Chapter 4
Disease, Domestic Dogs and the Ethiopian wolf: the Current Situation

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Introduction

Disease can play a pivotal role in the dynamics of endangered species and populations, but is nonetheless a relatively neglected issue in conservation biology. Pathogens can affect the size and viability of populations both directly, through effects on the hosts' survival and reproduction but also indirectly, by altering their behaviour, movement patterns, social system and community structure. Although in many cases an outbreak of disease may not directly extinguish a population, rapid population declines to very low levels may result, with increased susceptibility to chance events (Soulé 1987). Disease can also cause either single or repeated population bottlenecks and the loss of genetic variability.

Epidemiological theory highlights the importance of N_t, the threshold density and CCS, the critical community size, of susceptible host populations required for a disease to become established and to persist (Bartlett 1957, Anderson and May 1991). Large population sizes may be required to allow the persistence of the pathogen, particularly if the pathogen is highly virulent and is rapidly transmitted. The small population size of endangered species or populations is likely to preclude them from maintaining species specific pathogens that are a major threat to their viability. Thus pathogens which utilize a range of host species present the greatest threat to small populations (McCallum and Dobson 1995). Indeed, the majority of pathogens involved in declines of endangered populations or in extinctions have been independently maintained in other, reservoir, species which acted as the source of infection. In some cases, the pathogen may be more virulent in the "spill-over" endangered host or species than in the reservoir hosts, where coevolution between host and pathogen may have occurred.

With an increase in populations of humans and their domestic animals and a consequent increase in contact and conflict between domestic animals and wildlife, the frequency of transmission of common pathogens of domestic animals to wildlife is likely to increase. This is particularly true when the endangered population becomes fragmented and interactions, including hybridization, between domestic and wild species increase. For example, infection of European wildcats (*Felis silvestris*) with feline pathogens occurs in areas where domestic cats are common in rural areas and where hybridization also occurs (McOrist *et al.* 1991, Yamaguchi *et al.* 1996).

Although endangered species or populations may have small population size, locally high densities and certain social system may favour rapid pathogen transmission between individuals. Where small populations have reduced genetic variability due to past bottlenecks and inbreeding, loss of genetic diversity at immune system loci may increase susceptibility to a disease outbreak (O'Brien and Evermann 1988). In addition, repeated disturbance or stress, sometimes common in endangered populations, may predispose the establishment of infection.

This chapter aims to review the potential and current problems posed by disease transmission to Ethiopian wolves and show that domestic dogs are central to this conflict. It outlines potential management solutions to the problem, including that of dog population control, and discusses briefly some outstanding issues surrounding intervention in the situation. It is clear from this review that we do not yet have sufficient information to put forward detailed arguments on the advantages and disadvantages of each potential management action. However, the information that is urgently required is highlighted both in this chapter and in Chapter 10, the Action Plan. Clearer still, however, is that fast action is imperative.

Disease in Wild Canid Populations: the Potential

Disease has been shown to be a potent force affecting wild carnivore species and canids in particular. Three pathogens, rabies virus, canine distemper virus (CDV) and canine parvovirus are of special importance because of their worldwide distribution and pathogenicity. These generalist pathogens have been responsible for severe declines, in some cases to the brink of extinction, in a number of endangered species and populations (*e.g.* Guiler 1961, Thorne and Williams 1988, Macdonald 1993).

Rabies

Rabies virus causes, once clinical signs develop, an almost invariably fatal encephalitic disease in a wide range of mammalian species including humans, although successful transmission may depend to a degree on strain type and host (Cleaveland and Dye 1995). The rabies virus is excreted in the saliva of infected hosts and thus is most successfully transmitted to other hosts by biting.

For public health reasons rabies is probably the best studied canid pathogen. The virus is widespread in Africa and infects both domestic and wild species. The current increase in domestic dog and wildlife rabies is a cause for concern both for public health and for the conservation of endangered canids (Macdonald 1993, 1996). The conservation significance of this disease has been illustrated by outbreaks in the rare Blanford's fox (*Vulpes cana*, Macdonald 1993), the endangered African wild dog (*Lycaon pictus*, Alexander *et al.* 1992, Gascoyne *et al.* 1993) and the Ethiopian wolf (Sillero-Zubiri *et al.* 1996*a*). The effect of the disease can be devastating, whole groups of wild dogs, Ethiopian wolves and bat-eared foxes (*Otocyon megalotis*) have been wiped out (Gascoyne *et al.* 1993, Sillero-Zubiri *et al.* 1996a, Maas 1993).

In most situations in Africa domestic dogs are the reservoir hosts for rabies virus, capable of independent maintenance of disease and acting as sources of infection for other species. However, in some areas, where wild hosts occur at a reasonably high density, the rabies virus is maintained without the involvement of domestic dogs. In southern Africa mongooses are the reservoir species for the viverrid strain of rabies virus and black-backed jackals (*Canis mesomelas*) and bat-eared foxes are reservoir species for the canid strain (King *et al.* 1993, Swanepoel *et al.* 1993). Whether or not domestic dogs are the reservoir for rabies, they are the source of over 90% of human cases (WHO 1992). Similar situations occur with the red fox (*Vulpes vulpes*) in Europe and raccoon (*Procyon lotor*) and skunk (*Mephitis mephitis*) rabies in the USA (Carey *et al.* 1978; Winkler & Jenkins 1991, Charlton *et al.* 1991), where host-adapted strains persist in wild species.

Canine Distemper

Canine distemper virus, another generalist pathogen, is a common, highly contagious disease of domestic dogs and some wild carnivores. Canine distemper is transmitted by direct aerosol contact and is endemic in most areas of the world, except perhaps in hot, arid regions where the virus is rapidly inactivated by sunlight (Appel 1987). Morbidity and mortality can be significant in susceptible populations, with death occurring in 30–80% of infected dogs. Clinical signs are highly variable and include inappetance, a serous or purulent nasal and conjugal discharge coughing, vomiting, thickening up of the footpads and, if the disease progresses, nervous signs.

Apart from domestic dogs, all canids, mustelids, procyonids and some viverrids, hyaenas, ailurids and felids are susceptible to the disease. Canine distemper may have caused the extinction of the thylacine (Tasmanian wolf, *Thylacinus cynocephalus*) in the first decade of this century (Guiler 1961) and certainly drove the black-footed ferret (*Mustela nigripes*) to the very brink of extinction when it wiped out the remaining individuals in the wild and severely affected the captive breeding programme (Williams *et al.* 1988). The disease is a major source of mortality in grey foxes (*Urocyon cinereoargenteus*) in the southeastern USA (Davidson *et al.* 1992) and recently, killed nearly a third of the Serengeti lion population, with further cases in hyaenas and bat-eared foxes (Roelke-Parker *et al.* 1996). In addition, at least two groups of the endangered African wild dogs disappeared in the Mara-Serengeti at the time of a distemper epidemic amongst sympatric domestic dogs (Alexander and Appel 1994). Both dogs (Cleaveland 1996) and wildlife (Gorham 1966, Appel 1987) have been proposed as reservoirs for CDV. With canine distemper clearly a major threat to endangered carnivores control will not be effective without identification of reservoir species.

Canine Parvovirus

Canine parvovirus is also highly contagious, with large amounts of virus found in the faeces of infected dogs with the enteritic form of the disease. Recovered animals may shed the virus for weeks following infection and the virus is quite stable, thus infected areas can harbour virus for long periods, up to six months in temperate climes. The natural host range of canine parvovirus is undetermined but most canids appear to be susceptible. The disease emerged in the late 1970s and was pandemic amongst domestic dogs by 1980 (Appel and Parrish 1987) and epidemics have been reported in a range of captive canid species (Mann *et al.* 1980). Two synodromes have been described. If offspring from non-immune mothers are infected in the first eight weeks, myocarditis occurs leading to acute or more gradual heart failure. More commonly, in older pups and adults, enteritis occurs with vomiting and then diarrhoea, which can be haemorrhagic. The need for the virus to replicate in dividing cells accounts for the symptoms seen in different age hosts. Primary epidemics have given rise to mortality in all age groups, but in endemic areas, disease is usually seen only in pups. Thus, once the virus has entered a population, it is likely to cause only sporadic deaths amongst young animals. Serological surveys for CPV−2 antibodies among free-ranging canids have revealed prevalence from 32≥70%, thus providing evidence for circulating virus in the wild, even though the significance of such infections is unknown.

Other major pathogens that can cause clinical disease and mortality in domestic dogs include *Canine adenovirus*, *Bacillus anthracis*, *Leptospira*, *Bordetella*, *Mycobacteria* and the tick-borne pathogens *Ehrlichia canis* and *Babesia canis*. The significance of these infections in wild canids is generally unknown, although anthrax has caused mortality in free-living African wild dogs (Turnbull *et al.* 1991, Creel *et al.* 1995) and jackals are susceptible to *E. canis* and *B. canis* (van Heerden 1979, 1980).

Ethiopian Wolves and Domestic Dogs: the Problem

The presence of large numbers of domestic dogs in Ethiopian wolf habitat is the most immediate threat faced by the Ethiopian wolves in BMNP. Domestic dogs pose a threat to their wild relatives in three ways, by competition for food, by transmitting diseases and by hybridization. The background to the hybridization problem is discussed more fully in Chapter 5, and here we concentrate predominantly on disease issues.

Domestic dogs are present throughout most of the known range of Ethiopian wolves in BMNP and also at higher densities in the villages and settlements around the protected areas. Dogs are kept to guard livestock from predators, notably spotted hyaenas. Generally these dogs are semi-feral, supplementing a meagre diet of whey, grain and scraps with carrion and garbage. In the park the dogs range across wide areas of wolf habitat and also forage on rodents, the main food resource for the wolves. Wolves normally avoid direct contact with dogs, but in all interactions observed, dogs chased wolves away (Chapter 3). However, genetic testing has confirmed suspicions that male dogs have bred with female Ethiopian wolves (Gottelli *et al.* 1994). Dogs also travel regularly with their owners in and out of the mountains, thus there is ample opportunity for disease transmission between different areas. Dog density in the Web Valley, an area of optimal Ethiopian wolf habitat, was estimated in 1989 at 0.7 dogs/km² with an average of 11 dogs per settlement (Gottelli and Sillero-Zubiri 1990), but the present population size is unknown.

In recent years, the threat of disease to the Ethiopian wolf has become a reality and the consequences have been devastating. Interviews with local people in BMNP in the 1980s revealed the cyclic occurrence of an unknown illness, killing many domestic dogs and some Ethiopian wolves every 5−8 years (Gottelli and Sillero-Zubiri 1990). Rabies has been reported widely in domestic dogs in Ethiopia (Fekadu 1982, Mebatsion *et al.* 1992a). Its presence in the Bale Mountains area and the potential threat to wildlife was highlighted when a preliminary serological survey of canid sera revealed that eight of 10 dogs, two of 15 wolves and one golden jackal (*Canis aureus*) had detectable antibody against rabies virus (Mebatsion *et al.* 1992b). This, combined with reports from local hospitals of human rabies cases each year, suggests that rabies is endemic in the region.

The threat became reality when one, and possibly two rabies epidemics were identified in the Ethiopian wolf population. Between April and June 1990, 12 of 23 known individuals in Sanetti Plateau died or disappeared. A similar decline was observed between October 1991 and February 1992 in the Web Valley where 41 of 53 known wolves in five packs died or disappeared (Sillero-Zubiri *et al.* 1996a). Three of the Web Valley packs were decimated and eventually disintegrated. Close correlation between rates of known mortality and unaccounted wolf disappearance suggested that missing wolves died of similar causes to the ones found dead. While no definite cause was determined for the Sanetti decline in 1990, rabies virus was isolated from samples collected from three wolves found dead in the Web valley.

Rabies is thus the most likely cause of the dramatic decline in the Bale wolf population between 1989 and 1992. By 1995, however, the wolf population had slumped even further to just 120−160 adults (Chapter 2). Local people living in the Web Valley reported an outbreak in 1993−1994 of another dog disease, that they were adamant was not rabies; the clinical signs that they described were consistent with canine distemper virus infection. A limited serological survey in early 1995 of surviving domestic dogs confirmed that canine distemper was the most likely cause with all eight sampled dogs over two years of age being CDV seropositive, whereas nine of 10 younger dogs were seronegative (H. Thompson, unpubl. data). However, it is not known whether mortality occurred in Ethiopian wolves as the population was not concurrently monitored. This survey also revealed that canine parvovirus and adenovirus were also present in domestic dogs in the region with prevalence rates ($n = 18$) of 100% and 28% respectively (H. Thompson, unpubl. data).

The source of infection and routes of disease transmission to Ethiopian wolves are not known. Nevertheless it is most likely that domestic dogs are the reservoir of rabies virus and probably also CDV. First, there is no evidence that rabies can persist in small isolated populations; population size of Ethiopian wolves is almost certainly below that of the critical community size. Second, the rabies virus isolated from Ethiopian wolves was a minor variant of the serotype 1 rabies virus found in domestic dogs and wild canids in Africa (Sillero-Zubiri *et al.* 1996a). Removal or vaccination of the probable dog reservoir and the subsequent disappearance of disease from other species would be required to confirm dogs as reservoirs, an experiment that has not yet been carried out.

Nonetheless, golden jackals, spotted hyaenas (*Crocuta crocuta*) and smaller carnivores such as civets (*Civettictis civetta*) and mongooses are also found in and around BMNP and could be involved in the epidemiology of canid diseases. Indeed, rabies virus can persist in wild canid populations elsewhere in Africa (Swanepoel *et al.* 1993). Direct interactions have been observed between Ethiopian wolves and golden jackals, spotted hyaenas, serval cats (*Felis serval*) and honey badgers (*Mellivora capensis*) (Nicol 1971, Sillero-Zubiri 1994, 1996b). The density and population size of the wild carnivores in the region may be too low to allow pathogen persistence in any one species, but generalist pathogens could take advantage of the species mix.

Several characteristics of the Ethiopian wolf's ecology and behaviour may increase the likelihood of transmission within the population (Chapter 1). First, the social structure of individuals living in close-knit groups will accelerate transmission between individuals within the group. Behaviour within the group, such as frequent social greetings with direct oral contact and allo-grooming, close resting proximity and communal scent marking, will all increase the likelihood of intra-pack pathogen transmission. Second, Ethiopian wolves occur at naturally high local densities, of approximately one wolf/km², good conditions for the transmission of pathogens within the population. Third, pack ranges overlap by an average of 12%, with overlaps increasing during the mating season (Sillero-Zubiri and Gottelli 1995b). At this time aggressive encounters between packs, with chases and physical contact, also escalate. Fourth, the frequency of extra-pack copulation is high, thus transmission of pathogens between packs could be potentiated. Fifth, some dispersing females '*float*' between groups and thus have large home ranges and contact with several packs (Sillero-Zubiri *et al.* 1996b). Floating and dispersing females, particularly if prospecting for mates, could be responsible for transmission of disease over long distance and are more likely to have contact with domestic dogs.

No information is available on dog-wolf interactions in Ethiopian wolf populations other than in the BMNP, but contact between the species may be greater at the wolves lower altitudinal limit, where human density is higher (Chapter 3). Conflict is bound to increase in all populations with increases in human density and habitat fragmentation as wolves at the periphery of a population may be more exposed to contact with domestic dogs. Clearly, an assessment of the degree of conflict and contact between dogs and wolves is required for Ethiopian wolf populations other than in BMNP.

Potential Management Solutions

Domestic dogs undoubtedly pose a threat to the survival of Ethiopian wolves in the Bale region and possibly elsewhere. They are hosts for canid diseases, and hybridization with wolves occurs when male dogs breed with female wolves (Chapter 5). Land use pressures in and around the BMNP are severe and domestic animals are in increasingly frequent contact with wildlife. Local disease control measures are urgently required to counteract these problems, both to safeguard wildlife populations and to improve the welfare of local communities.

Control of Canid Diseases

A number of potential courses of action are available in the BMNP. The fundamental problem of overlap in range between dogs and wolves could be resolved by encouraging local people to leave the BMNP and refrain from using it for grazing their stock or as transport routes. However, such a strategy has been attempted in the past with little success (Hillman 1986). It seems certain that humans and their domestic animals will continue to live in Ethiopian wolf habitat. Thus the priority is to safeguard the Ethiopian wolves in areas of overlap.

Although we may assume that domestic dogs are the reservoirs of disease, without further knowledge of disease epidemiology in the Bale Region, particularly the role of wildlife, we should be cautious about making decisions as to the best management option (Karesh and Cook 1995). The epidemiology of many diseases of domestic animals is relatively well understood but there is comparatively little information on the occurrence and transmission dynamics of many diseases in wildlife and between domestic animals and wildlife. Basic epidemiological, demographic and behavioural data are now required so that local control programmes can be drawn up and targeted effectively. We need to know which species are affected by which pathogens, the prevalence and incidence of infection, geographical and seasonal patterns of infection, and we need to gather information on host population dynamics and behaviour.

On the assumption that dogs are the reservoirs of diseases threatening Ethiopian wolves, the chance of an

Table 4.1
Management options for the control of disease in the endangered Ethiopian wolf population of the BMNP

Option	Advantages	Disadvantages	Likely benefit/ chance of success
1. Do nothing	Cheap, easy, evades controversy.	Continuing high risk of disease outbreaks and EW population decline. No benefit or involvement of local people.	None
2. Reduce domestic dog density in BMNP and surrounds	Reduces pathogen transmission. Also reduces chance of hybridization.	Potentially severe cultural and logistical problems. No direct protection. Need for continuing and sustainable programme.	Dubious or limited in short term, perhaps better in long term.
3. Education programme and/or restrictions placed on dog movement	Reduces chance of hybridization. No direct intervention.	Long term work to build up good relations between local people and park. Continuing programme needed.	As above
4. Vaccinate domestic dogs against rabies and CDV	Reasonable feasibility. Local people benefit directly through reduced health risk to themselves, their livestock and their dogs.	Cost. Need for continuing and sustainable programme. Cannot guarantee prevention of disease outbreaks in wildlife. Dog population may increase.	Good
5. Vaccinate Ethiopian wolves	Direct protection of individuals.	Cost. Need for continuing and sustainable programme. Intervention required for CDV as oral preparation not available. Killed CDV vaccine ineffective. Protection of only those individuals directly vaccinated, and difficulty in reaching all the population. No vaccines tested for safety and efficacy in wolves. Safe and effective oral vaccines for CDV not available.	Good for rabies. Poor to none for CDV

outbreak of disease in Ethiopian wolves potentially could be reduced by a number of strategies. These include reducing the domestic dog population, vaccinating domestic dogs to increase “herd” immunity (the protection of susceptible individuals in a population by immunisation of a proportion of the population, to reduce pathogen transmission), educating owners to prevent contact between dogs and wolves and by vaccinating individual wolves. The major advantages and disadvantages of alternative strategies, which are not mutually exclusive, are outlined below (Table 4.1).

Consideration of management options raises a number of issues, of both a philosophical and scientific nature. These must be discussed and resolved before a course of action is decided and action implemented. An attempt to discuss some of these issues follows.

Is Intervention Justified?

Before the pros and cons of the different options outlined above can be discussed, there are philosophical arguments on whether human intervention in a “natural” process is acceptable, even when a disease is identified as an obvious threat to an endangered species. The crux of this issue is whether a particular pathogen arises “naturally” in the endangered host. If the pathogen is introduced by human activities via their dogs, then it is not a natural process and justification for action is considerably less controversial. This issue is clearly hard to resolve in most cases, as very little is known about the long term effect of diseases on wild populations and historical processes. In the Bale Region, however, the growth in the size of the local human and dog populations suggest that problems for Ethiopian wolves associated with disease and domestic dogs are human-related and may have increased relatively recently, although humans may have visited some areas of Ethiopian wolf habitat for centuries. Clearly, further research would be desirable to establish whether these pathogens occur naturally in the population and, if so, the frequency at which they occur. Nevertheless, it would seem reasonable to attempt to repair some of the damage that humans and their dogs have done.

A second issue, often raised when the possibility of vaccination of the target species is considered, concerns selection for natural resistance. This argument is actually relevant when any form of intervention to reduce the incidence of disease is considered, not just when vaccination is considered. If a pathogen occurs naturally in a host population, it can exert a strong selective pressure on the evolution of host resistance to the pathogen. Vaccination against the pathogen will reduce the force of selection for this trait. Thus if re-exposure occurs in the future in the absence of a vaccination programme, higher levels of mortality may result. However, the evolution of resistance to a pathogen depends on a number of factors. First, the frequency of exposure to the pathogen must be great enough for alleles conferring resistance to give a competitive advantage and become more frequent in the population. If a pathogen invades only sporadically or is on a long term cycle, with no selective pressure to maintain allele frequency in intervening generations, there may be no overall increase in resistance. Although the periodicity of epidemics in domestic dogs may be frequent enough to select disease resistant alleles, we do not know whether pathogens reach wild canids each cycle. Second, the susceptibility of the host is important. High mortality rates increase the selective advantages of survival but virtually all individuals may succumb to infection. Thus it may be more justifiable to vaccinate against, say rabies, where the mortality rate is very high, than against canine distemper, where survival from infection is more frequent and selection for resistance has greater material on which to act.

In the Ethiopian wolf situation, all the available evidence suggests that the canine pathogens that can affect Ethiopian wolves are human and domestic dog associated, which reduces the relevance of this argument against intervention. Nevertheless, the incidence of infection in wild canids could still be frequent enough, even as a spill-over host, for selection for disease resistance. However, as we do not have the required historical knowledge, nor the required epidemiological information, it is difficult to support or refute the relevance of this issue to the Ethiopian wolf’s predicament.

Deliberations over Vaccination

Although only directly applicable when considering the vaccination of Ethiopian wolves themselves, the guidelines set out by Hall and Hardwood (1991) on the evaluation of the need to vaccinate wildlife provide a useful framework when vaccination of dogs or wild canids is considered. Five key questions are highlighted by these authors. First, what is the potential effect of disease on the population? Second, what are the overall aims of the proposed vaccination programme? Third, what is the availability and trial status of possible vaccines? Fourth, what are the risks associated with that vaccine? Finally, how should a vaccination programme be designed? For the Ethiopian wolf, some of these questions are easily answered, but others highlight gaps in our knowledge and the available technology. It is clear that disease, certainly rabies but probably also canine distemper, can cause severe and population-threatening mortality in Ethiopian wolves. The aims of a vaccination programme should be to reduce mortality due to disease in Ethiopian wolves. This could be accomplished by direct vaccination of wolves and/or by establishing herd immunity in the potential reservoir, domestic dogs, thus reducing the chance of disease transmission to Ethiopian wolves. However, further research is required to establish whether dogs are a reservoir for these diseases, the role of wild canids in maintaining pathogens and the proportion of dogs that must be vaccinated against different pathogens to increase 'herd immunity" to a level where the population size of susceptible hosts becomes insufficient for pathogen persistence.

Vaccine availability: vaccination is the only effective method of control for most viral diseases because of the lack of chemotherapeutic antiviral agents. As a result, the development of viral vaccines is, in many ways, more advanced than that of their bacterial counterparts. Nonetheless, vaccines of an appropriate type have not necessarily been developed and excessive environmental exposure to virulent virus may still overcome levels of antibody protection that would be adequate under normal circumstances. At present, there are three main types of vaccines used commercially. Killed or inactivated virus vaccines are produced when the virus is treated in some way, usually with chemicals, so that the virus cannot replicate or cause disease but can still stimulate an immune response. There is no risk of vaccine-induced disease when an inactivated vaccine is used. The major drawback with this type of vaccine is that immunity may not be robust and long-lasting; several initial doses or booster doses may be required. In particular, killed canine distemper virus vaccines do not consistently confer protection. Killed vaccines against rabies are more effective.

The second type of vaccine available is the modified live, or attenuated vaccine. Viruses can be attenuated by repeated passage in tissue or animal culture, so that their virulence is markedly reduced. Attenuated vaccines have been developed for parenteral use against both CDV and rabies infection and for oral use against rabies. Oral live rabies vaccines have been extensively and successfully used to control rabies in foxes throughout Europe (Winkler and Bögel 1992), but their use in other species requires further development. One problem associated with the use of live attenuated vaccines is residual virulence. Although in the target species vaccines may cause a relatively mild disease, this is not necessarily the case in non-target species (Montali *et al.* 1983). Live attenuated CDV vaccine has caused deaths of African wild dogs (Van Heerden *et al.* 1989, Durchfeld *et al.* 1990), black-footed ferrets (Carpenter *et al.* 1976) and bush dogs *Speothos venaticus* (McInnes *et al.* 1992). However, the chance of viral reversion is dependant on the strain of virus used in the vaccine (W. Baxendale, pers. comm). Thus although a live vaccine is available and would be suitable for use in domestic dogs, the risk of inducing CDV infection in wolves may be too high to even contemplate a trial, although some vaccines would probably be safe. A further problem with live vaccines, particularly in tropical countries, is the need for a cold-chain to maintain their effectiveness.

Finally, genetically manipulated recombinant vaccines in which a gene responsible for inducing immunity has been incorporated into the genome of a relatively innocuous carrier virus genome have been developed for rabies virus. This single rabies gene is not infectious and cannot cause disease. Oral recombinant vaccines using a vaccinia virus carrier have been successfully used against rabies virus infection of dogs, red foxes and raccoons (Blancou *et al.* 1986, Baer 1988) but such vaccines against CDV are still at a preliminary experimental stage (Taylor *et al.* 1991). The safety of these recombinant vaccines has not been universally accepted as some scientists question whether there is a risk that they may recombine with naturally occurring viruses. Nevertheless considerable research has been carried out on baits and vaccine delivery systems for rabies in both urban and rural areas (WHO 1994) which could be drawn upon and applied in BMNP and its surroundings.

Although safe and effective vaccines against rabies and distemper are available for domestic dogs, the efficacy and safety of vaccines for Ethiopian wolves is unknown. In addition, a gap still remains between the available technology and its application in developing countries. The control of other canid diseases at the population level is even less well developed. Thus research into alternative control programmes, their feasibility and cost-effectiveness is essential.

Interference for vaccination: vaccination requires interference with the individual hosts and this may be a particular concern, particularly when endangered species are involved. Clearly, oral vaccination is the route of choice for both domestic and wild hosts, as no direct handling is required. Unfortunately this type of vaccine is the most poorly developed and it is also difficult to know whether the animal has been exposed to vaccine, even if the bait is taken. Parenteral vaccination (vaccine administered by injection) is thus presently the only route of vaccine administration available in many situations. This may be carried out by darting or may require capture and/or immobilisation. The capture and handling required may therefore present severe logistical difficulties, even for feral or semi-feral domestic dogs such as those in the Bale area which are not routinely handled. In addition, the repeated handling required for administration of booster, or repeated vaccination by dart, may be deemed too intrusive for an endangered population. Burrows (1992) put forward the hypothesis that the stress of a single dart vaccination or immobilisation caused the recrudescence of rabies several months later in wild dogs in the Serengeti National Park. Although this hypothesis was not supported by other authors (Macdonald *et al.* 1992, Creel 1992, Ginsberg *et al.* 1995) on the grounds that there was no evidence that this type of intervention caused the long term stress required for the validity of this hypothesis, nor was there evidence that these wild dogs died of rabies, nor that the rabies virus could be latent. However, some workers still favour the hypothesis (Burrows *et al.* 1994), although the most recent synthesis by Woodroffe *et al.* (1997) does not support it.

Programme design and sustainability: two further points are highlighted by Hall and Hardwood (1991) and should be considered. First, they emphasize that it is important to recognise the long term commitment involved in a vaccination programme and thus ways of designing a sustainable programme must be explored. However, this commitment is required for all the possible management options available, except of course that of inaction. In a developing country with relatively poor infrastructure, the potential for maintaining a vaccination programme might appear to be slight, but such programmes have been sustained for a significant length of time in a considerable number of countries. For example, the successful reduction in the incidence of rinderpest in Africa is attributable to a long term vaccination campaign. Similarly, after a vaccination campaign was mounted, rabies was absent in the Mara region of Tanzania between 1958–1977 (Magembe 1985). Clearly, some form of outside revenue or assistance would increase the likelihood of success. Recently, money for CDV vaccine in the Ngorongoro region of Tanzania was raised from cinema audiences and tourists. If the will is present, there are many such avenues to explore.

Second, prophylactic vaccination (or any other management option) is likely to be more effective than action in response to a disease outbreak. As disease surveillance in the region, particularly in wildlife, is difficult and currently limited, many individual animals may have already been exposed to the disease by the time it is noticed. In other words, problems with disease in the Ethiopian wolf should be tackled before another epidemic occurs.

Dog Population Control

The population size and distribution of domestic dogs in BMNP must be managed for three reasons. First, domestic dogs are hybridising with Ethiopian wolves, a situation which probably worsens where wolf populations are small; emigrating female wolves may be more likely to find and mate with a domestic dog than an Ethiopian wolf. Second, if mortality due to disease is reduced in the domestic dog population, there is potential for an increase in population size if disease is limiting or regulating the population. Such action would be irresponsible without simultaneous action to control dog population size and reproduction. Third, a reduction in the dog population size or in its mixing rates may decrease the spread of disease.

Options to control the dog population within BMNP and/or the surrounding area include the removal or culling, of either one or both sexes, tighter control on dog movements and the sterilisation of one or both sexes by surgical, chemical or immunological means (WHO/WSPA 1990). Some advantages and disadvantages of these options are outlined in Table 4.2. However, it is not immediately clear which is the best course of action, although it would appear that technological constraints preclude the most logistically attractive option: long-acting oral contraceptives are not currently available. Of the other options, direct culling of the host population has been used in a number of situations in an attempt to control the spread of rabies (Wandeler 1991). The effectiveness of this method at reducing disease is, however, limited because of the resilience of a host carnivore population with high reproductive potential and high carrying capacity (Wandeler 1991). In addition, culling is rarely acceptable to the local community. In Bale, periodic culling of domestic dogs in urban areas has been instigated in the past. While this was acceptable when culling involved stray dogs in towns, it was not tolerated inside BMNP where dogs had a direct function as guard dogs (Sillero-Zubiri, pers. obs.)

Thus, alternative methods of population control must also be investigated. If prevention of hybridization were the priority, control could be targeted at male dogs within and close to BMNP. Male dogs currently living in BMNP could be removed, or a longer term strategy adopted where local people could be asked or forbidden

Table 4.2
Management options aimed at controlling the size of dog population in the Bale Region and preventing dog–Ethiopian wolf hybridization

Option	Advantages	Disadvantages	Likely chance of success
1. Do nothing	Cheap, easy, evades controversy	Problems remain	None
2. Removal of:			
a) male dogs	Reduces hybridization risk substantially, female dogs meet people's requirements	No reduction in population size	Good for prevention of hybridization. Low for population and disease control
b) all dogs from BMNP and surrounds	Also reduces reproductive rate of population and disease transmission	Loss of dogs for guarding livestock. Low acceptability?	Good, if acceptable
3. Sterilisation of:	As above	Cost, sustainability. Technically difficult	
a) male dogs	Reduces hybridization	No reduction in population size	
b) female dogs	Reduces reproductive rates of population	No direct reduction of hybridization risk	

from acquiring new male dogs, or to exert tighter controls on the movements of their dogs. Alternatively, or in combination with the above strategy, male dogs could be castrated. This strategy would probably have little impact on the size of the dog population, as it would be impossible to reach every male dog. Thus, female sterilisation on a large scale would be required to control the reproductive rate of the dog population as a whole if this were the priority.

Further research is clearly required before a course of action can be decided, to assess the feasibility and effectiveness of implementing canine contraception in this rural community and to determine priorities (see appendix). This will involve investigation of the views and needs of the local people and the role of dogs in local culture (WHO/WSPA 1990). Without the cooperation of the local people, any action to control dog population size will be ineffectual in the long term and so considerable input into the development of good community relations is required. Technical research into the development of sterilisation techniques (*e.g.* immuno-contraceptives – Bradley 1994, Tyndale-Biscoe 1994), preferably those that can be administered orally, is still at preliminary stages but must be encouraged. Once techniques have been developed, field personnel must be trained so that the programme can be continued with minimum further assistance (Karesh and Cook 1995).

Appendix
Recent Developments in BMNP: Situation Assessment

Between January and March 1996 Karen Laurenson and Fekadu Shiferaw visited BMNP in an attempt to gather additional background information to evaluate the management options available to control domestic dogs and their diseases (Laurenson 1996). Here we provide recent information not included in the main text of this chapter.

Dog density in rural areas north of BMNP averaged 16 dogs/km² or one dog per 4.6 humans. In urban areas there was a higher dog density, but the dog:human ratio was lower. Towns acted as population sinks for rural dogs and harboured a higher proportion of unowned dogs. The annual growth of dog populations for areas without culling was estimated as 7.5%. The dog population was male biased in most places, probably as a result of the common practice discarding female pups. Dogs are rarely tied up and are difficult to handle as religious taboos forbid a close relationship between humans and dogs.

Rabies appears to be endemic in the area, with the incidence estimated to be as great as anywhere in the world. Economic losses per household were estimated at $7.5 per year. Anecdotal reports suggest that rabies prevalence in Bale has increased in recent years, which local inhabitants attributed to a concurrent increase in human and dog populations. Serological results show that canine distemper is also prevalent in the dog population and probably endemic, at least in densely populated areas. The need to establish the reservoir species for these canid pathogens was highlighted by local inhabitants reports of rabies in jackals and mongooses.

Analysis of serum samples from Ethiopian wolves (H. Thompson *et al.* unpub.), obtained between 1989–1992 revealed that canine distemper had invaded the wolf population prior to 1989, and 30% of the 30 wolves sampled were seropositive. Exposure of wolves to canine parvovirus was also detected, but only 10% were seropositive. In contrast, canine adenovirus might be endemic in the wolf population, with 67% seropositive. In the dog population, however, preliminary results suggest that this virus might be epidemic in some areas, raising the question of whether wild canids might be a reservoir.

Assessment of Options for Disease Control

Dog densities are much higher than the threshold that would reduce dog rabies from an endemic to an epidemic state. A reduction of the dog population of the magnitude required to control rabies is probably impossible, given the local perception that dogs are required as guards for houses and livestock. Compliance to restrain dogs and thus reduce disease transmission by reducing mixing rates, might be increased through a targeted education programme (Chapter 10). This programme would also help improve people's knowledge of how these diseases are transmitted and can be controlled. Ethiopian wolf vaccination is unfeasible at present, whatever the outcome of ethical debates. In contrast, a domestic dog vaccination programme may be feasible and is supported by the local communities, given the economic losses in livestock and public health problem. However this action should go hand-in-hand with a study of the role of wildlife in maintaining canid pathogens.

Assessment of Options for Dog Population Control and Prevention of Hybridization

Methods to limit the current growth of dog populations are available, but will require an extensive programme of owner education. Prevention of hybridization should be a priority and could be achieved by preventing the ownership of male dogs in the park and castration of the current dog population. This might be acceptable to owners as they prefer female dogs as guards, but help would be required to control female reproduction. Chemical control of female reproduction is acceptable to dog owners and has been requested by some. Otherwise pup euthanasia may be the optimal method of limiting birth rates, with culls used to control unowned dogs in urban areas. Local legislation should be drawn up to limit the number of dogs owned per household, dog registration and prevent the ownership of male dogs within the BMNP.

Various control measures regarding local domestic dogs could reduce the risks of hybridization and disease faced by Ethiopian wolves.

Recommendations

1. Control of Canid Diseases

a) An education programme should be instigated in the community to discuss how dog and zoonotic diseases are spread and how they can be controlled.

b) A dog vaccination programme should be initiated in and around BMNP against rabies and canine distemper, and possibly other canid pathogens. This will involve political negotiations and training of veterinary personnel.

c) Research into the possibility of using oral vaccines for dogs should be pursued and trials conducted.

d) Research into the most cost-effective method of vaccination should be conducted.

e) Epidemiological research should be extended to the North-east, East and South side of park, *i.e.* areas close to Sanetti Plateau.

f) Research should be conducted on the role of wildlife in the persistence of rabies and canine distemper. This can be done concurrently with a vaccination programme.

2. Control of Dogs and Their Reproduction and Measures to Prevent Hybridization

a) Education programmes to encourage responsible dog ownership and thus improve the proportion of dogs tied up should be adopted. These should incorporate discussions on dog behaviour, husbandry, development, training and control methods, the reproductive cycle of dogs and how dog reproduction can be limited, how litter and waste should be disposed
and the implementation of a dog registration scheme.

b) Discussion with local communities to reach agreements on local legislation to control dogs, in particular:

i) All male domestic dogs living within and immediately adjacent to Ethiopian wolf habitat should be castrated either surgically or chemically. In future park inhabitants should only be allowed to own female dogs,

ii) EWCO should give material help and provide means to control female dog reproduction in Ethiopian wolf habitat,

iii) No more than two dogs should be owned per household,

iv) All domestic dogs found roaming loose in National Parks should be destroyed,

v) The need to control urban dogs remains inescapable, and liaison should continue with the authorities in a quest for the most humane method.