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Disease at the wildlife-livestock interface: Acaricide use on domestic cattle does not prevent transmission of a tick-borne pathogen with multiple hosts

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ABSTRACT

Several prominent and economically important diseases of livestock in East Africa are caused by multi-host pathogens that also infect wildlife species, but management strategies are generally livestock focused and models of these diseases tend to ignore the role of wildlife. We investigate the dynamics of a multi-host tick-borne disease in order to assess the efficacy of tick control from an ecological perspective. We examined the efficacy of a widespread measure of tick control and developed a model to explore how changes in the population of ticks due to control measures on cattle impact dynamics of *Theileria parva* infection in a system with two primary host species, cattle and Cape buffalo (*Syncerus caffer*). We show that the frequency of acaricide application has a significant impact on the tick population both on the host and in the environment, which can greatly reduce the pathogen load in cattle. We also demonstrate that reducing the tick population through cattle-related control measures is not sufficient to diminish disease transmission in buffalo. Our results suggest that under current control strategies, which target ticks on cattle only, *T. parva* is likely to remain a significant problem in East Africa, and require the continued use of acaricides, which has significant economic and ecological consequences.

1. Introduction

Pathogens that infect multiple host species have very different population dynamics and require different methods of control compared to single host pathogens. In many cases, multi-host pathogens are important economically and in conservation as they can infect both domesticated and wild animals. However, despite their importance, there are few models that have examined the possibilities of control in this context (Dobson, 2004). While interventions are largely targeted at domesticated animals for logistical reasons, pathogen dynamics are also driven by their relationship with wild animals. The successful eradication of rinderpest demonstrated that interventions targeted at domesticated species can be effective (Roeder, 2011; The Global Rinderpest Eradication Programme, 2011), however, rinderpest was directly transmitted by contact between individuals, and the control strategies used in such a system may not be successful in a regime where the disease is transmitted by a vector.

To examine the effect of disease control in a multi-host system, we analyzed the case of the protozoan parasite *Theileria parva*, which is endemic in buffalo (*Syncerus caffer*) and is transmitted by the brown ear tick *Rhipicephalus appendiculatus*. This same parasite infects

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domesticated cattle causing East Coast fever and related diseases (Lawrence et al., 2004b). Though East Coast fever and the related Corridor disease were previously considered to be caused by different strains of *T. parva* (Uilenberg, 1999), today it is accepted that the diseases are caused by the same parasite (Lawrence et al., 2004a). The causative agent of Corridor disease is known as buffalo-derived *T. parva* and the causative agent of East Coast fever as cattle-derived *T. parva* (Lawrence et al., 2004b). After serial passages in cattle, the buffalo-derived strain behaves like the cattle-derived strain (Maritim et al., 1992), and this is likely to happen continuously where cattle and buffalo share grazing lands, such as in East Africa (Young et al., 1985).

In eastern Africa, where cattle and buffalo share grazing lands, East Coast fever has been reported to cause half a million deaths in cattle each year in both large-scale and small-scale production systems, as well as significant productivity losses associated with the reduced lactation of recovering cattle (Young et al., 1988; Minjauw and McLeod, 2003). The mortality rate has been reported to be as high as 90% in susceptible animals or epizootic situations (Minjauw and McLeod, 2003).

Tick control with acaricides is the most prevalent method of tick-borne disease control in livestock (Di Giulio et al., 2009). Acaricides are applied to the skin of the animal using a dip tank, spray race, manual (hand) sprayer, or other method. While acaricide use has continually been called unsustainable because of the expense, infrastructure, and organization required for regular application, as well as the potential for the development of resistance, the method has been in use since 1909 (Morrison and McKeever, 2006; Perry and Young, 1995). Acaricide use also fundamentally alters the ecology of tick populations, which has important ramifications for the risk of tick-borne infection in both cattle and buffalo (Randolph, 2004). The application of acaricides means that domestic animals act as a sink for ticks, leading to a reduction of the effective carrying capacity of ticks in the environment where acaricides are used (Petney and Horak, 1987). If the tick population is severely reduced by the practice of acaricide use on cattle, it could have a strong effect on the transmission and persistence of a tick-borne pathogen even in a multi-host system (Perry and Young, 1995). Here we investigate how acaricide application frequency impacts environmental tick levels on two ranches in Kenya, and we develop a model to explore how these changes likely impact transmission in the Cape buffalo population and across species.

2. Methods

The study consisted of two parts: a cross-sectional survey of tick burden on cattle and in the environment under different acaricide application strategies, and a transmission model to examine the effect of changes in tick burden on disease prevalence in cattle and buffalo.

2.1. Tick burden in the environment

The cross-sectional study was conducted in July and August 2009 at Mpala Ranch and Loisaba Wilderness, two adjacent commercial cattle ranches located approximately 200 km north of Nairobi in the Laikipia District of Kenya. This region is of mixed land use, with commercial ranches owned by affluent Kenyans and neighboring communal lands inhabited by local indigenous pastoral tribes such as the Maasai. Grazing cattle at low densities is the traditional use of land in the region because the area does not receive enough rain to support arable farming; cattle densities on the two ranches were both approximately 0.05 cattle per acre, with a mean of 2600 cattle on each ranch. Wildlife is abundant in the region and protected on private conservation areas as well as mixed-use areas such as the two ranches studied here. A recent aerial survey suggests that 4205 (standard error 2809) Cape buffalo live in the district, and that buffalo numbers have increased from 2000 to 2010 (Laikipia Wildlife Forum, 2010).

Two different methods of tick control were used on the ranches due to the different preferences of the ranch managers. At Mpala Ranch, cattle are dipped weekly in amitraz, an insecticide and acaricide, at strength 10% over recommended, while at Loisaba Wilderness they are dipped in amitraz at the recommended strength every other week. The cattle on both Mpala and Loisaba are primarily Boran, a breed developed to be resistant to heat, drought, and ticks (Felius, 1995). On both ranches, the ranch managers described only occasional cases of East Coast fever as well as other tick-borne diseases (Littlewood and Silvester, personal communications to JW).

For three herds at each ranch, we measured environmental tick loads as well as potential confounding factors for tick presence, such as wildlife presence, vegetation density and height, temperature, and relative humidity in the area where each herd grazed. We performed measurements while following the herds for two days before scheduled application of acaricides. We collected ticks from the environment by the dragging method (Norval et al., 1992). We dragged a square of plain white cotton one meter on a side attached to a pole along the ground in one-hundred-meter transects. Ticks of all life stages (adult, nymph, and larva) and any species were removed from both sides of the cloth every ten meters in order to ensure that ticks collected early in each transect did not fall off before being counted. On the same transect we tallied and identified all dung observed to determine wildlife presence.

We collected information on the percent cover, leafiness, and density of the vegetation, by using the pin drop method, whereby the tip of a vertical rod is placed on the ground and the plant matter that touches the pin is recorded (Rubenstein, 2010). We counted the leaves and stems that touched the pin as well as the height of the highest stem or leaf touching the pin. If a pin did not touch any vegetation, it was recorded as having a height of zero. We measured 30 evenly-spaced pin drops in each 100 m transect, and from this calculated the percent cover (percentage of pins that touched vegetation), leafiness (leaf hits to total hits), and density (hits per pin drop for each transect). A programmable temperature and relative humidity datalogger (RHT10, Extech Instruments, Nashua, NH, USA) took measurements every 30 s. For each transect, we averaged the temperature and relative humidity measurements over the time period of data collection.