# Impact of rainfall on East Coast Fever in cattle at Ol Pejeta Conservancy, Kenya

*Regnets inverkan på East Coast Fever hos boskap i Ol Pejeta Conservancy, Kenya*

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Degree project/Independent project • 30 credits
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Faculty of Veterinary Medicine and Animal Science
Veterinary Medicine Programme
Uppsala 2022

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| | |
|---|---|
| **Credits:** | 30 credits |
| **Level:** | A2E |
| **Course title:** | Independent Project in Veterinary Medicine |
| **Course code:** | EX0869 |
| **Programme/education:** | Veterinary Medicine Programme |
| **Course coordinating dept:** | Department of Clinical Sciences |
| | |
| **Place of publication:** | Uppsala |
| **Year of publication:** | 2022 |

| | |
|---|---|
| **Keywords:** | East Coast Fever, ECF, *Theileria Parva*, tick-borne disease, Kenya, cattle, precipitation, oxpecker |



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# Abstract

Weather conditions commonly have a large impact on tick-borne diseases as it affects the abundance of the tick vector. The cattle disease East Coast Fever (ECF) is no exception. Rainfall particularly seems to play an important role in the transmission of ECF.

In this study I examined the associations between precipitation and cattle mortality due to ECF in Ol Pejeta Conservancy in Laikipia, Kenya. Long-term data on daily ECF mortality during the years 2016-2021 was compared with rainfall during this same period. The results showed that ECF-related deaths follow rainfall with a peak lag effect on 21 days. The results suggest that control measures for reduction of ticks need to be increased during rainy periods and can possibly be decreased during periods of drought.

The close interaction between oxpeckers and large herbivores has been known for many years. The birds feed on ticks and other ectoparasites from their host animal. Whether the cleaning interactions between oxpeckers and cattle could be a good indicator of tick-load on the cattle was analyzed in this study. The intention was to investigate whether the quantity of oxpeckers could be used as a simple measurement for when treatment with acaricides is needed. Due to lack of oxpeckers in the observations performed it was not possible to detect a correlation between tick-load and number of oxpeckers on cattle in this study. The results point towards oxpeckers not being a good measurement of tick-load on cattle treated with acaricides.



*Keywords:* East Coast Fever, ECF, *Theileria parva*, tick-borne disease, Kenya, cattle, precipitation, oxpecker

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# Abbreviations

| | |
|---|---|
| COF | Pyrethroid-organophosphate Co-formulations |
| DMR | Daily mortality report |
| ECF | East Coast Fever |
| FMD | Foot and Mouth Disease |
| ILRI | International Livestock Research Institute |
| ITM | Infection and Treatment Method |
| OPC | Ol Pejeta Conservancy |
| SLU | Swedish University of Agricultural Sciences |
| SP | Synthetic pyrethroid |
| TBD | Tick-borne disease |

# 1. Introduction

East Coast Fever (ECF) is a disease that causes great loss of cattle in Central, Southern and Eastern Africa. It is one of the most important tick-borne diseases (TBD) in cattle in sub-Saharan Africa (Nene *et al.* 2016). ECF is a widespread disease and a major limitation to improvement of the livestock industry in great parts of Africa (OIE 2018).

In Kenya, as well as in many other African countries, livestock farming is an important source of income for a large part of the population. Cattle pastoralism is extensive in Africa and practiced from at least 2,000 years ago (Pleurdeau *et al.* 2012). It forms the foundation of life for millions of people across the continent (Hanotte *et al.* 2002). In Kenya there are nearly 50 different native tribes; many of these tribes are semi-nomadic pastoralists and their culture as well as social life is centred around their cattle (Meac, 2019). Loss of cattle is consequently devastating for a lot of people (Reporter 2022). East Coast Fever has been reported in 13 countries in Africa and at least 1 million cattle die every year because of it (Gachohi *et al.* 2012; OIE 2020). This causes large financial losses, and not seldom it is the small, resource-poor households being most effected (Gachohi *et al.* 2012).

Ol Pejeta Conservancy (OPC) works with wildlife conservation in a wildlife/ livestock integration system. With 6000 Boran cattle they operate the largest cattle farm in Kenya. After predation from big cats and hyenas, East Coast Fever has been the second biggest cause of mortality in cattle in Ol Pejeta Conservancy over the years (van Aardt, 2021). Tick-borne diseases have a great negative impact on livestock production, and it has been proposed that the effects of ticks and tick-borne diseases on cattle imposes the greatest barrier to economic development in all East Africa (Keesing *et al.* 2018). It is therefore important to map the risk factors of ECF. Since ECF is spread by ticks it is likely that the pattern of when cattle get infected is influenced by how the environment affects the tick populations. In this study, long-term data on Boran cattle mortality was used to determine the associations between rainfall and mortality due to ECF. The expectation was that this knowledge will provide a better understanding of when prevention measures should be taken.

# 2. Literature Review

## 2.1. East Coast Fever and the protozoa *Theileria parva*

Acute infection with the parasite *Theileria* spp. in cattle causes a grave lympho-proliferative disease known as East Coast Fever (Olds *et al.*, 2018). It is a potentially lethal tick-borne disease that cause major loss of cattle in Central, South and East Africa. The disease is caused by various types of the hemoprotozoa *Theileria* and is therefore also called Theileriosis (Norval *et al*., 1992). It is one of the most significant livestock diseases in Africa (reviewed in Olwoch *et al*., 2008). *Theileria parva* is the protozoan pathogen that primarily causes ECF in Eastern and Central Africa. It is transmitted by the ixodid brown ear tick *Rhipicephalus appendiculatus* (Taylor *et al.*, 2007).

The African buffalo (*Syncerus caffer*) is most likely the natural host of *T.parva* in Africa (Nene *et al.*, 2016; Taylor *et al*., 2007). The literature suggests that Theileriosis of cattle first originated in buffalo populations of eastern Africa, and became a disease of domestic cattle after their introduction and distribution in the area ~ 8000 years ago (Norval *et al.,* 1992; Morrison *et al*., 2020). The buffalos carry the parasite without it causing clinical disease and are still today an important way of transmission to domestic cattle (Nene *et al*., 2016; Morrison *et al.*, 2020). Transmission of *T. parva* from infected African buffalos to cattle usually causes a more acute and severe form of ECF referred to as Corridor Disease. In the past a sub-speciation of *Theileria parva* was described, known as *T. parva parva* and *T. parva lawrencei* (Latif *et al*., 2019). *T. parva parva* being adapted to cattle and *T. parva lawrencei* being adapted to buffalos. It was mainly based on differences in characteristics of disease that the parasites gave rise to when infecting cattle. However, this nomenclature was discarded when repeated findings showed genetic and antigenic resemblance in the parasite populations (Cook *et al*., 2021; Morrison *et al.*, 2020). They are now referred to as *T. parva* of cattle or of buffalo origin (Cook *et al*., 2021). More recent studies have shown a great antigenic and genotypic diversity of both cattle- and buffalo-diverted *T. parva* and confirmed the basis of antigenic cross-reactivity between the populations (Morrison *et al*., 2020).

### 2.1.1. Clinical picture

The incubation time for ECF is usually 8-12 days (OIE, 2020). Enlarged lymph nodes are normally the first observable clinical symptom, typically the parotid. Followed by general lymphadenopathy and rapid onset fever (40-42°C), increased respiratory rate, dyspnoea, tachycardia, and petechial haemorrhages may occur in mouth and on vulva (Taylor *et al.*, 2007; OIE, 2020). Affected animals often show rapid loss of condition, become anorexic and emaciated. A decrease in milk production and diarrhoea, often bloody, can sometimes also be seen (Taylor *et al.*, 2007). In the terminal stage, it is not seldom that froth runs from the mouth and nostrils. Animals usually succumb to disease within 3 weeks of infection (Taylor *et al.*, 2007). Animals that recover, become persistent carriers of *T. parva* after the acute phase of infection. Such cattle act as reservoirs of infection for ticks. This persistence is a key factor for the maintenance of disease in a group of animals (Morrison *et al.,* 2020).

In case of death, the most pronounced pathological changes are seen in the respiratory organs. Signs of pneumonia and pulmonary oedema with froth in the trachea, bronchi and nostrils are amongst the most common findings together with enlarged lymph nodes, especially submandibular, parotid and prescapular. Other general post-mortem findings are petechial haemorrhages in heart (epicardium and endocardium), in lungs and pleural cavity, sometimes kidneys, intestines and under the tongue. Also, its common to see emaciation and changes in the spleen, either mushy or dry, enlarged or shrunken depending on the stage of disease. Ulcers in the abomasum plus intestines can have a characteristic appearance and in young animals' atrophy of thymus with necrosis can usually be seen (Brown, 1990; Irvin and Mwamachi, 1983).

In susceptible herds *T. parva* causes both high levels of morbidity and mortality (Morrison *et al.*, 2020). Several factors affect the mortality rate of ECF, such as the strain of the parasite, infective dose, host characteristics and susceptibility (OIE, 2020). Even though some indigenous breeds, such as Ankole, can have a lower mortality rate in endemic areas, in more susceptible animals the mortality rate can be more than 90% (Latif *et al.,* 2019).

### 2.1.2. Diagnosis and control measures

In the field the diagnosis of ECF is mainly based on clinical examination, although there are confirmatory tests available (Cook *et al.,* 2021). Looking for *Theileria* parasites in Giemsa-stained blood smears and smears from lymph node from fine needle aspiration biopsy is one of the simplest tests. Although, most theilerial piroplasms are morphological identical and it is therefore not possible to get a species-specific diagnosis (Taylor *et al*., 2007). To get a certain diagnosis laboratory testing using PCR and DNA probes are available, as well as the detection of antibodies with ELISA (OIE, 2020).

Control measures predominantly focus on prevention of disease as ECF often has a fatal outcome (Morrison *et al.*, 2020). There are three principal ways of controlling ECF. These are tick control with treatments with acaracides (a pesticide that kills ticks and mites), treatment of sick animals and with the Infection and Treatment Method (ITM) with live vaccination (Gachohi *et al.*, 2012).

Tick control includes different methods of application of acaricides on cattle through spray races, dipping, pour-ons, hand spray etc. This is the most commonly used control method, which is effective in the absence of acaricide resistance. The downside of acaracide treatment is that it is expensive, toxic for the environment, and there is a risk for resistance development in tick populations (Gachohi *et al*., 2012).

Treatment of sick animals is traditionally done with tetracyclines, which according to Taylor *et al*. (2007) have a therapeutic effect if given at the time of infection, but does not work when the disease have become clinical. Other studies have shown effect on cattle with low parasitaemia, consequently leading to the development of carrier states in these cattle (OIE, 2020.). In clinical cases treatment with chemotherapeutic agents such as buparvaquone and parvaquone are preferable according to Taylor *et al.* (2007). These drugs are, however, expensive (Gachohi *et al.,* 2012).

Vaccination against ECF is done with the Infection and Treatment Method; live vaccine containing debilitated strains of *T. parva* and then treatment of the animal with tetracyclines. The Muguga cocktail as the vaccine is called, contains sporozite stabilates from three different *T. parva* strains, called Muguga, Serengeti-transformed and Kiambu-5. Long-term tetracyclines are then given to lower the severity of disease, thus the cattle gain immunity. An improvement of the vaccine is needed since it is difficult to produce, expensive and can give rise to severe disease (Nene *et al.*, 2016).

## 2.2. The brown ear tick (*Rhipicephalus appendiculatus*)

*Rhipicephalus spp.* are brown to reddish-brown in color and belong to the family Ixodidae (hard ticks) (Spickler, 2022). They exist in eastern, central and southern Africa (Perry *et al.*, 1991). Adult *R. appendiculatus* mainly feed from the ears of their host, which explains why the first symptoms of ECF typically is enlargement of the parotid lymph nodes (OIE, 2020). Larvae and nymphs usually attach to ears, head and neck, but can sometimes be found in other places on the body (Njaa, 2017). Preferable hosts include buffalo, cattle and antelope species (Bovidae), although immature ticks may also be found on smaller herbivores, carnivores and other species (Spickler, 2022).

### 2.2.1. Transmission of disease

The ticks become infected when having a blood feed from infected animals during larval and nymphal stage of the life cycle (Gachohi *et al.*, 2012). *R. appendiculatus* is a three-host tick and the transmission to cattle is transstadial (Nene *et al*., 2016). *T. parva* multiplies and undergoes obligate sexual stage development within the tick. The tick serves as an intermediate host for *Theileria parva* and ingests erythrocytic merozoites which later develop into primary and secondary sporoblasts in the adult tick (Taylor *et al.*, 2007). Sporozoites, which are the lifecycle stage infective to cattle, are then produced and released into the saliva of the tick. Infected nymphs and adults then transmit sporozoites to the host when sucking blood (Nene *et al.*, 2016). The sexual cycle in the tick vector results in wide parasite genotypic and antigenic diversity (Nene *et al.,* 2016). Being a three-host tick, *R. appendiculatus* has the capability to infect more than one host during its lifetime (Olds *et al.*, 2018; Gachohi *et al.*, 2012). According to studies done by Olds *et al*. (2018), another factor that facilitates the transmission of the parasite to cattle is the possibility of *R. appendiculatus* to obtain *T. parva* from carrier animals even in the absence of detectable parasitaemia.

### 2.2.2. Environmental factors affect vector-borne diseases

As a tick-borne disease, the epidemiology of ECF is prone to be largely influenced by environmental conditions since these influence the vector and its lifecycle (OIE, 2020; Gachohi *et al.*, 2012).

The ecology of *R. appendiculatus* is influenced by a number of factors, the most important of which are climate, vegetation and herbivore host availability (Norval *et al.*, 1992; Wanzala, 2009). *R. appendiculatus* is, as mentioned, a three-host tick and even though it infests its host for several days while it feeds; at least 90% of its life cycle is spent in the environment rather than on the host animal (Spickler, 2022). This means that the microclimate, such as vegetation cover, temperature and rainfall is key for the survival of the free-living stages of the tick (Branagan 1973; Wanzala, 2009). It has a tendency to disappear from areas where the vegetation cover is reduced due to overgrazing and removal of trees etc. (Norval *et al.* 1992; Wanzala, 2009). Savannah and grassland or woodland-savannah habitats are preferable for the brown ear tick (Perry *et al.,* 1991; Wanzala, 2009). However, the results of a study by Cumming (2002) show that climate variables are better predictors of tick abundance and distribution than vegetation-related variables.

Monthly rainfall has a strong positive correlation with the abundance of adult and nymphs *R. appendiculatus.* While larvae seems to be less effected by cumulative precipitation (Mooring *et al*., 1994). At least 400-600mm of annual rainfall and relatively cool biotopes with less than 30°C daily maximum are favoured (Perry *et al.,* 1991; Wanzala, 2009). Summarised by Mooring *et al*. (1994), various field studies have shown that the number of ticks on host animals increases pronouncedly with onset of rains and usually remains high throughout wet season. The abundance then decreases during dry season. Understanding the influence that precipitation has on the abundance of different tick species is essential for anticipating tick challenge and effectively achieve tick-control (Mooring *et al*., 1994).

## 2.3. Oxpeckers

There are two species of tick birds which make up the family Buphagidae. These are the red-billed oxpecker (*Buphagus erytrorhynchus*) and the yellow-billed oxpecker (*Buphagus africanus*), which have similar habits when it comes to nesting and feeding according to Mengesha (1978). Oxpeckers are often found on the larger herbivorous animals in East, central and southern Africa, such as rhinoceros (Rhinocerotidae), giraffes (Giraffidae), and buffalos (see figure 1). The close interaction between the birds and the large grass eaters has been known for many years (van Someren, 1951). Hence the name ox-pecker, which also is the explanation of the genus Buphagus. Bous meaning “ox” and phagos meaning “eating” in ancient Greek (Winkler *et al*., 2020). The birds feed on ticks and other ectoparasites as well as scurf, mucous, hair, earwax etc. (Mengesha, 1978; Adeyanju and Adejumo, 2020). They have an overlapping bill tip which makes it easier for them to remove ticks and feed from their mammal hosts (Winkler *et al.*, 2020). Moreau (1933) examined the stomach contents of 58 red-billed Oxpeckers and found in total 2291 ticks of all stages of development in 55 of the birds, which showed that their main diet probably is ticks and other blood-sucking parasites. Out of these ticks, 95% were found to be potential vectors of tick-borne diseases in East Africa, such as heartwater and East Coast Fever.

Feeding upon large mammals is an efficient way to find food without needing to spend a lot of energy (Adeyanju and Adejumo, 2020). Oxpeckers typically spend their whole days on their hosts, where they feed, sunbath and even sleep (Winkler *et al*., 2020). Cattle serves as a suitable host for the birds to feed upon since they are quite tolerant, unlike elephants who will not tolerate them (van Someren, 1951; Winkler *et al.*, 2020). In many parts of West Africa, cattle and donkeys are now the main host species, and they are also common hosts in other parts of the continent (Winkler *et al.*, 2020). According to a study made by Ndlovu and Combrink (2015) in South Africa, oxpeckers are continuous foragers with peak feeding periods in the morning between 8.00 am to 10.00 am and in the afternoon between 4.00 pm and 6.00 pm. Oxpeckers forage in small groups and several separate groups may feed on one herd of herbivores (Winkler *et al.*, 2020).

*Figure 1. A wild buffalo with four oxpeckers on its back in Ol Pejeta Conservancy. Credit: Julia Wallin.*

# 3. Aims of study

The purpose of this study was to examine the relationship between precipitation and cattle deaths due to ECF to investigate if there is a pattern for when OPC loses most cattle due to East Coast Fever. Long-term data on precipitation within the conservancy and Boran cattle mortality was used to determine the associations between rainfall and mortality due to ECF. The study aimed to provide a better understanding of when prevention measures should be taken.

Being able to assess and reduce tick-load on cattle is an important part of the preventive work. Furthermore, one aim of the study was to examinate whether the cleaning interactions between oxpeckers and cattle could be a good indicator of tick load on the cattle. The hypothesis was that number of oxpeckers sitting on the cattle was positively correlated with tick-load. The intention was to investigate whether the quantity of oxpeckers could be used as a simple measurement for when treatment with acaricides is needed.

In this study, the impact of the acaracide treatment of the cattle was also tested. This was done with a tick-count on the animals right before spray and then after spray. Furthermore, the spraying interval of the cattle is discussed.

# 4. Material and Methods

This study was carried out in collaboration with Ol Pejeta Conservancy and Swedish University of Agriculture (SLU).

## 4.1. Study area and population

Material for this study was collected in Ol Pejeta Conservancy, in Laikipia County located in central Kenya. The study has both a retrospective part and an active part that took place during wet season in November and December 2021. Precipitation in the area is typically bimodal, with rain seasons in March to May and in October to December (Kisaka *et al.*, 2015).

The semi-arid land of Ol Pejeta Conservancy covers approximately 370 $km^2$ and is surrounded by a 120 km long, solar powered, electric fence, with the exception of three corridor openings. These corridors are designed to allow wildlife to freely move in and out of the reserve, apart from rhinos which are kept within the fenced area for protection (Ol Pejeta Conservancy, 2022a; 2022b). OPC work with wildlife conservation together with community development and is one of the leading reserves in Kenya when it comes to protection of endangered species (Ol Pejeta Conservancy, 2022c).

In addition to research in wildlife conservation, Ol Pejeta runs the largest livestock ranch in Kenya, with about 6000 head of purebred Boran cattle and approximately 200 head of Ankole cattle (van Aardt, 2021). An extra 1500 domestic cattle owned by external farmers and companies are also grazing within the fence of OPC (Ol Pejeta Conservancy, 2022d). These herds do not mix with OPC cattle. The average herd size has, since year 2019, increased from about 100 head a herd to around 250 cows, and sometimes the same number of calves in the same herd. Herds of heifers and steers vary between 250-300 animals, but also smaller herds exist. An increase in ECF cases has not been observed since increasing the herd sizes (van Aardt, 2021). There are two calving seasons a year, one in April to May, and one in November to December. Bull calves get castrated at the age of 7 months. Calves are about 8 months old when they get weaned. After weaning the animal is not considered a calf anymore.

Categorization of age groups at OPC:

- Calves: 0-8 months.
- Heifers: 8 months – 2 years.
- Steers: 8 months – 2 years.
- Cows: from first calf and forward
- Bulls: normally 2.5 years and above. (Since they usually are ready to breed at this age).

OPC has their own slaughterhouse, where they operate two times/week. About 20 animals get slaughtered at a time and the cattle walk from the pasture to the slaughterhouse. Steers are slaughtered at approximately three years of age and cows usually around 10 years, depending on the animal's condition.

Beef production together with tourism is how Ol Pejeta funds their wildlife protection and conservation work (Ol Pejeta Conservancy, 2022e). Inside Ol Pejeta Conservancy the domestic cattle share pasture grounds with wildlife, which according to OPC is both beneficial and challenging. Integrating cattle with wildlife has shown to be advantageous for the productivity of the grassland and wild herbivores are more attracted to areas that have been grazed on by cattle. This has been recorded by camera traps that has been set up in livestock-grazed areas. Thriving wild herbivores due to well fertilized rangelands will have a knock-on effect on the rest of the food chain, such as endangered large carnivores (Ol Pejeta Conservancy, 2022f).

Predation from big cats and tick-borne diseases, particularly spread from buffalo, are the two greatest challenges OPC faces with the wildlife/livestock integration system (Ol Pejeta Conservancy, 2022f). Approximately 2500 African buffaloes live in the conservancy. The buffaloes migrate and can move freely in and out of the conservancy through the three corridor openings. The buffalo migration makes it possible for new strains of *T. parva* to enter the reserve. As in most parts of Kenya, East Coast Fever is a major problem in Ol Pejeta Conservancy and kills about 1% of the cattle annually (van Aardt, 2021).

## 4.2. Daily mortality reports and precipitation

OPC keep track of their loss of cattle by recording death, and the cause of death, in records called "Daily morality reports" (DMR) (see figure 2). The DMR's are made in Excel by OPC staff, and all death are recorded in the files. One excel file per year and every file is divided into 12 sheets, one for each month. Every sheet has 10 columns (A-J); date, category, brand no., chip no., no. head, cause, herder, location, reported by, remarks.

Some of the most common causes of death of cattle that was found in the files were predation, ECF and Foot and Mouth disease (FMD). Diagnosis of disease was done by a veterinary animal technician employed by OPC. Main clinical signs used for diagnosis of ECF was fever, swollen submandibular and parotid lymph nodes, froth from nostrils and panting. To ascertain the diagnosis a necropsy was performed whenever an animal succumbs to ECF. Postmortem findings that lead to diagnosis was:

- frothy trachea
- frothy bronchi and inside lungs
- enlarged submandibular, parotid and/or prescapular lymph nodes
- petechial haemorrhages under the tongue, heart and/or lungs

An assessment was done from case to case, but at least two of the criteria's above was needed to set the diagnosis ECF, and at least one of the findings needed to be either froth or enlarged lymph nodes.

Data on death due to East Coast Fever was collected from the DMR's between January 2016 and December 2021, in total 6 years. Data on precipitation were also collected from this same period. Ol Pejeta Conservancy has 10 rain stations within the conservancy where they measure precipitation. It is done manually with a rain collector and one field assistant visits all the stations every morning at 7.00 am to document the rainfall. The registration is done in an Excel file. A daily average of all 10 stations was used in this study.

Precipitation was then put in relation to death due to ECF. An Excel file was made with all dates between January 1$^{st}$ 2016 and December 31$^{st}$ 2021, containing deaths diagnosed with East Coast Fever. Since the number of days not containing any deaths was much greater than the days containing deaths, a categorization was done. Deaths were categorized as 0 = zero deaths (n=1747), 1 = one dead (n=141), and 2 = two or more deaths (n=29). To investigate whether precipitation had an indirect effect on ECF, through its effect on the vector by which the disease is spread, we looked back at how much rain had fallen within a certain time span from each date. Timespans that were studied to begin with was 7 days back, 14 days back, 21 days back, and 28 days back. Because of the outcome of the results of the timespans just mentioned, further studies of each day between 15-28 days back from every date were performed and also each day between 30-38 days back from every date.

Since one day of rain is not going to make that much difference if the days before and after consists of drought; precipitation from a seven-day period was taken into consideration when looking at the relation to ECF deaths. Rainfall from three days before and from three days after every date, starting from the 1st of January 2016, constituted the seven-day period.

### 4.2.1. Statistic methods

To analyze the associations between ECF death and precipitation an Anova GLM test was performed in Minitab. Cattle mortalities due to ECF was used as the response variable and rainfall as the predictor variable. This was analyzed in different time series as explained above, to allow examination of the association between rainfall and mortality with a lag effect. The results were processed to descriptive graphs in Excel.

## 4.3. Oxpeckers as a measurement of tick load

To study the correlation between the number of oxpeckers and the number of ticks on cattle, oxpeckers were counted on a number of herds the days before they were treated with acaricides. The number of ticks on the cattle was then counted right before they were getting sprayed. The following days after acaricides treatment oxpeckers were counted again in the same way as before spraying. Another tick count for observation on tick load was also performed the day after acaricides treatment to confirm the reduction of ticks.

With help from a Swahili-English translator questions about oxpecker presence around the cattle were asked to the herders to get a better perception of when and where the birds were most frequently seen.

### 4.3.1. Oxpecker count

Observations were performed using a pair of binoculars, Nikon Monarch 5. All together 14 herds were observed during the months of November and December, 2021. Since the literature suggest that oxpeckers forage throughout the day and spend most of their time on their host, observations were done three times a day: morning, mid-day, and afternoon. Six observations were done in the morning between 8.00 and 9.00 o'clock, 5 were done mid-day between 10.30 and 12.30 and 3 observations were carried out in the afternoon between 15.30 and 16.30. The size of the herds that was observed varied between 2 and 300 cattle, and with different age and sex. Because of lack of oxpeckers sitting on the cattle no further observations were done.

## 4.3.2. Tick count

Ticks were counted before and after acaricide treatment. Boran herds get treated with acaricides every 5th - 7th day, while ankole herds get treated ones a month (van Aardt, 2021). The animals are driven through a so-called spray race. Acaricides are sprayed with high pressure from above, underneath and from the sides of the animal (see figure 3). The spray track runs with the help of a petrol engine. There is in total seven spray tracks located in different areas within the conservancy, and they are named by their location – Kamok, Sirrima, Morani, Muturu, Scotts, Sidai and Lourugurugu. Approximately 1500 animals are being sprayed each day at one or two of the seven spray tracks. The acaricide used is Tickatraz (Amitraz) 12.5% (van Aardt, 2021).

*Figure 3. The spray track, showing the high-pressure nozzles in the floor and the walls. Credit: Julia Wallin*

The tick-count served several purposes. The spraying interval used for the Boran cattle is based on routine without any specific indicators for when to spray. Ankole are sprayed less frequently since they get less affected by ticks and tick-borne diseases (van Aardt, 2021). One reason for the tick-count was to get an indication on if there might be some immunity in the ticks against the acaricides. The results of the tick-count were also used to discuss if it is necessary to spray every 7th day, or if it would be possible to prolong this interval.

For this analysis, 11 herds were selected for tick count. Herds were selected by two factors; when they were getting sprayed and accessibility, where the herd were grazing at the moment. Herds that were grazing close to the spray-tracks were selected to make it as easy as possible for both herders and cattle, to avoid making them walk far distances and to minimize the impact on their daily schedule. Other factors taken into consideration were the ability to handle the animals selected in a safe way. Therefore, herds with older bulls and cows were avoided.

Ten animals were randomly selected from each herd by the animal technician of OPC. Ticks were counted just before spraying on two different herds each day of counting. Hence ticks were counted on 20 new animals that was last sprayed 7 days ago. Ticks on the same 20 animal were then counted again the day after spraying. To be able to distinguish the cattle in their herd, a number between 1-10 was painted on the back of the individuals included in the tick count. Ticks were counted on 110 animals in total. Each of them counted two times, before and after treatment with acaricides. The same way of counting the ticks was applied on all animals, checking the ears, head and under the tail of the cattle. This was a method of counting ticks used by OPC veterinary animal technician that we adopted in this study. Any tick attached or crawling around in the fur, not yet attached, was counted and documented. No differences were made depending on species of ticks. They were all counted.

## 4.4. Ethical aspects

Most of the study was done by retrospectively going through documented data and journals, and by observing animals. Hence, no animals nor people was exposed to any physical or psychological harm. The active part of counting ticks may have caused some discomfort for the animals when being handled in the corral. Although, mild discomfort is considered acceptable since the study is performed to help develop methods to prevent disease, to reduce animal suffering and economic loss.

# 5. Results

## 5.1. Deaths due to ECF

In total 232 cattle given the diagnose ECF died during the period of January 2016 and the end of December 2021. The deaths occurred on 177 days and a maximum of 7 cattle died on the same day. The year that most cattle died due to ECF was the year 2019 when a total of 86 head died. Year 2021 only 7 cattle died which was the year with the least number of deaths due to ECF. Out of the 232 deaths 33% were steers (76 head), 32% were heifers (75 head), 26% were calves (61 head), 5% (11 head) were cows, and 4% (9 head) were bulls (see table 1). Out of these 9 bulls, 2 was marked as "young bull".

*Table 1. Number of deaths due to ECF per category every year between 2016 and 2021.*

| Category | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** |
|---|---|---|---|---|---|---|
| **Calf** | 11 | 7 | 9 | 9 | 22 | 3 |
| **Heifer** | 4 | 10 | 14 | 40 | 7 | 0 |
| **Steer** | 6 | 10 | 16 | 32 | 8 | 4 |
| **Cow** | 3 | 4 | 2 | 1 | 1 | 0 |
| **Bull** | 0 | 1 | 5 | 4 | 0 | 0 |
| Total | 24 | 32 | 46 | 86 | 38 | 7 |

## 5.2. ECF deaths in relation to precipitation

Since Ol Pejeta Conservancy covers a large area, precipitation sometimes vary greatly between the ten rainfall stations. During the 6-year period included in the study the mean maximum precipitation in one day was 52.7mm for all ten stations. At the most 120mm rain was documented from one station in one day.

The study showed an association between rainfall and mortality due to ECF. Figure 4 shows mean daily rainfall of a certain number of days before zero death (n=1747), one dead (n=141) and two or more deaths (n=29) of cattle due to ECF. The results present significant difference in precipitation between days with zero deaths and days with multiple deaths, with a peak 21 days after more heavily rainfall (Anova GLM). This means that ECF deaths follow rainfall with a peak lag effect on 21 days ($p<0.001$, $f=27.40$). These results suggest that ECF morbidity is lower during dryer periods.

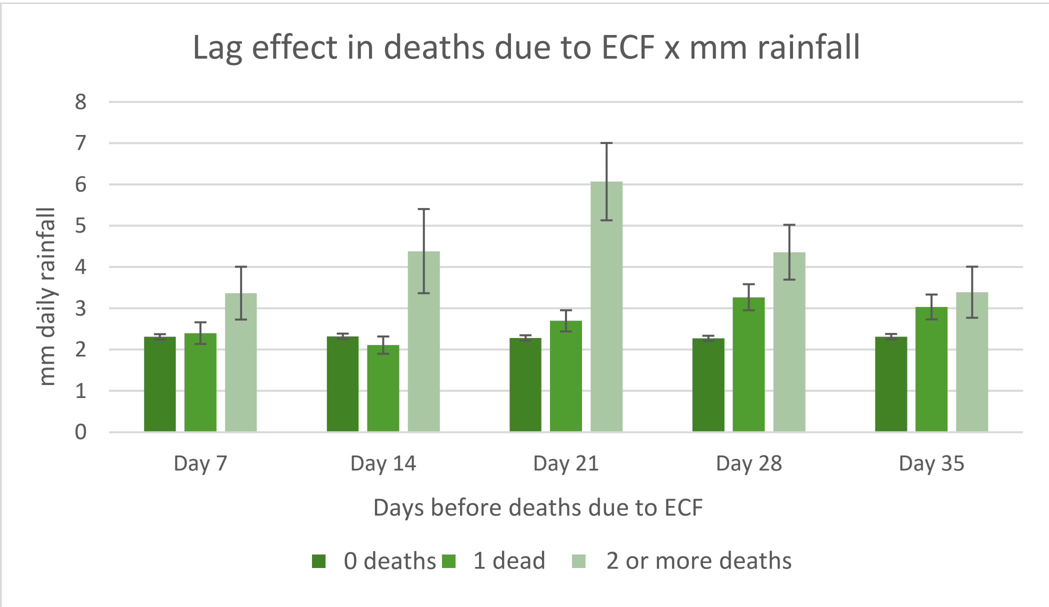


*Figure 4. This graph shows the impacts of precipitation at certain numbers of days before deaths due to ECF.*

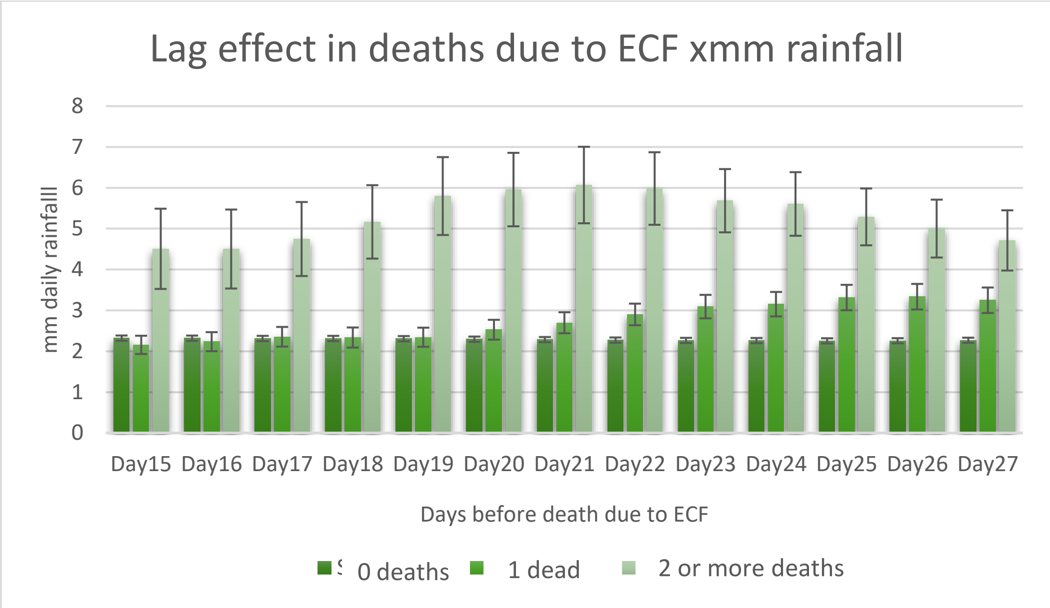


*Figure 5. This graph shows the impact of precipitation at certain numbers of days before deaths due to ECF.*

Looking at both figure 4 and 5, it is clear that the relationship between previous precipitation and deaths grows stronger up to 21 days for multiple deaths and then fades after that peak (Anova GLM). If we look at the stack for one dead, the correlation is not as strong and the association is not significant until after 21 days. No significant different in precipitation is seen between zero deaths and one dead until day 21, and is statistical significant between day 22 and 27 ($p<0.05$).

## 5.3. One oxpecker was found

In all 14 oxpecker observations that were carried out, only one oxpecker was found, sitting on an Ankole bull at 8:14 am. Hence, the hypothesis that both number of ticks and oxpeckers would be reduced after acaricides treatment was not possible to analyze because of lack of oxpeckers. The size of the herds that was observed varied between 2 and 300 head, and with different age and sex. The observations were made during the months of November and December 2021. The Ankole bull that was found with an oxpecker was grazing together with one other bull, a Boran. In all the other observations zero oxpeckers were found. Due to this, no further observations were made.

## 5.4. Tick-Count

The number of ticks found on the cattle differed a lot between the herds. Ticks were counted on 110 animals in total. At the most 173 ticks were found on one heifer.

Zero ticks before spraying were found in 9 animals (8.2%). Before spraying 26.4% of the animals had 50 ticks or more on them before and 11.8% had more than 100 ticks. The majority, 67.3%, had collected between 1 and 50 ticks since they were last sprayed.

*Table 2. Total tick-count per herd before treatment with acaricides and follow up-count after treatment.*

| **Name of herd** | **Category** | **Tick-count per 10 animals before spray** | **Tick-count per 10 animals after spray** |
|---|---|---|---|
| Akula | Steers (n=10) | 24 | 3 |
| Nanok | Steers and heifers (n=10) | 3 | 3 |
| Kaprio | Heifers (n=10) | 49 | 7 |
| Cyrus | Steers and heifers (n=10) | 50 | 1 |
| Kirimi | Steers (n=10) | 140 | 18 |
| Mwenda | Heifers (n=10) | 210 | 22 |
| Okoth | Young bulls (n=10) | 961 | 10 |
| Akriket | Heifers, steers, cows (n=10) | 57 | 3 |
| Einuria | Unknown (n=10) | 41 | 8 |
| Erusters | Steers (n=10) | 766 | 7 |
| Mutege | Heifers (n=10) | 1204 | 2 |
| Total | 110 animals | 3505 | 84 |

There was a great difference between the tick-count before and after spray, with an obvious decrease in ticks the day after (see table 2). A t-test was used in Minitab to evaluate the decrease in ticks ($p=0.040$, $t=-2.36$). Mean number of ticks before spray per herd (n=11) was 319 (SE=132), while mean number of ticks after spray was 7.7 (SE=2). Out of the 84 ticks found on the follow-ups, only 9 ticks were attached, and the rest was crawling in the fur. The difference was found to be greater on the herds with higher tick-load, than the ones with less ticks.

# 6. Discussion

East Coast Fever is a disease of great importance for stockholders in sub-Saharan Africa where the disease is endemic. Not only is it a cause of decrease in cattle numbers and economic loss, but also a decrease in animal welfare. Additionally, it limits the introduction of improved dairy breeds since they are more susceptible to ECF (Olds *et al.*, 2018). Thus, research in the matter is of great importance. Ol Pejeta conservancy is a suitable study site. It is the largest cattle ranch in Kenya, and keeps thorough documentation on cattle, treatments, and mortality. It has previously been used for research on ECF by International Livestock Research Institute (ILRI), amongst other researchers.

The aim of this study was to analyze the association between precipitation and mortality in cattle due to ECF. Furthermore, the aim was to evaluate if oxpecker-count could serve as a feasible measurement of tick-load on cattle. Additionally, I evaluated the effect of acaricide treatment used at OPC for Boran cattle in particular.

## 6.1. Deaths due to ECF

Deaths by ECF affected all sexes equally; however, it was clear that young animals were overrepresented. Calves together with steers and heifers stood for over 90% of the deaths during this time. These results could be expected given that young animals do not have an equally developed immune system as an adult animal. Additionally, there is a higher risk that younger animals has not encountered as many *T. parva* strains and are more naïve to it than an older animal. There is a bigger chance that an older animal previously encountered some *T. parva* strains and developed some level of immunity. Out of the 9 bulls that died due to ECF, two were also younger animals, marked as young bulls. The number of bulls that died due to ECF, however, cannot be seen as reliable, as there are notedly fewer bulls in the conservancy compared to other categories.

## 6.2. Rainfall and mortality in cattle due to ECF

With this study, we wanted to investigate if and how long after rainfall the effect on ECF mortality was seen. No significant difference in mortality was expected after 7 to 14 days after rainfall as this time was expected to be too short to influence the whole chain that leads to death due to ECF. It is thought not to be enough time to; influence tick abundance and activity, for the ticks to bite and infect cattle, for the disease to break out and for the animal to succumb. The incubation time for ECF is normally 8-12 days (OIE 2020). The severity and time course of ECF depend on several factors, amongst others, the infective dose, and the strain of parasite (Nene *et al.*, 2016). In a study made by Cook *et al*. (2021) at Ol Pejeta Conservancy mean time from onset of clinical signs to death was 9 days. The mean time from *T. parva* exposure to death was found to be 18.4 days in the same study. In our study death due to ECF was seen with a peak lag effect on 21 days after cumulative rainfall. Although these results are within the frames of what could be expected, a few days more as peak lag effect would be reasonable since some days may be needed for the rainfall to influence the ticks. One explanation for the peak lag effect seen on at 21 days and not later could be that periods of rain starts a bit earlier than the days with most precipitation, which are the days that appear in our statistics being a predictor for two or more deaths. Thus, would give enough time for rainfall to affect tick abundance and activity. The time it takes for *R. appendiculatus* to complete a whole lifecycle varies extensively. The tick goes from larvae to nymph and then to adult. A whole lifecycle developing from egg to engorged adult can take between four month and around a year (King *et al.*, 1988). Nymphs and adult ticks are the life stages that can transmit *T. parva* and it is consequently the abundance and activity of these lifecycle stages that are of higher importance in ECF morbidity (Gachohi *et al.*, 2012). The development rate from one lifecycle stage to another is determined by prevailing climatic condition (King *et al.*, 1988). Rainfall has shown to have a strong positive correlation with abundance of nymphs and adult *R. appendiculatus*, while larvae seems to be less affected by precipitation (Mooring *et al.*, 1994). To get a better understanding of exactly how rainfall affects ECF mortality more research in the influence of each lifecycle stage of the tick is needed. In this study, the connection between rainfall and death due to ECF was established and it was not within the limitations of the study to examine why.

A significant difference in ECF deaths was already seen with a lag effect on 14 days between the group 2 or more dead and zero dead. The relation grows stronger up to the peak of 21 days and then fades after that peak. That periods of rain starts earlier than the 7-day period used in the calculation could probably also be the explanation for this. For the group of 1 dead, the liaison between precipitation and deaths is not visible until day 21 and then grows stronger before it declines around day 28. There is a significant difference between the group of one dead and zero deaths at day 28 ($p<0.001$). I can only speculate in reasons for this. A reasonable explanation would be that there are always a few latecomers. Some cattle get sick posterior the majority. It may be due to various reasons, such as; longer time passed before these cattle got bit by a tick, incubation time being in the upper limit of days or longer than average, or animals fighting the disease for a longer period, taking longer for them to succumb to disease. Also, a combination of more than one of these reasons.

## 6.3. Oxpecker as a measurement of tick-load

In this study it was not possible to establish if the quantity of oxpeckers sitting on cattle could serve as a measurement on tick load. Only one oxpecker was found feeding upon cattle during the observations that were carried out. Thus, no correlation between the amount of ticks and the amount of oxpeckers was found. These results imply that the number of oxpeckers on cattle cannot be used as a measurement of tick-load. However, the result cannot be assumed to represent other areas nor other time of the year. Repeated studies are needed to get answers in the matter.

The ability to use oxpeckers as an indicator of tick-load would be very helpful for stockholders. Especially for small, resource-poor households that does not have the means to treat their animals with acaricides every week like many big cattle farms usually do. Counting oxpeckers could then be a very easy way for them to decide if treatment is needed. It would of course not be a completely reliable measure since there could be many factors influencing the oxpeckers behavior. Such as mating, nest building, taking care for their young ones etc. Still, it might be a useful indicator that could give some guidance.

Besides recordings of oxpeckers on cattle, of the record observations of oxpeckers sitting on buffalo herds were also carried out during the same period. A comparatively large number of oxpeckers were found feeding upon buffalos as well as other wild herbivores such as zebras (Equidae) and giraffes. It is not surprising that the cleaning birds rather choose to feed upon wild herbivores that does not get treated with acaricides and presumably have a higher tick load. Additionally, there is less human activity surrounding wild animals. Cattle herders in OPC have their cattle moving whilst grazing most of the day which could also affect the birds' opinion of them as hosts and to choose wild herbivores over cattle. Even though oxpeckers can cling on to their host while the host is moving, it may make it more difficult for them to feed. With that said, conversations with herders at OPC indicated that oxpeckers were frequently seen amongst the cattle herds. However, there were scattered opinions about when and where the oxpeckers usually visited the herds. Some herders said that they usually came in the forenoon while others said that they were usually seen amongst the cattle in the evening. Some said that they barely see any oxpeckers at all. The conversations were held with help of a Swahili translator. Still, it was difficult to make sure that the questions were properly understood, and the answers are not considered reliable. If we were to assume that the answers from the herders were reliable, then these variant answers might imply that the behavior of oxpeckers vary a great deal. In that case oxpeckers might not be a good measurement of tick-load. Repeated studies and more research are necessary to be able to draw any conclusions.

## 6.4. Tick-count and tick-load

The tick-count showed that the cattle collected a significant amount of ticks during the period between treatments. The spraying interval could consequently be considered necessary to keep the tick load down. However, the counting of ticks at the end of the interval was only carried out once on each herd. Also, the counting was performed during the months of November and December, which counts as wet season, a time with usually more rainfall. Precipitation has, as mentioned before, a big impact on tick abundance and is therefore an important factor to take into consideration when deciding the spraying interval. High cumulative rainfall has a positive effect on tick abundance and activity (Keesing *et al.*, 2018). The tick-load on the cattle is therefore expected to be higher during wet season. Repeated tick-counts needs to be done to actually test the spraying interval and it needs to be done in all weather conditions, in months with less rainfall. It is not possible to rule out that the spraying interval can be prolonged in dry season. With less tick abundance and tick-load on the cattle it perhaps would be possible to extend the days between acaracide treatment.

It would be beneficial for reasons more than one to be able to prolong the spraying interval. Spraying is one of the biggest costs at OPC. The costs for anti-tick pharmaceutical and petrol for the engines at the spray races roughly comes to 5000 US dollars a month. Other hidden costs are maintenance of the tracks, staff, coordination and planning. Additionally, reduced growth may be an effect for younger animals due to stress at the spray tracks and cattle are not grazing during the time of treatment (van Aardt, 2021). For calves, mostly, it can be a bit stressful learning to go through the high pressure spraying at the tracks, but older animals are habituated. Another factor that is important to take into consideration is the risk of acaricide resistance in the *Rhipicephalus* ticks. According to Obaid *et al*. (2022) most acaricide treatments now faces increasingly high risks of failure, due to resistance selection in various tick populations. The persistent or incorrect use of tick chemicals can lead to immunity in ticks, which means that the ticks can survive the acaricides application and it will no longer be effective (Department of Industry, Tourism and Trade, 2022). Resistance develops through genetic changes in the tick population. That can result in increased metabolism or metabolic detoxification of the acaricide, modifications to the target site, or reduced ability of the chemicals to penetrate the tick's body and outer protective layers (Guerrero *et al.*, 2012; Obaid *et al.*, 2022). In a study made in Uganda in 2016 resistance against acaricides was studied at farms that had problems with acaricide failure. *R. appendiculatus* and *R. decoloratus* made up 95.6% of the tick species out of the 1357 ticks identified in the farms sampled. Worryingly results were found; resistance against the acaricide class synthetic pyrethroid (SP) was detected in 90% of the tick populations tested, and 60% respectively 63% of these ticks were super resistant (0% mortality) against cypermethrin and deltamethrin. Resistance was also found against synthetic pyrethroid-organophosphate co-formulations (COF) in 43.3% of the populations. Resistance against amitraz, which is the acaricide used at OPC, was only found in 13% of the ticks (Vudriko *et al.*, 2016). Amitraz was found to be the most efficacious molecule against SP and COF resistant ticks in the area (Vudriko *et al.*, 2016). Since OPC has been using Tickatraz (Amitraz) as anti-tick pharmaceutical for the last 20 years according to Richard van Aardt, he had some concerns about resistance selection. However, the result from the tick-count showed a 97.6% efficiency in removal of ticks. Out of the few ticks that were found the day after spraying 75/84 (89.3%) were crawling on the animal, no longer attached. This could indicate that they were on their way to drop of the animal or were new ticks that did not want to bite because of the treatment on the animal. This result lowers the concerns about resistance in the tick populations at OPC.

## 6.5. Limitations and possible improvements of study

It would have been interesting to compare the amount of ticks between different categories, especially since the ECF mortality rate was found to be much higher in younger animals. But unfortunately, it was not practically feasible nor safe to count ticks on cows and bulls with the equipment and settings that we had. It is something that could have been improved in the study. However, more time would have been needed to get any trustworthy results. Since the number of ticks on the cattle depends on several factors, such a trial would need to be set up with different livestock categories grazing in the same areas and to include repeated tick-counts over time.

An improvement of the study would be if rain over a longer period of time were to be examined in correlation to mortality due to ECF. Rainfall during a 7-day period is in this study used when looking at the lag effect of the following deaths due to ECF. Rainfall during different length of time should be tested to get a better understanding of the association between ECF deaths and precipitation. Adding other variables such as temperature and vegetation would also improve the study. Vegetation cover and temperature also affects the microclimate, which plays a central role in the survival of the free-living tick (Wanzala 2009). Temperature being of more value since previous studies point at climate having a lager impact on tick abundance than vegetation (Cumming 2002). A laboratory study made by Branagan (1973) found that the development rate of all stages of *R. appendiculatus* was influenced by temperature. Cumming (2002) concluded that the covariance of rainfall and temperature was the most influential variables on tick density. Obviously, both precipitation and temperature are determinant for vegetation, and also indirectly on host availability since host density is influenced by vegetation cover and access to water. It is therefore not that easy to study only one predictable factor without any bias. To analyze the associations between mortality due to ECF and several of these predictable factors would be preferable.

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# Populärvetenskaplig sammanfattning

East Coast Fever (ECF) är en sjukdom hos nötkreatur som finns i Afrika söder om Sahara. Sjukdomen har rapporterats i 13 länder i Central-, Syd- och Östafrika. Det är en av de viktigaste sjukdomarna hos boskap i dessa länder och orsakar stora förluster av nötkreatur. Detta orsakar i sin tur stora ekonomiska förluster och inte sällan är det mindre, fattiga hushåll som drabbas hårdast. Kenya är ett av de länder där ECF är ett uttalat problem och en stor begränsning till utvecklingen inom boskapsindustrin. I Kenya, precis som i många andra afrikanska länder, är boskap en viktig inkomstkälla för en stor del av befolkningen. Många människor är pastoralister och beroende av sin boskap för att överleva.

East Coast Fever orsakas av en parasit som heter *Theileria parva*. Den sprids med fästingar inom familjen Ixodidae, även känd som brun öronfästing. Fästingarna blir smittbärare när de suger blod från infekterade djur och för sedan smittan vidare när de biter nästa mottagliga djur. Nötkreatur som blir sjuka drabbas vanligtvis av svullna lymfkörtlar, feber, ökad andningsfrekvens och svårigheter att andas. Ofta blir sjuka djur snabbt sämre, slutar äta och blir utmärglade. Vanligtvis dör djuren inom 10 dagar efter första symptom. I de fall då djuren överlever sjukdomen bildar de ett immunförsvar emot den, de blir dock också bärare av ECF och sjukdomen kan spridas vidare genom att fästingar förvärvar den när de biter dessa så kallade bärare. Väder och vegetation har stor inverkan på fästingburna sjukdomar eftersom det påverkar fästingens livscykel. Nederbörd är en av de faktorer som har störst inverkan på utbredning och aktivitet hos fästingen som sprider ECF.

I den här studien undersöktes sambandet mellan nederbörd och dödsfall på grund av ECF. Data om nederbörd samt dödsfall till följd av ECF från ett naturvårdsområde (Ol Pejeta Conservancy), i Laikipia, centrala Kenya användes. Data från totalt 6 år, mellan januari år 2016 och december år 2021 analyserades. Analysen visade att ECF-relaterade dödsfall hos nötkreatur ökade efter regn. Tydligast var ökningen av dödsfall 21 dagar efter perioder med mer nederbörd.

Att kunna mäta och reducera fästingtrycket som boskapsflockarna utsätts för är en viktig del i det förebyggande arbetet mot ECF. Det är därmed viktigt att hitta enkla och billiga sätt för boskapsägare att utvärdera fästingbelastningen. Det är speciellt viktigt för mindre, resursfattiga hushåll som inte har möjlighet att behandla sina djur med fästingmedel varje vecka som många stora nötkreatursgårdar brukar göra. Vi undersökte därför i denna studie om antalet oxhackare, en fågelart som ofta ses sittandes på korna, kunde användas som ett förenklat mått på när behandling med fästingmedel behövs. Oxhackare lever nära stora växtätare på savannen och livnär sig på fästingar och andra parasiter som förekommer på dessa däggdjur. Det skulle alltså kunna finnas ett samband mellan fästingtrycket och antal oxhackare som vistas på korna. Detta undersöktes i studien genom att räkna både fästingar och oxhackare på flera flockar, innan och efter behandling med fästingprofylax. Det gick tyvärr inte att säkerställa något samband mellan antalet oxhackare och antalet fästingar i studien då endast en enda oxhackare hittades vid de observationer som utfördes.

Sammanfattningsvis pekar resultatet från studien på att antal oxhackare sittandes på en flock inte fungerar som ett mått på fästingbelastningen hos nötkreaturen. Dock så hittades en tydlig ökning av dödsfall till följd av East Coast Fever efter perioder av regn. Tydligast sågs en ökning tre veckor efter en 7-dagarsperiod av regn. Dessa resultat pekar på att förebyggande åtgärder för att minska antalet fästingar behöver intensifieras under perioder med regn, och kan eventuellt minskas under perioder av torka.

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