The distribution of heartwater in the highveld of Zimbabwe, 1980–1997

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ABSTRACT

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Heartwater, the tick-borne disease caused by the rickettsia *Cowdria ruminantium* has historically been confined to the southern and western lowvelds of Zimbabwe. Since 1986, however, cases of heartwater have been diagnosed with increasing frequency in the central and eastern regions of the previously heartwater-free highveld plateau. During the same period, collections of the two major tick vectors of heartwater in Zimbabwe, *Amblyomma hebraeum* and *Amblyomma variegatum*, were made for the first time in these areas, suggesting that spread of these ticks was responsible for the changed distribution of the disease. The factors associated with this spread have not been determined, but increased cattle and wildlife movement and reduced intensity of dipping undoubtedly play important roles. Currently, the distribution of heartwater and its vectors in the highveld is still largely restricted to the central and eastern regions. The northern regions of the highveld appear to be predominantly uninfected, though it is likely that, eventually, heartwater will spread further with considerable impact on livestock production in Zimbabwe.

Keywords: *Amblyomma hebraeum*, *Amblyomma variegatum*, heartwater, spread, Zimbabwe

INTRODUCTION

Heartwater (also known as cowdriosis) is a tick-borne disease of ruminants caused by the rickettsia *Cowdria ruminantium* (Cowdry 1925a). Outbreaks of heartwater are usually severe, with case mortality in naive animals ranging from 5–100% (Camus, Barre, Martinez & Uilenberg 1996). The direct economic losses incurred are compounded by the costs of prophylactic control and the limitation on the genetic upgrading of livestock through the introduction of susceptible exotic breeds in endemic areas. The distribution of heartwater closely follows that of its vectors, members of the tick genus *Amblyomma*, of which 13 species have demonstrated vectorial capacity (Cowdry 1925b; Jongejan 1992). The disease affects livestock throughout most of sub-Saharan Africa and on several neighbouring islands off the African continent, and is established on three islands within the Caribbean (Camus *et al.* 1996; Perreau, Morel, Barre & Durand 1980; Birnie, Burridge, Camus & Barre 1985). The control of heartwater in Zimbabwe is primarily by acaricide treatment of livestock, though new vaccines are being developed (Martinez, Maillard, Coisne, Sheikboudou & Bensaid 1994; Mahan, Andrew,

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Tebele, Burridge & Barbet 1995; Martinez, Perez, Sheikboudou, Debus & Bensaid 1996; Nyika, Mahan, Burridge, McGuire, Rurangirwa & Barbet 1998).

In Zimbabwe, heartwater has long been considered a disease restricted to the hot and dry lowveld regions of the south, where it is transmitted by *Amblyomma hebraeum* ticks, and north-west, where the vector is *Amblyomma variegatum* (Norval 1983). The central highveld plateau, which is cooler and has higher rainfall, has been predominantly free of the disease and its vectors. The historical occurrence of heartwater and *Amblyomma* in Zimbabwe has been described in detail (Lawrence & Norval 1979; Norval 1983; Norval, Perry, Meltzer, Kruska & Booth 1994). First recorded officially in 1927 in association with *A. hebraeum* (Sinclair 1928), the disease has since undergone considerable fluctuation in distribution, largely due to changes in the distribution and abundance of this vector. The distribution of *A. variegatum* has been restricted mainly to the northwest of the country and appears to have undergone little change. Between 1927 and 1942 heartwater outbreaks within the southern lowveld occurred with increasing frequency (Fig. 1A, B), suggesting rapid local spread of *A. hebraeum*. However, rigorous short-interval dipping of cattle herds country-wide, combined with legislation preventing livestock movement out of heartwater-problem areas, eventually led, by 1975, to the restriction of heartwater, as determined by the register of officially reported cases, to three small foci in the southern lowveld (Fig. 1C). Between 1975 and 1980, a breakdown in government-provided dipping services in small-holder communal farming areas associated with civil war is believed to have resulted in the spread of *A. hebraeum* and heartwater throughout the southern lowveld and northwards across the central highveld plateau (Fig. 1D). Heavy livestock losses were incurred, and it is estimated that heartwater, combined with the other major tick-borne diseases (TBDs), namely anaplasmosis (caused by *Anaplasma marginale*), babesiosis (caused by *Babesia bigemina* and *B. bovis*) and theileriosis (caused by *Theileria parva*), killed 20–50% of cattle in affected areas, amounting to approximately one million head (Norval 1978; Lawrence, Foggin & Norval 1980). After the end of the war in 1980, attempts were made to re-establish the intensive dipping service in communal lands. While this objective was never fully attained, the disease was reported to have been eradicated from the highveld and restricted to the southern and western lowvelds (Norval *et al.* 1994).

Starting in the late 1980s, reduced fiscal allocation for dipping services in the communal areas resulted in reduced frequency of dipping in these areas. In response to these limitations, in 1989–1990, the Department of Veterinary Services (DVS) began to review and revise its policies for tick and tick-borne disease control. Due primarily to economic pressure, and supported by expert consultations (Perry, Mukhebi, Norval & Barrett 1990), the dipping frequency in communal lands was formally reduced in 1993 from weekly in summer and biweekly in winter to weekly in summer and monthly in winter. The intention of this change was not only to reduce dipping costs, but also to promote endemic stability, which is a situation in which host, disease agent and vector coexist in the virtual absence of clinical cases of tick-borne disease, as an alternate control strategy (Norval, Perry & Young 1992; Perry & Young 1995; O'Callaghan, Medley, Peter & Perry 1998). Dipping within the privately-owned commercial herds, however, continued to be predominantly intensive. The reduction of dipping in communal areas raised concerns over the potential for the re-introduction of *A. hebraeum* and heartwater into the highveld where livestock production is intensive and large proportions of the national herds of cattle (50%) and small ruminants (30%) exist (Norval, Perry & Hargreaves 1992; Norval *et al.* 1994). Outbreaks of heartwater and collections of *A. hebraeum* have already been reported at several foci in the highveld between 1987 and 1992 and it has been predicted that *A. hebraeum* will spread further, resulting in considerable economic loss from heartwater (Norval *et al.* 1994).

This study reports the results of investigations into the occurrence of heartwater and its vectors in the highveld from 1980 to June 1997. This is part of a larger investigation into determining the extent, rate and pattern of heartwater spread in Zimbabwe, with the aim of identifying livestock populations at various levels of risk, and predicting the eventual outcome of this spread and the potential benefit of new disease control measures, such as vaccines.

MATERIALS AND METHODS

Region classification

The terminology "lowveld" and "highveld" has been used in previous studies on heartwater distribution (Norval 1983; Norval *et al.* 1994) to describe two geographically distinct regions of the country (Fig. 2) that have historically been considered as heartwater-infected and heartwater-free, respectively. For continuity, this terminology is maintained in this study. The highveld includes most of the central plateau (> 900 m; 450–1 000 mm rainfall/annum) and consists of Natural Regions I, II and III of Zimbabwe (Vincent & Thomas 1961). The lowveld (< 900 m; < 650 mm rainfall/annum) consists of Natural Regions IV and V and borders the highveld to the north, west and south. This classification into highveld and lowveld, in the context of studies on heartwater, is based on agro-ecological differences between the two regions, and not solely on altitude, which is sometimes also used to define these terms. This is because climate, land use and vegetation, which define agro-ecological

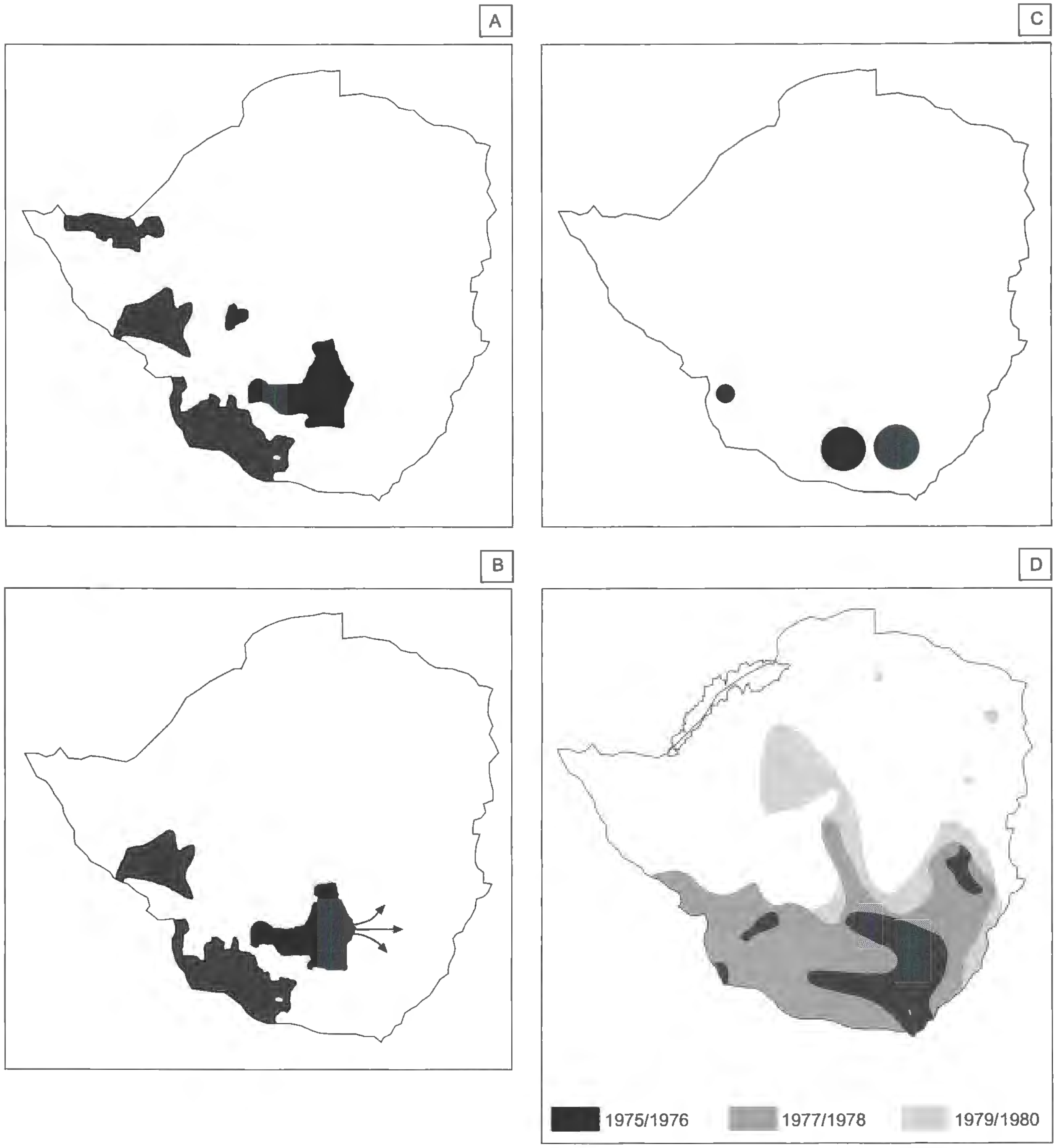

FIG. 1 Designated heartwater areas in Zimbabwe in 1930 (1A) and 1938 (1B), known foci of heartwater infection in 1975 (1C) and the distribution of *Amblyomma hebraeum* in 1975/76, 1977/78 and 1979/80 (1D) (from Norval *et al.* 1994)

zone, have greater direct influence than altitude on the ecology of ticks and the diseases they transmit.

Data on heartwater occurrence collected for this study were available by administrative district. In order to determine which heartwater cases occurred in the highveld, the rural districts of Zimbabwe were categorized by highveld and lowveld. Most of the districts within the provinces of Manicaland, Midlands and Mashonaland East, West and Central lie fully or predominantly within the highveld and identifications of heartwater or *Amblyomma* occurring within them are taken as highveld cases (Fig. 2). Districts lining the borders of the lowveld, in the provinces of Masvingo, Midlands, Matebeleland North and Manicaland and in the northern-most regions of Mashonaland East,

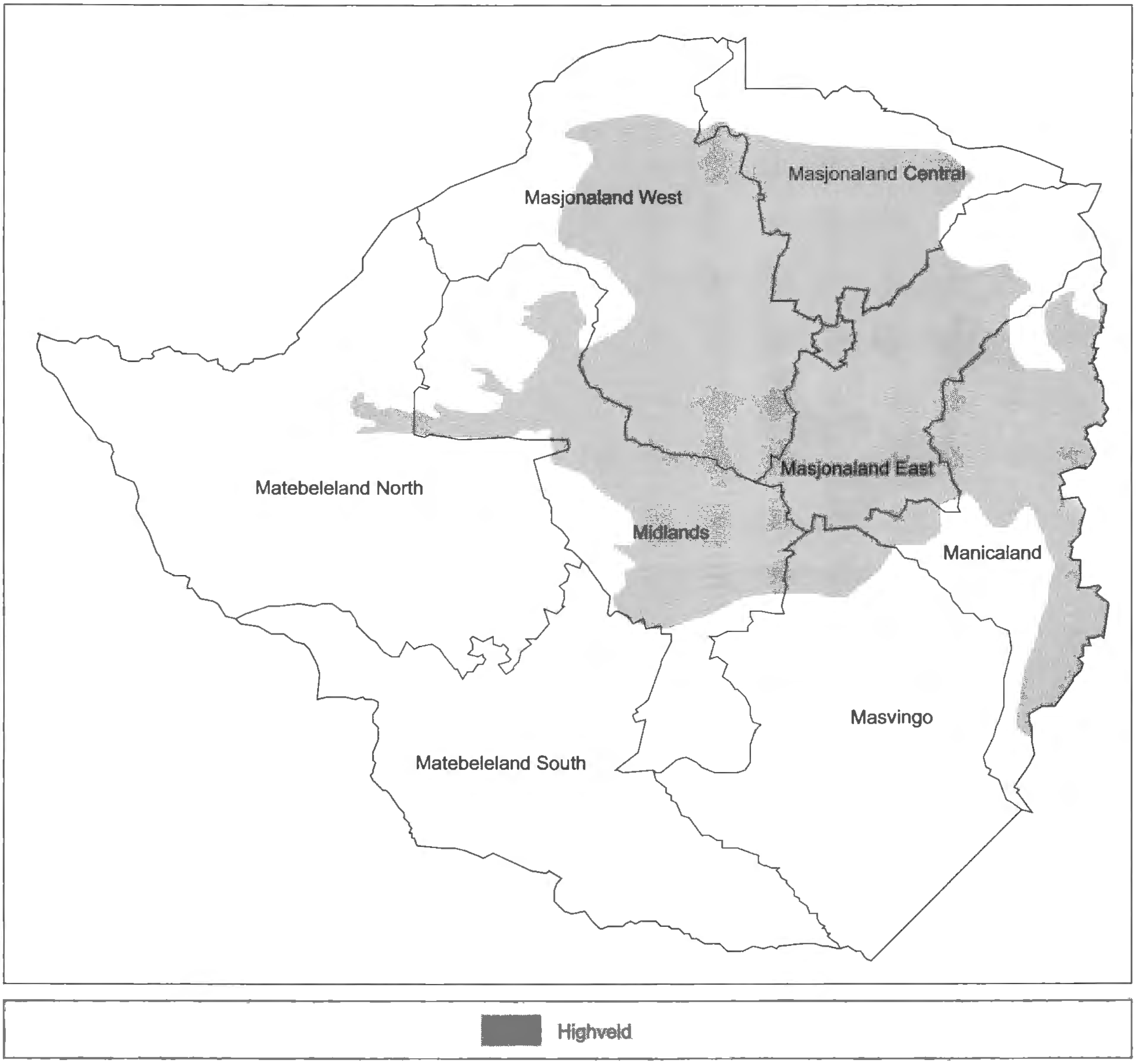

FIG. 2 Provinces of Zimbabwe in relation to the highveld

Central and West provinces, lie partly within the highveld and heartwater and *Amblyomma* identifications occurring within these districts are classified as being within the highveld or lowveld on the basis of their point locations. The remaining districts lie fully within the provinces of Masvingo, Midlands, Matebeleland North and Matabeleland South, and are designated as the lowveld.

Production systems

In Zimbabwe, agricultural land-use falls into four main categories (GFA 1987) on the basis of type of production, size of holding, tenure status and management type. Privately owned and managed large-scale commercial (LSC) farms take up 38% of the agricultural land area. Livestock production on these farms is based on one or more of the following: beef, dairy, sheep, goats, poultry, pigs and wildlife. Approximately 33% of the national cattle herd is within the LSC areas. Tick and tick-borne disease control for domestic ruminants on these farms is implemented at the discretion of farm management, with periodic DVS inspections, and, particularly in the highveld, frequently involves intensive acaricide treatment. Forty-nine percent of the agricultural land is utilized as communally grazed areas, called communal lands, which carry 60% of the national cattle herd. These areas are state-owned and livestock production is predominantly beef, goats, sheep and poultry for subsistence and marketing of surplus output. Tick and tick-borne disease control in communal lands is not intensive and relies predominantly on strategic dipping services provided by the government through the DVS. Four percent of the agricultural land is resettlement areas which are state-owned regions, often adjacent to communal lands, into which people and livestock are introduced, sometimes from distant locations. Resettlement areas carry about 3 % of the national cattle herd and livestock production and tick-borne disease control is similar to the communal lands. Small-scale commercial farming areas occupy 8% of the agricultural land and carry 4% of the national cattle herd. These farms are individually owned and managed but unlike the LSC farms, are frequently similar in management type and the effectiveness of tick-borne disease control to the communal lands. Due to similarities in livestock production and tick-borne disease management within communal lands, resettlement and small-scale commercial farms, these areas are combined for the analysis of heartwater distribution in this study, and termed small-holder (SH) areas. Differences in production systems also occur by geographical region. In the highveld, livestock production tends to be more intensive and closely managed. In the lowveld, however, the grazing system is more extensive and animals are usuallly less intensively managed.

Sources of data

Information was collected from archival sources on the location and dates of heartwater outbreaks and *Amblyomma* collections in each of the highveld districts from 1980 to June 1997. Additionally, field investigations were made to establish whether the disease and its vectors persisted at sites where they had previously been recorded. The sources of data utilised are summarized in Table 1 and described below.

Heartwater outbreaks

Records of suspected and confirmed cases of heartwater in the highveld of Zimbabwe from 1980 to June 1997 were obtained from the monthly Provincial Reports of the DVS. Additional records of cases from 1994 to June 1997 were gathered from the Immediate Reporting System database initiated in 1994 and maintained by the DVS. Under the Immediate Reporting System, government veterinary personnel are required to submit to the DVS detailed epidemiological information on all diagnosed field cases of the notifiable diseases listed by the Office International des Epizooties. Each DVS-reported heartwater case was categorized as either:

- laboratory confirmed by brain smear and/or post-mortem examination; or
- suspected heartwater on the basis of clinical signs, and/or response to antibiotic treatment.

As the diagnosis of heartwater can be difficult, and there are several diseases and conditions, which should be considered in its differential diagnosis, only reports of heartwater cases that were confirmed by brain smear and/or post-mortem examination were included in the analysis. The first confirmed cases of heartwater, at least a single case, occurring within a defined area (i.e. LSC farm or SH area) were designated as outbreak.

Amblyomma *surveys*

Information on the distributions of *Amblyomma* ticks in the highveld was obtained from surveys of ticks infesting cattle. These were:

- passive collections in limited areas from 1980–1987;
- active country-wide collections from 1988–1991 by the Tick Section of the Veterinary Research Laboratories (DVS, unpublished data 1992); and
- active country-wide collections in 1996 (T. Peter, B. Perry, C. O'Callaghan, G. Medley, W. Shumba, W. Madzima, M. Burridge & S. Mahan, in press).

In the 1988–1991 and 1996 tick surveys, collections of ticks were made from cattle attending diptanks in all four production systems. For the current study, information on the date, location and tick species of *Amblyomma* collections in the highveld between 1980 and 1996 was extracted from the survey data sets.

Field investigations

Between July 1995 and April 1997, visits were made to locations within the highveld where heartwater cases had occurred and been reported to the DVS between 1980 and 1996. These included large-scale

TABLE I Data sources for heartwater and *Amblyomma* distribution

Data source	Period of collection	Data type
DVS Provincial Field Reports	1980–1997	Non-compulsory, passive reporting of heartwater cases
DVS Immediate Reporting System	1994–1997	Compulsory, passive reporting of heartwater cases
Tick Survey I	1988–1991	Cross-sectional survey of ticks infesting cattle (DVS, unpublished data)
Tick Survey II	1996	Cross-sectional survey of ticks infesting cattle[a]
Field Investigations	1995–1997	Field confirmation of DVS-reported outbreaks

[a] T. Peter, B. Perry, C. O'Callaghan, G. Medley, W. Shumba, W. Madzima, M. Burridge & S. Mahan, in press

beef and dairy farms and small-holder areas. This was done to determine whether the disease and vector were established in each area. Five communal lands in the highveld (Mhondoro, Chinamora, Mutoko, Wedza and Zvimba) were visited between July 1995 and August 1996. Cattle attending one to four diptanks within each communal land were examined, prior to dipping, for *Amblyomma* ticks and any specimens found were collected and transported to the Veterinary Research Laboratory in Harare. In addition, collections of *Amblyomma* ticks were made from cattle within two further highveld communal lands (Koronika and Chiduku) by DVS field staff, and the ticks sent to the Veterinary Research Laboratory for analysis. All collected ticks were identified, and attempts were made to isolate *C. ruminantium* from them. For *C. ruminantium* isolation, batches of 30–60 ticks from each site were placed in tick feeding bags on susceptible sheep or goats within 24 h of collection. Rectal temperatures of the recipient animals were monitored daily. If an animal developed a febrile reaction (> 40,5 °C), an attempt was made to isolate *C. ruminantium* from its blood plasma between the 2nd and 4th day of the febrile reaction (Byrom, Yunker, Donovan and Smith 1991). Confirmation of death from heartwater was by post-mortem and brain smear examination (Purchase 1945).

Between August 1996 and April 1997, visits were also made to 16 LSC farms in the highveld on which heartwater had been diagnosed and reported through the DVS between 1994 and 1996. Cattle on these farms were examined for *Amblyomma*. Isolation of *C. ruminantium* was attempted from ticks from three of the farms, two infested with *A. hebraeum* and one infested with *A. variegatum*. The levels of *Amblyomma* infestation on the remaining farms were too low to collect sufficient ticks for transmission attempts. Thirty to 60 ticks were used for each transmission attempt.

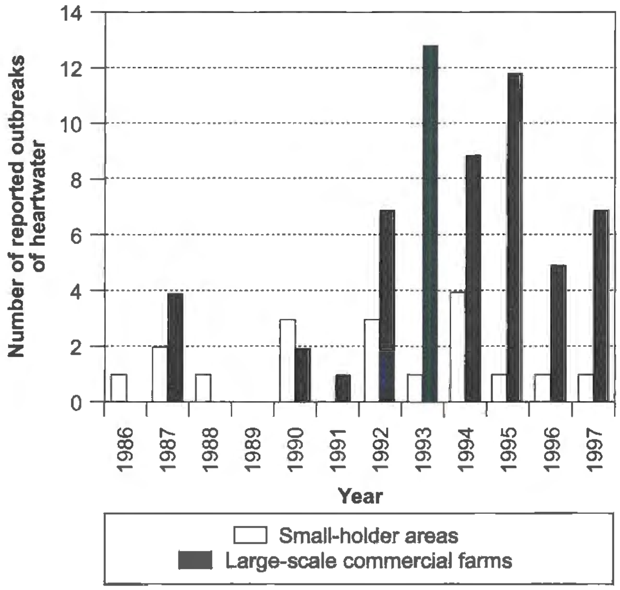

FIG. 3 Heartwater outbreaks in small-holder and large-scale commercial farming areas in the highveld of Zimbabwe:1986–1997

RESULTS

Heartwater and *Amblyomma* in the highveld

The pattern of heartwater outbreaks in the highveld from 1980 reveals three distinct periods: 1980–1985, 1986–1991 and 1992–1997, which differ markedly in the frequency of cases (Fig. 3).

No confirmed cases of heartwater, or *Amblyomma* collections, were reported to the DVS in the highveld between 1980 and 1985. Between 1986 and 1991, the first known highveld cases and tick collections were recorded, at low frequency initially within SH areas. Heartwater was reported within seven SH areas within the southern region of the highveld, some lying adjacent to each other (Fig. 4). The presence of *A. hebraeum* has since been confirmed in each of these areas. *Amblyomma variegatum* has also been collected from two of the SH areas, Mhondoro and Zvimba communal lands, and was found in association with dermatophilosis in cattle in Mhondoro communal land. Additionally seven LSC farms, mainly within the central and eastern regions of the highveld, reported heartwater and the presence of *A. hebraeum* was confirmed on three of these farms. Between 1986 and 1991, collections of *Amblyomma* ticks were made from five SH areas and from one LSC farm in the absence of reported heartwater. Three of these SH areas subsequently reported cases of heartwater between 1992 and 1997.

From 1992, the frequency of reported cases of heartwater and *Amblyomma* collections increased dramatically in both SH and LSC areas (Fig. 5). While the majority infected farms were clustered within the central and eastern regions of the highveld, there also appeared to be some limited northward spread of infection. Reports of heartwater were made in 11 new SH areas, with 70% of reports occurring from 1994 onwards (Fig. 3). Collections of *A. hebraeum* were made in all but four of these areas, three of which were not examined for ticks. One SH area had both *A. hebraeum* and *A. variegatum* (Koronika communal land) while another SH area had *A. variegatum* alone (Kenzamba communal land). *Amblyomma* ticks were collected in a further 12 SH areas where heartwater had not previously been reported to the DVS. Five of these areas had both *A. hebraeum* and *A. variegatum* and one area had *A. variegatum* alone. Isolation of *C. ruminantium* was successful from *A. hebraeum* ticks collected from the communal lands of Chiduku, Koronika, Mhondoro and Zvimba, while

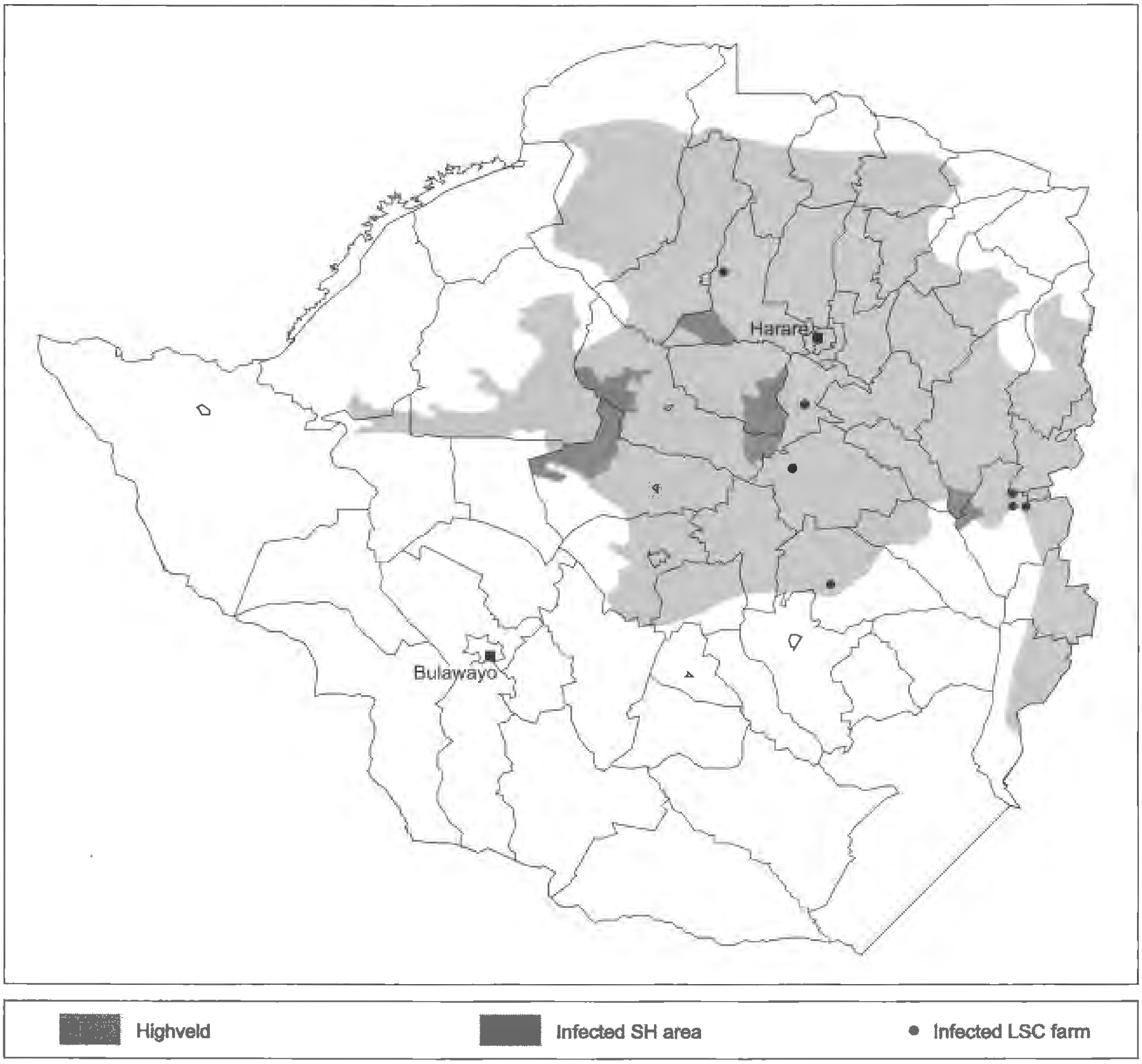

FIG. 4 Heartwater outbreaks in the highveld:1980–1991 (fine lines indicate district borders)

attempts to isolate *C. ruminantium* from *A. hebraeum* ticks collected in Chinamora, Mutoko and Wedza failed.

Between 1992 and mid-1997, heartwater outbreaks were reported for the first time on 53 highveld LSC farms (Fig. 5). The presence of *A. hebraeum* was confirmed on 15 of the farms and *A. variegatum* was collected on three farms on which heartwater occurred and one farm on which the disease had not yet been recorded. *Cowdria ruminantium* was isolated from *A. hebraeum* ticks collected from one of two heartwater-positive farms tested, but an attempt to isolate *C. ruminantium* from *A. variegatum* ticks collected on a heartwater-positive farm failed.

These studies indicate that heartwater, *A. hebraeum* and *A. variegatum* initially became established in the southern area of the highveld between 1986 and 1991. The infection has persisted mainly in this area, as evidenced by the increase in reported cases post-1991, though is clustered in the central and eastern regions. The northern regions of the highveld appear, at present, to be predominantly free of the disease.

DISCUSSION

Heartwater and two of its vectors, *A. hebraeum* and *A. variegatum*, have become well established within the previously heartwater-free highveld of Zimbabwe, placing large numbers of livestock at risk and

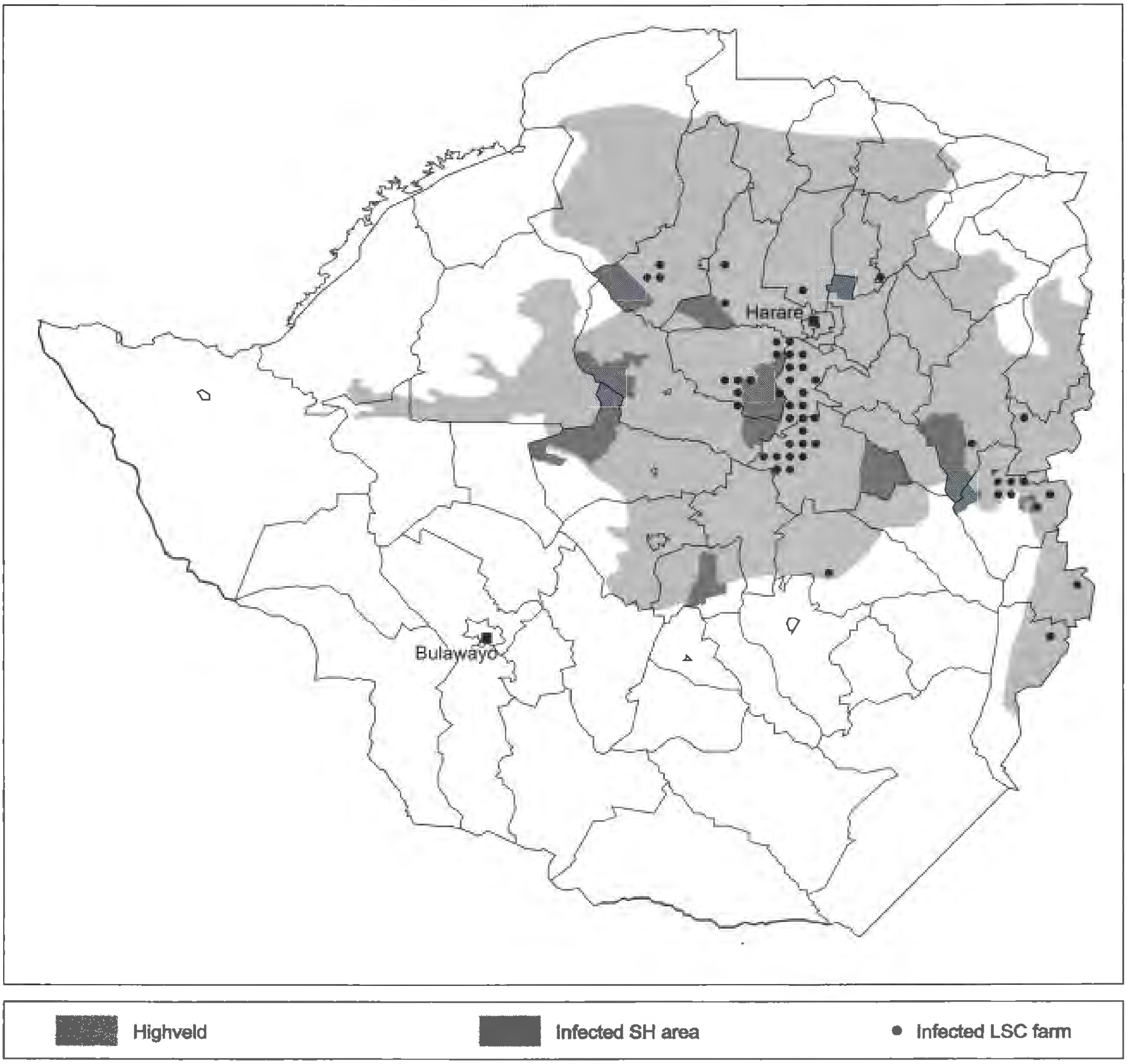

FIG. 5 Heartwater outbreaks in the highveld:1980–1997 (fine lines indicate district borders)

confirming predictions made about the increased importance of the disease in this region (Norval *et al.* 1992; Norval *et al.* 1994). Although this study documents a dramatic rise in the incidence of heartwater reports between 1986 and 1997, it is difficult to determine when and how the spread of the disease may have occurred. The lack of official reports between 1980 and 1985 suggest that heartwater may have been absent from the highveld at that time. The scattered reports made between 1986 and 1990 are suggestive of a gradual introduction of the vector and disease, followed by extensive spread, as indicated by the considerable increase in case reports post-1990. However, in interpreting these results, the following points should be taken into consideration. Firstly, heartwater is difficult to diagnose in the field. Frequently its diagnosis is not confirmed because brain smears are not prepared and examined for the presence of *C. ruminantium*. Secondly, DVS heartwater surveillance in Zimbabwe, upon which most of this study is based, is a passive reporting system reliant on limited staff who are responsible for reporting many diseases in large, extensive farming areas. Thirdly, farmers familiar with the disease may not report cases if they have treated them successfully and have had few losses, or because they fear the imposition of quarantine restrictions. Finally, as heartwater was made a notifiable disease in Zimbabwe only in 1993, cases occurring before to this would not necessarily have been reported to the DVS. The result is that there is likely to have been an under-reporting of the disease, particularly prior to 1993. The increase in reported heartwater cases and *Amblyomma* collections after 1993 may be partially due to increased vigilance and frequency of reporting and to the active studies, i.e. the field investigations and country-wide tick surveys. As the efficacy of disease monitoring was probably not uniform throughout the study period, the retrospective analysis of heartwater incidence presented here is not a definitive account of the spread of the disease. However, it does provide preliminary observations of heartwater incidence and distribution in the highveld in recent years and tentative suggestions as to how the disease may have spread.

The pattern of heartwater outbreaks in the highveld suggests that the introduction of the disease may have been due both to gradual encroachment from the heartwater-endemic lowveld and to several independent introductions into specific sites within the highveld, followed by expansion from these foci. *Cowdria ruminantium* infection can only be spread through the movement of infected animals and/or infected vector ticks, and thus movements of cattle and wildlife infested with *Amblyomma* from heartwater areas into heartwater-free areas are likely to have been primarily responsible. Infection of highveld districts adjacent to the lowveld (e.g. in the eastern highveld region) may have been by contiguous spread due to local straying of cattle between neighbouring properties or inter-farm wildlife movement. Introductions further into the highveld (e.g. in the central highveld region) are more likely to have been associated with long-distance translocations of animals from endemic areas. Norval *et al.* (1994) suggested that wildlife translocations associated with increased game farming on LSC farms in the highveld may have facilitated *Amblyomma* spread through the introduction of tick-infested animals, and by providing undipped alternate hosts for the ticks where domestic livestock were effectively dipped. The wild species implicated were kudu (*Tragephalus strepsiceros strepsiceros*), giraffe (*Giraffa camelopardalis*), eland (*Taurotragus oryx*) and warthog (*Phacochoerus aethiopicus*), which are amongst the major wildlife hosts of *A. hebraeum* (Norval *et al.* 1994; Norval 1983; Horak, Potgieter, Walker, De Vos & Boomker 1983; Minshull 1981; Horak, MacIvor, Petney and De Vos 1987), and whose distributions in the highveld approximated the known distributions of heartwater and *Amblyomma* at the time (Norval *et al.* 1994). Furthermore, recent experimental studies have demonstrated that kudu, giraffe, eland and blue wildebeest (*Connochaetes taurinus*) are susceptible to *C. ruminantium* infection and are capable of infecting *A. hebraeum* ticks (Peter, Anderson, Burridge & Mahan 1998). These animals may therefore have also served as initial sources of *C. ruminantium* infection for ticks in newly infested areas.

Despite the reasonably clear implication of wildlife movements in heartwater spread, the importation of cattle into the highveld from heartwater-endemic areas, presumably for sale and grazing purposes, has occurred on a larger scale and thus may have played a greater role (T. Peter, B. Perry, C. O'Callaghan, G. Medley, W. Shumba, W. Madzima, M. Burridge & S. Mahan, unpublished data 1998). Water shortages, for example during drought years, and trends towards reduced dipping may have resulted in animals being moved without total removal of ticks, despite DVS regulations stipulating that animals should be cleaned of ticks prior to translocation. The introduction of infested and likely infected cattle into the highveld, where dipping intensity may also have been reduced, is likely to have contributed to the establishment of the vectors and heartwater. Livestock introductions have not been restricted to LSC farms. Resettlement of communal families, as part of the land redistribution programme in Zimbabwe, is likely to have resulted in the importation of cattle into the highveld from remote, possibly heartwater-endemic, areas.

The presence of *A. hebraeum* in the highveld has been previously documented in 1979/80, when dipping was disrupted by the civil war. An alternative explanation for the current distribution of heartwater may be that residual foci of *Amblyomma* infestation persisted in the highveld after 1980 and expanded when dipping intensities were reduced due to financial restrictions and/or drought-induced water shortages. In areas where cattle are intensively dipped, heartwater may not occur in the cattle population, but *Amblyomma* and *C. ruminantium* might exist in an independent association with wildlife. As the distribution of *Amblyomma* was not actively surveyed between 1980 and 1986, the observation that *A. hebraeum* had been eradicated from the highveld (Norval *et al.* 1992; 1994) may have been premature. In addition, it has been noted that the resumption of dipping services in communal lands after the civil war was unlikely to have effected total control of *Amblyomma* ticks due to:

- the use of the acaricide dioxathion which has a short residual period; and
- the slow restoration of dipping infrastructure and dip attendance damaged during the war (Norval *et al.* 1992).

It has been suggested that the highveld conditions may be climatically and vegetationally unsuitable for the survival of *Amblyomma* ticks (Jooste 1967; Norval 1983). Norval *et al.* (1994), however, demonstrated with the CLIMEX model for ecoclimatic suitability (Sutherst & Maywald 1985), that the highveld climatic conditions are highly favourable for *A. hebreaum* and *A. variegatum* survival. During the present study, visits to infected highveld commercial farms and communal areas on which acaricide usage was limited have confirmed that *A. hebraeum* can thrive in the highveld and produce infestations of cattle that are at least equal in intensity to those of cattle in the lowveld (unpublished observations). Furthermore, *A. hebraeum* appears to have spread more aggressively into the highveld than *A. variegatum* and has been associated with the majority of heartwater outbreaks. This supports previous field observations in Zimbabwe (Norval *et al.* 1994) and Mozambique (Asselbergs, Jongejan, Ranga, Nevis & Alfonso 1993) which suggest that *A. hebraeum* is a more aggressive vector and causes more severe outbreaks of heartwater. Additionally, Mahan, Peter, Semu, Simbi, Norval & Barbet (1995) demonstrated that *A. hebraeum* can carry higher intensities of infection with certain strains of *C. ruminantium* than *A. variegatum*. The spread of *A. variegatum*, nevertheless, has resulted in the introduction of another debilitiating disease, dermatophilosis, to new areas.

In 1994, Norval *et al.* predicted that heartwater could spread throughout Zimbabwe and they proposed three options for heartwater control in the highveld:

- to re-introduce intensive dipping to eradicate the vectors;
- to establish a buffer zone of intensive tick control along the margins of the highveld; or
- to continue with reduced dipping and allow heartwater to become endemic in the highveld.

As heartwater is already established in the highveld and some introductions appear to have been caused by long-distance translocation, the second option is no longer realistic. As dipping in communal lands is unlikely to intensify due to economic limitations on this government-subsidized service, eradication of *Amblyomma* from the highveld is also unlikely to be achieved. Furthermore, the existence of substantial populations of wildlife hosts, which are difficult to treat with acaricide, may make elimination of the vector impossible. The option of promoting endemic stability for heartwater (Deem, Yonow, Peter, Mahan & Burridge 1996; O'Callaghan, Medley, Peter & Perry 1998) may be the only option still available. Endemic stability for heartwater (and probably for other tick-borne diseases) appeared to have been established in some of the communal lands in this study. *Amblyomma* ticks were common and the isolations demonstrated that *C. ruminantium* infection is present, but clinical heartwater is rarely seen. Within areas not yet affected by heartwater, as well as on LSC commercial farms that have experienced outbreaks of heartwater and re-intensified tick control, vaccination of susceptible livestock followed by reduced dipping may be the most cost-effective means by which to achieve endemic stability without experiencing heavy losses to the disease (Mukhebi T. Chamboko, C. O'Callaghan, T. Peter, R. Kruska, G. Medley, S. Mahan & B. Perry, unpublished data 1998). Heartwater vaccination is currently carried out by inoculation with virulent infected blood, and requires close monitoring and treatment of vaccinates (Van der Merwe 1987). It is expected that improved vaccines for heartwater and the other major tick-borne diseases of cattle in Zimbabwe will soon be available. A shift to endemic stability for heartwater through vaccination and reduced acaricide use cannot be accomplished without consideration of the threat from other TBDs. For example, within areas of the highveld affected by *Theileria parva* infection, which is transmitted by the brown ear tick *Rhipicephalus appendiculatus* and commonly known in Zimbabwe as January disease, intensive dipping has been carried out on commercial farms and is likely to continue until a vaccine for this disease is widely available. Similar restrictions will exist in susceptible herds under threat from anaplasmosis and babesiosis. An integrated TBD vaccination strategy will, therefore, be required.

The prediction that, as a result of reduced intensity of livestock dipping, *Amblyomma* and heartwater will become established in the highveld (Norval *et al.* 1994) has already been largely borne out and substantial livestock losses due to heartwater have been incurred on many highveld farms (T. Chamboko, A. Mukhebi, C. O'Callaghan, T. Peter, R. Kruska, G. Medley, S. Mahan & B. Perry, unpublished data 1998). While infection currently predominates within the central and eastern regions of the highveld, some northward spread may be occurring and future losses will be high if effective control measures are not instituted (A. Mukhebi, T. Chamboko, C. O'Callaghan, T. Peter, R. Kruska, G. Medley, S. Mahan & B. Perry, unpublished data 1998). The rate and pattern of heartwater spread is difficult to predict and will probably be dependent upon acaricide use practices, livestock movement and the presence of certain wildlife species. Further studies are required to evaluate the influence of these factors on the spread of the disease and to help predict the ultimate impact of the disease on the livestock industry.

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