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East Coast fever and multiple El Niño Southern oscillation ranks

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Abstract

East Coast fever (ECF), a tick-borne disease of cattle, is a major constraint to livestock development in Africa in general and southern Zambia in particular. Understanding the transmission patterns of this disease complex is very difficult as shown by previous studies in southern and eastern Zambia due to the interplay of risk factors. In this long-term study, we investigated whether global weather changes had any influence on disease transmission in traditionally kept cattle in southern Zambia. The results from this study show a strong association between increased *Theileria parva* contacts in cattle and the presence of El Niño, clearly linking a simple climatic index to disease outbreaks. We therefore propose that in southern Zambia, the simple and readily available multiple El Niño Southern oscillation index (MEI) ranks be used in planning ECF control programmes and early warning.

Keywords: *Theileria parva*; El Niño; ENSO; Zambia

1. Introduction

The protozoan *Theileria parva* causes East Coast fever (ECF) in African cattle. The disease is transmitted transstadially by the ticks *Rhipicephalus appendiculatus* and the closely related *Rhipicephalus zambeziensis:* larvae and nymphs can become infected with *T. parva* while feeding on an infected host and transmit it in the next stage. ECF remains one of the most important cattle diseases in terms of economic losses (US$ 168 million in 1989, MacInerney et al., 1992) and restriction of livestock development in

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eastern, central and southern Africa (Norval et al., 1992).

Previous studies (Mulumba et al., 2000, 2001) explained transmission patterns of ECF in southern Zambia, but the disease is a very complex matter and incidence remains difficult to predict. The above studies demonstrated that the majority of contacts in southern Zambia were mainly due to nymphal transmission during the early part of the dry season in years with below-average rainfall, while during wet years adult ticks were equally responsible for transmission. Mulumba and co-workers also observed that in dry years a *R. appendiculatus* stock, indistinguishable from *R. zambeziensis*, was found to infest cattle. However, this tick stock was no longer found when normal rains returned. They concluded that this change of tick stock played a very important role in the transmission of ECF in the area. Predicting disease pressure and infection peaks thus relies on having precise knowledge of a series of parameters, including climate and tick phenology and taxonomy. This still makes it difficult to optimise control programmes.

The current work was aimed at investigating the possibility of a link between El Niño and disease pressure, thereby providing a simple way to forecast outbreaks. El Niño, the warming phase of the Southern oscillation, has been associated with malaria epidemics in East Africa (Patz et al., 2002; Lindblade et al., 1999), in Colombia (Bouma et al., 1997) and in India and Sri Lanka (Bouma and Van der Kaay, 1996). To the best of our knowledge, no association between this climate index and transmission of a parasite of veterinary importance has been documented. An understanding of the role that global weather changes play in ECF transmission is useful for forecasting and early warning. In this study, we investigate the association between *T. parva* contacts in cattle and El Niño using the multiple El Niño southern oscillation index (MEI) ranks.

2. Materials and methods

2.1. Study area

The study was carried out in the Southern Province of Zambia, which has a total surface area of 85,000 km^2 and a cattle population of circa 575,000 (Anon, 2003). Two sentinel herds were studied: one at Nteme (Monze) on the plateau (16°10′S, 27°29′E, 1050 m) and the other at Halubilo in the Gwembe valley (16°26′S, 27°42′E, 780 m) as shown in Fig. 1. The sentinel herds were selected on the basis of preliminary studies done by the Assistance to the Veterinary Services of Zambia (ASVEZA) project in 1993–1994 (Mulumba et al., 2000). Briefly, the plateau herd was typical of the endemic disease situation, while the valley herd represented the epidemic situation. Management of the sentinel herds was traditional with no tick control and animals were let to graze on communal pastures. The 9-year study started in January 1994 and ended in December 2002.

2.2. Sampling

All calves born in the two sentinel herds were followed up from birth until their first contact with *T. parva*. Age at and calendar time of first contact were recorded. Age at first contact is used as a measure to assess whether an area was endemic or epidemic (Billiouw et al., 2002). Animals were examined clinically weekly. Blood slides were made weekly and checked for parasitaemia. Biopsies were made and examined for schizonts in case of swollen lymph nodes. Blood was collected weekly to test for *T. parva* antibodies using the indirect fluorescent antibody test (IFAt) (Burridge and Kimber, 1972). The cut-off titre for seropositivity was taken at 1/160. Seroconversion was defined as 3 weeks consecutive sero-positive samples and the date of contact with *T. parva* was set 1 month before the date of first sero-conversion (Billiouw et al., 1999).

2.3. Meteorological data

Rainfall data were collected from meteorological recording stations in the study areas and also the Meteorological Department in Lusaka, Zambia. Multiple El Niño Southern oscillation index (MEI) ranks were retrieved from the National Oceanic and Atmospheric Administration (NOAA) website (http://www.cdc.noaa.gov, NOAA, 2004). El Niño Southern oscillation (ENSO) is used to describe both warm (El Niño) and cool (La Niña) ocean atmospheric events in the tropical Pacific (http://www.ggweather.com, EOG,

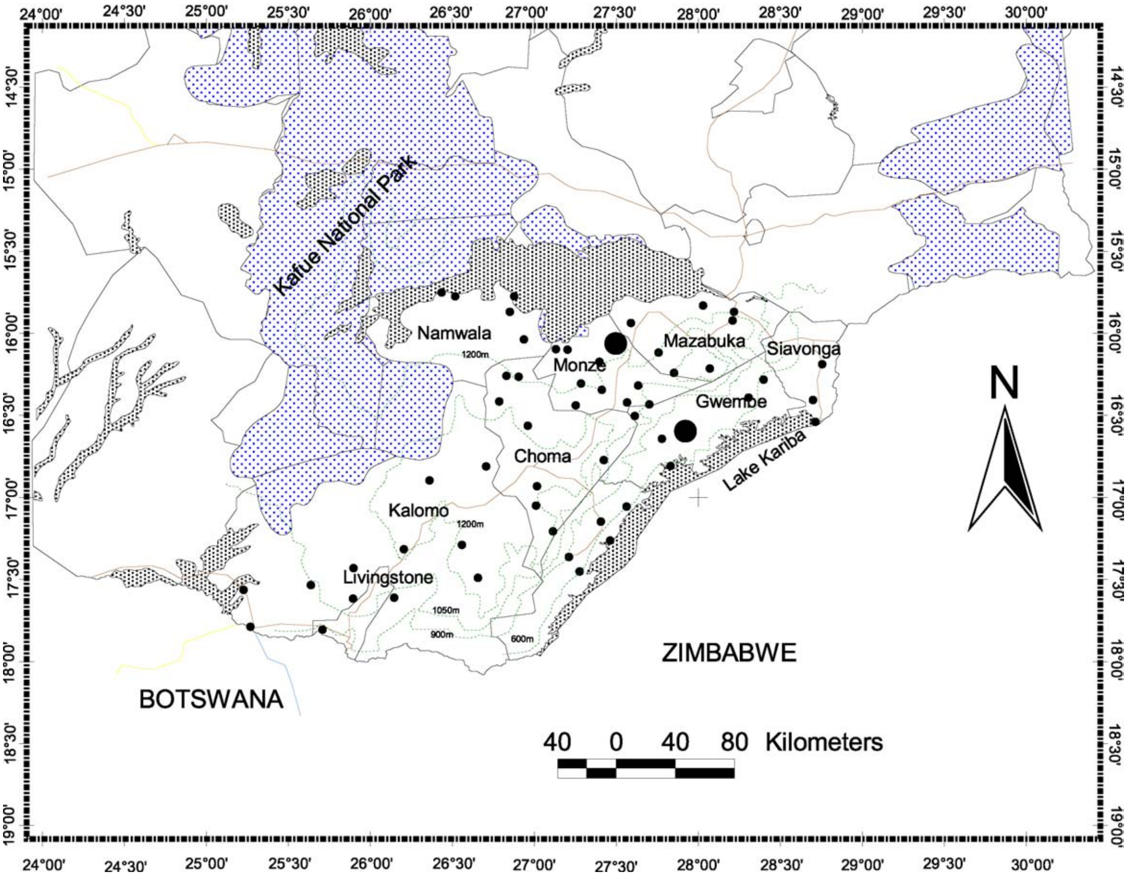

Fig. 1. Map of southern Zambia. The two big dots show sentinel herd localities on the plateau in Monze and in the Gwembe valley.

2000). The MEI is a composite index using sea surface temperatures, surface air temperatures, sea-level pressure, zonal (i.e. east-west) surface wind, meridional (i.e. north-south) surface wind and total amount of cloudiness. Multiple El Niño Southern oscillation index ranks from 1–18 denote strong to weak La Niña conditions, while the range 38–55 denotes weak to strong El Niño conditions.

2.4. Statistical methods

The data were analysed with a Cox proportional hazard model in Stata SE/8.0 (StataCorp., 2003), with the time to first *T. parva* contact as response and the year of birth and area (epidemic versus endemic area) as covariates. The Cox proportional hazard model is a semi-parametric model in that it makes no assumptions about the specific hazard function. It only assumes proportionality of the hazards, a condition that has to be checked explicitly. The time to first contact is inversely related to the probability of contact (sometimes wrongly referred to as disease pressure) and this is expressed a hazard, which is the instantaneous probability of contact (the probability of becoming infected at this instant provided the animal has survived uninfected thus far). Traditionally, results are presented in terms of hazard ratios. In this study, we use the ratio of the hazard for animals born in a particular year to the hazard for animals born in 1996 (animals born in 1996 had the lowest hazard to come into contact with *T. parva*, i.e. had on average a higher age at first contact). Animals born in 2002 and calves showing seropositivity when less than 1 month old were excluded from the analysis to minimise the possibility of detecting passively derived maternal antibodies (Moll and Lohding, 1984; Billiouw et al., 2002).

3. Results

3.1. Multiple El Niño Southern oscillation indices

The MEI indices indicating the presence or absence of El Niño are shown in Fig. 2. Of interest for the present study is the distinct El Niño episode in 1997–1998, flanked on both sides by La Niña conditions. Multiple El Niño Southern oscillation index ranks rise again from 1999 onwards to new El Niño levels by 2002. The onset of the El Niño event was accompanied by heavier rainfall (Table 1).

3.2. East Coast fever transmission and El Niño

An animal's year of birth influenced its hazard of coming into contact with *T. parva* at the two locations. Fig. 2 shows the hazard ratios estimated with a Cox regression model for the different years of birth compared to the year of birth 1996. In the same figure MEI ranks are presented. The analysis showed that hazard ratios were higher on the plateau than in the valley in most of the years. However, hazard ratios went up sharply when El Niño was present (year 1997) ($p < 0.001$). Hazard ratios were higher in the epidemic area (Halubilo, valley) than in the endemic area of Nteme (plateau) when El Niño was present ($p < 0.001$). Hazard ratios in Nteme were also seen to increase in the year when El Niño was present though not as high as at Halubilo. The hazard ratios at the endemic area remained high in the following year even when El Niño was waning. It must be noted that most of the animals, born in 1997 (height of the El Niño event), become infected later in the year of in the following years. There is thus a delay between the El Niño event and the increased probability to become

Table 1
Rainfall figures for Monze and Gwembe districts where the sentinel herds are located

Year	Monze (Nteme) (mm)	Gwembe (Halubilo) (mm)
1994	460.0	401.9
1995	490.0	338.9
1996	710.3	754.0
1997	1031.8	992.2
1998	515.6	434.0
1999	833.2	653.3
2000	850.7	880.9
2001	762.4	770.9
2002	603.4	458.4

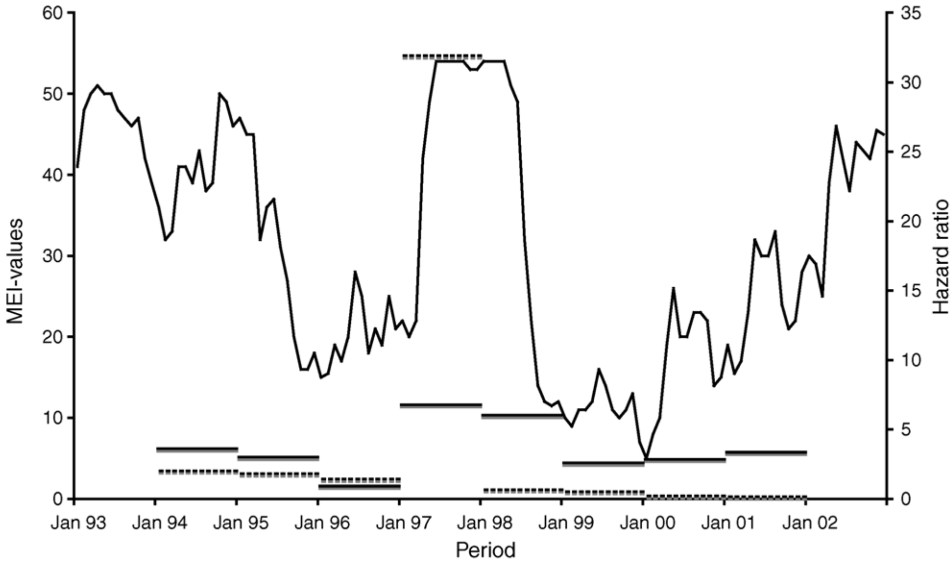

Fig. 2. Monthly MEI values (continuous line) and hazard ratios for Nteme (endemic area, full line) and Halubilo (epidemic area, dotted line) with 1996 as reference category.

infected by *T. parva*. It is also for this reason that no effect is discernible for the second (much smaller) El Niño event in 2002–2003 (this would only be so for the 2002 cohort).

4. Discussion

This study confirms the results found by Fandamu et al. (2005), where population-level antibody levels against *T. parva* were used, rather than the more accurate age at first contact in different calf cohorts. It is well known that El Niño, the warming phase of the Southern oscillation produces heavier than normal rainfall in some parts of the world (Lindblade et al., 1999). The results from this study are in agreement with the findings of Kovats et al. (2003) who reported excessive rainfall in some areas of the southern Africa region during the 1997–1998 El Niño event. The heavier than normal rainfall is indeed very likely related to the increased disease transmission due to higher tick numbers, especially so in the drier valley region of southern Zambia. The hazard ratios in the epidemic valley area (Halubilo) were significantly higher than the endemic area of Nteme (plateau) when El Niño was present. This may be explained by the low challenge in 1994, 1995 and 1996 that resulted in a large population of susceptible animals. High tick numbers and large population of susceptible animals result in a high number of infections, creating a pool of infective animals, which in turn infect the current population of larvae and nymphs, thus ensuring that newborn animals become infected at an early age. In other words, in arid/dry areas like those of southern Zambia, *R. appendiculatus* may not survive easily, reducing the chances for the ticks to become infective. This way, ECF is not common in the area, and therefore the population lacks protective immunity and is more vulnerable when conditions for transmission improve. The effect of the higher rainfall is also short-lived in these arid areas, as hazards immediately returned to their normal levels. In the endemic area of Nteme, high hazard ratios were recorded even a year after El Niño had ended. This is possibly a result of the El Niño effects persisting for longer periods in areas with more rainfall on average, e.g. because higher tick population densities do not collapse so quickly as in more arid areas.

Our results indicate a strong association between the presence of El Niño and the increased transmission of ECF in cattle especially in the drier valley areas of southern Zambia. Though this is a veterinary study, it is essentially in agreement with Nicholls (1993) who suggested that the incidence of most vector-borne diseases in humans was associated with El Niño Southern oscillation. It must be pointed that the higher probabilities of contact follow the high MEI ranks: high MEI ranks are recorded when the animals are born, i.e. this study provides evidence that MEI ranks have predictive power as far as ECF outbreaks in low rainfall areas (e.g. valley regions) are concerned. Farmers could therefore be forewarned of major outbreaks in order to prevent or at least reduce losses and the use of this simple index will facilitate better disease control.

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