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The current epidemiological status of bovine theileriosis in eastern Zambia

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Summary Results of a longitudinal study conducted in the eastern province of Zambia from 1994 to 1997 indicate that it is doubtful whether a state of endemic stability of East Coast fever (ECF) can be reached in the near future. Even in endemic areas, the mortality of *Theileria parva* infections is still estimated above 50%. The main factors limiting progress towards endemic stability are high innate susceptibility of the Zebu cattle, the virulence of the parasite and the climate. The unimodal rainfall pattern results in restricted activity of *Rhipicephalus appendiculatus* instars and year-to-year variation in rainfall causes fluctuations in tick phenology and *T. parva* transmission. Adult tick activity invariably peaks during the rains and is associated with the highest ECF incidence. Nymphal transmission of *T. parva* to cattle appears to be less important. Second periods of activity of both adult and nymphal instars are pronounced only when the climate is suitable. These second waves of tick activity ensure a more continuous and efficient transmission of *T. parva* and also play a key role in the dynamics of prolonged outbreaks in epidemic areas. ECF control methods may have an important influence on ECF epidemiology. Immunizations as well as chemotherapy of clinical cases create a reservoir of virulent parasites in susceptible cattle, resulting in artificial endemic stability.

keywords theileriosis, epidemiology, Zambia

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Introduction

East Coast Fever, the most important animal health problem in the eastern province of Zambia (Nambota *et al*. 1994), is responsible for killing a large number of cattle each year. The causative agent of ECF is *Theileria parva*, which is transmitted by the ixodid tick *Rhipicephalus appendiculatus*. In most of the affected areas, the infection has been endemic for decades and only the calf population is at risk. The disease is routinely controlled by the method of immunization and treatment. However, so far the province has not achieved endemic stability, defined as a state where all calves below the age of 6 months have been in contact with *T. parva* while clinical disease is rare (Yeoman 1966). In more recently infested areas, a large percentage of both adult and calf populations is still susceptible to ECF and major epidemics cause high losses of cattle each year. The introduction of ECF into previously unaffected areas is often explained by mixing susceptible cattle from ECF-free areas with carrier cattle from infested neighbouring areas during periods of drought in search of water (Norval *et al*. 1992). This paper aims at describing and explaining the current epidemiological status of ECF in the region and at evaluating whether a state of endemic stability is within reach in the near future. Information on major factors influencing the epidemiology of the disease, including climate, abundance of the *R. appendiculatus* instars and incidence of first contact with *T. parva* was obtained from two longitudinal studies, one in an endemic area and one in an epidemic area.

Materials and methods

Two sentinel herds were selected, one at Wafa, in an endemic ECF area and one at Mayela, an epidemic area. The large majority of the livestock is of a Zebu type. The study started in January 1994 at Wafa and in August 1994 at Mayela. This analysis includes data up to July 1997 for both studies.

Wafa

Wafa village (13°35.1'S, 32°29.7'E) lies at an altitude of 980 m, 30 km north-west of Chipata. Immunization and treatment was introduced as the method of ECF control in 1988 and is now performed routinely on calves between 2 and 8 months of age. All newborn calves in the sentinel herd were enrolled in the study and monitored on a weekly basis. During each visit, a routine clinical examination was performed including palpation of the parotidian and prescapular lymphnodes; counting of adult and nymphal *R. appendiculatus* on both ears and blood sampling for Indirect Fluorescence Antibody tests (IFAT). Note that nymphs are less likely to migrate to ears than adults so that these counts may not be a good reflection of the actual nymphal challenge. The counts should, however, reflect seasonal patterns. When ECF was suspected, ear-vein blood smears and lymph smears were prepared for parasitological confirmation of the diagnosis. The date of contact was defined as the first day of observation of schizonts minus seven days. IFATs were carried out according to the method described by Burridge and Kimber (1972). The cut-off titre indicating a positive test was taken at 1/160. A subclinical case was diagnosed when an animal tested positive on three consecutive occasions. The date of contact was set one month before the day of first seroconversion.

Mayela

Mayela (14°25.8'S, 31°54.7E) is a group of six villages in Katete, on the border with Mozambique. The study started in August 1994 after major outbreaks of ECF had occurred in neighbouring areas. As far as we know there was no history of ECF at Mayela before the study. The animals (39 in total, mainly adult cattle) of one *kraal* were monitored for ECF following the same protocol. They were clinically examined weekly and ticks were counted at the same time on a sample of six to 10 cattle. Blood samples for IFAT were taken once a month.

Statistical methods

The monthly infection hazard was calculated as the proportion of susceptible animals that came into contact with *T. parva* per month. Tick abundance patterns refer to the average tick count per animal for each month. The ratio of the monthly hazard to the monthly average tick count per animal is introduced as a measure to evaluate the efficiency of *Theileria parva* transmission and should in fact reflect the infection prevalence in the ticks. The Kaplan-Meier estimates of *T. parva* free survival distributions were obtained with GLIM software. The survival data were computed by means of median age at first contact with 95% interval estimation. We used SAS software for a logrank test for equality of survival distributions over strata.

Results

Seasonal rainfall

Figure 1 shows the temporal variation in rainfall, humidity and temperature in Chipata district from July 1994 to March 1997. Total rainfall for the seasons 1993–94 and 1994–95 was well below normal (1000 mm). The rains in 1995–96 and 1996–97 were above normal.

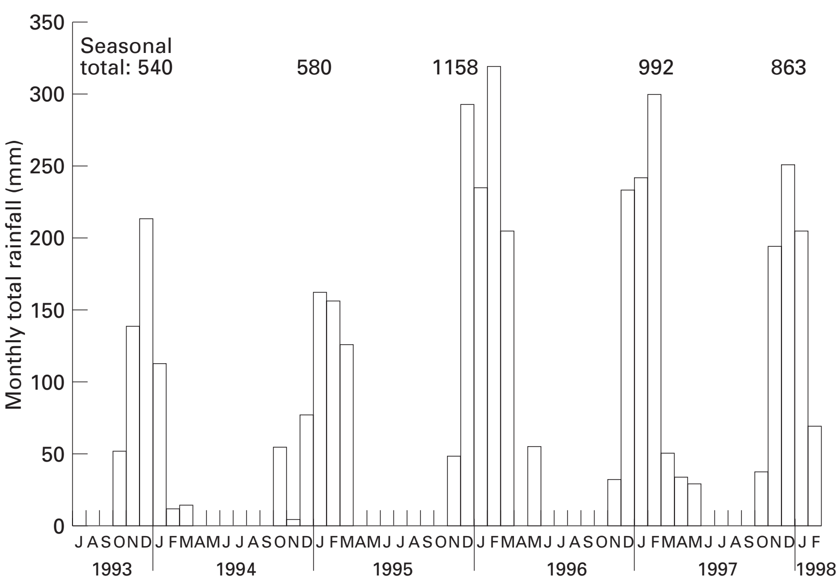

Figure 1 Rainfall pattern in eastern Zambia (1994–1998). Source: Msekera Agricultural Research Station, Chipata.

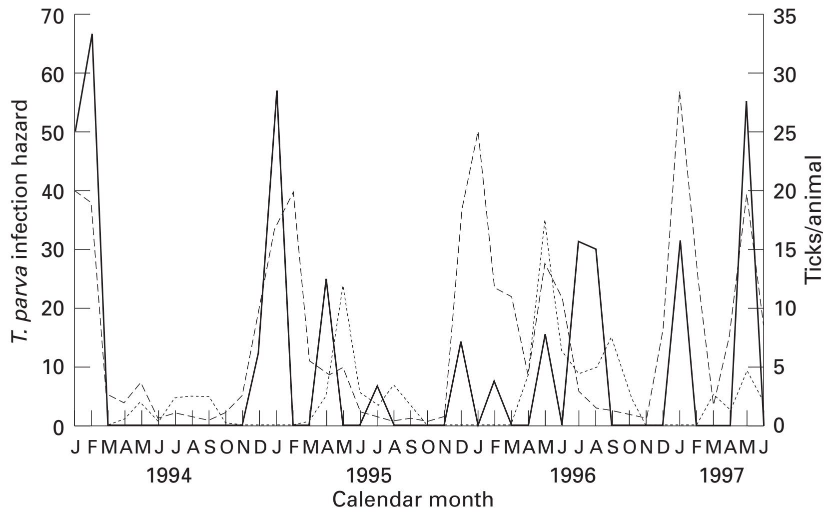

Figure 2 Monthly hazard of *T. parva* infection in calves (——) and average *R.appendiculatus* adult (-------) and nymph (·········) burdens at Wafa (1994–1997).

Sentinel herd Wafa-endemic area

Forty-six calves were enrolled at Wafa from January 1994 to July 1997. Thirty cases of East Coast fever were recorded; 17 clinical cases recovered with and 3 without treatment. Five calves died (3 treated and 2 untreated). Five subclinical cases were diagnosed by means of IFAT seroconversion. Fourteen calves were censored before the date of analysis while 2 calves in the herd are still susceptible. In 10 calves censoring was due to death unrelated to ECF: babesiosis (2), anaplasmosis (1), helminthosis (2), accident (3), unknown cause (2). Four calves were transferred before contact with *T. parva* could occur.

Figure 2 outlines the time trend of *T. parva* transmission throughout the study period. During the first 2 years the intensity of *T. parva* transmission declined sharply. The first wave of adult *R. appendiculatus* activity was only mildly affected by low rainfall, and second waves of adult tick activity did not occur. The risk of infection, which peaked at almost 70% in February 1994, dropped to less than 10% even at the height of a good rainy season in January-February 1996. The ratio of risk to average tick count, which reflects tick prevalence, dropped from > 3 to < 1. Over the next 2 years *T. parva* transmission was gradually restored, and adult *R. appendiculatus* responded with a pronounced second wave of activity immediately after the first good rainy season. The risk of infection increased, together with tick

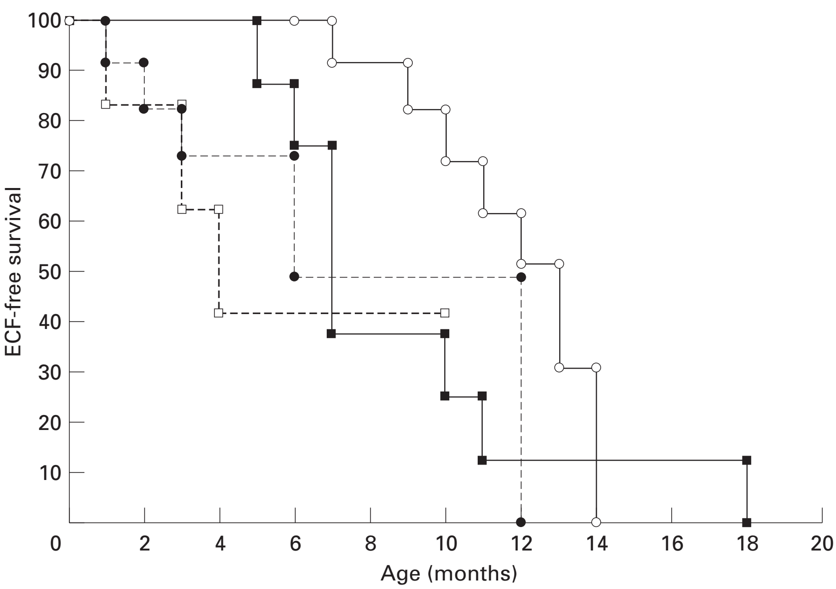

Figure 3 ECF-free survival in 46 calves at Wafa: calves born in 1994 (■), calves born in 1995 (○), calves born in 1996 (●), calves born in 1997 (□).

abundance, to a maximum of about 60% at the joint peak of adult (second wave) and nymph (first wave) activity. Another peak of transmission was observed in July-August 1996 at a time when mainly nymphs were active. Remarkably 4 of the 5 subclinical infections were recorded in these months.

Figure 3 plots the *T. parva*-free survival for calves at Wafa in relation to their year of birth. The difference in distributions was statistically significant ($\chi^2 = 18.1$; $P = 0.0012$). The median age at first contact was about 7 months for calves born in 1994, increased to 13 for those born in 1995 and dropped to 4 months for those born in 1997 (Table 1). Note that calving is seasonal with a peak in June-July (Figure 4). It is impossible to obtain an accurate estimate of the *T. parva* infection mortality since most clinical cases were treated. Five of the 30 cases died (17%), and 8 (27%) survived without treatment (including the five subclinical cases). The clinical history of the 17 surviving treated calves indicates that 13 (75%) would have died without treatment. Based on this assumption, mortality is estimated at 60% (18/30).

Table 1 Summary statistics for age at first *T. parva* contact (46 calves, Wafa village)

Year of birth	Median (months) Lower	Upper	95% confidence interval
1993	3	2	4
1994	7	6	11
1995	13	10	14
1996	6	3	12
1997	4	3	–

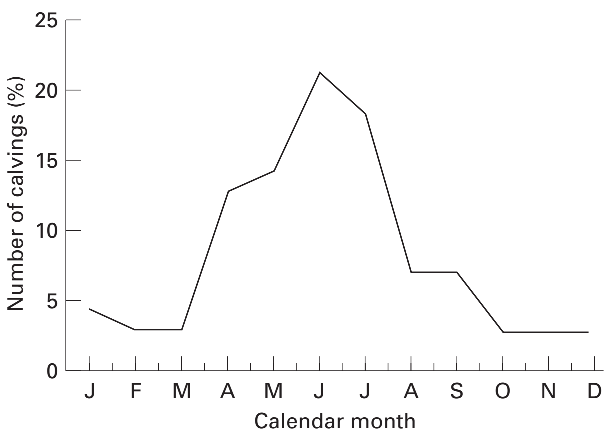

Figure 4 Seasonality of calving at Wafa (1994–1996: total 34 calves).

Sentinel herd Mayela – epidemic area

Thirty-nine cattle (calves and adult animals) were enrolled at the start of the study. All were seronegative on IFAT from August to December 1994. The first animal to seroconvert was the first clinical case diagnosed in January 1995. Twenty-one *T. parva* contacts were subsequently recorded: 18 presented with clinical symptoms, 6 were left untreated of which 5 died. The other 12 survived with the aid of treatment. Three subclinical cases were diagnosed. Ten animals were censored. The most common reasons for censoring were transfer (4) and slaughter (2). Eight animals in the herd are still susceptible to ECF.

The epidemic curve of *T. parva* infection is shown in Figure 5 against adult *R. appendiculatus* abundance and seroprevalence in cattle. The first major outbreak in the sentinel herd was recorded in April-May 96 during the second wave of adult *R. appendiculatus* activity. Two more periods of intensive *T. parva* transmission to cattle were observed during the first and second wave of adult tick activity in 1997. The ratio risk of infection to tick count reached values as high as 5 : 1. The Kaplan-Meier estimate of the ECF-free survival in the original herd (Figure 6) indicates that at Mayela about 70% of cattle born before commencement of the study came in contact with *T. parva* between September 1994 and August 1997. Taking into account the proportion of subclinical infections (3 in 21 or 14%), mortality is estimated at 70%.

Discussion

A state of firm endemic stability of theileriosis, implying constant high but nonlethal transmission of the infection, cannot be confirmed in the eastern province of Zambia. Even in the endemic area of Wafa, the epidemiological state fails to meet the criteria of stability, although immunizations have been performed for more than 10 years. The *T. parva* challenge varies greatly from year to year and the infection still causes more than 50% mortality. Two constraints for East Coast fever to reach a stable endemicity are the virulence of the *T. parva* parasite in the region and the high innate susceptibility of the Zebu cattle to its effects (Morzaria *et al.* 1988). More importantly, perhaps, the unimodal rainfall pattern results in restricted activity of the *R. appendiculatus* instars (Norval *et al.* 1992) and the year-to-year variation in rainfall causes important fluctuations in tick abundance and thus in the intensity and temporal patterns of *T. parva* transmission. We showed how the transmission of *T. parva* infection in cattle steadily decreased to minimal levels in 2 years of drought, whereas two good rainy seasons were sufficient to restore high risks of infection. A key factor in the regeneration of *T. parva* transmission were second waves of adult and nymph tick activity, which appear to recur immediately when the climatic conditions become favourable, i.e. after one

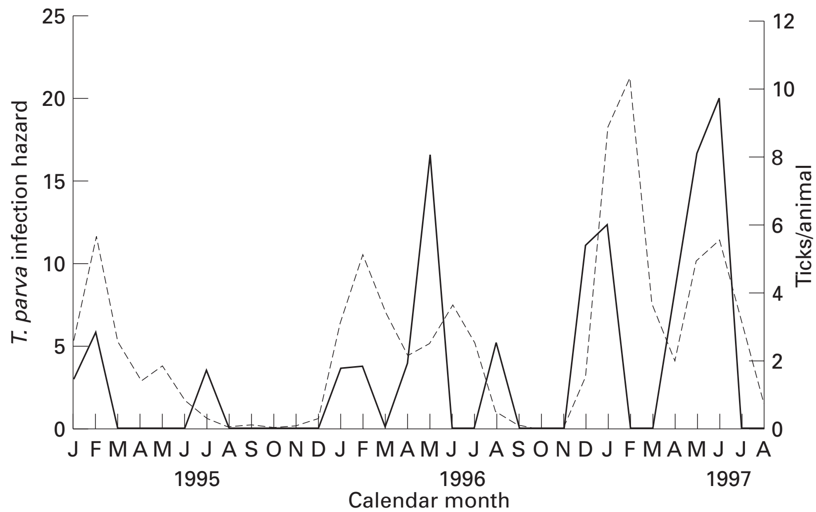

Figure 5 Monthly hazard of *T. parva* infection in adult cattle (——) and average *R. appendiculatus* adult burdens (--------) at Mayela (1995–1997).

good rainy season, and may influence the transmission dynamics of *T. parva* in at least three ways. Firstly, they assure a more continuous presence of transmitting instars throughout the year, with adult tick peaks in January and May and nymph peaks in May and September. Secondly, the second wave of adult ticks is non-diapausing ticks which transmit *T. parva* infection soon after moulting, when the parasite is still highly infective (Young *et al.* 1987). Thirdly, they result in an overlap of transmitting instars, leading to highly efficient transmission of *T. parva* since fast transmission from cattle to cattle is possible and, perhaps more importantly, because infection may be caught from clinically ill cattle (Norval *et al.* 1991). This is corroborated by the high tick infection prevalences observed during the outbreaks in the epidemic area of Mayela. Most of the *T. parva* infections causing clinical disease in cattle are transmitted by the adult stage of *R. appendiculatus*. The contribution of nymphal transmission is, however, difficult to evaluate since the major period of nymph activity coincides with the second wave of adult activity. In any case, nymphal transmission of *T. parva* to cattle was virtually absent during years of drought, when diapausing populations of *R. appendiculatus* dominate and carrier cattle form the sole reservoir of *Theileria parva*, illustrating the difficulty for larvae to pick up infection from carriers (Norval *et al.* 1992). Nymphal transmission of *T. parva* to cattle may lead to subclinical infection more frequently than adult transmission. Nymphal transmission could therefore play an important role in the progress towards endemic stability by both assuring the continuity of *T. parva* infection challenge while at the same time reducing its mortality.

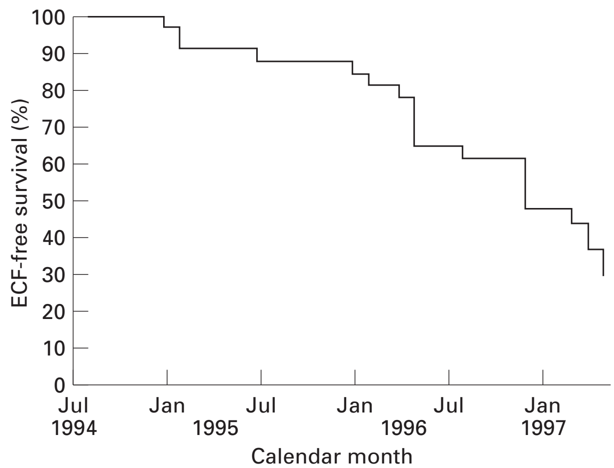

Figure 6 ECF-free survival in adult cattle at Mayela (1995–1997).

Control methods undoubtedly have an important influence on the epidemiology of infectious disease. Both the immunization and treatment method and the chemotherapy of animals suffering from primary infection create a reservoir of virulent *T. parva* in the highly susceptible Zebu cattle of eastern Zambia, thus artificially inducing endemic stability.

Conclusions

There is no endemic stability of theileriosis in eastern Zambia. Continuity of the infection challenge depends heavily on the occurrence of a second wave of activity of the transmitting instars of *R. appendiculatus*. These second waves are only pronounced when climatic conditions (humidity, rainfall) are suitable. Mortality is still high. Further studies are needed to investigate the importance of nymphal transmission of *T. parva* to cattle in advancing towards more stable endemicity.

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