

Patterns of Rift Valley fever activity in Zambia

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SUMMARY

An hypothesis that there was an annual emergence of Rift Valley fever virus in Zambia, during or after the seasonal rains, was examined with the aid of sentinel cattle. Serum samples taken during 1974 and 1978 showed evidence of epizootic Rift Valley fever in Zambia, with more than 80% positive. A sentinel herd exposed from 1982 to 1986 showed that some Rift Valley fever occurred each year. This was usually at a low level, with 3–8% of the susceptible cattle seroconverting. In 1985–6 more than 20% of the animals seroconverted, and this greater activity was associated with vegetational changes – which could be detected by remote-sensing satellite imagery – which have also been associated with greater virus activity in Kenya.

INTRODUCTION

Zambia has experienced several epizootics of Rift Valley fever (RVF), and these have generally occurred at the same time as epizootics in the neighbouring countries of the region. This suggests that the conditions which predispose to the RVF epizootics occur on a regional or even continental level, and thus involve several countries at the same time. A major determining factor is considered to be the rainfall, and this has been analysed with relation to the epizootics of the disease in Kenya [1]. The regional rainfall patterns are largely determined by the characteristics of the intertropical convergence zone (ITCZ). The rainfall is considered to influence the onset of disease by producing a rising water table, to the point where seasonal flooding occurs, particularly in certain geomorphic formations known as *dambos*. These are shallow streamless depressions at the headwaters of drainage systems and are widespread throughout the plateau region of Zambia where RVF is seen [2].

In Kenya and in Zambia, the flooding of the *dambos* is accompanied by an emergence of many floodwater-breeding *Aedes* mosquito species, in particular of *Aedes mcintoshi* (as *Aedes lineatopennis*) [3]. There is evidence to suggest that *Aedes mcintoshi* can transmit RVF transovarially and is responsible for initiating epizootics of RVF, which then recruit other vector species for its propagation [4, 5]. The flooded *dambos* are also favoured breeding sites for a variety of mosquito species, which are capable of transmitting RVF [4, 6, 7].

Some *dambos* flood annually in parts of Zambia, and this might be expected to allow the emergence of RVF-infected mosquitoes and infect some animals every year. To examine this possibility, a sentinel herd, established for studies on tick control, was used and sera collected over the period 1982–6. There were no manifestations of clinical RVF epizootic activity at the site during this period. The results of RVF serology from Zambia in previous post-epizootic periods have been included to demonstrate the extent of the challenge, which occurs in susceptible cattle or sheep at periods of high RVF activity.

MATERIALS AND METHODS

Sentinel cattle

The sentinel cattle were kept at Lutale near Mumbwa (27° 01' E, 14° 57' S). This is an area of *miombo*-type woodland, principally *Brachystegia*, *Julbernardia* and *Isoberlinia*, interspersed with a network of grassland *vleis*, as the dambo systems are known. The rainfall records for this site are shown in Table 1. Three groups of Sanga cattle were involved in the study. The first two groups were bought at 6–8 months of age from traditional farmers in the Namwale district of Southern Province. The first group of 59 animals was obtained and first bled for serum on 26 November 1982; and a second of 49 were first bled on 13 December 1983. The third group was composed of 2 to 3-year-old heifers; these were purchased in September and October 1985 and were bled for serum on 24 June 1986.

Serum collections

Sera were collected in Zambia after episodes of widespread abortion in sheep and cattle, to confirm the clinical diagnosis of epizootic RVF. The sera were taken in 1974 and 1978 and were from the Chisamba district (1974) and from Chisamba, Mazabuka, Lusaka and Ndola (1977–8).

Sera from the sentinel cattle were first collected as above and subsequently as shown in Table 2. They were stored at -20°C .

Serological methods

An indirect fluorescent antibody test (IFAT) was used initially to examine the sera for RVF antibody [8, 9]. Later the virus serum neutralization test (VSNT) was used in a microtitre system. The sera were inactivated at 56°C for 30 min. Minimum essential medium (Eagle's MEM) at pH 7.2 with antibiotics was added to alternate rows of a microtitre plate in 0.2 ml volumes; 0.01 ml of each serum was added to one well of a row in a recorded sequence to give a 1/21 dilution. The test plates were prepared with 0.025 ml of the medium (MEM with 10% bovine serum) in each well. The rows of sera already diluted to approximately 1/20 were transferred with a multichannel pipette (Titertek) to the first row of a test plate in 0.025 ml volumes. These were diluted and thoroughly mixed to give an initial dilution of 1/40; this was transferred to the second well and doubly diluted again to give serial dilutions of 1/40 to 1/320. Control positive and negative sera were similarly diluted and the challenge virus was also titrated. Approximately 50–100 50% tissue culture infective doses of the Smithburn strain of RVF were added to all wells, with serum dilutions in 0.025 ml volumes. The mixtures were left for 1 h

Table 1. Rainfall at the Lutale sentinel herd site, 1982-6

	Month									Total
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
1981-2	0	2	74*	53	181	276	119	9	0	714
1982-3	12	135	133	150	150	92	133	33	3	1161
1983-4	0	4	85	227	104	189	210	6	0	825
1984-5	0	1	145	223	207	72	110	0	14	772
1985-6	0	38	60	250	152	58	65	76	0	699

* Rainfall per month to the nearest millimetre.

Table 2. Seroconversions to Rift Valley fever virus in three groups of sentinel cattle at Lutale, Zambia, 1982-6

Group 1		Group 2		Group 3	
26 Nov. 1982	2/59* 3%	13 Dec. 1983	2/49 4%	4 June 1986	24/96 25%
17 May 1983	0/47 0%	14 Feb. 1984	0/47 0%		
14 Nov. 1983	0/47 0%	11 July 1984	0/41 0%		
2 May 1984	0/38 0%	31 Oct. 1984	0/44 0%		
6 Dec. 1984	3/38 8%	28 May 1985	3/47 6%		
25 May 1985	0/33 0%	4 June 1986	3/31 12%		
4 June 1986	5/22 29%				

* Number positive/number tested.

at 37 °C when Vero cells were added in the MEM growth medium, approximately 10000-15000 cells per well. The plates were sealed with a non-toxic sealing tape and examined for cytopathic effects (cpe). When these were obvious, usually after 3-4 days, the plates were stained with crystal violet in 70% ethanol. End-points were taken where 75% or more of the cpe produced by the virus was suppressed by the particular serum dilution.

The sentinel herd cattle sera were also tested against a Kenyan strain of ephemeral fever virus (EFV) (K 86) [10] using exactly the same system as for RVF, but with EFV, and a starting dilution of serum at 1/20.

Remote sensing satellite data (RSSD)

To determine the potential for RVF virus activity at the sentinel herd site, data obtained from the National Oceanic and Atmospheric Administration (NOAA) satellites 7 and 9 were used to measure changes in the vegetation biomass caused by rainfall patterns. The principles of the method and its application to a study of RVF virus emergence at a study site in Kenya [5] and to the detection of flooding in *dambos* [11] has been described. Basically, a normalised-difference vegetation index (NDVI), which is a transformation between data collected from

the visible and the near-infra-red channels of the advanced very-high-resolution radiometer, was calculated for a single 7×7 km grid cell (pixel) centred over the study site. The highest NDVI values at this site during each month were chosen to represent the 1-month composite for each of the 63 months from October 1981 to December 1986. An increasing NDVI is associated with higher rainfall and a greater potential for the flooding of *Aedes* breeding sites in *dambos*.

RESULTS

Sera collected after clinical RVF epizootics

The sera collected from aborting cattle in May 1974 were found to have IFAT titres of 100–1000 or greater. In the five groups of sera the results were 6/6, 6/6, 2/6, 5/5, 5/5 positive for RVF antibody, and these results suggest that there had been an epizootic of RVF in Chisamba district at that time in 1974.

The sera which are collected in 1978 were from farms where many abortions had occurred both in sheep and cattle. The sera were from 15 different farms, 201 from cattle and 186 from sheep. Of these 334 had titres of 100–1000 on IFAT for RVF antibody. These results suggest that there had been an epizootic of RVF in Chisamba, Ndola, Lusaka and Mazabuka districts in 1977–8.

Sera collected from sentinel cattle in an inter-epizootic period

The results of the VSNT in the sentinel herds are shown in Table 2. The sera which were found positive for RVF antibody had titres of at least 320 and remained at 160–320 or greater for the whole of the test period. The two groups of young animals which were recruited in 1982 and 1983 from Namwale districts each contained two which had already seroconverted to RVF before arrival at Lutale. This was not considered to be maternally derived antibody, for the animals remained positive for the whole test period of 4–5 years. There clearly had been RVF virus activity at Namwale both in 1982 and 1983, probably during or after the October–December rains.

Three animals seroconverted to RVF during the period June–December 1984 at Lutale, and a further three animals between November 1984 and May 1985. Of the 149 animals exposed from May 1985 to June 1986, 32 became positive for RVF. This was the highest seroconversion rate encountered during the study period (22%). Ninety-six of the animals included in this study were brought to Lutale in May 1985 at 2–3 years of age. Twenty-four of this group of 96 (25%) had high titres – 320 or greater – to RVF virus. They may have been exposed in the years 1983, 1984 or 1985 at Namwale or at Lutale after their arrival in 1985. Amongst the remaining seronegative cattle of the first two groups, 8/36 (22%) seroconverted between 28 May 1985 and 4 June 1986. There had been RVF virus activity approaching epizootic proportions in the Lutale study area during or after the rainy seasons of 1985 and/or 1986.

Evidence of clinical RVF in the sentinel herd

There were several abortions in the sentinel herds during the periods when the seroconversions occurred. The aborting cattle had not seroconverted to RVF, and the abortions were due to other causes.

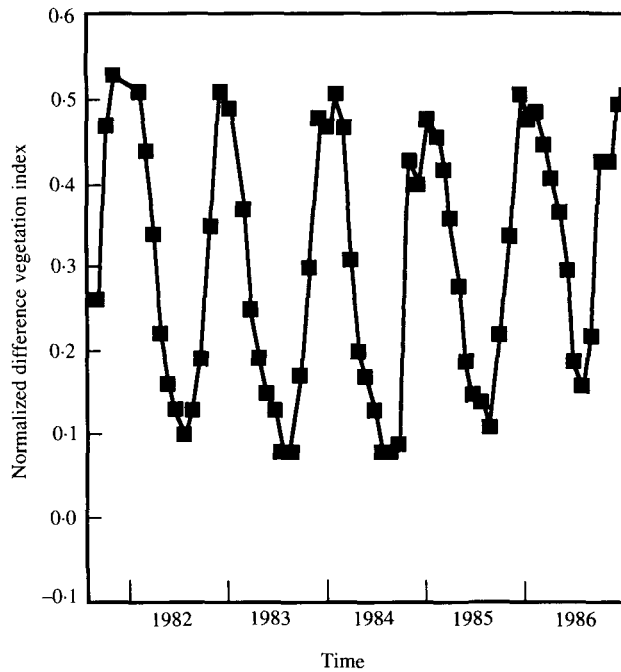


Fig. 1. Plot of AVHRR NDVI values for Lutale, Zambia from October 1981 to December 1986. Each NDVI value is a monthly composite for a single 7×7 km grid cell (centred at 15° S, 27° E).

Remote sensing satellite data (RSSD)

The monthly NDVI for the Lutale district is shown in Fig. 1. There is a significant increase in NDVI values approaching or exceeding 0.5 coinciding with or following the rainy season for each of the years for which data have been collected. In Kenya RVF virus activity and the flooding of *dambo*s was associated with an NDVI of 0.43 or higher. At levels of 0.5 some RVF virus emergence would have been expected at the site during each of the years of the study. Relatively high NDVI values occurred during the dry seasons in mid-year 1985 and 1986.

Ephemeral fever

The sentinel cattle were also screened against a strain of ephemeral fever virus. Two sera from the first sampling of Group A had low (20 and 40) titres to ephemeral fever, which were not detected subsequently. These titres probably resulted from maternally derived antibody. No clinical ephemeral fever was seen at Lutale from 1982 to 1986.

DISCUSSION

Anecdotal evidence from Zambian farmers had suggested that RVF caused some abortions in susceptible *Bos taurus* cattle during or after most rainy seasons. Results from Kenya throughout the epizootic range for RVF showed that little or no RVF virus activity occurred during the inter-epizootic periods [1, 4, 9]. Scott

and colleagues [12], working during an epizootic period, suggested that the annual increased incidence might be associated with the previous short rains. Kenya generally receives a much lower annual rainfall in such areas than is the case in Zambia, where nearly twice as much rain is expected. There is good clinical evidence, supported by serological results, to show that the epizootics of RVF with many abortions and some mortality do occur in Zambia. In Zimbabwe serological evidence was found of RVF activity in aborting cattle over the 7 interepizootic years 1971–7 and the temporal pattern suggested a possible annual emergence of infected mosquitoes [13].

This study was carried out to confirm these findings and to determine whether annual RVF virus activity occurs and is associated with the seasonal rains.

The results obtained from the sentinel cattle at Namwale and Lutale show that some RVF virus activity did occur in each of the years 1982–6. Some 3–8% of the 59–96 cattle exposed each year seroconverted to RVF virus. The clinical reports from the farmers were clearly correct. It must be emphasized that the clinical manifestations of RVF virus infection would only be obvious amongst the highly susceptible *Bos taurus* cattle populations or amongst imported sheep breeds [14, unpublished observations]. The sentinel cattle at Lutale were of the Sanga breed, they are thought to have originated from crosses of *Bos indicus* × *Bos taurus*. They may well show no clinical sign of the RVF infection. No clinical disease, which might have been RVF, was recognized in the cattle at Lutale.

The rainfall at Lutale of 699–1161 mm during the rainy seasons of 1982–6 was sufficient to increase the NDVI values to the level where RVF virus activity might have been expected. This had not been the case at the Kenya site where the annual rainfall was lower and the NDVI value of 0.5 not often reached [5, 11]. Reports from farmers showed that some *dambos* were flooded in each year of the sentinel herd study, which were not exceptional for rain in Zambia, when on occasion up to 1500 mm of rain might fall.

The seroconversion rates in 1985–6 suggested that near-epizootic amplification of RVF was occurring. Greater amplification and propagation of the virus may have followed the infections, had more susceptible breeds of cattle been exposed, instead of the indigenous breeds at Lutale. The exotic cattle develop a higher level of viraemia which persists for a much longer period. In other parts of Zambia during this period, clinical RVF was seen in *Bos taurus* cattle and in sheep in the epizootic areas of Mazabuka, Lusaka and Chisamba. A report showed that of 63 sera taken from herds with clinical disease and abortions, during the period January–March 1985, 52% were positive by the haemagglutination inhibition test [15]. Only three seroconversions had occurred at Lutale by 25 May 1985, and most of the virus activity there must have been later in the year, or in 1986. The relatively high NDVI observed during the dry seasons in 1985 and 1986 suggests that there had been dry-season rainfall. This would lead to the prolongation of the mosquito breeding season in flooded *dambos*, and result in increased numbers of potential secondary *Culex* species vectors. This would explain the higher rate of seroconversions observed in 1986.

These results support the initial hypothesis that sufficient rain falls most years in Zambia to allow some RVF virus activity to occur. The rainfall and RSSD data for the years 1982–6 suggest that some emergence of RVF-infected vectors

might have been expected to occur. The field observations showed that some *dambos* were flooded in each of these years, with more extensive flooding in 1985, and the seroconversions in the sentinel cattle confirm that RVF virus activity occurred each year. A key question remains: to determine precisely what generates epizootics from this low level of seasonal virus activity.

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