Dog ecology in eastern and southern Africa: implications for rabies control

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ABSTRACT

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With an apparent decline in rabies vaccination coverage in dog populations in many parts of eastern and southern Africa, consideration should be given to more effective targeting of rabies vaccination to protect those sectors of the dog population with the greatest capacity to transmit rabies. This paper discusses the potential contributions that dog ecology studies may make to the improved delivery of rabies control measures and the targeting of vaccination programmes in the region. Data requirements on dog population size and structure are discussed, methods for collection of such data are summarized, and the studies on dog ecology carried out to date within the region are reviewed.

INTRODUCTION

The domestic dog is by far the most important species in the maintenance and transmission of rabies in Africa, although the degree of its importance varies from region to region. In general, it appears that rabid dogs constitute a greater proportion of confirmed rabies cases in eastern Africa than in southern Africa (reviewed by Perry 1993). In the latter region, certain wildlife species, notably the yellow mongoose (*Cynictis penicillata*), the black-backed jackal (*Canis mesomelas*), the side-striped jackal (*Canis adustus*) and the bat-eared fox (*Otocyon megalotis*), play significant roles in certain areas (Barnard 1979; Bingham 1993; Thomson & Meredith 1993). Perry (1993) discussed the possible reasons for regional differences in species associations, suggesting that they were a result of both real and artificial phenomena. Real phenomena include the differing wildlife species distributions, population densities, ecologies and land-use systems between the regions, which may affect the species associations of rabies. In addition, the rabies virus isolated from the yellow mongoose can be differentiated from the dog-associated rabies virus prevalent in the region on the basis of differing reactions with a panel of antinucleocapsid monoclonal antibodies (King 1991; 1993). This suggests that differences in species susceptibility to rabies viruses demonstrating different antigenic characteristics may exist, similar to the phenomena reported in several wildlife species in North America (Smith 1988; Smith, Reid-Sanden, Roumillat, Trimachi, Clark, Baer & Winkler 1986). Artificial phenomena include possible regional differences in dog rabies control, with apparently better control in southern Africa than in eastern Africa; in Europe and North America wildlife species became increasingly important in the epidemiology of rabies following the control of the disease in dogs (Steck & Wandeler 1980; Perry 1987). The recent dramatic increase in the proportion of rabid dogs in South Africa, reportedly as a result of a decrease in the dog vaccination coverage in Natal and KwaZulu (Bishop 1993), is a clear illustration of this.

Not only is the domestic dog the most important species overall in eastern and southern Africa, but also the disease in dogs has been reported with apparent increasing incidence over the last twenty years or so, with many countries of the region currently reporting record numbers of cases (Perry 1993). Given our understanding that there is a close relationship between the rates of increase in population sizes of dogs and humans, it is likely that the dog population has increased significantly over this period. There are very few estimates of dog population growth in the region, but in Zimbabwe, Foggin (1988) calculated a rate of growth of the dog population of 5,15 % per annum over the period 1954 to 1986. It is likely that the detection rate of rabies (i.e. the number of confirmed positives as a proportion of the total rabies cases) has declined in many parts of the region over the same twenty year period due to the decreasing financial resources at the disposal of government veterinary services in many countries and the resulting constraints on the effective delivery of diagnostic services (De Haan & Nissen 1985; De Haan & Bekure 1990; WHO 1984). The combination of increases in reported disease incidence, apparent increases in dog population sizes and assumed decreases in rabies detection rates leads one to believe that dog rabies is a substantially greater problem in the region than is documented.

Is it possible to reverse this trend and if so, how? There are numerous inactivated rabies vaccines now available on the international market that have been shown to be highly efficacious in dogs, and it is generally believed that the constraints to effective dog rabies control are economic and logistical rather than technical, namely the poor accessibility of dogs to vaccination, the inadequate availability of rabies vaccines in many countries and the high cost of vaccines. For this reason, there is a strong argument for new approaches to be taken in the delivery of these effective vaccines to dog populations. The common theme of such approaches is effective targeting of rabies vaccine, a concept that has received considerable attention in the control of human diseases such as hepatitis B (Anderson 1992) and this raises two important questions:

- What are the high risk components (segments) of the dog population in terms of their capacity to transmit rabies?
- Is it possible to develop methods to access these components with vaccination and other control measures, both effectively and at the appropriate frequency?

Studies of dog ecology can provide much of the information required to answer these questions and this approach has been identified by several workers (Beran & Frith 1988; Wandeler, Budde, Capt, Kappeler & Matter 1988) and pursued by WHO (WHO 1988; WHO/WSPA 1990). This paper will discuss the potential contributions of dog ecology studies to improved delivery of rabies control in eastern and southern Africa, summarize the requirements of such studies and briefly review data currently available from the region.

TARGETING THE DELIVERY OF DOG RABIES CONTROL MEASURES

Effective dog rabies control requires the immunization of a large proportion of the dog population in order to reduce the contact rate between rabid and susceptible dogs to a level too low to sustain rabies transmission within the population. In broad terms, this requires high levels of vaccination coverage and WHO (1984) has proposed a target level of 70 % of the dog population. However, required immunization levels to control endemic dog rabies will vary considerably from place to place depending on numerous factors, including the potential contact rate between infected and susceptible dogs (a function of dog densities, dog movement restriction and dog dependency on owners for food). Thus in spite of the ideal requirement of vaccinating high proportions of all dogs, in an economic environment currently characterized by severely limited resources, it is likely that the cost effectiveness of dog rabies vaccination could be improved considerably by identifying those sub-populations at greater risk, and concentrating resources on them to achieve the required immunization levels. But how can high risk dog populations be identified? Although in general terms these are likely to exist where contact rates exceed "a certain threshold", little work has been done on defining what such threshold levels might be and what factors contribute to differences in contact rates (although such work has been carried out for some viral and bacterial infections of humans; Anderson & May 1991, and for rabies in some wildlife species; Bacon & Macdonald 1980; Bacon 1985; and, more recently, for feral dog populations; Macdonald & Carr 1993). It is likely that in many cases high risk components of the dog population are also those that require special consideration as far as access vaccination. In some communities, such as the more affluent urban and rural societies who keep dogs in confined compounds, rabies risk is probably lower and, in addition, high vaccination coverages can generally be achieved in these communities with the minimum of effort, due to their access to the media and financial resources to purchase quality veterinary services. High risk dog populations are likely to exist in many high density urban suburbs, where close proximity between households and minimal dog movement restriction result in high dog to dog contact rates. Clearly, numerous intermediate situations exist. Fig. 1 illustrates the hypothetical difference in spatial terms between dog population densities and overlapping home-ranges (and thus potential contact rates) between a high density, low income, urban suburb setting and a rural setting. It is intuitively apparent that the vaccination coverage levels required to interrupt rabies transmission would be different for these two examples.

The WHO has recommended the use of a matrix classification system for dogs, based on the level of dependence on human beings for food, shelter and companionship, and on the level of restriction or supervision imposed (WHO 1988). It is designed to improve the targeting of dog rabies control measures and to provide a framework for their delivery (Fig. 2). Under this classification, dogs fall into four broad categories: restricted (fully dependent and fully restricted); family (fully dependent and semi-restricted); neighbourhood (semi-dependent and semi-or unrestricted); and feral (independent and unrestricted). Although very simplistic, this framework can be adapted to specific conditions for practical use in a country or area with the input of appropriate dog ecology data. For example, the restricted dogs and the family dogs are likely to be highly accessible for immunization by traditional injectable means, but family dogs may also be the target for dog removal if not immunized in a vaccination programme. Furthermore, owners of restricted dogs are more likely to have the resources to seek private veterinary services. Neighbourhood dogs might be the target for oral rabies vaccine distributed at key dog assembly points (Perry & Wandeler 1993). True feral dogs should be removed if possible. The term stray dog, commonly used in the past, is considered a misleading term and WHO (1988) recommends it be used only to describe a dog not in compliance with local regulations. Under the WHO classification, a stray dog may thus be a feral dog, an abandoned or lost animal or merely a free-roaming family dog.

An important component of identifying high rabies risk dog populations is a well documented understanding of rabies epidemiology, including species distributions and interactions, age and sex incidence rates. Furthermore, in order to develop quantitative approaches to determine levels of vaccination cover required in different dog populations, data on the prevalence of rabies infection, incubation period, duration of virus excretion, etc. are required. Although there are broad understandings and perceptions of these parameters from most of the countries in the region, there are few examples of the effective utilization of accurate diagnostic records to provide good, quantitative, epidemiological data on rabies occurrence in dogs. A notable exception is Zimbabwe, where among other things, Foggin (1988) analyzed data accompanying rabies submissions over the period 1950–1986, in which he included an analysis of data on age-specific incidence, incubation period, clinical signs and the interaction of rabid dogs with other species. He reported that almost 76 % of confirmed rabies cases were in dogs over 12 months old, and only 4 % of cases in animals under three months of age. Relating the age-specific incidence to the results of the Zimbabwe dog census carried out in 1986, in which 20 % of dogs were found to be under three months of age (Brooks 1990), Foggin (1988) concluded that the low incidence of rabies in dogs of this age group, a group that is not legally required to be vaccinated in Zimbabwe, is unlikely to pose a significant threat to the control of dog rabies. Of 687 rabid dogs for which data were gathered for the period 1982–1986, 193 were observed attacking and biting other dogs. Foggin (1988) suggested that this observation of one dog in five biting at least one other dog was probably a gross underestimate of the number actually exposing other dogs, as few would have been under close supervision during the entire course of the clinical disease. Very few of these observed rabid dogs (about 3 %) exposed other domestic animals.

DATA REQUIREMENTS ON DOG ECOLOGY

The types of data required for effective targeting and delivery of rabies control measures have been summarized by WHO (1984); WHO/WSPA (1990), and these documents provide selected methods for obtaining such data. Of particular importance are total dog population size and structure, proportion of dogs accessible for a given control strategy and dog population turnover. However, the types of data required depend on the questions being asked and in a rabies control programme these questions are likely to centre around three potential control measures: vaccination by traditional injectable means; oral vaccination by bait delivery; and dog control (principally by dog removal). Immunization with injectable vaccines has been and will continue to be the most important method for the control of dog rabies in eastern and southern Africa. Oral vaccines administered by bait delivery to dogs are still in the early stages of development, but it is likely that they will play an increasingly significant role in the future, given their potential to allow immunization of a proportion of the dog population not easily accessible by injectable vaccines (Perry & Wandeler 1993). Dog control in the form of quarantine, movement control and dog removal has in the past been a valuable adjunct to vaccination programmes. However, in recent years it has rarely been applied effectively in the region and in some cases its use has been counter

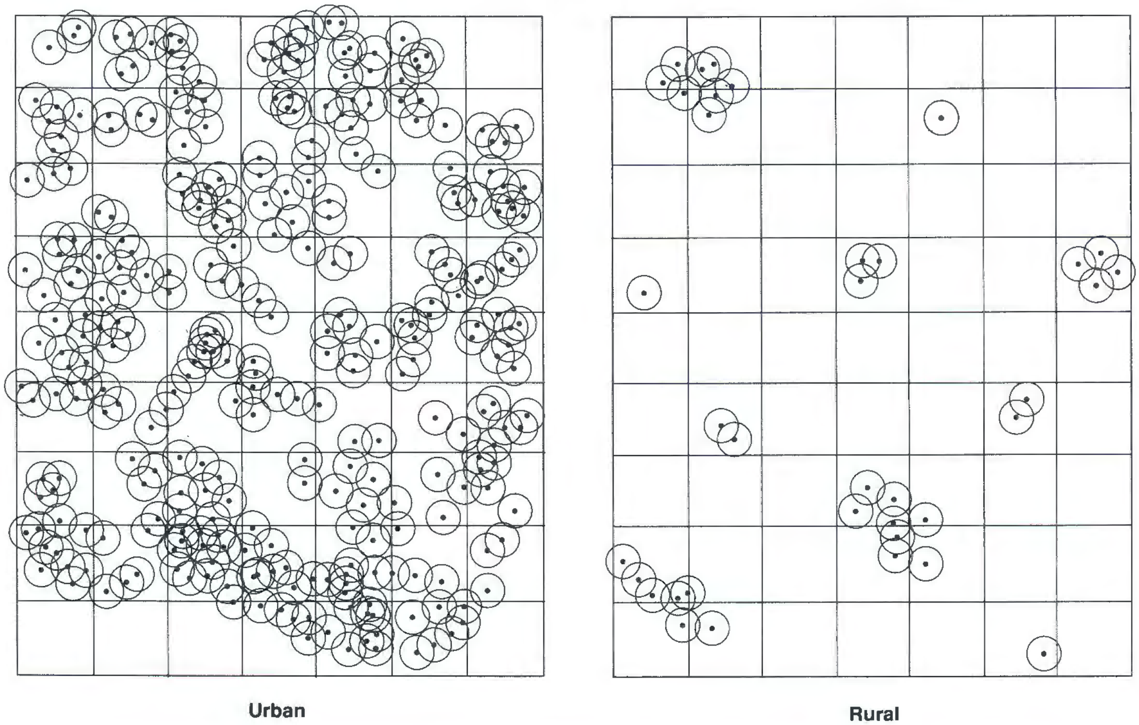

FIG. 1 A hypothetical diagrammatic representation of the difference in potential contact rates between dogs in urban and rural settings. The points represent the location of dogs, and the circles represent their home ranges. For simplicity, each home range is the same, but in reality this is unlikely to be the case

	Full restriction Dog is physically separated from the rest of the population	**Semi-restriction** Dog has access to the rest of the population some of the time	**No restriction** Dog has free access to the population at all times
Full dependency Dog given all of its essential needs intentionally by humans	Restricted dog	Family dog	
Semi-dependency Dog is given a proportion of its essential needs intentionally by humans		Neighbourhood dog	Neighbourhood dog
No dependency Dog is given none of its essential needs intentionally by humans			Feral dog

FIG. 2 A matrix classification of dogs, based on their dependency and restriction. Developed by WHO (1988)

productive, removing dogs which are easily accessible for immunization and provoking public antipathy to rabies control programmes (Perry 1993). Nevertheless, if properly targeted and applied in conjunction with immunization and at the appropriate frequency it may be valuable in reducing the contact rate between high risk subpopulations of dogs.

Table 1 lists three major questions for each of the three control options mentioned and identifies the data requirements in each area. For each parameter, a series of techniques have been described for gathering or assembling data and the reader is referred to two publications by the WHO where these procedures have been well reviewed and documented

TABLE 1 A summary of the questions raised in dog rabies control programmes that require dog ecology data and the categories of dog ecology data required

Questions	Data requirements
1(a). How many doses of vaccine are required? - injectable - oral 1(b). How many dogs require to be removed?	- Total dog population size ? population size by risk group (? high, medium, low), by dog type (family, neighbourhood, etc). - % coverage required in population (? and risk groups, dog types) - Dog population structure - (Habitat)
2. How can coverage of each of the three methods be optimized?	% accessible of risk groups, dog types by each control method - ownership - responsibility - supervision - attitudes to dogs, rabies and rabies control
3. How often do these measures need to be applied?	Dog population turnover

TABLE 2 A summary of the methods used to collect and derive data on different parameters of dog ecology. Modified from WHO/WSPA (1990)

Parameter	Method
Dog-population size	1. Inference and calculation from human population statistics and estimated human:dog ratio 2. Total or direct counts 3. Estimation from rate of capture 4. Estimation from rate of recapture 5. Estimation from photographic recapture
Dog functions and accessibility	1. Questionnaire surveys 2. Observational studies
Dog-population structure	1. Questionnaire survey 2. Observational studies (sex) 3. Tooth wear of handled/killed dogs (age)
Dog movement	1. Observational studies 2. Tracking with markers (dyes, radiotelemetry)
Population turnover	1. Observational studies 2. Questionnaire of dog owners

(WHO 1984; WHO/WSPA 1990). In broad terms there are three types of approach: those using calculations based on human population size, those using observational techniques derived from studies of wildlife populations, and those using questionnaire surveys of dog owning communities. Techniques for gathering data on the major dog-ecology parameters are summarized in Table 2 and results of the few studies carried out within the region are given below. Other results from studies carried out in Machakos, Kenya and Lusaka, Zambia, are presented in this volume (Kitala, McDermott, Kyule & Gathuma 1993; De Balogh, Wandeler & Meslin 1993). In all dog ecology studies, it is important to consider the units of measuring dog population sizes and structure, in order that the results can be compared from one study to another and used for decision-making purposes. Dog population sizes, for example, are usefully expressed as dogs/human, dogs/household and dogs/square kilometre, and calculated by administrative units (e.g. province), by land-use category (e.g. urban, rural) and, if possible, by the socio-economic status of owners and keepers.

Dog population size

There are very few studies of dog population sizes reported for eastern and southern Africa. Using the estimated range of dog:human ratios of 1:8–1:11 presented by Bögel, Andral, Beran, Schneider & Wandeler (1982), Perry (1993) calculated the dog population sizes of Kenya, Tanzania and Malawi for 1990, using projected human-population figures of the World Bank (1986). These were estimated to be 2,3–3,2 million (Kenya), 2,5–3,4 million (Tanzania) and 0,73–1,0 million (Malawi). When compared to rabies vaccine-issue statistics published for the three countries (Luusah 1988, Machuva 1988, Msiska 1988), estimated vaccination coverage rates of 2,4 % (1979), 3,9 % (1988) and 5,0 % (1987) were calculated for Kenya, Tanzania and Malawi, respectively (Perry 1993).

However, the most comprehensive study to date of dog-population size at a national level in eastern and southern Africa, was that of Brooks (1990), in which a full national dog census for Zimbabwe was carried out. The total dog population was found to be 1,3 million, providing an overall dog:human ratio of 1:6,3 (based on an estimated human population of Zimbabwe for 1986, the year of the dog census, of 8,5 million; World Bank 1986).

At the sub-national level, dog population sizes and dog:human ratios have been estimated in studies in South Africa and Kenya. In South Africa, Arbuckle (personal communication 1990) carried out a random sample survey of households by ethnic group in nine regions of Natal and Kwazulu, and estimated the number of dogs per household and the dog:human ratio (Table 3). In Kenya, Perry, Kyendo, Mbugua, Price & Varma (1994) used a visual capture/recapture method to estimate the dog population size in a high density, low-income suburb of Nairobi. During a rabies vaccination campaign, vaccinated dogs were fitted with a nylon collar. One week later, a team traversed the study area observing and counting collared and uncollared dogs. Using the Lincoln index method

TABLE 3 Summary of dog population sizes in Natal and KwaZulu (from Arbuckle 1990, personal communication)

Ethnic group	Human:dog ratio	Dogs/household
Asian	7,6:1	0,60
Black urban	15,6:1 (11–23)	0,48
Black rural	6,8:1	1,10
Coloured	8:1	0,58
White	2,9:1	1,20

of calculation (Seber 1973; WHO/WSPA 1990) the dog population was estimated to be within the range 580–635 (with 95 % confidence), and the vaccination coverage was calculated as 68–75 %.

Further sub-national level studies have now been carried out in Kenya and Zambia, the results of which are reported in this volume (Kitala *et al.* 1993; De Balogh *et al.* 1993) so it is possible that a clearer understanding of dog-population sizes in several parts of the region, particularly in relation to human populations sizes, will emerge.

Dog population structure

In addition to the studies in Kenya and Zambia reported elsewhere in this volume (De Balogh *et al.* 1993; Kitala *et al.* 1993), studies of dog population structure have been carried out at a national level in Zimbabwe, and at local levels in South Africa and Kenya.

The dog census of Brooks (1990) in Zimbabwe provided valuable and detailed information for the different provinces; a summary of the findings is presented in Tables 4 and 5. However, in the current economically constrained environment, it is not envisaged that such a detailed national census will be easily repeated in other countries, and sample surveys or highly geographically restricted studies are likely to be more cost-effective. The dog population studies carried out in South Africa and Kenya were both very site specific, thus their relevance to other situations even in the same countries, is unknown.

TABLE 4 Distribution of characteristics of the dog population surveyed by province in Zimbabwe (from Brooks 1990). Key for heading listed below this table

Province	A	B	C	D	E	F	G	H	I	J	K	L
Manicaland	814	744	0,91	2,3	325(40 %)	141(19 %)	353	250	0,59:0,41	233 102	1:5,3	6,7
Mashonaland												
central	495	363	0,73	2,3	161(33 %)	82(23 %)	152	129	0,54:046	93 937	1:6,8	3;4
east	669	403	0,60	2,1	194(29 %)	78(19 %)	167	158	0,51:0,49	98 074	1:8,0	3,9
west	536	445	0,83	2,5	168(38 %)	125(28 %)	185	135	0,58:042	169 132	1:5,6	2,8
Masvingo	735	768	1,04	2,0	363(49 %)	114(15 %)	383	271	0,59:0,41	240 283	1:4,8	5,4
Matabeleland												
north	340	348	1,02	2,4	160(47 %)	91(26 %)	132	125	0,51:0,49	102 679	1:5,2	1,4
south	379	375	0,99	2,1	175(46 %)	90(24 %)	169	116	0,59:0,41	108 609	1:5,1	1,6
Midlands	746	825	1,11	2,1	397(48 %)	132(16 %)	374	319	0,54:0,46	262 761	1:4,7	4,5
Zimbabwe	4 714	4 271	0,91	2,2	1 933(41 %)	853(20 %)	1 915	1 503	0,56:0,44	1 308 577	1:6,5	3,4

A No. of households interviewed
B No. of dogs in interviewed households
C Ave no. of dogs/household
D Ave no. of dogs/household in dog-owning households
E No. of households with dogs (% of total)
F No. of pups in interviewed households (% of total)
G No. of adult male dogs in interviewed households
H No. of adult female dogs in interviewed households
I Sex ratio (♂:♀)
J Extrapolated no. of dogs in 1986
K Ave dog:human ratio
L Ave no. of dogs/km^2

TABLE 5 Distribution of characteristics of dog population surveyed by land use in Zimbabwe (from Brooks 1990). Key for heading is listed below Table 4

Land use sector	A	B	C	D	E	G	H	I	F
Urban	868	235	0,25	1,7	136(16 %)	112	84	0,57:0,43	39(17 %)
Communal lands	2 736	3 252	1,19	2,2	1 480(54 %)	1 473	1 109	0,57:0,43	670(21%)
Large scale commercial farms	691	120	0,17	2,4	49(7 %)	52	29	0,64:0,36	39(31 %)
Small scale commercial farms	240	446	1,86	2,9	156(65 %)	183	186	0,50:0,50	77(17 %)
Resettlement areas	179	218	1,22	1,9	113(63 %)	95	95	0,50,0,50	28(13 %)
Zimbabwe	4 714	4 271	0,91	2,2	1 933(41 %)	1 915	1 503	0,56:0,44	853(20 %)

TABLE 6 Summary of the characteristics of the dog population of Maboloko town, Bophuthatswana (from Rautenbach *et al*. 1991)

Human:dog ratio	11,1:1
Dogs/dwelling	0,68
Male:female ratio	5,6:4,4
Mean age	30,8 m (range 3–96)
Unrestrained	58 %
Chained at times	15 %
Permanently chained	26 %
Permanently in cages	1 %

In South Africa, Rautenbach, Boomker & De Villiers (1991) gathered some data on the dog population of Maboloka town in Bophuthatswana while studying their health status, and a summary of their results is presented in Table 6. In Kenya, the study of Perry *et al.* in a high-density suburb of Nairobi found the mean age of dogs to be 3,1 years (± 2,5) and the male:female ratio to be 6,4:3,6. About 80 % of dogs encountered had not previously been vaccinated against rabies.

CONCLUSIONS

In much of eastern and southern Africa, the major constraints to dog rabies control are logistical and economic rather than technical. These logistical and economic constraints comprise principally the accessibility of dogs to vaccination, the availability of rabies vaccines and the cost of vaccines. It is considered that the accessibility of dogs to vaccination can be improved substantially through better targeting of rabies vaccine delivery to those sectors of the dog population of greatest importance in their capacity to transmit rabies. Studies of dog ecology will permit such sectors of the dog population to be more clearly identified and will facilitate the development of more efficacious methods of accessing them with parenteral and, in the future, oral rabies vaccines. Well structured dog ecology studies will also generate data, which, in conjunction with data on the epidemiological characteristics of rabies in dog populations, will allow the development of quantitative models of dog rabies and its control, which could form the basis for decision support systems for use by governments, rabies control officers and veterinarians in the future.

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