The epidemiology of rabies in Zimbabwe. 1. Rabies in dogs (*Canis familiaris*)

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ABSTRACT

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The epidemiology of rabies in dogs in Zimbabwe is described using data from 1950, when rabies was re-introduced after a 37-year absence, to 1996. Dogs constituted 45,7 % of all laboratory-confirmed rabies cases and were the species most frequently diagnosed with the disease. Slightly more cases were diagnosed from June to November than in other months. From 1950 to the early 1980s, most dog cases were recorded from commercial farming areas, but since the early 1980s most have been recorded from communal (subsistence farming) areas. This change appears to be due to improved surveillance in communal areas and not to any change in the prevalence of rabies. Dog rabies therefore appears to be maintained mainly in communal area dog populations, particularly the large communal area blocks. Urban rabies was not important except in the city of Mutare. Where dog rabies prevalence was high, the disease was cyclic with periods between peak prevalence ranging from 4–7 years. Dog rabies cases were, on the whole, independent of jackal rabies and rabies in other carnivores. There was a significant negative relationship between the annual number of rabies vaccine doses administered nationally to dogs and the annual number of dog rabies cases lagged by one year, indicating that the past levels of immunisation coverage have had a significant effect on the number of rabies cases. However, dog vaccination coverage has clearly not been adequate to prevent the regular occurrence of rabies in dogs.

Keywords: *Canis familiaris*, domestic dog, epidemiology, rabies, Zimbabwe

INTRODUCTION

The first reported cases of rabies in Zimbabwe occurred in 1902. Domestic dogs (*Canis familiaris*) were the principle species involved in the epidemic and although it spread to cover most of the country, rabies was no longer present after 1913, apparently due to the large number of dogs killed and the strict dog laws that were introduced to control the disease (Swanepoel, Barnard, Meredith, Bishop, Brückner, Foggin & Hübschle 1993). Apart from a minor outbreak in dogs on the Zambian border in 1938, rabies was not diagnosed in the country until 1950, when it was introduced across the southern and south-western borders by dogs. This outbreak spread rapidly in the dog population and within 4 years the disease was present in most areas of Zimbabwe (Foggin 1988).

Rabies in domestic dogs was the main source of human rabies in Zimbabwe between 1950 and 1986. During that period 105 human cases were confirmed in the laboratory and 90 % of these were caused by dog bites. Dogs also cause most of the bites which require anti-rabies treatment (Foggin 1988).

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Control of dog rabies by mass vaccination campaigns was initiated in 1951 with Flury low egg passage (LEP) live vaccine. In the early 1980s the use of inactivated tissue culture vaccines supplanted Flury LEP (Foggin 1988). Legislation stipulates that dogs must be vaccinated at 3 and 12 months of age and thereafter within every 3 years. In the communal (subsistence farming) areas the majority of dog vaccinations are administered during annual vaccination campaigns conducted free of charge by the Department of Veterinary Services. When rabies prevalence within localised areas is high, two or more campaigns may be conducted annually. Urban dogs are vaccinated by government or private veterinarians. In 1986, Brooks (1990) estimated that 40% of dogs above the age of 3 months had been vaccinated at least once.

The aim of the study reported in this paper was to determine the epidemiological patterns of rabies in dogs in Zimbabwe. Conclusions from this study could be important in predicting the future prevalence and patterns of dog rabies and in planning control strategies. The epidemiology of jackal rabies in Zimbabwe is reported in a separate paper (Bingham, Foggin, Wandeler & Hill 1999).

MATERIALS AND METHODS

Data sources

Prevalence data on all laboratory-confirmed rabies cases, which occurred from 1950–1996 inclusive, were used in the analysis. The diagnosis of rabies was carried out at the Central Veterinary Laboratory, Harare, using specimens consisting of glycerol-saline preserved or formalin-fixed brain tissues. Until 1967 rabies was diagnosed histologically (Seller's stain) and biologically (intracerebral inoculation of mice) but thereafter the histological test was replaced with the fluorescent antibody test (FAT) (Dean, Abelseth & Atanasiu 1996). Since then, the FAT and the mouse inoculation tests (Koprowski 1996) have been the principal means of diagnosis (Foggin 1988).

Records of each positive case, which included data on date of receipt of the specimen at the laboratory, species, landuse type and the geographical grid reference at the point of origin, were entered into a computerised database (dBase 4, Borland).

Data on dog vaccination records were obtained from Department of Veterinary Services' monthly and annual reports. Vaccination coverage is best expressed as a percent of the total dog population, but as no regular dog census data exists, whereas human census data is available, dog vaccinations are expressed as doses per 1 000 people, with the assumption that the dog:human ratio remains constant. Data on human populations were obtained from census reports (Central Statistics Office 1985, 1994). In the years between censuses, the human population was calculated from the inter-census growth rates. For the years 1993–1996, the pre-1992 inter-census growth rate was used.

Data analysis

Most data analysis was carried out using dBase 4 programming language. This included analysis of temporal and spatial trends and relationships between cases of different species. Geographical analysis was assisted by the use of Idrisi for Windows software (Clark University, Worcester, MA, USA) to display maps with case localities and case frequency data.

For the determination of distance (d) between cases a dBase 4 routine was compiled based on the formula $d = \sqrt{((105x)^2 + (110y)^2)}$, where x and y are the differences between the longitude and latitude co-ordinates, in degrees, respectively. One degree of latitude is 110 km, while one degree of longitude varies between 103 and 107 km in Zimbabwe. Using a median longitude of 105 km gives a maximum distance error of less than 2%. This was considered sufficiently accurate for the purposes of this study, particularly as the study was only concerned with distances less than 100 km and the resolution of geographical reference co-ordinates was 1 km.

Jackal-associated cases are defined as those dog rabies cases for which at least one jackal rabies case occurred within a radius of 30 km and a period of 180 d.

In order to determine the temporal pattern of dog cases in communal areas, cases from three communal land blocks in which dog rabies had been frequently diagnosed were counted for every year. The blocks are shown in Fig. 7A as follows:

Block 1: The areas of the middle eastern region from Chiduku to Ndanga Communal Lands

Block 2: The communal areas on the north-eastern border with Mozambique

Block 3: The middle northern areas including Gokwe and surrounding communal lands

In addition, similar analyses for dogs were done for Mutare city and surrounding areas and for the Chipinge area, a commercial farming area with high dog rabies prevalence along the eastern border region.

Regression analyses were carried out between the total number of dog rabies vaccine doses administered per year and the total annual dog cases, and between vaccine doses administered and with cases lagged 1 year and with cases lagged 2 years.

RESULTS

Fig. 1 shows the towns and provincial boundaries for purpose of reference and Fig. 2 the species and species groups which were diagnosed with rabies. Most rabies cases (45,7%) were diagnosed in domestic dogs, followed, in order of prevalence by jackals (25,2%) and cattle (18,9%). The breakdown of the different species occurring in the commercial farming, communal and urban sectors is given in Fig. 3. Proportionately higher levels of dog rabies were reported in the communal and urban sectors, while high levels of jackal and bovine rabies occurred in commercial farming areas.

Prevalence in domestic dogs

The number of cases of dog rabies diagnosed annually from 1950 to 1996 is shown graphically in Fig. 4. Dog cases constituted the highest number of rabies cases every year except during years of jackal epidemics, which were 1966–1967, 1971–1973, 1981 and 1993–1995.

Rabies entered Zimbabwe along the southwestern border and by 1954 was present in most areas of the country, except the large protected (wildlife and forest) areas and the Gokwe region. The reported prevalence of the disease in dogs during the subsequent 10 years was relatively low, the cases occurring principally in the area west of Bulawayo and along the eastern border. During the 1960s most of the cases occurred in the eastern third of the country, while during the 1970s the southern areas were also affected. In 1979 and 1980, the prevalence increased markedly, the disease occurring in most regions except the large protected areas. Since then the high prevalence and widespread occurrence of

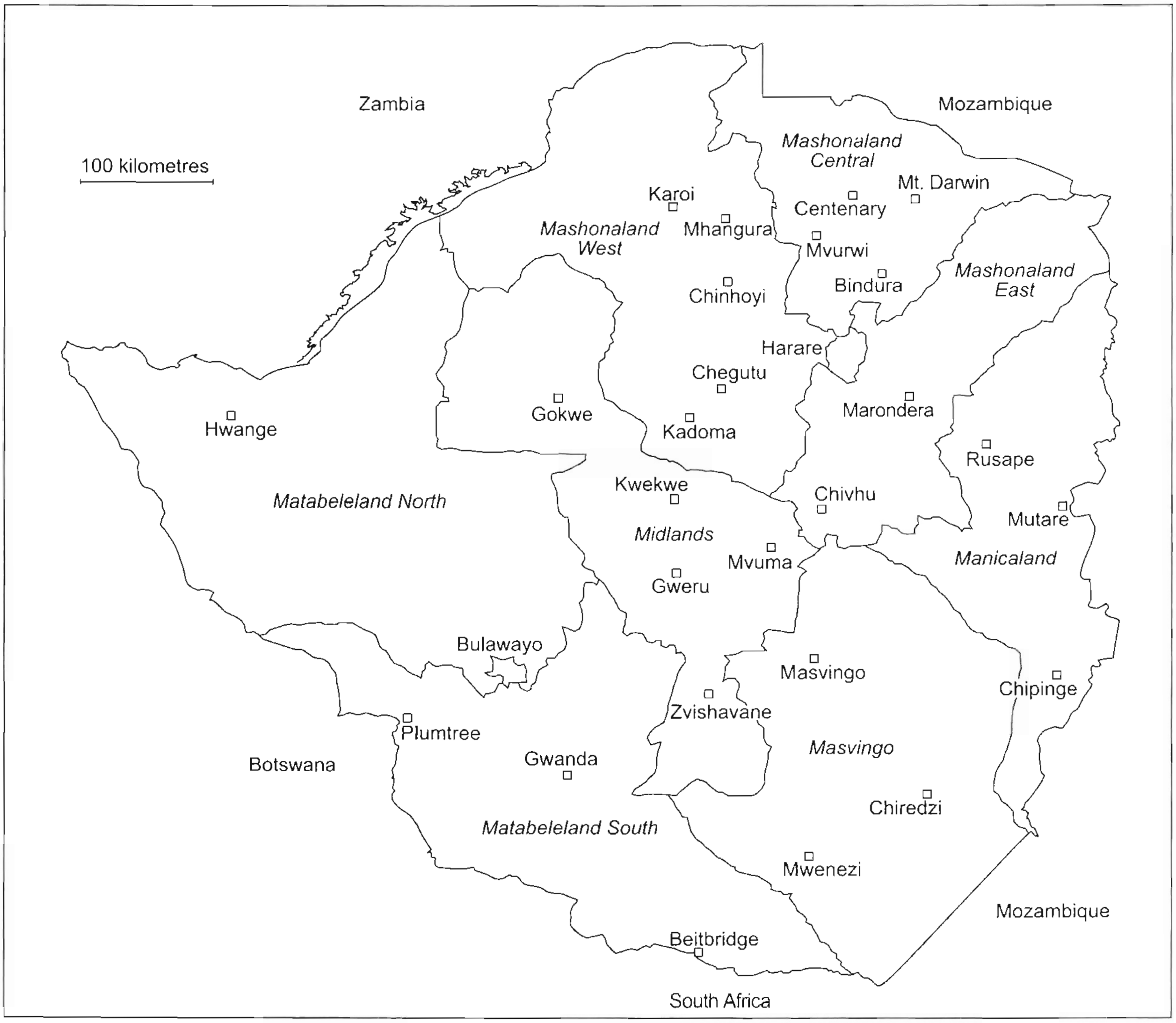

FIG. 1 Map of Zimbabwe showing the provinces and the major urban areas

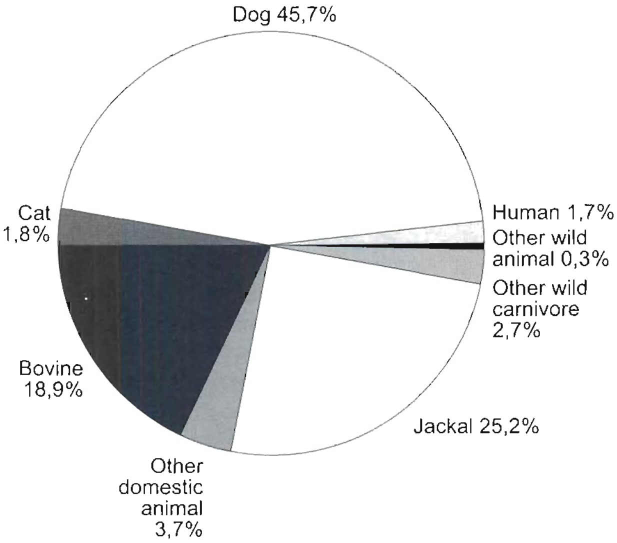

FIG. 2 Rabies cases in Zimbabwe from 1950–1996 showing the proportions of species and species classes

dog rabies has persisted. From the mid-1980s dog rabies occurred with higher frequency in Gokwe Communal Land, in which it had previously been rare. This increase in the number of cases was associated with the eradication of tsetse flies, the transmitters of trypanosomiasis, which allowed human settlement in this area.

Seasonality

The monthly occurrence of all the dog cases from 1950–1996 is shown in Fig. 5. There was no pronounced seasonal variation, although there were slightly more cases diagnosed during the months of June to November than in the remainder of the year.

Geographical trends

Of the 4628 laboratory-confirmed dog cases diagnosed from 1950–1996, 43% originated from commercial farming areas, 34% from communal areas, 22% from urban areas and 0,8% from protected areas. From 1985–1996, when communal area surveillance had improved, 1 877 dogs were confirmed rabid and of these 30,7% originated from commercial farming areas, 55,6% from communal areas, 13,4% from urban areas and less than 0,2% from protected areas. The number of dog cases diagnosed annually in the different landuse sectors is shown in Fig. 6. From 1950 until the early 1980s most cases of rabies in dogs were reported from the commercial farming sector. During every year after 1984, the most dog rabies cases were reported from the communal sector.

Fig. 7A and 7B show the dog cases diagnosed in the communal areas and commercial farming areas,

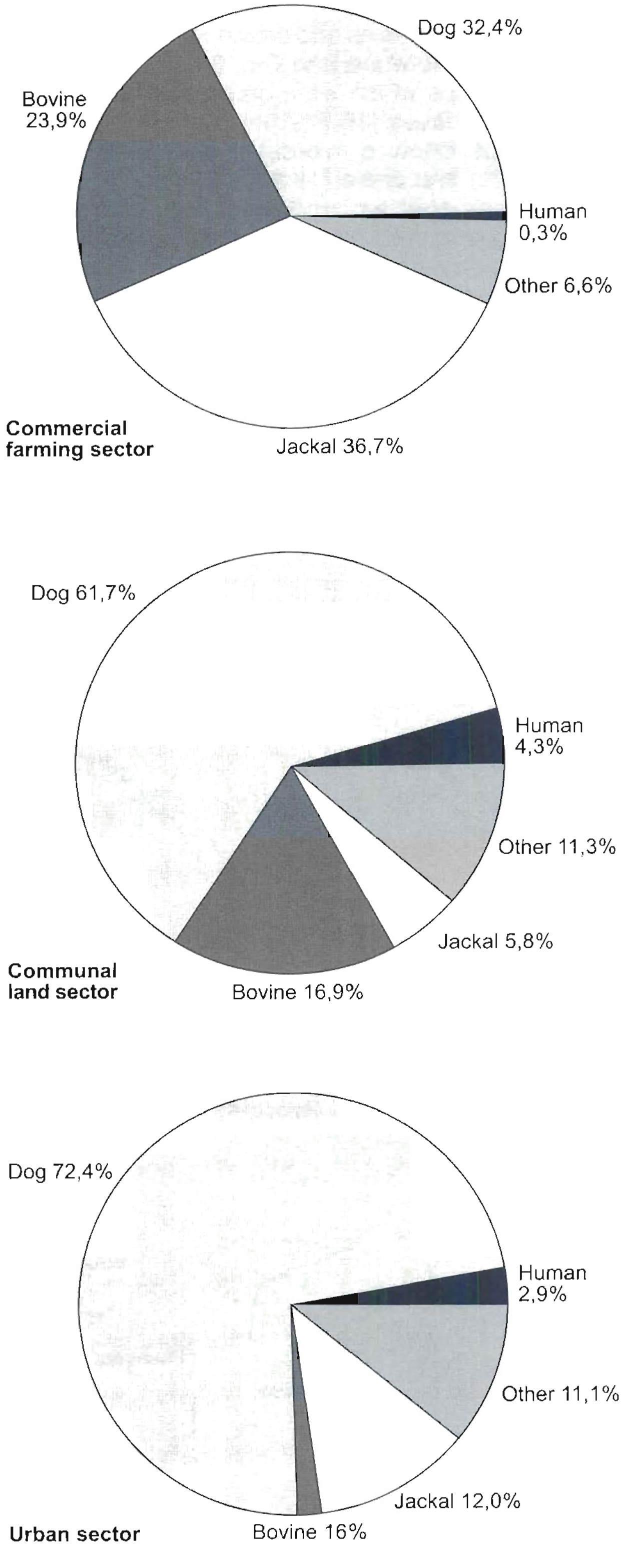

FIG. 3 The proportions of the different species diagnosed with rabies from 1950–1996 in the three main landuse sectors in which rabies occurred

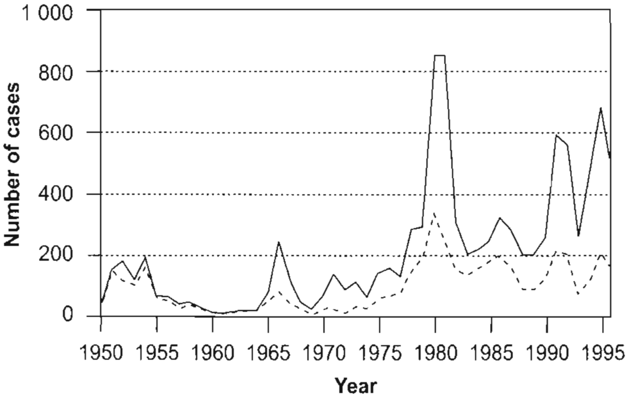

FIG. 4 Total number of rabies cases in animals (solid line) and dogs (dotted line) from 1950–1996

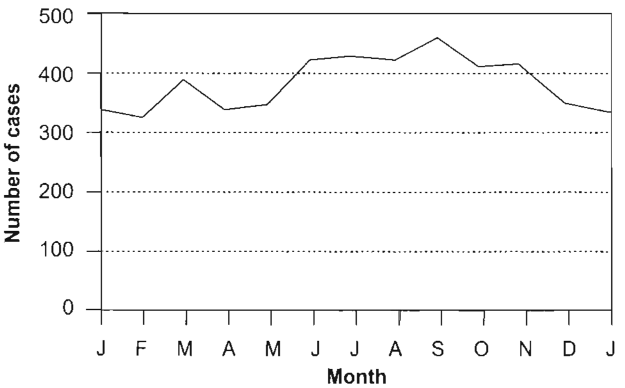

FIG. 5 The months of the year in which all cases of rabies in dogs were diagnosed from 1950–1996

respectively from 1950–1996. The small number of positive specimens received from protected areas came from small parks or forest areas which were in close proximity to communal areas or commercial farmland, or from near border river crossings.

Temporal trends

The countrywide dog rabies prevalence by year is shown in Fig. 4. However, national figures obscure more local trends, necessitating analysis of smaller areas. Fig. 8 shows the dog rabies prevalence by year for three communal land blocks and also for Mutare city and Chipinge area (mainly commercial farmland), all areas where the number of positive cases was high.

Influence of rabies in jackals

The epidemiology of rabies in jackals (*Canis adustus* and *Canis mesomelas*) is described in detail elsewhere (Bingham *et al.* 1999). How does jackal rabies affect the patterns of the disease in dogs? The numbers of jackal-associated and non-jackal associated cases are shown in Fig. 9, the former being those dog rabies cases for which at least one jackal rabies case occurred within a radius of 30 km and a period of 180 d. The number of jackal-associated cases never exceeded that of non-jackal-associated cases, even in years of high jackal rabies prevalence, although

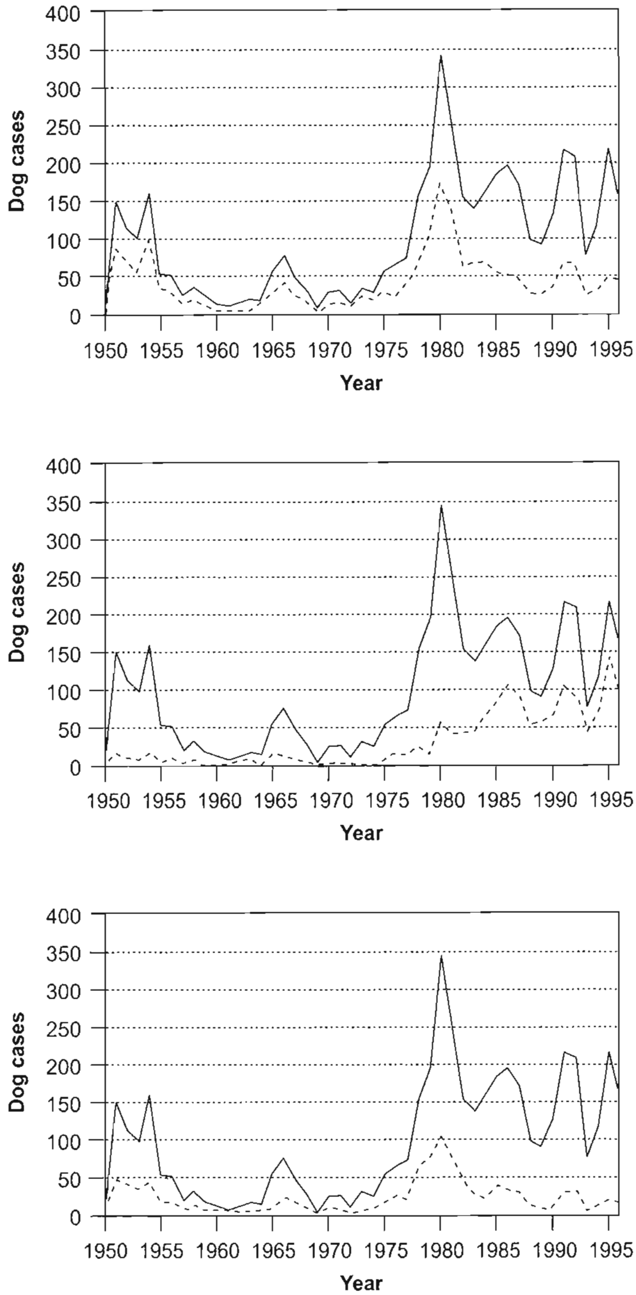

FIG. 6 Cases of rabies in dogs diagnosed annually in the different landuse sectors from 1950–1996 [commercial farmland (top), communal areas (middle) and urban areas (bottom)]. The solid line represents the total number of cases in dogs and the dotted line the cases in the respective landuse sector

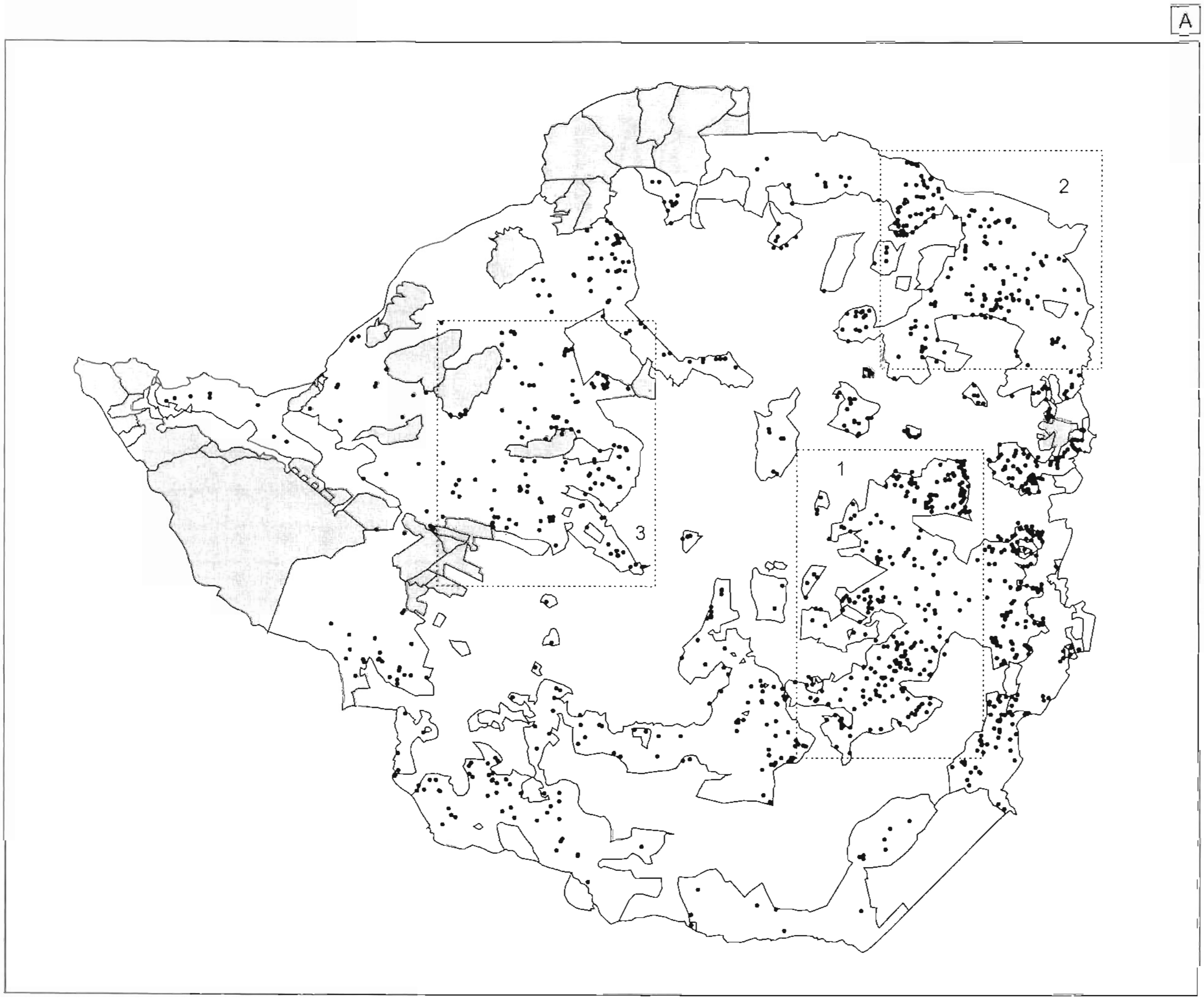

FIG. 7A Dog rabies in communal areas showing boundaries of communal lands (internal lines) and location of protected areas (shaded regions), with the delimited blocks for temporal analysis (dashed lines)

during the early 1980s and the 1990s, when large outbreaks in jackals occurred, jackal-associated cases made up a large proportion of the total dog cases. Overall, 21,2% of dog cases were associated with jackal cases and 74,2% with other dog cases within 30 km and 180 d, while 18,1% were not associated with cases in any other species, 56,6% were associated with dog cases in the absence of the disease in jackals and 3,5% were associated with jackal cases in the absence of dog rabies cases. Jackal-associated cases accounted for 25,7% of dog cases in commercial farming areas and 12,8% of cases in communal areas.

Dog vaccination

The vaccination trends of dogs during the period under review are graphically compared to the total number of dog cases in Fig. 10. Dog vaccination commenced in 1951. In the early 1960s vaccination levels declined, possibly due to complacency caused by the low numbers of cases diagnosed positive (Foggin 1988). During the late 1970s vaccination levels decreased markedly due to the escalation of civil war, which adversely affected rural animal health programmes (Lawrence, Foggin & Norval 1980). After the cessation of war and independence in 1980, the number of dogs vaccinated against rabies increased again. The drop in vaccination levels seen after 1990 was probably related to declining Veterinary Department resources and to the diversion of available resources to other disease programmes.

There was a significant negative relationship between national annual vaccine doses administered and cases lagged one year ($r = 0{,}35$; $P = 0{,}019$), but

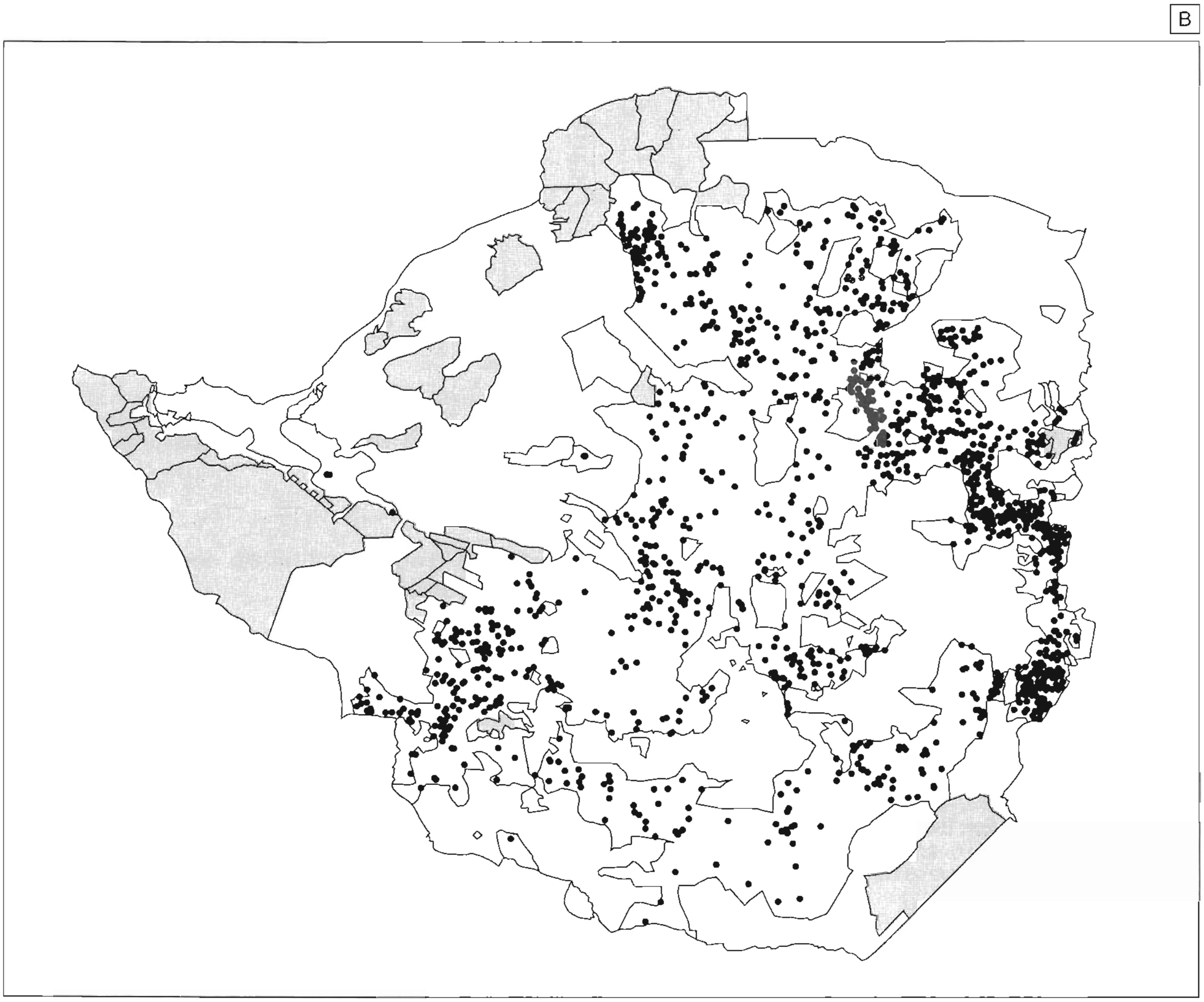

FIG. 7B Dog rabies in commercial farmland showing boundaries of communal lands (internal lines) and location of protected areas (shaded regions)

there was no significant relationship with same-year cases nor with cases lagged 2 years.

DISCUSSION

Zimbabwe is divided into four major landuse categories: commercial farmland, communal farmland, urban areas and protected areas. Commercial farmland, which constitutes 43% of the total land area, is mainly privately owned, the predominant activities being commercial crop and livestock production and game ranching. In recent history commercial farmland has been owned predominantly by farmers of European descent who have practised modern farming techniques. Many of these farms have moderate to large labour forces, which reside on the properties with their families. A small proportion of this sector also includes "small-scale" farming enterprises, owned by farmers of African descent. Since independence in 1980 a certain amount of commercial farmland has been acquired for resettlement schemes and has been settled by families originating from over-populated communal areas. In 1986, resettled land amounted to almost 7% of total land area (16% the commercial farming land area) (Brooks 1990) and since then the resettlement programme has continued expanding. Human populations vary from low in the extensive ranching areas in the south, west and central regions, to moderate in the more intensive crop farming areas in the north. Dogs densities are low mainly because many commercial farmers do not allow their labour force to keep dogs (Brooks 1990).

Communal farming areas are settled by low-income families practising mainly subsistence agriculture using traditional farming techniques. These areas, which comprise 42% of the country's surface area,

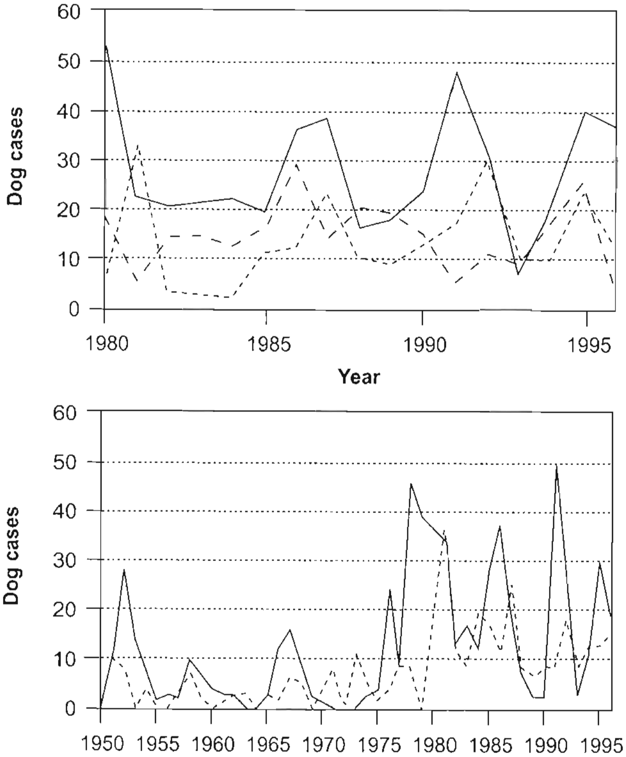

FIG. 8 Numbers of dogs diagnosed per year in (top) three communal land blocks, as given in Fig. 7A, from 1980–1996 (Block 1: solid line; Block 2: dashed line; Block 3: dotted line) and (bottom) in and around Mutare city (solid line) and in the Chipinge area (dotted line) from 1950–1996

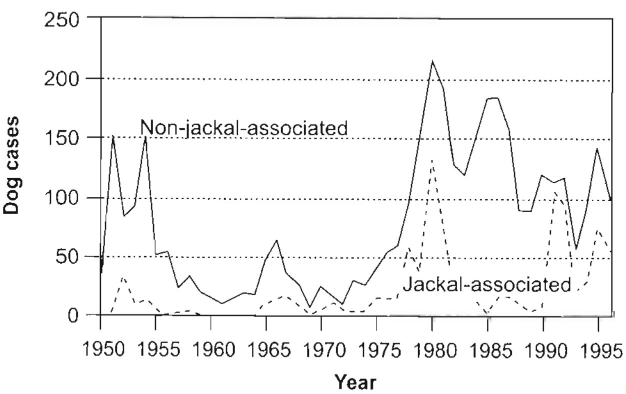

FIG. 9 Jackal-associated (dotted line) and non-jackal-associated (solid line) rabies cases in dogs diagnosed each year from 1950–1996. Jackal-associated cases are defined as those with at least one case of rabies in a jackal within a radius of 30 km and a period of 180 d

contain 51,4 % of Zimbabwe's human population (Central Statistics Office 1994). Veterinary infrastructure historically has been poorly developed in the communal areas: it was not until after independence in 1980 that the veterinary infrastructure was developed by building animal health centres staffed by extension personnel.

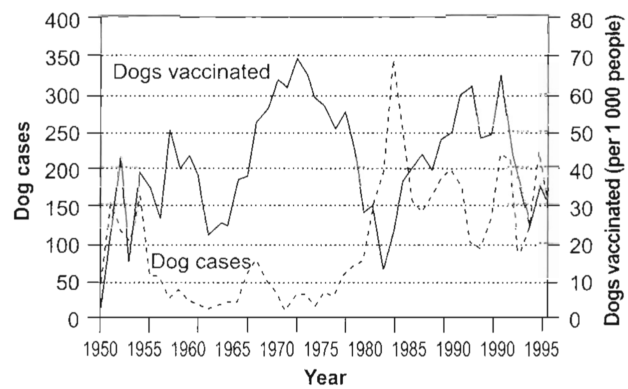

FIG. 10 Annual number of cases of rabies in dogs in Zimbabwe from 1950–1996, showing the number of doses of vaccine (per 1 000 people) administered to dogs in each of the years

Protected areas are specially designated areas for the protection of habitats and include government or parastatal-run national parks, forest land, safari areas and recreational parks. These areas consist mostly of marginal land unsuitable for agriculture, but may support large populations of wild animals, including jackals.

Brooks (1990) found that Zimbabwe had a total dog population of 1,3 million in 1986 and the dog population growth rate was estimated at 4,7 % per annum. Most of the dogs (71,3 %) lived in the communal areas, where the dog-to-human ratio was 1:4.5. Dog populations had densities of between 1,4 and 6,7 dogs per km^2, depending on the province. In a subsequent survey communal area dogs had an average age of 2 years and 41,8 % were below 1 year of age (Butler 1995). The average estimated dog density for seven communal lands was 21 dogs per km^2. Communal area dogs live an almost entirely unrestricted life although very few are not owned.

Although the highest number of reported dog rabies cases originated from the commercial farming areas during 1950–1996, in the more recent part of the study period the majority had been reported from the communal areas. Since this apparent change in the relative prevalence within the landuse sectors coincided with the improvement of rabies surveillance in communal areas, it is possible that the earlier prevalence figures are not a true reflection of the prevailing situation as it was then. Despite the improvement in communal area surveillance, it is still considered inadequate, particularly in the more remote regions where the large majority of cases are probably not being reported. Surveillance in the commercial and urban sectors is unlikely to have changed significantly during the period under review. Dog rabies, therefore, appears to have been maintained predominantly in the communal areas. This is to be expected, given that about 71,3% of dogs in Zimbabwe live in these areas (Brooks 1990).

Rabies in dogs was most frequently diagnosed in the large communal land blocks with high human populations. Communal lands in the agriculturally marginal areas in the western, northern and south-eastern regions of the country, which do not support dense human populations, had fewer reported cases. Small isolated communal areas also had few cases. It is considered that this is related to the different communal land dog population sizes; small isolated populations being unable to maintain rabies.

Urban dog rabies does not appear to be important, except in the city of Mutare. The reason for the high frequency in Mutare compared to other urban areas may be related to the close association of this city with susceptible dog populations from adjacent communal areas (Fig. 7A and B).

Dog cases in commercial farming areas (Fig. 7B) were most frequent in the eastern regions. There was also a high density in the Mashonaland region and some of these cases were associated with jackal epidemics. That large numbers of cases which are not associated with jackal rabies and occurred in the commercial farming areas some distance from communal areas indicates that these areas are probably also capable of maintaining dog rabies.

Examination of the geographical spread of rabies over the different years of the study period reveals no pronounced geographical pattern of disease movement, except for those cases which were associated with the large jackal epidemics. However, the detection rate of cases may have been inadequate to demonstrate such a pattern with accuracy.

In areas where the dog rabies prevalence was high it was cyclical in frequency with periods of 4–7 years (Fig. 8). Interestingly, the cycles in the different blocks appear to be somewhat synchronized, with high and low prevalence periods occurring concurrently. It is possible that these rabies cycles follow natural dog population density fluctuations. Vaccination levels and surveillance may also affect rabies prevalence, but these factors are likely to affect the prevalence only at a local level and not the observed major temporal trends.

To what extent is dog rabies influenced by rabies in other vector species, particularly jackals? Jackals constitute over 25% of diagnosed cases and are a major vector of the disease in the commercial farming sector (Bingham *et al.* 1999). However, jackal-associated cases, which are those with at least one jackal case occurring within a radius of 30 km and a period of 180 d, never exceeded non-jackal-associated cases, even in years of high jackal rabies prevalence, although during the early 1980s and the 1990s, when large jackal outbreaks occurred, jackal-associated cases made up a large proportion of the total dog cases. Although this association does not prove that jackals were responsible for transmission to jackal-associated dog cases, it does give some indication of how much influence jackal rabies may have had on the prevalence of the disease in dogs. In most years this appears to be small in the commercial farming areas and probably insignificant in the communal areas. The numbers constituting other carnivore species, such as domestic cats (*Felis domestica*), mongooses of various species (Family Herpestidae), honey badgers (*Mellivora capensis*) and civets (*Civettictis civetta*), were considered too low to have had any significant effect on dog rabies epidemiology, and may rather have been spillover from dogs and jackals. It is evident that dogs are reservoir hosts of rabies and are capable of maintaining the disease for long periods without the presence of rabies in other species. Nevertheless, at least one outbreak in dogs was initiated by jackals. This occurred in the Hurungwe area in 1982 after the large jackal epidemic of the early 1980s in Mashonaland (Foggin 1988; Kennedy 1988).

The vaccination level at which outbreaks of rabies will be prevented is generally regard to be around 70 % (Coleman & Dye 1996). Brooks (1990) estimated that 40% of dogs in Zimbabwe were vaccinated in 1986. From Fig. 10 it would appear that the 1986 vaccination level (as doses per 1 000 people) may have been exceeded only during the late 1960s and early 1970s and from 1987–1991, while lower levels were reported in other years. Extrapolating from 40% vaccination coverage in 1986, vaccination levels may therefore have varied between about 10% and 50%. The significant negative correlation between dogs vaccinated and dog cases implies that these past levels of population immunity are likely to have had, not surprisingly, some influence on disease levels. However, these vaccination levels are clearly inadequate in controlling dog rabies, as evidenced by the high rabies prevalence.

Dog rabies vaccination levels are expressed in doses per 1 000 people because no regular data on dog population numbers are available. It is assumed that the dog population is directly proportional to the national human population. This is considered justified as dogs in Zimbabwe appear to be entirely dependent on humans for their resource requirements and the number of truly unowned dogs appears to be low (Brooks 1990; Butler 1995). The expression of dog vaccination levels in doses per 1 000 people also assumes that peoples' dog keeping habits are constant from year to year. Because the dog:human ratio is different in the different landuse sectors (Brooks 1990), this ratio will be influenced by demographic changes between landuse sectors. However, analysis of changes in human population demography as it may relate to dog husbandry is beyond the scope of this study.

The use of national figures for vaccine doses administered and case numbers may obscure more significant correlations present in local areas. It would be useful to compare dog rabies cases and vaccination figures for limited areas. Such a study, using provincial data, has been carried out by Foggin (1988). However, more accurate answers could be found by using areas of uniform socio-ecological attributes, such as individual communal area blocks or urban areas. Unfortunately vaccination figures for specific areas were not readily available and such analysis is beyond the scope of this study. Given accurate and long-term data on local vaccination levels, however, this analysis would be an important study to determine the effect of vaccination on the prevalence of rabies and on determining the vaccination levels required to bring about control of rabies.

This study characterized some of the epidemiological features of domestic dog rabies in Zimbabwe. For the control of dog rabies, it will be important to increase the vaccination coverage of dogs, particularly in the large communal area blocks, where rabies appears to be maintained. Effective vaccination campaign strategies need to be developed in order to raise this coverage, as conventional vaccination strategies clearly have not succeeded in achieving adequate control.

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