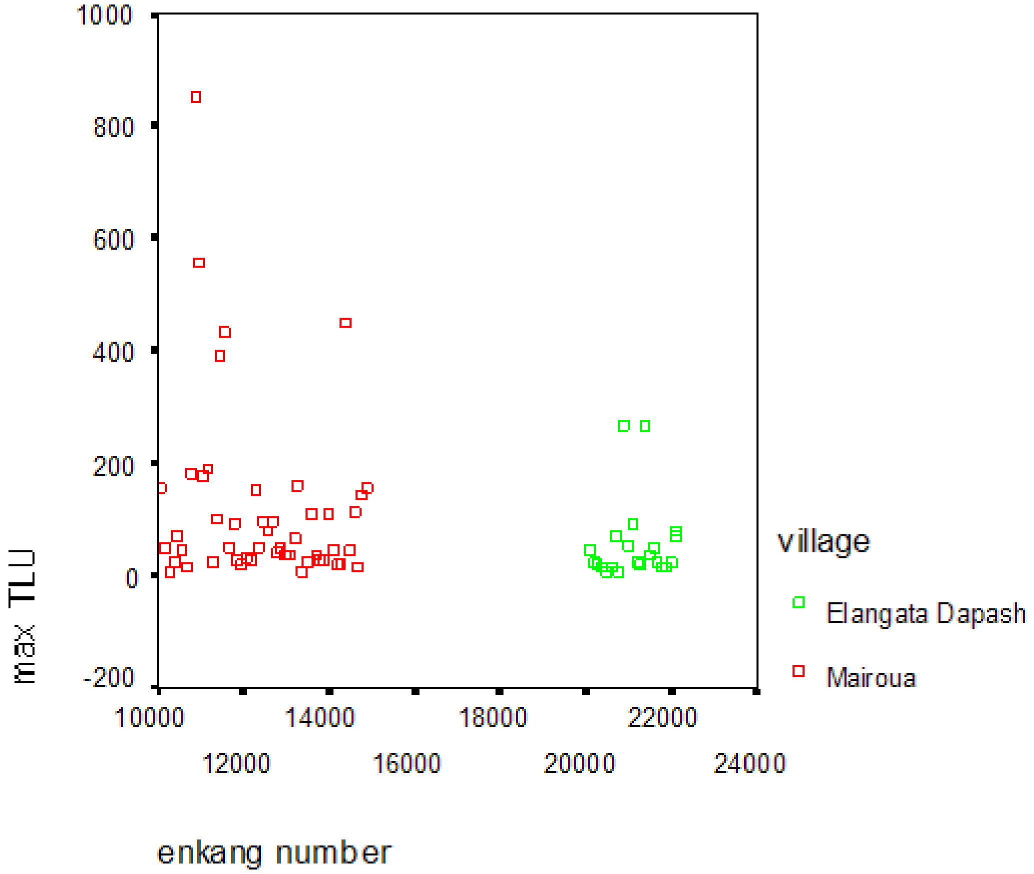
Livestock performance differed between the two study areas, with the highland area showing inherently higher mortality of unvaccinated animals, both adult and of immatures. The vaccine has a significant and major impact on survival in both areas. Around 33% of unvaccinated animals on the register had died, compared to only 2% vaccinated.

Vaccination is strongly associated with wealthy households and with trading livestock. Vaccinated animals are significantly more likely to be taken off for sale, and are reported to receive a higher price. There is no clear relation between uptake of vaccination and level of farming activity, nor with any measure of education.

There are potentially environmental issues concerning the outcomes of a dramatic reduction in calf mortality associated with vaccine uptake. The results suggest that improving calf survival is linked with increased turnover and offtake. Further research is needed to establish whether vaccination may be driving increasing herd numbers on the one hand, and on the other, whether the reduction in acaricide use that accompanies vaccination may be bringing positive environmental effects. Qualitative data suggest the causal link with wealth lies in the fact that only the better off can afford to vaccinate, rather than that vaccination *per se* has made these herd-owners rich. In several cases removing the five wealthiest households of the sample also removed significant effects.

Medium and poor households find it hard or impossible to access the benefits of the vaccine for two reasons. First, the vaccine is provided on a cost recovery basis which exceeds the means of the poor households and represents a difficult investment choice for households of medium wealth. Second, the vaccine is provided in straws which are diluted in the field to 32–35 doses. In this extensive pastoralist system with isolated homesteads scattered over a wide area, poor transport and communications, and erratic veterinary attendance, only large-scale operators can gather the necessary numbers of calves for vaccination at one place and time. It is difficult for smaller producers to coordinate enough individual herdowners with a few calves each to achieve this but they cannot afford to vaccinate less than the 32 minimum.

The Infect and Treat method used in Longido is highly effective in veterinary terms and hailed as such by local producers. However, the logistics and economics of access mean that it may be driving differentiation, rather than alleviating poverty. Government promotion of this and comparable interventions need to consider the poverty impacts and take measures to widen access.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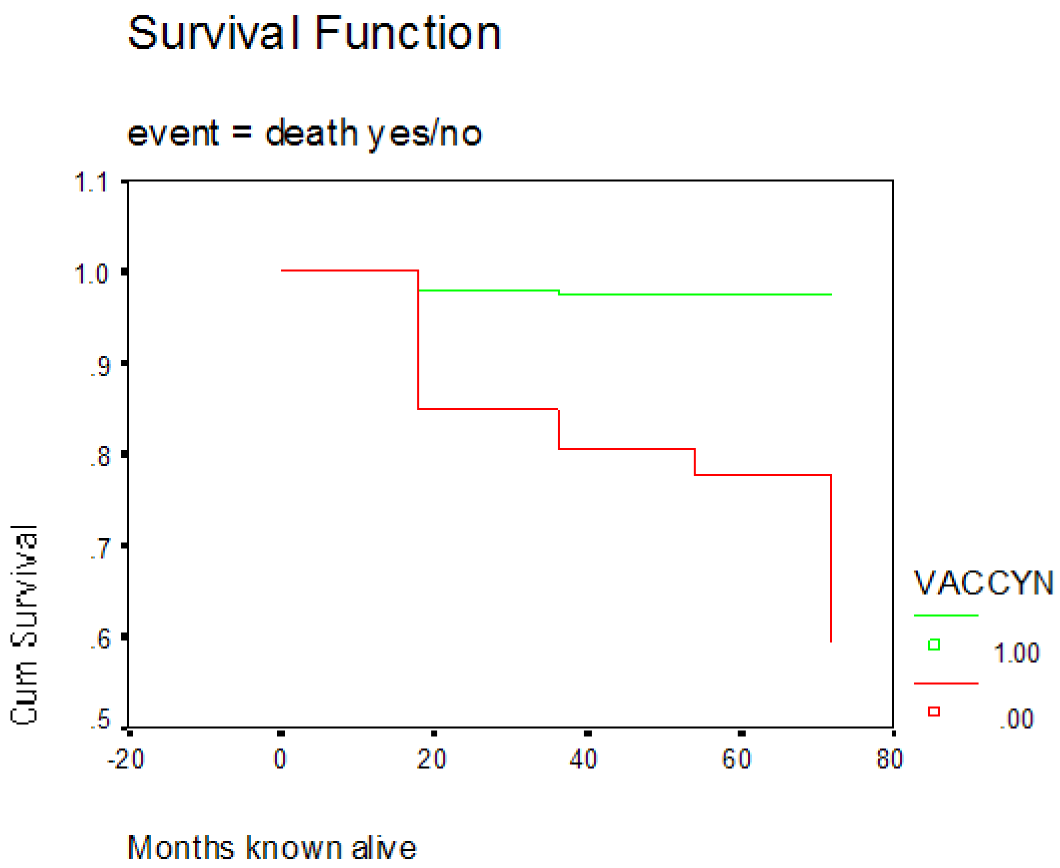
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DECISION SUPPORT TOOLS

1. Livestock owners and local leaders

a) Impacts of ITM:

Our studies have shown that

i. around one–third of unvaccinated animals die young, and most of those deaths (more than two-thirds) are caused by ECF
ii. of any hundred ITM-vaccinated animals, only two die young
iii. ITM vaccination has a very great impact on survival of calves. It also improves survival from other diseases and helps overall growth rates
iv. vaccinated immatures sell for more than unvaccinated animals: if you are able to pay to vaccinate your calf, when you sell that calf as an immature animal you will make a profit several times the cost of the vaccine, over and above the sum you would get for selling an unvaccinated animal

b) ECF transmission

Our studies have shown that;

1. All calves are getting infected with ECF, but only some become ill with the infection
2. We do not yet understand why some calves become very ill and die, while others show no sign of sickness. We do know that there is a difference between the ticks, which only give animals a very mild infection, and those ticks whose bite makes the animals very ill.
3. Although you can't see the difference between those two kinds of tick just by looking at them, we know that the ticks which feed on a very sick animal will be fierce ticks themselves. When they drop off the sick animal, and later they climb onto another calf and feed again, they will make the second calf very sick too
4. You can reduce the number of sick calves in your boma if you don't let ticks from a very sick animal drop off and survive in your boma to attack other calves. Animals that are sick need to be sprayed and their ticks killed

2. Private Sector

a) Market:

1. There is a very strong demand for ITM vaccine among pastoral and agropastoral livestock owners, though the cost is a significant outlay for an average household.
2. Current uptake in pastoral and agropastoral areas is limited by the packaging which requires herdowners to gather 32 calves to make full (and economic) use of the doses in a single straw
3. Future production should aim to make variable packaging from 5 to 50 doses per straw and/or with variable diluent volumes to meet the range of needs of suppliers and herdowners

b) Delivery:

Pastoral and agropastoral areas are remote and homesteads are widely scattered. Private sector needs to address the barriers to best delivery including:

a. cold chain (or invest in the development of alternative chemical/ freeze-dried vaccine maintenance mechanisms)
b. numbers of delivery agents (paravets? Other trained agents)
c. concern by the veterinary profession that vaccination may undermine their profits

3. Public sector

a) Government has a role to play in:

1. disseminating information about ITM
2. supporting delivery by private agents
    i. with enabling measures (as indicated in Livestock Development Policy)
    ii. as partner in delivery, particularly in rural and remote pastoral areas
3. providing checks and balances: quality control/ regulation/ ensuring accountability of private delivery system/ ensuring only legal vaccine provided
4. supporting/funding monitoring activities ensuring that vital information is available e.g. on medium- and long- term changes in biology of the disease (e.g. strain/ virulence); environmental impacts of changing livestock numbers and shifting land use patterns; socio-economic impacts; impacts on local and regional economy).
    i. livestock numbers
    ii. ECF incidence/prevalence (ECF must remain a reportable disease)
    iii. ITM Vaccine efficacy
    iv. Trends in household economy related to ITM
    v. Trends in vaccine provision (public sector review of immunisation figures recorded by delivery agents)

b) In addition, Government should take note of:

1. the household herd-level approach used in the DFID study, which has proved to be a powerful method for providing important information on vaccine impacts, implications for sales and the livestock economy, and differentiated socio-economic impacts including poverty implications
2. the likelihood of additional benefits at community level, over and above individual uptake of vaccination if at least 80% animals of any one household herd are vaccinated

4. Donors

ITM has a major and extremely significant effect on ECF, which is the main cause of mortality in East African pastoral and agropastoral systems (and the potential for a similar impact in other countries of Central and Southern Africa where ECF is endemic.

Enhanced survival due to ITM is strongly linked with increased sales, primarily of vaccinated animals, at higher prices than fetched by unvaccinated animals.

Vector and disease dynamics studies and modelling give clear messages on optimal herd management (see attached guidelines for livestock owners).

Uptake of vaccine is limited by cost, and is strongly associated with wealth, though a majority of households have at least one vaccinated animal in their herd. Differential access is likely to drive socio-economic differentiation in poor agropastoral and pastoral groups. Poverty reduction means prioritising work on the best ways of widening access to ITM

Household level methods of monitoring and evaluating ITM uptake and impacts as well as associations with socio-economic status, sales and cross investment are essential if differential access and economic impacts as well as environmental implications are to be understood and appropriate responses made at local, national and international level.

Dissemination media and formats
The outputs have been disseminated to some of the end users. A visit to the study sites was made by a team form the ITTBD project to discuss the results with herd owners. Leaflets and radio programs have not been made as yet. The message was again disseminated during the regional agricultural show between 1-8 August 2003. The data set has been circulated to the national institutions

CONTRIBUTION OF OUTPUTS

The main out puts from this study are;

- Epidemiological and socio-economic database made available to NARS.
- Decision support information on ECF transmission and the impact of ITM in local setting available to livestock owners and local leaders. This information is relevant to other pastoralists in East Africa.
- Decision support information on the market potential and the barriers to the delivery of ITM in pastoral systems available for the private sector.
- Information on the constraints and possible solutions to adoption of ITM available to the public sector.
- Information on the differential impacts of ITM on the livelihoods of the poor available to donors.
- Formats for information dissemination to different stakeholders under preparation.
- Reduced morality due to ECF leads to increased sales, which are associated with cross investments.
- Reduced risk of ECF through immunisation is encouraging keeping of improved breeds of cattle.

The household herd level approach combining epidemiology, modelling and socio-economic aspects used in the study proved to be a powerful method for providing important information on vaccine impacts, implications for sales and the livestock economy and differential socio-economic impacts including poverty implications.

These outputs contribute to both AHP purposes. Improved epidemiological and socio-economic knowledge allows policy makers and other stakeholders to target and implement appropriate and cost-effective strategies to control ECF. These strategies will include promoting and targeting ITM. The study showed ECF, has important effects on the livelihoods of poor pastoralists and its control will have a number of implications. The knowledge from household and focus group allows making ECF control appropriate in a broader pastoral livelihoods context.

The project addresses priorities in the DFID-supported National Development Plan and links to previous DFID-ESCOR projects (R6828 and R7638). Field studies will be complementary with the recently funded AHP project on cerebral theileriosis in Tanzania (R8022). The project will also have links and gain from the experience of AHP projects R7360 to improve targeting and appropriate use of drugs for trypanosomosis and (R7596) on decision support systems for trypanosomosis control in south-eastern Uganda. Information from this project will greatly benefit the targeting and use of new vaccines for ECF being developed at ILRI with DFID funding.

The outputs are likely to benefit the poor pastoralists in the study areas. Their already developed and revealed demand is the greatest indicator of likely impacts and benefits. The knowledge generated by this project would also benefit pastoralists in other areas of Tanzania and Kenya.

APPENDICES

Appendix 1: Project LogFrame

Narrative Summary	**Indicators of Achievement**	**Means of Verification**	**Risks and Assumptions**
Goal			
Benefits for poor people generated by application of improved management of livestock disease.			
Purpose			
1. Cost-effective and appropriate strategies developed to sustainably control diseases of livestock that affect the livelihoods of the poor. 2. Promotion of proven strategies to control diseases of livestock that affect the livelihoods of the poor. The research theme addressed is decision support systems aimed at tick borne disease.	By 2005: 1. Improved ECF immunisation coverage in pastoral areas (2) 2. Lower ECF mortality and increased transmission by carrier animals in seasonal and year-round transmission areas (2) 3. Improved knowledge of TBD control and pastoral risk management strategies by poor livestock keepers (1)	1. Sales of ECF immunisations in pastoral areas (1) 2. Epidemiological surveys and disease reports (2) 3. Government reports (1, 2) 4. Household surveys (2)	• The political and institutional environment for livestock development and provision of livestock health services remains favourable • Sustainable production of ITM and its provision to pastoral areas is successfully maintained
Outputs			
1. A decision support system to help livestock policy makers 1.1 target TBD control, particularly ECF immunisation, to pastoral areas in which the greatest livelihood benefits to poor livestock keepers can be obtained, and 1.2 adjust these TBD control activities as appropriate to fit within the broader sustainable risk management strategies of pastoralists 2. Media and formats for knowledge transfer to technical and field staff, NGOs and pastoral groups	By the end of the project period: 1.1 Model-based decision support system used to generate recommendations regarding ECF immunisation strategies in pastoral systems 1.2 System presented to policy makers with emphasis on context and heterogeneities 2. Dissemination of media developed and delivered to policy makers	1.1 Project and workshop reports, including scientific publication; reports by target institutions 1.2 Project and workshop reports 2. Project reports and extension publications; reports by target institutions	• Government continues to support livestock services and maintains TBD control as a high priority • Target institutions and their staff take up and apply project results

Activities			
1. To achieve output 1 1.1 Conduct longitudinal field studies of TBD infection dynamics, pre- and post-immunisation 1.2 Apply ECF infection dynamics model to pastoral areas 1.3 Conduct household surveys / focus group studies to assess impact of ECF control on pastoral livelihoods and its implications for ecosystem use 1.4 Develop decision support tools for policy makers 2. To achieve output 2 2.1 Develop dissemination media for technical and field staff, NGOs and pastoral groups	By the end of the project period: 1.1 Longitudinal data collection successfully implemented in two sites; TBD epidemiology in sites described and infection dynamics model validated 1.2 Predictions of ECF dynamics and impact of immunisation generated for each study site 1.3 Surveys successfully implemented in two sites and role of TBD control in pastoral livelihoods analysed 1.4 Impact and viability of ECF immunisation in pastoral systems evaluated using infection dynamics model, and policy recommendations identified 2.1 Decision support tools documented and policy recommendations translated into dissemination media	1.1 Documented dataset, project reports and scientific papers 1.2 Project reports and scientific papers 1.3 Documented dataset, project reports and scientific papers 1.4 Project reports, policy brief 2.1 Manual for model applications, extension publications	• No extremes in climatic conditions making extrapolation across time difficult • Effective collaboration between project partners is successfully maintained • Key stakeholders recognize relevance of project outputs • Government continues support to livestock services and maintains TBD control as high priority

Appendix 2:Papers Accepted for publication

Di Giulio, G., Lynen, G., Medley, G., O'Callaghan, C.J., Kiara, H.K, and Mcdermott, J.J. 2003. Characterization of theileriosis in pastoral production systems in Northern Tanzania. Proceedings of the 10th International symposium for Veterinary Epidemiology and Economics, Vina del Mar, Chile,17-21, November 2003.

Kiara, H.K., Bakuname, C., Di Giulio, G., Lynen, G., Risk management strategies of tick-borne diseases within sustainable pastoral systems. Poster presented during the CGIAR Annual General meeting, Nairobi, Kenya, October 2003.