

6 DISCUSSION

6.1 Cross-sectional study

6.1.1 Questionnaire survey

The objective of the questionnaire survey was to seek information from farmers on livestock husbandry practices and disease management. The results of the survey indicated that the average family size per household in Busia district was 8.5 persons. The Ministry of Finance and Planning of the Government of Kenya (1999) indicated that Busia District has a population of 370,608 people. Farmers in the District depend on mixed crop/livestock production systems for their livelihoods (Machila *et al.*, 2003). However, it is reported that this production system is barely subsisting. This might be the major contributory factor to the high proportion of the population (60%) living below the international poverty line of US\$1 a day (Ministry of Finance and Planning, GoK, 2002).

Keeping of livestock (cattle, poultry, pigs, sheep and goats) was perceived as an economically important activity by the respondents, being a source of traction, milk, manure and cash incomes. The average size of a cattle holding per household in the district was reported to be 4.5 where Budalang'i and Funyula Divisions are in the lead with a mean of 5.9 and 7.3, respectively. In the current survey, livestock production was perceived to be constrained by important diseases; i.e. trypanosomosis, tick-borne diseases, helminthosis, pneumonia and notifiable diseases like LSD and FMD, in that order. Farmer-ranking of trypanosomosis first instead of TBDs contradicts what was reported by Machila and co-workers (2003) who undertook similar studies in the same area in July 1999. It is during this time that farmers were reporting high losses of cattle to an "apparently strange disease", which was ultimately diagnosed as trypanosomosis. The vigorous campaign by FITCA-K (FITCA-K, 2001) to put the situation under control was accompanied by farmer education, which might have altered their perception on the importance of trypanosomosis.

The disease problem in the district is compounded by lack of adequate government veterinary services due to the privatization of veterinary services and reduced budgetary allocations. In addition, poor veterinary infrastructure, poor diagnostic capabilities by the AHAs and cattle owners treating their animals, further aggravate the poor animal-health situation. For instance, 53.5% of all treatments in Busia are administered inappropriately, i.e. to cases perceived to be diseases other than trypanosomosis and 27.1% of farmers treat their own animals (Machila *et al.*, 2003). This raises concerns of trypanocidal drug usage in the area since widespread and uncontrolled use will invariably lead to drug resistance, as was for instance confirmed in West Africa in the common border region between Burkina Faso and Mali (Clausen *et al.*, 1992).

Farmer-initiatives on dealing with conditions that they are familiar with, like helminthosis and tick burdens are also low. Although 68% of the respondents recognised helminthosis as an important constraint, the mean number of antihelmintic treatments administered to calves was only 0.8/year. This implies that some farmers do not drench their animals at all in a given year. Given that a majority (71.7%) of respondents were involved in some form of tick control, the main concern is on the frequency of spraying and the dilution of the acaricides.

Although when properly managed, a smallholder production system offers continuous self employment and sustainable source of proteins to the resource-poor farmers, the current trend in Busia District must be reversed for the system to subsist. With the GoK policy of increasing milk and meat production from the smallholder sector by initiation of breeding programmes to upgrade local cattle slowly trickling down to Busia District, numbers of exotic and crossbred cattle are on the rise. It is therefore deemed necessary that the most important disease constraints be identified and their importance with respect to livestock production be addressed in order to reduce the disease risk, especially for the incoming 'naive' cattle. Improved animal production through concerted efforts on disease control will be an important step towards alleviation of the projected massive deficits in meat and milk supplies by 2025, as projected by Winrock International (1992) and eventually will have a positive impact on the standards of living of the people. The entry of private animal health providers into the District through the joint efforts of FITCA-K, the Kenya Veterinary Association Privatization Scheme (KVAPS) and private veterinarians, to take-up clinical operations, will go along way in improving the current situation. This should be coupled with farmer training in the identification of the important disease risks.

6.1.2 Trypanosome infection

The trypanosome prevalence in cattle with regard to age, sex, location, husbandry system and apparent tsetse density was investigated in a cross-sectional survey. The overall trypanosome prevalence in cattle in Busia District was 4.7%. Four types of infections were recorded in various parts of the District in the following proportions: *Trypanosoma vivax* 40.6%, *T. congolense* 35.3%, *T. brucei*, 19.5% and mixed infection 4.5%. Therefore, the majority of trypanosome infections were contributed to *T. vivax* followed by *T. congolense*, *T. brucei* and mixed infections in that order. Findings from this study indicated that the Divisional-dependent trypanosome prevalence can be stratified in two main levels: low (Nambale 2.4%, Matayos 2.1%, Township 3.0% and Butula 4.0%) and moderate (Budalang'i 8.5% and Funyula 6.4%).

It is evident that the high trypanosome infection rates (up to 40%) in cattle from Busia District reported earlier by Angus (1996) and by Murilla *et al.* (1998) seem to have considerably reduced. This might be especially through the FITCA-K tsetse and trypanosomosis control

campaign that started in 2001 in Busia District (FITCA-K, 2001). This initiative is still on-going and involves FITCA-K, the Department of Veterinary Services and farmers. Animals are sprayed twice a month with a deltamethrin preparation (Decatix[®], Coopers Kenya Ltd) in community crush pens. For every animal sprayed, the farmer contributes about KSh. 20, which goes toward replenishment of the deltamethrin and the maintenance of the pump and the crush pen. Previous work carried out in Burkina Faso by Bauer and co-workers (1999) indicates that use of deltamethrin treated cattle and impregnated targets were able to reduce the incidence of bovine trypanosomosis, initially exceeding 30%, to below 5% and tsetse populations by 90% in less than 7 months. This need-driven intervention appears to be sustainable and it is recommended that the technology be disseminated to cover most parts of Busia and the surrounding Districts. It would be important however, to establish the critical mass (proportion of animals) that need to be sprayed for effective mopping up of the fly populations. By the end of 2003, over 50 crush pens had been established in Busia District by community-organized committees. Each committee was initially provided with a spray pump (with farmers paying 1/3 of the cost) and a litre of deltamethrin, as a start-up kit. Farmer-anecdotal reports indicate that they have started to observe increased milk production, reduction of the population of tsetse flies and other biting insects and improved vigour and fertility of the sprayed livestock. Livestock health, production and marketing are envisaged as future components of crush pen activities and hence transforming them into community animal health and marketing centres.

Although it has been observed that *T. congolense*, followed by *T. vivax* infections predominate in cattle in various parts of Africa (Rowlands *et al.*, 1993; Leak, 1999; Karanja, 1999; McDermott *et al.*, 2003), our observations in Busia District differed with these previous reports. During the survey, the majority of infections were due to *T. vivax*. Similarly, data collected from Orma Boran cattle raised in Galana Ranch (Coastal Province), Kenya, over a period of 10 years (from 1990-2000) indicate that there were significantly higher *T. vivax* infections in cattle as compared to *T. congolense* infections (Bett *et al.*, 2004). In the coastal strip, cases of haemorrhagic *T. vivax* infections have previously been reported (Wellde *et al.*, 1983; Mwangela *et al.*, 1983; Stevenson and Okech, 1997). In Busia and the neighbouring Teso Districts, previous surveys have also reported cases of haemorrhagic *T. vivax* from 1997 (Murilla *et al.*, 1998). Whether there is a relationship between the predominance of *T. vivax* infections and the occurrence of the

haemorrhagic-type remains to be explained. However, during the study, no cases of haemorrhagic *T. vivax* were reported.

A significant finding during this survey was the relatively high proportion of *T. brucei* infections in cattle in the various Divisions: in Budalang'i (23.7%), Funyula (19.6%), Butula (18.7%), Nambale (15.4%) and Matayos (20.0%). The District is part of an old sleeping sickness focus where cattle have been implicated as part of reservoirs for the disease in man (Angus, 1996). In addition, dogs are suspiciously viewed as part of the peri-domestic cycle of sleeping sickness in the area. During the study, we examined 15 dogs suspected to be infected with trypanosomosis, at the request of farmers. Out of these, 3 were blind and had high parasitaemia due to *T. brucei* infection. In addition, a survey carried out in 2000 by Matete (2003) revealed a *T. brucei* prevalence of 2.5% after sampling 200 dogs in the District. During his work, blood from two naturally infected dogs were tested for the presence of the serum resistance associated (SRA) gene as described by Welburn *et al.* (2001) and one dog tested positive, confirming it as human infective (*T. brucei rhodesiense*). Occurrence of blind dogs as a result of *T. brucei* infection is considered an early warning sign of an impending human African trypanosomosis (HAT) outbreak. These findings are further compounded by the fact that *T. brucei brucei* (considered less pathogenic than *T. congolense* and *T. vivax* in cattle) is morphologically, serologically and biochemically identical to *T. brucei rhodesiense*, the sleeping sickness causing parasite (Welburn *et al.*, 2001). It is therefore recommended that, for villages with high proportions of *T. brucei* infections in cattle and cases of blind dogs, blanket treatment of cattle using diminazene aceturate should be undertaken so as to reduce possible animal reservoirs of this parasite. In addition, more intensive sleeping sickness active surveillance should be emphasised by the responsible institutions e.g. KARI-TRC, to establish whether any human cases exist unreported in the area.

Age-dependent trypanosome prevalence differed significantly, with adults having higher infection rates (5.6%) than calves (2.1%). However, the infection rate in heifers (4.0%) was not significantly different from that of adults or calves. Similar observations have been reported earlier when analysis of data from the African Trypanotolerant Livestock Network on the age-prevalence patterns of *T. congolense* and *T. vivax* infections in cattle from East and West Africa

(McDermott and Coleman, 1999) was undertaken. In the Southern Rift valley of Ethiopia, Karanja (1999) noted that adult cattle were 7.5 times at a higher risk of trypanosomosis as compared to calves. These observations are attributable to the fact that calves are usually tethered around homesteads and hence face a lower challenge. In addition, young animals are thought to be naturally protected to some extent by maternal antibodies in colostrums from their dams (Fimmen *et al.*, 1982).

Sex was not a significant predictor of trypanosome infection in cattle from Busia District, although male animals had apparently higher infection rates as compared to females. This is not in agreement with the observations of Okech *et al.* (1996), Chicoteau *et al.* (1990) and Rowlands *et al.* (1995) who reported previously that female cattle, especially in stress of lactation, are usually at a higher risk for trypanosome infection than non-lactating animals. In this study, the most plausible reason may be that the use of male animals for the provision of draft power renders these animals more susceptible to trypanosome infection due to the stress of traction as compared to cows. The draft oxen may also be more relatively exposed to tsetse habitats in the course of ploughing. In addition, the mean daily milk production per Zebu cow in Busia is only about 2 l/day and consequently, stress of lactation may not be considered an important risk factor.

Considering the three husbandry practices (free grazing, tethering and free grazing/tethering) for Zebu cattle in Busia District, results indicate that the trypanosome prevalence of free grazed (5.5%) and free grazed/tethered (5.1%) cattle were significantly higher than that of tethered (1.9%) animals. In Busia district, only 31% of the land is under cultivation leaving over 60% as idle and/or bushy land (FITCA-K, 2001). This is attributed to a shortage or complete lack of means of opening land, especially through draught animals. Swallow (1997) reported in his review on the impact of trypanosomosis on African agriculture that, in mixed farming systems where trypanosomosis is severe that it constrains the number of oxen, it can reduce the average area planted per household by as much as 50%. Farmers in Busia claim that they lost most of their draft animals during the 1999 trypanosomosis outbreak. Personal field observations indicate that a relatively high percentage of the bushes comprise of *Lantana camara* which present good tsetse habitats. Animals that are therefore let to graze freely in these bushes experience a higher

challenge as compared to animals tethered near homesteads. Results from the entomological survey corroborate these findings in that the relic populations of *G. pallidipes* were found in overgrown bushes from idle land. This might also explain to some extent the significantly higher infection rates observed in adults as compared to calves, as calves are more likely tethered than adult animals.

It would be important to note that changes in land use have an ever-increasing importance in changing trends of tsetse apparent densities. A case study of the Nguruman area in Magadi, Kenya, indicated that due to a substantial increase in woodland vegetation, there was a two to three fold increase in the area of tsetse infestation (KETRI/DFID, 1998). This calls for increased utilization of draught animal technology to help open up land. Work carried out in Zimbabwe (Ellis-Jones *et al.*, 1997) indicates that animal traction remains the most economical form of draft for many smallholder farmers with the cost of ploughing by tractor being some 600% greater than with oxen. It is anticipated that improved use of draft power will invariably lead to reduced bush coverage and consequently clear the favourable habitats for tsetse. Efforts by FITCA-K to train farmers on good utilization of draft animal technology were in place by the time these data were collected. Meanwhile, we recommend that restocking draft animals be emphasised jointly with preferential treatment of the already existing ones. Preferential treatment can be approached via isometamidium prophylaxis or through routine two-weekly spraying with deltamethrin. On the other hand, restocking should be considered on two levels. Firstly, restocking from within the herd by improving the husbandry of male calves e.g. through good deworming regimens. Secondly, buying and rearing steers from neighbouring farmers should also suffice.

The mean apparent density for *G. pallidipes* was 0.32 flies/trap/day while that of *G. fuscipes* was 4.9 flies/trap/day. The mean infection rate for *G. pallidipes* was 3.6% while for *G. fuscipes* it was 1.9%. There was a positive significant correlation ($p < 0.05$, $R = 0.78$) between the trypanosome prevalence and tsetse apparent density. This has been previously observed in Somalia (Mohamed and Dairri, 1987), Cote d'Ivoire, Togo, Zaire and Ethiopia (Leak *et al.*, 1988; Leak *et al.*, 1993). In this current study, although the apparent density of *G. pallidipes* is quite low, its importance as a potential vector for bovine trypanosomosis cannot be downplayed, especially after considering the high fly infection rates. In addition, the vectorial capacity of *G. pallidipes* for

animal trypanosomes (*T. congolense* and *T. vivax*) is known to be higher than that of *G. fuscipes*, which is a comparatively good vector of *Trypanozoon* trypanosomes (Leak, 1999). When considerations are made with regard to the proportion of *T. brucei* infections in cattle, coupled with the cases of blind dogs, and the potential of these parasites being human infective, the role of *G. fuscipes* in the dynamics of sleeping sickness in the area cannot be ignored.

The mean PCV of aparasitaemic cattle in Busia District was 26.9% while that of parasitaemic cattle was 23.8%. Student t-test comparison revealed that the mean PCV of aparasitaemic cattle was significantly higher than that of parasitaemic cattle. Various authors have observed this in the past in Ethiopia (Abebe and Jobre, 1996; Karanja, 1999; Afewerk *et al.*, 2000) and Kenya (Bett *et al.*, 2004). It has been reported that during trypanosomosis, pancytopenia is a common occurrence (Seifert, 1996). This is a result of the direct influence of the parasite on the red cells or the phagocytic defence reaction of the organism, which may be an auto-immune reaction.

Findings from this study therefore call for control interventions at both the parasite- and the vector-level. At the parasite level, proper case detection (diagnosis) by animal health providers is important. In addition, in the event that farmers in Busia District continue to treat their own animals (27.1% of farmers still treat their animals: Machila *et al.*, 2003), their knowledge on bovine trypanosomosis needs to be enhanced. Consequently, prompt treatment of positive cases will ultimately take care of the parasite in the absence of resistance or treatment failure. Stratified training at both the personnel (on clinical and parasitological diagnosis) and farmers (on clinical diagnosis) level needs to be emphasized. To this end, a training program on parasitological diagnosis of vector-borne diseases was initiated by FITCA in 2003 and targeted the AHAs in the five project Districts (Busia, Teso, Siaya, Bondo and Bungoma). During the training, 15 AHAs from each District were trained on collection of blood and faecal samples, smear preparations, microscopic examination and interpretation of results (FITCA-K, 2003). Emphasis should now focus on farmer trainings in various aspect of disease detection. In addition, training should emphasise rational drug use where improved use of drugs will minimise the emergence, spread and deterioration of resistance (Grace *et al.*, 2004). The other level of disease control should target the vector. Work carried out in various parts of Africa (Stevenson *et al.*, 1991; Bauer *et al.*, 1992; Fox *et al.*, 1993; Leak *et al.*, 1995) recommends insecticide-treatment of cattle as an

appealing method of control. It is important to reiterate that efforts of using deltamethrin-treated animals as targets are on-going in the District and should suffice.

6.1.3 Tick-borne diseases

Results indicate that in Busia District the overall prevalences of *Anaplasma*-, *Babesia*- and *Theileria*-spp-infection were 16.4%, 4.8% and 6.9%, respectively. There was no significant difference in the prevalence of TBD-parasites between the six Divisions. Three main tick-species were identified in the District in the following proportions: *Boophilus decoloratus* (16%), *Rhipicephalus appendiculatus* (48%) and *Amblyomma variegatum* (36%). Examination of animals on a half-body basis revealed that over 50% of adults and young cattle had moderate (20-50 ticks) to high (>50 ticks) tick infestation, while about 30% of calves were in this category. Generally, about 80% of adult and young cattle and about 65% of calves had detectable numbers of ticks.

The high proportion of cattle with tick infestation is of fundamental importance in the establishment of enzootic stability for anaplasmosis and babesiosis, as long as the tick numbers remain within a given threshold for the establishment of such enzootic stability. This is a state where, as a result of high and continuous tick- and TBDs-challenge, the incidence of clinical disease and resultant mortality rates are low (Perry *et al.*, 1992; Perry and Young, 1995). This condition, although applying to all age groups of animals, seems to favour young animals. Enzootic stability reduces the severity of anaplasmosis, babesiosis and cowdriosis and the immunity achieved following initial infection, reduces the probability of subsequent exposure resulting in disease (du Plessis and Malan, 1987; 1988). In the current study, this seems to have been the case since the prevalence of infection with both *Anaplasma* and *Babesia* parasites in calves was significantly lower than that of adults and young animals. Even then, the level of clinical disease in the adults and young ones does not correspond to the prevalence of exposure, since not all cases of exposure result in clinical disease.

In the current study, age was not an important risk factor for the prevalence of infection with theilerial parasites in cattle. Eisler *et al.* (2002) noted that the relative likelihood of enzootic

stability, arising from challenge of ticks and TBDs, varies among diseases, being widespread and common for anaplasmosis and babesiosis but uncommon for ECF. For *T. parva* infection, factors other than age susceptibility relationship may be as important in accounting for the discrepancy between levels of infection and of disease; notably, the severity of disease is more dependent on the dose of sporozoites inoculated by the infesting ticks than the age of the host (Young, 1981). The other factors (location, sex and husbandry system) showed no significant differences in the levels of TBDs. This was mainly because the distribution of tick challenge to cattle was not significantly affected by these variables.

6.1.4 Helminthosis in calves

Results from the survey indicated that the mean FEC in calves was 1160. Based on the classification by Skerman and Hillard (1966), approximately 30% of calves had moderate to low FEC while about 70% had heavy infections. There were significantly more calves with heavy infection than those with moderate infection. However, sex was not an important predictor of FEC shedding in calves.

Results from the questionnaire survey indicated that the mean number of anthelmintic treatments in livestock was only 0.8/year implying that some farmers do not deworm their animals at all within a given year. This might explain the high early calf mortality rates (up to 80%) reported by farmers during the interviews and the observed stunted growths of the surviving ones. The choice of anthelmintics may also play a role in the level of infestation. Anthelmintic analysis work carried out by Mugambi (1998) indicated that some levamisole-derived generics such as Dewormin[®]-plus only did contain 78.7% of the indicated ingredient, instead of the required amounts. Another product (Dewormin[®]) contained 0% of the expected amounts. These are some of the products that farmers in Busia reported during the interviews of having used. However, it still is suspected that a number of other factors influenced the observed level of helminthosis in calves, among them location, age, breed and husbandry system.

Although these preliminary findings were based on point estimates (point prevalences), they provide an indicator to the expected level of helminthosis in calves. Therefore, in order to come

up with recommendations geared towards control, a longitudinal survey was planned to assess the various risk factors associated with helminthosis in adult cows, heifers and calves. In addition, the effect of the level of helminthosis on the performance of cattle in two Divisions (Budalang'i and Funyula) was to be assessed.

6.2 Longitudinal study

The specific objectives of the longitudinal survey were: to assess the risk of trypanosomosis with regard to tsetse relative density, infection rates and trypanosome incidence in cattle; to assess the effect of single/concurrent trypanosome, TBDs and helminth infection in cattle over time; to assess the impact of trypanosomosis, helminthosis and TBDs in cattle with regard to age, sex, breed and production parameters (milk, body weight and reproductive health indicators) and to assess the importance of single or combined isometamidium chloride and anthelmintic treatment in cattle. It is important to note that prevalence studies are only point estimates with which it is difficult to establish a causal association between risk factors and occurrence of the event of interest. Therefore, having conducted a prevalence study on trypanosome- and helminth-infection and infection with TBD-parasites in cattle in Busia District, a longitudinal study was planned and executed in Budalang'i and Funyula Divisions (areas identified as having moderate risk of trypanosome infection in cattle), in both local and exotic/crossbred cattle. Four treatment groups (group I: untreated controls; group II: ISMM treatment group; group III: albendazole treatment group; group IV: albendazole and ISMM treatment group) were designed in both Divisions. Each treatment group consisted of 50 animals, stratified as adult cows (20), heifers (15) and calves (15).

6.2.1 Trypanosome incidence

Results from the trypanosome incidence study indicate that in Budalang'i Division, on keeping 100 animals for 52 animal-weeks at risk, 343 cases of trypanosome infection would be detected in an untreated control group. In the ISMM treated group, 83 cases would be detected. In the albendazole treated animals, 203 cases would arise while in the albendazole and ISMM treated group, 57 cases of trypanosome infection in cattle would be detected. When this is translated into

a measure of risk using the hazard ratio (reciprocal of the ratio of mean CHR in treated compared to control animals), untreated animals had a 4.13 higher risk of new trypanosome infection than the ISMM treated cattle. In addition, the untreated controls were at 1.69 and 6.0 times higher risk of new trypanosome infections than the albendazole treated and the albendazole/ISMM treated animals, respectively. In Funyula division, on keeping 100 animals for 52 animal-weeks at risk, 270 cases of trypanosome infection in cattle would be detected in the untreated control group, while 62 cases would be detected in the ISMM treated animals. For the albendazole treated and albendazole/ISMM treated cattle, 156 and 47 cases would be detected, respectively. Therefore, the risk of new trypanosome infections in the untreated controls was 4.33 times higher than that of the ISMM treated cattle. In addition, the risk of new infections in the untreated animals was 1.73 and 5.78 times as high as that of albendazole treated and albendazole/ISMM treated ones, respectively.

These results indicate that in the two Divisions, ISMM prophylaxis was able to reduce the incidence of new trypanosome infections in cattle by 4 to 6 times. Previous studies indicate that the compound has been successfully used to maintain the productivity of Zebu cattle exposed to tsetse challenge in both village and ranch management systems in East Africa (Moloo *et al.*, 1987). On Mkwaja ranch in Tanzania where there was a high tsetse challenge, cattle maintained under isometamidium prophylaxis were 80% as productive as high quality Boran cattle on a trypanosomosis-free ranch in Kenya (Trail *et al.*, 1985). This is evidenced by our observations on the differences in weight changes of calves in the different treatment groups. During the study, it was observed that by the 16th week of treatment, calves in all treatment groups had gained significantly more weight than calves in the untreated control group. This involved both calves that were treated with ISMM and those that had combined albendazole/ISMM treatment. The mortality rates of calves were also higher in untreated control animals as compared to the ISMM treated ones and hence increasing the losses incurred by farmers. In addition, the conception rates in untreated adult cows were consistently lower in all cases than the ISMM treated ones. Eventually, abortions were only restricted to the untreated controls and the albendazole treated animals. No abortions were recorded in the ISMM treated cows within the 9 months follow-up period. These findings are also in agreement with the review by Swallow (1997), which indicated that the incidence of trypanosomosis in various parts of Africa has the

following impact: i) reduces calving rates by 1-12% in tolerant breeds and by 11-20% in susceptible breeds of cattle; ii) increases calf mortality by 0-19% in tolerant breeds and by 10-20% in susceptible breeds of cattle; iii) reduces the offtake of milk from trypanotolerant cattle by 10-26%.

However, with all the advantages that prophylaxis has on the performance of cattle, ISMM treatment of cattle needs to be monitored and regulated in order to avoid development of drug resistance. While working in Burkina Faso and Mali, Clausen and co-workers (1992) confirmed that widespread and uncontrolled use of trypanocides will invariably lead to drug resistance. This is usually due to the strong selection pressure that mass treatments with trypanocides exert on the trypanosome populations (Geerts and Holmes, 1998). Consequently, as a result of indiscriminate use of ISMM treatment of cattle in Mkwaja ranch, there was development of multiple drug resistance to the trypanosome populations circulating in the ranch (Fox *et al.*, 1993; Peregrine, 1994; Geerts and Holmes, 1998). In the present study, it was observed that 18.4% and 14.7% of untreated control cattle in Budalang'i and Funyula Divisions, respectively, were infected by the 8th week of investigation. Based on the recommendation for chemoprophylaxis by Eisler *et al.* (2000) who recommended that prophylaxis for trypanosome infection in cattle be undertaken if 25% of control cattle are infected within 8 weeks, then ISMM prophylaxis in cattle is not recommended in the two Divisions. We recommend the adoption of the suggested guidelines for the avoidance of trypanocidal drug resistance (ICPTV, 2000) which encourage use of the sanative pairs of trypanocides and minimising drug use by vector control and/or by decreasing vector-host contacts.

In the current study, result revealed that even with ISMM prophylaxis, there were breakthrough infections. In Budalang'i Division, within 8 weeks of investigation, 7% of ISMM treated cattle had experienced trypanosome infections. In Funyula Division, 3% of ISMM treated cattle had turned trypanosome positive by 8 weeks of investigation. Consequently, based on the recommendations of Eisler *et al.* (2000) of suspecting drug resistance if 25% of the ISMM treated cattle became parasitaemic within 8 weeks of treatment, drug resistance cannot be confirmed. However, it is recommended that a more in-depth assessment of the sensitivity of

trypanosome populations to ISMM in the area be conducted, in order to establish whether there is any drug resistance problem.

In general, the implication of this initial method of calculation of the risk of trypanosome infection in cattle for the farmers is that it offers reliable benchmarks that could easily be incorporated into user-friendly extension messages. Firstly, these findings offer an estimation of risk in cattle in a language that farmers can easily grasp. Consequently, once a farmer is made aware of the number of cases to expect in a herd per year, it is then easy to translate this into the costs that will be incurred for treatment. Comparison of the number of new cases between different treatment groups facilitates farmer's estimation of the impact of treatment on trypanosomosis risk. Eventually, the farmer's perception of the risk of trypanosomosis in this perspective might influence his future participation in activities geared towards tsetse and trypanosomosis control.

6.2.2 Multivariable analysis for failure-time in trypanosomosis

During the study, it had been planned *a priori* that the time-to-new-cases of trypanosome infection in cattle would be used for survival analysis. The new cases of trypanosome infection were therefore termed as failures in line with the definition by Dohoo *et al.* (2003). However, unlike in conventional survival analysis (Cleves *et al.*, 2002), it was realized that some animals experienced multiple trypanosome infections within the follow-up period and that therefore the failure times were correlated within the cluster of animal identity hence violating the independence of the failure time assumption. The simplest way of analyzing multiple failure data is to examine time-to-first-event, ignoring additional failures. However, this approach has been described as inadequate because it wastes possibly relevant information (Cleves, 1999). Consequently, the marginal risk set model (Wei *et al.*, 1989) was used to assess the association of several risk factors with recurrent trypanosome infections in cattle.

Multiple-recurrence of trypanosome infection in cattle was significantly associated with location, treatment group, husbandry and age of the animal. Isometamidium treatment significantly reduced the probability of multiple failures, leaving untreated control and albendazole treated

animals with significantly higher levels of recurrent trypanosome infections than those treated with ISMM and albendazole/ISMM. Free grazed and free grazed/tethered animals further experienced significantly higher repeat infections as compared to stall-fed and tethered animals. In addition, adult cows and heifers experienced significantly higher recurrent trypanosome infections than calves. However, there was no significant difference in the occurrence of recurrence of trypanosome infections between local Zebu and exotic/crossbred cattle.

Observations of recurrence of trypanosome infections in cattle emphasize the persistent challenge to which cattle are exposed in the two Divisions. During the 9 months follow-up period, a concurrent tsetse survey in the area indicated that the overall mean apparent density of *G. fuscipes* was 10.1 flies/trap/day and that of *G. pallidipes* was 4.2 flies/trap/day, in Budalang'i Division. In Funyula Division, the apparent density for *G. fuscipes* was 9.2 flies/trap/day and that of *G. pallidipes* was 5.8 flies/trap/day. The trypanosome infection rates in these flies ranged between 1.5-3.8%. At the same time, examination of bloodmeals taken from the tsetse flies indicated that between 42-88% of the bloodmeals were derived from ruminants. Consequently, the close interaction between particularly ruminants and the tsetse flies creates a good opportunity for the maintenance of an animal-fly-animal transmission cycle, resulting to repeat infections in the same animal.

Unlike in tick-borne diseases (anaplasmosis, babesiosis and cowdriosis) where previous exposure and sustained challenge to these infections leads to the establishment of enzootic stability (Perry *et al.*, 1992; Perry and Young, 1995), this is not the case with trypanosomosis. When an animal is infected with trypanosomes, antibodies against the variant surface glycoproteins (VSG) are produced. Trypanosomes though have various genes that code for different VSG molecules, allowing the new variants to evade the immune system (Leak, 1999). This process is termed antigenic variation and results in the persistent infections. Antigenic variation has thus prevented the development of a vaccine and permits re-infection when animals are exposed to trypanosomes with VSG of a new antigenic type (Blood *et al.*, 1989). In addition, the ability of trypanosomes to continuously change their surface-coat-antigens leads to the exhaustion of antibody production by the host, leading to immunosuppression (Brown *et al.*,

1990; Hörchner, 1993). This increases the potential of re-infection of cattle with trypanosome species.

The effect of treatment with ISMM on the significant reduction of multiple failures for trypanosomosis in cattle is associated with the prophylactic efficacy of this compound as has been previously reported by other investigators (Kirby, 1964; Pinder and Authie, 1984; Peregrine *et al.*, 1991). Apart from the reduced number of recurrent trypanosome infections, ISMM treatment resulted in improved performance of calves (as predicted through weight gains and reduced mortality) and adult cows (improved conception rates and reduced rates of abortion), as discussed earlier. It is important to note that although there was no significant difference in the recurrence of new infections between the untreated control and albendazole treated animals, the latter had consistently lower trypanosome incidence than the untreated controls. This is an indication that there is a positive interaction between trypanosome- and helminth-infection. This effect is more likely to occur when the first infection has an immunosuppressive effect on the host, thus making the latter more vulnerable to other parasites (Sharma *et al.*, 2000). These findings imply that practically the costs incurred by a farmer for the treatment of cases of trypanosomosis in dewormed cattle, are reduced. Apart from the direct losses incurred in treatment costs, there are other non-monetized losses that tend to go un-noticed. Affected animals develop anaemia, reproductive disorders (Ikede *et al.*, 1988), decline in milk yields (Agyemang *et al.*, 1991) and the PCV% never recovers to the original values (Coetzer *et al.*, 1994). It is these compounded losses that farmers should try to limit if their enterprises are expected to break-even or better, make profits.

Husbandry system was significantly associated with recurrent trypanosome infections in cattle. This is attributed to the differences in the risk of trypanosomosis within the various levels of husbandry. Free grazing is practiced on communal fields and in furrow land. In the two Divisions, this land consists of overgrown bushes with high proportions of *Lantana camara*, hence forming good habitats for tsetse. Grazing along river banks and on the shores of Lake Victoria is also prevalent especially during the dry season, when pastures are limited. This exposes cattle to higher challenge than when cattle are stall-fed or tethered around homesteads. It has been observed that the level of tsetse challenge usually influences the grazing patterns in a

community. Basset (1993) reported that at the height of the rainy season, the Fulani herders in northern Côte d'Ivoire move their cattle away from the major rivers to the upland agricultural areas to avoid tsetse. Wachter *et al.* (1994) reported that in The Gambia cattle grazing was generally focused on the village, while tsetse were concentrated in a woodland area to the north of the village and cattle were grazed in an area of relatively high tsetse density only during the wet season, when crops were planted in the fields around the village. However, this may not be possible in Budalang'i and Funyula Divisions partially because of the limited land sizes (2-5 hectares/household; Machila *et al.*, 2003) caused by human population pressure (about 230 persons km⁻²; Ministry of Finance and Planning, GoK, 1999; FITCA-K, 2001; Muriuki and Ndung'u, 2001). This leaves the people with very little room to manoeuvre. Therefore, opening up of the idle land and clearing bushes to leave low grass for the animals remains an important option that is within the reach of the farmers.

The exotic/crossbred cattle in the two Divisions are held mostly under stall-feeding (zero-grazing) while a few are tethered near homesteads, away from the height of the risk of trypanosome infection. In addition, the majority of the owners of these cattle are retired former civil servants and financially able people who can afford some form of supplementation for the animals (personal field observations). Ownership of the exotic/crossbred animals is taken with pride and farmers go to great lengths to offer improved management and feeds. These husbandry practices and improved management may contribute to reduced risk of trypanosome infection to the exotic/crossbred cattle. As a result, the incidence and recurrence of trypanosomosis in these animals did not differ significantly from that of the local animals, contrary to our expectations.

Recurrence of trypanosome infections in cattle was age-dependent, with adult cows and heifers recording significantly higher recurrence than calves. This confirms what was observed in the cross-sectional study (calves with significantly lower trypanosome prevalence than adults) and with the incidence of new infections. In the Ghibe valley of Ethiopia, Rowlands *et al.* (2001) observed that the infection incidence was lower (9.7%) in 0-9 months old calves and higher (20.9%) in 10-15 months animals. Similar observations were made in N'Dama cattle (Trail *et al.*, 1994) where a three-fold increase in the *T. congolense* infection rate immediately after weaning led these authors to speculate that pre-weaners appeared to have some protection from

trypanosome infection. At other sites in Kenya (Dolan, 1997), the Southern Rift Valley of Ethiopia (Karanja, 1999) and West Africa (d'Ieteren *et al.*, 1988), patterns of higher prevalences of *T. congolense* infections in adults rather than calves have been previously reported. Rowlands *et al.* (2001) continue to argue that, at Ghibe, this difference may be partly explained by the fact that calves stayed at the homestead until their dams ceased to be milked, most joined the herd at around 9 months of age and therefore, are less exposed to tsetse than their dams. These facts further confirm the role of husbandry practices on reducing the risk of infection in calves.

6.2.3 Entomological survey and bloodmeal analysis

In Busia District, the vegetation consists of bushes interspersed with grass. Remnants of *Lantana camara* are frequent in untilled land. The riverine vegetation consists of overgrowth bushes forming good fly-resting sites. Land in the area is used for agriculture and it is graded as a medium productivity zone and the rate of land tillage ranges from 35 to 55% (Ministry of Finance and Planning, GoK, 2002). The overall mean apparent densities for *G. fuscipes* and *G. pallidipes* in Budalang'i Division were 10.1 flies/trap/day and 4.2 flies/trap/day, respectively. In Funyula, the apparent densities for *G. fuscipes* and *G. pallidipes* were 9.2 flies/trap/day and 5.8 flies/trap/day, respectively. Results of the monthly tsetse densities indicated that there was a time-lag between the peak of the rains and that of *G. fuscipes* densities. Fly numbers tended to be low during the rainy season and peaked towards the end of the rainy season. However, the population of *G. pallidipes* increased with increase in rainfall and decreased with decrease in rainfall. Similar findings were observed earlier in Taita and Taru ranches in Kenya where, work carried out by Kamau and co-authors (2000) indicate that the tsetse apparent density seemed to be related to the season, with an increase in tsetse densities 3 weeks after the onset of the rains, and the numbers being proportional to the amount of rainfall. In the Ghibe valley of Ethiopia (Leak *et al.*, 1993), a positive correlation between rainfall and tsetse density was reported and this had a time-lag of three months. However, this correlation was attributed to the dispersal of flies rather than simply to changes in the population size. In the current study, changes in tsetse apparent density with change in rainfall could be attributable to two main processes. Dispersion of *G. fuscipes* (riverine species) and absolute population increases for both *G. fuscipes* and *G. pallidipes* (Savanna species) during the rainy season. However, since we started our data

collection in the middle of the long rainy season (April) and terminated the study after the short rains (December), longer tsetse surveys (about 3 years) are recommended for better understanding of tsetse population dynamics in relation to seasonality in the area.

The major livestock kept in the District include cattle, sheep, goats and pigs. Due to high human population densities (230 km⁻²; Ministry of Finance and Planning, GoK, 1999; FITCA-K, 2001; Muriuki and Ndung'u, 2001), only relics of wild animals are found in the District including antelopes, hares, monkeys, warthogs and wild pigs. Along the rivers Nzoia and Suo and on the shores of Lake Victoria, crocodiles and monitor lizards are predominant. Results of this work identified four main sources of bloodmeals for both *G. fuscipes* and *G. pallidipes*, namely ruminants, reptiles, Homidae and Suidae. This conforms to the available probable sources of bloodmeals. In Budalang'i Division, ruminants and reptiles were the main sources of bloodmeal for both tsetse species. On the other hand, the main sources of bloodmeals for tsetse in Funyula Division were ruminants with only a few flies feeding on reptiles. The observed difference might be due to the fact that the entire length of the western side of Budalang'i Division borders Lake Victoria and hence has a higher population of reptiles than Funyula Division. Only a small part of Funyula Division in contrast borders the Lake, in addition to some reptiles found along River Suo. The proportion of tsetse feeding on ruminants was higher in Funyula Division as compared to Budalang'i Division. This may be due to the fact that the population of cattle in Funyula Division is much higher than that of Budalang'i (a large part of the Division is usually flooded for most part of the year). Previous work carried out by Moloo *et al.* (1979) indicated that both *G. fuscipes* and *G. pallidipes* had most of their bloodmeals from bovids, although *G. fuscipes* had a wider feeding pattern than *G. pallidipes*. Apart from ruminants and reptiles, *Suidae* were important sources of bloodmeals for both *G. fuscipes* and *G. pallidipes*. While working to identify the origin of vertebrate blood in the gut of wild-caught flies from various ecological zones of Africa, Clausen *et al.* (1998) observed that apart from *Bovidae*, *Suidae* were an important host for *G. pallidipes*. Although some bloodmeal samples from *G. fuscipes* (2.9% in Budalang'i and 4.3% in Funyula) were identified as having originated from Homidae, none were detected from *G. pallidipes*. This was also the trend observed by Moloo *et al.* (1979) who reported the presence of human bloodmeal samples from *G. fuscipes* but not from *G. pallidipes* during their work in South-eastern Uganda. The requirement of odours (acetone, cow urine etc)

to attract *G. pallidipes* into traps and targets suggests that the fly will rarely be attracted to humans in the presence of hosts with similar odours.

This study found both *G. fuscipes* and *G. pallidipes* being important vectors of pathogenic trypanosomes, based on the trypanosome infection rates in the flies and the fly-feeding patterns. Using the method described by Leak *et al.* (1993), tsetse challenge was estimated as the product of apparent tsetse challenge, mature trypanosome infection rate in dissected flies and the proportion of bloodmeals taken from ruminants. In Budalang'i, the challenge was estimated to be 1455 and in Funyula 2757. The main factor that seemed to influence the observed difference was the proportion of bloodmeal taken from ruminants whereby, in Funyula, the proportion almost doubled that in Budalang'i Division. In return there was twice as high a risk index in Funyula Division as in Budalang'i Division. It is important to point out that our estimation of challenge can only be considered a crude estimate. This is due to the fact that the tsetse bloodmeals were identified only up to the ruminant group and not to the species level; this must have biased the estimation of challenge. Work carried by Clausen *et al.* (1998) indicated that ELISA is a useful tool for tsetse bloodmeal identification. These investigators observed that repeated absorption of antisera with the most cross-reacting antigens will yield highly host-specific antisera and that cross-reactivity between members of different groups of animal families can be eliminated. However, they further stated that even after repeated absorptions, a slight cross-reactivity will remain between phylogenetically closely related species like pigs, bush pigs and warthogs, hindering species-level identification. The recent adaptation of a combined polymerase chain reaction-restriction fragment length polymorphism analysis (PCR-RFLP) by Steuber *et al.* (2004) for the accurate identification of important bovid species is expected to overcome this problem of cross-reactivity. Our second concern is that results of the bloodmeal analysis are based on 173 samples only. This limited sample size must have also influenced the outcome of our estimated challenge. A larger sample size as was used by Clausen *et al.* (1998) would have been preferable. This may also be due to that fact that we conducted our survey for only a short period of time (9 months) and that the larger proportion of the collected flies do not dispose of a sufficient bloodmeal relic (Leak, 1999).

6.2.4 Tick-borne diseases

The prevalence of TBD-parasites in cattle in the four different treatment groups was investigated during the 9 months follow-up period to assess the importance of control of trypanosomosis and helminthosis on the level of infection with the TBD-parasites. Results indicated that the risk of infection with *Anaplasma* spp. was significantly reduced in cattle receiving both albendazole/ISMM treatments every three months. Adults and heifers were at a significantly higher risk of infection with *Anaplasma* spp. than calves. Exotic/crossbred cattle were also at a higher risk of infection with *Anaplasma* spp. than the local Zebus. In the case of infection with *Babesia* parasites, age was the only significant predictor of the risk of infection with adults and heifers being at a higher risk of infection than calves. For the infection with *Theileria* spp., breed was the only important predictor of the risk of infection whereby exotic/crossbred cattle were at significantly higher risk of infection than the local Zebus.

The impact of combined albendazole/ISMM treatment on the level of infection with *Anaplasma* spp. is an important finding. This seems to suggest that control of both trypanosome- and helminth-infections can significantly reduce the risk of anaplasmosis. This may be explained by an improved immune status of the treated animals. It is well documented that severe cases of trypanosomosis are characterised with immunosuppression (Murray and Dexter, 1988; Brown *et al.*, 1990; Hörchner, 1993). Positive interaction between trypanosomosis and helminthosis has also been previously reported (Griffin *et al.*, 1981; Catley *et al.*, 2001) and often leads to severe disease that may further contribute to lowered immunity.

Findings from this study confirm that the risk of infection with *Anaplasma* and *Babesia* spp. in cattle is age-dependent. Young animals tend to be at a lower risk of infection with these two diseases compared to adults, unlike infection with theilerial parasites. Reports by various authors (du Plessis and Malan, 1987; 1988) indicate that the severity of anaplasmosis and babesiosis is reduced in young animals and immunity following initial infection reduces the probability of future exposure, resulting in disease. In contrast, in the case of infection with theilerial parasites age was not identified as an important risk factor. This is in agreement with the findings of Muraguri (2000) which indicated that the annual mortality rate of cattle in Kwale District, as a result of ECF was 6% and was irrespective of the age of an animal. The role of husbandry

system on reducing the infection rate in calves cannot be ruled out. The holding of calves around homesteads may in return reduce their exposure to heavy tick burdens and consequently lead to lower infection rates.

The results also confirm that exotic/crossbred cattle are more susceptible to TBD-parasites than local Zebus. One of the reasons could be the susceptibility of the exotic/crossbred cattle to ticks as compared to local cattle. Work carried out in Kenya by Mwangi *et al.* (1998) on host resistance to tick infestations among trypanotolerant *Bos indicus* cattle breeds indicated that, for both *Rhipicephalus appendiculatus* and *Boophilus decoloratus*, breed susceptibility to infestation increased in the order: Maasai Zebu, Orma Boran, Galana Boran and Friesian. The results generated by this pilot study suggested that variation in susceptibility to tick infestations exists among the four breeds. The Orma Boran and Maasai Zebu (both considered to have some degree of trypanotolerance: Njogu *et al.*, 1985; Mwangi *et al.*, 1993) showed greater resistance to tick-infestations than the Galana Boran and Friesian. This suggests that utilization of trypanotolerant cattle breeds could be feasible even in the face of tick challenge and should therefore be considered when planning integrated trypanosomiasis and tick control strategies.

When the results of infection with TBD-parasites from both the cross-sectional and longitudinal studies are considered, it is recommended that disease control efforts should focus on reduction of tick populations to the minimum threshold required for maintenance of enzootic stability. Although the results of the questionnaire survey indicate that a good proportion (71.7%) of the farmer-population undertakes tick control in their stock, 28.3% of the respondents do not spray their animals at all. The other questionable practice was the fact that none of the respondents seemed to adhere to the recommended dilutions of the acaricides used. The concern in this case is the potential of development of acaricide resistance to ticks (if not already in place) and an eventual upsurge of clinical cases. In addition, even in the absence of disease, studies conducted in Zimbabwe (Norval *et al.*, 1989) indicated that infestation of cattle with *Amblyomma hebraeum* caused daily weight losses of 9-19g for each engorging tick, while *R. appendiculatus* caused a reduction of 3-8g. In Zambia, Pegram *et al.* (1991) estimated that the damage coefficient caused by every engorging female of *A. variegatum* tick was 45-60g.

Therefore, although data on the direct effects of tick infestation on milk yields is virtually unavailable (Gitau *et al.*, 1999), the present level of tick infestation in cattle in Busia District is of concern. Nevertheless, as has been earlier mentioned, the current use of deltamethrin for spraying animals is expected to maintain the tick levels to a minimum. Three aspects that must however be addressed are: 1) the frequency of application of deltamethrin should be one that allows for maintenance of tick populations to a certain minimum threshold that can conserve enzootic stability, while at the same time not compromising the efficacy of tsetse control. Farmers are hereby advised to continuously monitor their animals and if they notice that the tick population has drastically reduced, they should increase the spraying interval to once a month from the current twice a month; 2) applying the insecticides to a subset of a cattle population (critical mass important) and/or avoiding the treatment of tick attachment sites may also suffice; 3) treatment of only the preferred fixation sites (udder, groin, distal part of legs). The cost and benefits of these strategies have been shown to reduce the insecticide costs by 95% and mitigate the impact on non-target species, including ticks, with little reduction in efficacy to tsetse flies (Torr *et al.*, 2000). In event of clinical disease, early-case detection by animal health service providers, followed by prompt treatment, will remain an integral part of disease control and avoidance of heavy losses (especially for exotic breeds) by the farmers.

6.2.5 Helminthosis

The level of FEC in cattle was assessed with regard to location, treatment, husbandry, age and breed over a period of 9 months. All the variables are as described under the trypanosomosis section. Since some animals had zero counts, the data were heavily skewed to the right and efforts to normalize it by normal transformation failed. The overall variance was 119939.03 and the mean 286.50 and even after transformation, the variance was more than twice the mean. Consequently, a negative binomial error distribution in a generalized linear model was used to analyse the data.

Descriptive statistics revealed that in Budalang'i Division, the FEC in adult cows ranged from 0 to 1800, in heifers it was 0 to 2250 and in calves it was 0 to 6480. In Funyula Division, the FEC range for cows was 0 to 1620, for heifers it was 0 to 1800 and in calves it was 0 to 5760. In adult

cows and heifers, strongyle eggs dominated the counts. However, in calves, both strongyle and ascarid eggs were detected. The effectiveness of albendazole in reducing the FEC was estimated using the method as described by Coles *et al.* (1992). There was more than 95% reduction in FEC of albendazole and albendazole and ISMM treated cattle. However, the FECR in ISMM treated cattle was less than 13%, indicating that ISMM did not significantly influence shedding of FEC.

For all age-groups, there existed a significant faecal egg count reduction (FECR) in the albendazole treated animals. However, in the untreated controls and the ISMM treated animals, periodic fluctuations of FEC were observed. In all the cases, the ISMM treated animals had lower FEC than the untreated control animals although no significant differences in the counts were established. Work carried out on N'Dama cattle in The Gambia (Dwinger *et al.*, 1994) for 2-4 year old animals revealed that there were clear indications of an increased susceptibility to trypanosomosis in animals affected by helminths. Similarly, animals infected with trypanosomes were more frequently infested with strongyles and egg counts were higher than in cattle in which no trypanosomes were detected. In our study, treatment with ISMM significantly reduced the incidence of trypanosome infection in cattle and might have therefore influenced the level of FEC in animals, although not significantly. Longer follow-up studies, as was the case in The Gambia might have revealed the full impact that concurrent trypanosome infection has on the shedding of FEC.

It is important to note that in the untreated control and ISMM treated animals, shedding of ascarid eggs also reduced over time and reached undetectable levels by the time the calves were 6-8 months of age. This confirms previous reports by Urquhart *et al.* (1996) who noted that calves usually get infected with *Toxocara vitulorum* from the milk of their dams but will eventually rid-off the infection with age, due to development of resistance. In addition, work carried out by Fall *et al.* (1999) on N'Dama cattle in Senegal indicated that the age of cattle had a significant effect on the frequency of samples infested with *Toxocara* spp. and *Strongyloides* spp. Animals less than 1 year old were more frequently infested with *Toxocara* spp while adult animals were free.

Results from the negative binomial regression revealed that treatment group, husbandry system, age and investigation week were significantly associated with shedding of helminth eggs by cattle. However, there was no significant difference between FEC of cattle located in Budalang'i Division and those in Funyula Division. There was also no significant difference in FEC between local Zebu and exotic/crossbred cattle.

Taking the control animals as the baseline, coefficients of the negative binomial regression indicated that albendazole and albendazole/ISMM treatment of cattle every three months significantly reduced shedding of FEC in both Divisions, regardless of husbandry, age or breed. This supports the findings of the FECR where the effectiveness of albendazole in reduction of FEC was indicated. These findings provide preliminary indications that albendazole resistance may be absent in both Budalang'i and Funyula Division. Work carried out by the Kenya Agricultural Research Institute (KARI/DIFD, 1999) on helminth control in Kenya has resulted in mapping of some areas like Kericho, central highlands (Kiambu and Nyandarua) and Samburu, where pockets of anthelmintic resistance were reported. However, no related work is recorded to have been carried out in Busia District. It would be therefore be important to confirm our findings using studies designed specifically for the purposes of assessing the efficacy of the anthelmintics used in the area. This would form a better basis for recommendations on the use of anthelmintics. Under the current situation, we recommend rational use (right dosing, frequency and rotation of anthelmintic groups) of these compounds in the area to avoid development or aggravation of resistance.

Stall-fed cattle had significantly lower FEC than free grazed, tethered and free grazed/tethered animals. The observed differences can be explained through the effects of confinement, source of forage, mode of feed presentation and herd sizes. Stall-fed animals are usually kept under zero-grazing units where animals are fed from feeding troughs and water is provided in basins or watering troughs. In both the divisions, our observations revealed that the herd sizes in the units range between 1 to 6 animals. Except on few occasions, most farmers hold these animals within the units for most part of the year. It is therefore reasonable to stipulate that these animals are usually at a lower risk of collecting infective larvae as compared to animals under the other husbandry practices. Some proportion of the herbage provided is from cultivated forage (Napier

grass) which again reduces the risk of infection. Although these animals may contaminate the floor/ground with faecal eggs, feeding from the troughs minimizes the risk of an animal collecting infective larva from the ground. Frequent collection of dung and cleaning of the units also helps reduce the faecal egg load available to the animals. Although these factors may not completely eliminate the risk of helminth infection in cattle, they no doubt contribute significantly to the reduction of the risk of infection.

Comparison of age-dependent FEC shedding revealed that calves had significantly higher FEC than either adult cows or heifers. However, there was no significant difference between FEC in adults and heifers. The high FEC in calves significantly influenced some production parameters in this age stratum. During this time, both Zebu and exotic/crossbred calves in the untreated control group remained at significantly lower weight levels than the ISMM, albendazole and albendazole/ISMM treated calves. The albendazole/ISMM treated calves had the highest weight gain, followed by the albendazole treated calves and then the ISMM treated ones. The fact that albendazole/ISMM treated calves gained significantly more weight than the albendazole treated calves demonstrates the importance of interaction between helminthosis and trypanosomosis in young animals. It also appears that weight gain in calves in the two Divisions is more severely constrained by helminth- than by trypanosome-infection. Concurrent control of the two conditions resulted in maximum benefits as indicated by the weight gains in calves.

The mortality rates were also lower in albendazole and albendazole/ISMM treated calves, although not significantly so. This seems to support the findings of Kaufmann *et al.* (1992) in The Gambia when investigating the interaction of *T. congolense* and *Haemonchus contortus* infection in N'Dama calves. These authors noted a markedly reduced prepatent period of *H. contortus* infection from the usual 3 weeks to 2 weeks and an increased pathogenicity of this infection when superimposed on a patent *T. congolense* infection. Conversely, a *T. congolense* infection superimposed on a patent *H. contortus* infection drastically aggravated the disease process caused by *H. contortus*. They observed increased egg output, a reduced prepatent period, rapid decreasing PCV and albumin levels, and also drastically increasing weight loss and mortality in cases where animals were initially infected with the trypanosome. Further work carried out by Ndao *et al.* (1995) revealed that even after a single season antihelmintic treatment

of N'Dama cattle on communal pastures in the Gambia, a significant weight gain in the treated animals was detected from the 2nd month and was maintained throughout the 7 months follow-up. In the current study, although no significant differences were detected between the untreated and the albendazole and albendazole/ISMM treated cows with regard to conception, calving and abortion rates, our results nevertheless indicate consistently lower conception and calving rates and higher mortality rates in the untreated cows.

It is therefore recommended that calves be dewormed every three months starting early January (dry period) and then again in late March (just after the onset of the long rains). Consequent treatments should then be spaced every three months. This regime should be sustained until animals are about 12-18 months. In the case of animals from 2 years, it is recommended that deworming be undertaken twice a year: once during the dry season (November to February) and the next after the onset of the long rains (March to May), but only when there is economic justification. In the case of The Gambia, although single dry season treatment of cattle with anthelmintics led to significant increase in weight, the authors observed that the parasites acquired during the rainy season and carried over to the dry season compromised the productivity of their hosts, as the pastures were of poor quality and low nutrition value during the dry season (Ndao *et al.*, 1995). Zinsstag *et al.* (1997b) also demonstrated that two treatments a year for animals with a mean age of 3.3 years helped to significantly improve production parameters as compared to untreated groups.

6.2.6 Shedding of trematode eggs

In the current study, shedding of trematode eggs was restricted mainly to adult cows and heifers. Calves did not shed trematode eggs at the beginning of the study but towards the end of the study three calves had already started shedding eggs. In both Budalang'i and Funyula Divisions, there were significantly more adult cows shedding trematode eggs than heifers, with respect to breed. In addition, there were significantly more adult cows from Budalang'i shedding trematode eggs than in Funyula. For both adults and heifers, there were significantly more local Zebus than exotic/crossbred cattle shedding trematode eggs. Albendazole treatment at 10mg/kg bw (fluke dose) every three months significantly reduced the number of animals shedding trematode eggs

and by 12-20 weeks after the first treatment, no treated animals were shedding eggs. In the following weeks of follow-up, the proportion of albendazole and albendazole/ISMM treated animals shedding trematode eggs remained at less than 2%. The proportion of ISMM treated animals shedding trematode eggs remained significantly higher than that of albendazole and albendazole/ISMM treated animals, throughout the study. However, towards the end of the study, the proportion of ISMM treated animals that were shedding trematode eggs was significantly lower than that of untreated controls.

The findings on shedding of trematode eggs from this study are discussed with reference to trematodes in general rather than only *Fasciola* infection. This is due to the fact that during the study no active data collection was undertaken from the abattoirs with respect to liver flukes. Therefore, the results were based on observation of trematode eggs by microscopy. The large size of the operculated eggs (approximately 130-200 μm), the yellow colouration and the fine granulation (cluster of vitelline cells) helped in partial differentiation between *Fasciola* and *Paramphistimum* eggs. Although we identified the majority of the trematode eggs as *Fasciola* eggs, it was not possible to confirm that the eggs were those of *Fasciola* and not *Paramphistomum*. However, information gathered from the former District Veterinary Officer of Busia District on the level of condemnation of cattle livers at slaughter due to fasciolosis revealed that over 30% of livers are routinely condemned in various parts of the District due to infection with *Fasciola gigantica* (Orot, personal communication). These reports were an indicator to the effect that our observations on trematodes had a high likelihood that these were *Fasciola* eggs. Reference is therefore made to fasciolosis in some parts of this discussion. Future work should however be corroborated with abattoir reports.

In the past, losses due to fasciolosis were more associated with high mortality in sheep flocks. However, in the recent past, fluke-related deaths have also been reported in adult cattle (Mitchell, 2003). Fasciolosis is considered a disease of adult cattle and, to a lesser extent, young animals (Schwabe and Kuoajok, 1981). In our study, age was a significant risk factor for shedding of trematode eggs, with adult cattle being at a higher risk than heifers, while calves were not shedding eggs early in life. However, by the end of the study, cases of calves shedding trematode eggs were on the increase, indicating that infection was age-dependent. The shedding of

trematode eggs by adults and heifers might have been compounded by concurrent helminth and trypanosome infection. The occurrence of fasciolosis and trypanosomosis has been associated with severe loss of condition in affected animals. In southern Sudan, the occurrence of both fasciolosis and trypanosomosis was incriminated for the chronic wasting characteristic of animals harbouring the two conditions (Catley *et al.*, 2001). Indeed, Catley and co-workers noted that it was likely that the pathology due to *Fasciola*, *Haemonchus* spp. and *Schistosoma* would be exacerbated in cattle that were also infected with *T. congolense*.

Results of the current study indicate that in Budalang'i and Funyula Divisions of Busia District, occurrence of a high prevalence of cattle shedding trematode eggs requires for further investigations. The prevalence of cattle shedding trematode eggs was significantly higher in Budalang'i as compared to Funyula Division. This may be due to the fact that for most parts of the year large areas of Budalang'i Division are flooded (Daily Nation, 2005) and therefore present good opportunities for the development of the intermediate hosts (snails) and therefore enhancing transmission. Of major importance is the fact that local Zebu cattle appear to have a significantly higher prevalence of shedding trematode eggs than exotic/crossbred cattle, contrary to expectations. This breed difference in infection rates may be explained by the fact that the majority of exotic/crossbred animals are held within zero-grazing units and are rarely taken out to graze freely. As a result, their exposure to marshy areas is limited and the only chances of transmission arise from fodder collected from flooded areas. This agrees with the findings of Muraguri (2000) who reported that zero-grazed cattle from the coastal lowlands of Kenya experienced significantly lower exposure to helminths, including liver flukes.

Albendazole and albendazole/ISMM treatment of cattle significantly reduced the number of animals shedding trematode eggs. In addition, ISMM treatment alone was able to achieve significant differences in the number of infected animals when compared with untreated controls. This seems to suggest that there is a positive interaction between trypanosome infection and shedding of trematode eggs. It is possible that as animals are protected from trypanosome infection through prophylactic treatment with ISMM; their immune status improves and boosts the defence against trematodes. Another important observation was that even after albendazole treatment, the prevalence of animals shedding trematode eggs reduced gradually to reach zero

levels by the end of 12 to 20 weeks. This indicates that not all the trematodes are cleared immediately after treatment with albendazole. The possible explanation could be the fact that albendazole is effective against adult flukes only, but has no effect on early and late immature flukes (Rommel *et al.*, 2000; Mitchell, 2003). As a result, presence of immature flukes at the time of treatment ensures that some animals continue to shed trematode eggs as these immature flukes turn into adults. However, with repeated treatment every three months, the animals turned negative, probably indicating that all previously immature flukes had already turned into adults and therefore had been eliminated. In addition, even with effective treatment, animals continue to shed trematode eggs for 6-8 weeks after treatment (Mitchell, 2003), probably arising from eggs held in the gall bladder.

It is important to observe that after animals turned negative from shedding trematode eggs, during the ensuing weeks to the end of the study, other infections were established although at a lower prevalence (below 2%). This could be due to the fact that combined treatment against nematodes and trematodes using the same compound is not the best option of clearing flukes from infected animals. Previous studies have indicated that single treatments for either flukes or nematodes give better results. While reviewing the treatment and control of liver flukes in sheep and cattle in Scotland, Mitchell (2003) reported that single products used against a combined fluke and gastrointestinal helminth infection may not be suitable if immature flukes are present, and that there is increasing evidence of acute disease occurring after this treatment. Similar observations were made by Maingi and co-workers (2002) in Kenya when looking at the effects of anthelmintic treatment regimes against *Fasciola* and nematodes on the performance of ewes and lambs. These investigators stated that the common practice of giving combined anthelmintic treatments against liver flukes and gastrointestinal nematodes during the wet season or at times recommended for control of *Fasciola* is less effective and should be discouraged. Therefore, single products like triclabendazole, which are effective against all the stages of *Fasciola* fasciolosis (Rommel *et al.*, 2000), should be used.

6.2.7 Packed cell volume (PCV) profiles

Changes in PCV% were monitored in cattle during the 9 months of follow-up in order to assess the effect of trypanosome and helminth-infection on PCV values. Results revealed that in both Budalang'i and Funyula Divisions, the mean PCV% of untreated cattle remained significantly lower than that of treated cattle starting from 2 weeks after treatment. In addition, the mean PCV% of ISMM and albendazole treated animals did not differ significantly but remained significantly higher than that of untreated controls. Finally, the mean PCV% of albendazole/ISMM (group IV) treated cattle remained significantly higher than that of all the other groups, during the 9 months period. A within-treatment group comparison of mean PCV% of aparasitaemic and parasitaemic (trypanosome positive) cattle revealed that aparasitaemic cattle had significantly higher PCV% values than parasitaemic ones.

These results imply that trypanosome- and helminth-infection significantly reduce the PCV% of infected animals. Especially for trypanosome infection, resistance by animals to develop anaemia has been proposed as a measure of trypanotolerance, even though a strong association between control of parasitaemia and anaemia in trypanotolerant animals has not been found (Paling *et al.*, 1991; Bett *et al.*, 2004). This is because it is easier to monitor the change in PCV than parasitaemia, given that representative numbers of parasites are not always present in the peripheral circulation for quantification by parasitological techniques (Taylor, 1998). These approaches have been complicated by the occurrence of TBDs and helminthosis in animals infected with trypanosomosis (Bett *et al.*, 2004).

In the current study, positive interaction between trypanosome- and helminth-infection were depicted through the significant improvement of PCV% values of animals that received combined albendazole/ISMM treatment as opposed to untreated ones or animals receiving single treatments (either ISMM or albendazole). Although anaemia in cattle is associated mainly with trypanosomosis and TBDs in areas where these diseases occur, helminths are equally potent and highly prevalent anaemia-causing pathogens (Chiejina, 1986; Kaufmann and Pfister, 1990). Fall *et al.* (1999) also observed that strongyle-free N'Dama cattle from Senegal had higher PCV% values than infected animals. The authors further reported that, although the effect of the interaction between strongyle and trypanosome infections was not significant, PCV values

suggested an additive effect of these infections on the development of anaemia. It is therefore more serious when these diseases occur concurrently because their potentiation leads to much lower PCV values in the animals.

6.2.8 Weight changes in calves

Results indicate that in both Budalang'i and Funyula Divisions, untreated calves (group I) had significantly lower weight gains than the ISMM, albendazole and albendazole/ISMM treated ones, over the 9 months of follow-up. The highest weight gains were recorded in the albendazole/ISMM treated calves followed by the albendazole treated group and then the ISMM treated ones. As mentioned in the section under trypanosome- and helminth-infection, it is clear that these two conditions significantly constrain the growth rate of calves. It was evident that although trypanosome infection impacts negatively on the health and growth of calves, helminth-infection may be the single most important factor associated with severe reduction/delayed weight gain. Low weight gain results in delayed maturation of the animals. Some animals may be so stunted that eventually they are culled before being served, and hence replacement animals have to be sought from elsewhere at a cost. Work carried out by Zinsstag *et al.* (1997b) in The Gambia suggests that there is a positive effect of strategic gastrointestinal parasite control on the age at first calving and calving rate, where annual calving rates of animals treated twice per year (52.2%) were significantly higher than that of untreated cattle (43.6%).

In the current study, the growth curves indicate that farmers will continue to perceive some growth in calves in the absence of disease-control interventions but high opportunity costs for lack of interventions are incurred. These are due to severe reduction in weight gains, loss of body condition and relatively higher mortality rates. Ultimately, in the absence of capital investment, the labour invested in animal production activities becomes a waste and chances for sustainability are highly compromised. This scenario must be reversed. We therefore recommend a sustained regime of deworming (every three months) in calves in the region if reasonable weight gains and body condition scores are to be achieved.

6.2.9 Conception, calving and abortion rates

During the 9 months follow-up period, 53.3% of untreated Zebu and 60% of untreated exotic/crossbred cows turned pregnant in Budalang'i Division. From the ISMM treated group, 80% of Zebu and 60% of exotics/crossbreds turned pregnant. In the albendazole treated group, 66.7% of Zebu and 60% of exotic/crossbred cows became pregnant. Finally, from the albendazole/ISMM treated cows, 86.7% of the Zebu and 80% of the exotic/crossbred cows turned pregnant. In the same Division, between 6.7 to 20% of Zebu heifers turned pregnant while between 0-20% of exotic/crossbred heifers turned pregnant. In Funyula Division, 60% of untreated Zebu and 60% of untreated exotic/crossbred cows conceived. From the ISMM treated group, 66.7% of Zebu and 80% of exotic/crossbred cows turned pregnant. In addition, 80% of Zebu and 60% of exotic/crossbred cows from the albendazole treatment group turned pregnant. Finally, 80% of Zebu and 100% of the exotic/crossbred cows became pregnant. Meanwhile, between 6.7-26.7% of Zebu heifers from different treatment groups became pregnant while between 0-40% of exotic/crossbred heifers turned pregnant during the 9 months follow-up period.

The mean calving rate in Zebu cows from Budalang'i Division ranged from 37.5% (untreated controls) to 53.6% (albendazole/ISMM treated cows). The calving rate for the exotic/crossbred cows ranged between 33.3% (untreated controls) and 75% (albendazole/ISMM treated cows). In Funyula Division, the calving rate in Zebu cows ranged from 44.4% (untreated controls) to 66.7% (albendazole/ISMM treated cows). For the exotic/crossbred cows, the calving rate was between 66.7% (untreated controls) and 80% (albendazole/ISMM treated cows).

As mentioned earlier, abortion was only detected from untreated (group I) control and albendazole (group III) treated cows in both divisions. In Budalang'i Division, the overall abortion rate in untreated (group I) pregnant cows was 45.5% and that in albendazole treated animals was 23.1%. In Funyula Division, the overall abortion rate in untreated (group I) pregnant cows was 33.3% while that in albendazole treated cows was 13.3%.

Parasitic diseases have been associated with reproductive disorders of varying degrees of intensity. For instance, *T. congolense* infection in susceptible Boran heifers has been reported to

cause acyclicity with low plasma progesterone levels (Llewelyn *et al.*, 1988; Lorenzini *et al.*, 1988), persistent corpus luteum and short cycles with low mean luteal concentrations of progesterone (Llewelyn *et al.*, 1988). It has been speculated that experimental infection with *T. vivax* may either cause failure of conception or early embryonic death in susceptible Zebu heifers (Ogwu *et al.*, 1984). Work carried out by Okech *et al.* (1996) using Galana and Orma Boran cattle in Kenya indicate that, three out of six Galana Boran cattle experimentally infected with *T. vivax* in early and mid pregnancy aborted, while one had a stillborn calf. On the other hand, no abortion was registered in un-infected control cattle. In the current study, although no significant difference was detected between the conception rates of untreated and treated cattle, untreated controls had consistently lower conception rates than treated animals.

The most significant finding was that there was no abortion recorded in the ISMM prophylaxis and albendazole/ISMM treatment groups. In contrast, in both the untreated control and albendazole treated animals, abortions were recorded. This confirms reports linking trypanosomosis with abortion (Krampitz, 1970; Murray *et al.*, 1981; Ogwu *et al.*, 1986; Okech *et al.*, 1996). The effect of deworming on the reproductive performance of cattle indicates better conception and calving rates in dewormed as compared to untreated animals. In addition, although there were abortions in the dewormed animals, the abortion rates were lower than in untreated cattle. These results confirm the observations by Itty *et al.* (1997) in The Gambia, who reported higher performance rates in the treated group in terms of live weights, calving rates, age at first calving and lower mortality rates of cattle over 2 years of age. However, even in their case, statistically significant differences only occurred in the case of live weights of animals between 1-4 years of age and in the case of age at first calving (Zinsstag, *et al.*, 1997a; 1997b). It is important to point out that although our work is a reflection of what happens under natural field challenge, the time of observation might have been inadequate and therefore, longer observational studies are recommended to confirm these observations. There however seem to exist no other reports on the importance of concurrent trypanosome- and helminth-infection on the productivity of cattle in the East African region. For this reason, we have highly relied on the work carried out in the Gambia for our discussion. It is hoped that these findings will encourage further related work in the East African region and especially Kenya. Since these observations agree in most aspects with those of Zinsstag *et al.* (1997b), we also recommend as they did,

strategic control of gastrointestinal nematodes not only in calves but also young heifers up to first calving, but only if there are financial benefits.

6.2.10 Milk production

The mean daily milk yield of Zebu cattle in Budalang'i Division was 1.7 l/cow/day while that in Funyula it was 2.2 l/cow/day. The exotic/crossbred cattle had significantly higher mean daily milk yields than the Zebu cattle in both Divisions. The mean daily milk production by exotic/crossbred cattle in Budalang'i Division was 6.8 l/cow/day and in Funyula it was 7.9 l/cow/day. Although there were no significant differences in the mean daily milk yields of cattle from the same breed with regard to treatment group, animals receiving combined treatment performed better than others. In addition, untreated controls had the lowest performance when compared to other animals.

The estimation of a mean daily milk yield from local Zebus (2 l/cow/day) in this study is higher than that reported (1 l/cow/day) by Machila and co-workers (2003). The difference might be due to the fact that their estimates were based on a questionnaire survey and not actual measurements. At the current level of milk production from the local Zebus, it is difficult for such a production system to subsist, when milk is considered the product of importance. Actually, such a system might lead to a drain of resources like labour, pasture and costs of treatment rather than make profits.

Considering that the mean cattle-holding in Budalang'i Division was reported to be 5.9 and 7.3 animals in Funyula Division, it means that a household in Budalang'i with 2 cows/herd has access to 3.4kg of milk daily while that in Funyula with 3 cows/herd has 6.6 kg of milk daily. This is by assuming that up to 40% of animals in a herd are cows. With the average family size estimated at 8.5 for Busia District (questionnaire survey), the amount of milk per household does not guarantee enough for home use and for sale. On the other hand, although the current production level of the exotic/crossbred animals does not match that of similar breeds of animals in the central highlands of Kenya (over 12.3 kg/cow/day) as reported by various workers (Muriuki, 2001; Omore, 1997; Mbugua *et al.*, 1999), it provides a window of hope for reversing

the current milk production situation in the two Divisions. However, only a conservative (15.7%) number of households own exotic animals in the District. This further limits the full exploitation of animal feed resources available, since most of these feeds are used by the poorly producing Zebu cattle.

Although the effects of albendazole and ISMM treatment every three months on milk production are not significantly different from those in untreated cows, they point out that helminth- and trypanosome-infection constrain milk production in the two Divisions. Work by Swallow (1997) in The Gambia indicated that trypanosomosis reduces milk offtake from trypanotolerant cattle by 10-26%. Work by Bauer *et al.* (1999) in Burkina Faso emphasised the importance of integrated control of trypanosomosis and TBDs on cattle productivity and especially on milk production, where improved sale of milk created a gross income of about \$US 3/day for the Fulani women. It is therefore important to incorporate integrated disease management aspects in rural development programmes aimed at poverty alleviation. Any surplus milk produced by these farmers, however little, will be a step towards reducing the proportion of people (currently over 60%) in this region living under \$US 1/day.

Although our estimations of milk production are based on actual measurements, there are various possible sources of biases in this study. The length of time that the cows were monitored (9 months) does not cover an entire lactation cycle. Another concern is that different cows were at various phases of the lactation cycle (early, peak or late) and therefore at different production potential. Other sources of errors could arise from the physiological (e.g. pregnancy) state of an animal, differences in feeding management between different farmers and between different breeds of animals and the fact that the follow-up did not cover the a whole weather cycle (seasonality). However, these preliminary results form part of the baseline data on which future work may build on.