Status Survey and Conservation Action Plan

The Ethiopian Wolf

Compiled and edited by
Claudio Sillero-Zubiri and David Macdonald

IUCN/SSC Canid Specialist Group

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Preface

The Ethiopian wolf is an endemic and highly endangered canid which lives in the highlands of Ethiopia. The majority of the remaining wolves are to be found in Bale Mountains National Park (BMNP), which supports the necessary afroalpine ecosystem.

The major threats to Ethiopian wolves in BMNP are habitat destruction, competition for food, and hybridization with and disease transmission from domestic dogs. These problems are fundamentally associated with human settlement in BMNP and its buffer zone.

Research activities have been conducted by expatriates and native Ethiopians on the ecology, behaviour and disease of Ethiopian wolves. Studies have revealed a dramatic decline in the Ethiopian wolf population due to the aforementioned factors.

A fundamental solution requires us to devise a strategy which discourages the settlement of local people in BMNP, thus reducing the pressure that inevitably results from their domestic animals grazing the fragile ecosystem. In addition this will mitigate the unwanted dog population. The disease problem can be alleviated by vaccination of domestic dogs and wolves preferably using oral vaccines in bait. Routine contraception of local dogs may also reduce hybridization between dogs and wolves.

Short and long term action plans for the preservation of the Ethiopian wolf in its native habitat need to be developed in sympathy with the requirements and views of the local community. The involvement of international bodies in further research implementation of proper management practices in order to achieve this final goal is highly appreciated.

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Foreword

For centuries canids have impinged upon the human mind in fables, literature and daily life. We have taken the dog into our home, made the grey wolf a totem of wilderness, and reluctantly admired the red fox's ability to outwit us. Although we view many species as competitors, we also admire their hunting skills, elegance, and devoted family life. Highly adaptable, most species have endured in spite of relentless persecution, habitat destruction, and decimation of their prey. Yet only the Falkland Island wolf has in recent times become extinct. Of the 34 remaining canid species, the Ethiopian wolf could be the next to lose its place on earth. It is now the most endangered of the canids, perhaps only 400 surviving in a few highland tracts in Ethiopia. What can be done to save this strikingly handsome creature?

Conservation and management programmes must be built on sound knowledge, a fact all too often ignored by conservation organizations which may fund cursory surveys but hesitate to invest in the long-term field work that is needed to elucidate the biology of a species. The Ethiopian wolf has been fortunate that Claudio Sillero-Zubiri and Dada Gottelli were able to devote years to chronicling its life. With perseverance and dedication they gathered data on home ranges, territoriality, dispersal patterns, food habits and other aspects of biology, as well as on the dangers threatening the species, from hunting and habitat modification to hybridization with domestic dogs. At the same time the investigators became familiar with the local peoples, learning of their problems and aspirations, and they were able to seek their support for a conservation effort. This Action Plan, written by Claudio and David Macdonald, is thus based on critical information and comprehensive knowledge about the Ethiopian wolf and its environment. Because of this, their plan is insightful, realistic, authoritative, and innovative, a solid prescription for providing the Ethiopian wolf with a future.

However, the Action Plans represents more than just a blueprint for the survival of the Ethiopian wolf. Though this animal is a natural icon of the Ethiopian highlands, it is only one of many endemic and other species there. The goal is to protect and manage a whole unique Afroalpine ecosystem, for the benefit of plants and animals, including the local peoples whose future also depends upon the health of the land.

The local peoples, the Ethiopian government, and the international conservation community must now cooperate to implement this Action Plan. The struggle to save the Ethiopian wolf is a task of decades, requiring constant vigilance. This plan represents an affirmation of hope that the species will not vanish quietly into oblivion.

Dr George B. Schaller
Wildlife Conservation Society

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Appendix: A Resolution Supporting a Captive Breeding Programme for the Ethiopian Wolf

The Ethiopian wolf (*Canis simensis*) is the rarest canid in the Old World; the species is found only in a few isolated mountains of Ethiopia. Fewer than 500 adult animals survive, most of them in the Bale Mountains. This represents a decline of 30% of the known population in the last two years. The reasons for the decline in population levels are numerous: loss of habitat; habitat fragmentation; disease; and persecution by pastoralists. Additional threats to the ever smaller populations include inbreeding and loss of genetic diversity and those arising from sympatric populations of domestic dogs, *i.e.* competition, disease and risk of hybridization.

Ethiopia, and the rest of the world, are at a great risk of losing the species if action is not taken immediately. Each of the remaining populations of Ethiopian wolf is faced with a near certain risk of extinction. Actions are required both in Ethiopia and elsewhere. In particular, we believe that immediate action is needed to obtain a representative sample of the population for intensive captive breeding.

To this end, The Canid Conservation Assessment and Management Plan (Canid-CAMP) Workshop, held under the auspices of the American Association of Zoological Parks and Aquariums Canid Taxon Advisory Group (AAZPA Canid TAG) and the IUCN Canid and Conservation Breeding Specialist Groups, strongly recommends the following actions to be taken immediately:

1) Establish an integrated in-country and out-of-country captive breeding program. The priority is to establish the program as effectively and quickly as possible. Each site has equal priority and efforts should be made to facilitate construction and implementation in Ethiopia and at an out-of-country facility. Because such facilities already exist at many out-of-country zoos and captive breeding centres, propagation outside the range state could proceed while an establishment is being built in Ethiopia.
2) We understand that the captive breeding of endangered species is a difficult task. The IUCN Species Survival Commission and the AAZPA Canid TAG offer the Ethiopian Government whatever technical assistance they require to pursue their goals. There is no previous experience in breeding Ethiopian wolves in captivity hence extensive research on husbandry techniques may be required. As a result, the out-of-country location(s), where expertise and extensive laboratory facilities already exist, may be able to offer the Ethiopian Government immediate assistance in establishing a protocol for captive breeding to be used at both the in-country and out-of-country captive sites. In the long term, in-country captive breeding offers direct access to, and simpler provision of, the unique prey and habitat the species requires for long term survival.
3) The establishment of a captive breeding program, while of critical necessity, cannot be seen as a replacement for further in situ habitat and species conservation and management.

We acknowledge the efforts to date of the Ethiopian Government and urge them to continue to support such activities. We also urge the world conservation community to support the lead role of the Ethiopian Government.

Signed:

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[1] *Canid CAMP workshop held in Texas, USA in May 1992 (Grisham* et al. *1994).*

Executive Summary

Ethiopia is blessed with extensive and unique environmental conditions. These have resulted in the evolution of a plethora of endemic animal and plant species, especially those confined to the afroalpine ecosystem. The future of several of these wildlife species is in question, due to the continuing and insidious pressures on the habitat and on the species themselves. The Ethiopian wolf is one of the many species endemic to the highlands of Ethiopia. With probably less than 400 adult individuals surviving, it is the most endangered canid in the world. The species is less common and has a more reduced range now than in the past. It survives in only a few mountain ranges and is in danger of extinction. The largest population is found in the Bale Mountains National Park. Elsewhere, Ethiopian wolves may be on the verge of extinction. With the probable exception of Menz and Arsi, remnant wolf populations are so small that they may not be viable.

The afroalpine range is threatened by loss of habitat to high altitude subsistence agriculture and livestock overgrazing. The small size and isolation of the remaining wolf populations have brought in new threats, such as inbreeding and loss of genetic diversity, and those arising from sympatric populations of domestic dogs such as disease and hybridization. Development in areas of Ethiopian wolf habitat may also have a negative impact upon its survival, with road traffic accidents and shooting bringing in new mortality factors. Each of the remaining populations could become extinct due to further destruction of habitat, inbreeding, hybridization or an epizootic decimating an entire population.

In view of the persistent human impact on the overall distribution of the Ethiopian wolf and its vulnerability to extinction, immediate action on three fronts is required to conserve the afroalpine ecosystem and its top predator. Protective measures in the case of the Ethiopian wolf require the consolidation of the management of protected areas, active efforts to monitor and protect its remaining populations, backed up by the establishment of a population management programme. This Action Plan provides a detailed strategy for the conservation and management of the remaining Ethiopian wolf populations. Better management in Bale and the Simien Mountains, and the establishment of other conservation areas in Menz and possibly elsewhere, will help protect the afroalpine ecosystem and many of its rare highland endemic plants and animals. Improved park patrolling, control of domestic dogs and community education, backed up by further epidemiological and demographic studies are required.

In order to ensure the long-term survival of the Ethiopian wolf, we advocate a mixed strategy of active population management. While we show that captive breeding *per se* will not suffice to protect the Ethiopian wolf, it will serve as another stepping stone to avoid extinction. A small captive breeding nucleus will contribute to the conservation of genetic variability and purity. This operation may take place in a future captive breeding facility or facilities in Ethiopia, for which proposals are being prepared and funding has been pledged. Each wolf population, including the captive one, must be considered as part of a global metapopulation, with some genetic flow occurring among them. Thus a limited number of captive-bred or wild-bred wolves may be exchanged between populations, reintroduced to areas where the wolves have been extirpated, or used to restock depleted populations.

The launch of such programme is dependant upon developments in funding, possible locations and Government approval. This population management strategy will be complementary to efforts to protect wild populations and their afroalpine habitats. Conservation priorities must be decided pragmatically with regard to the allocation of resources and manpower. Provided the Ethiopian authorities step up appropriate park management with increasing support from the international community, the Bale Mountains will remain the best refuge for the survival of these unique and fascinating canids. Menz may soon become a conservation area, providing protection for an additional wolf population. Ethiopia's current progress in securing long-lasting peace and stability may help secure more international funding for afroalpine conservation. We hope that by highlighting the plight of the Ethiopian wolf, and turning it into an Ethiopian flagship species, we will trigger renewed efforts to conserve the afroalpine ecosystem, and thus conserve many other of its less known endemic fauna and flora.

Chapter 1
Portrait of an Endangered Species

Scientific name:	*Canis simensis* Rüppell, 1835
Sub-species:	*C. s. simensis* Rüppell, 1835 *C. s. citernii* de Beaux, 1922
Important synonyms:	*Canis semiensis*, *Simenia simensis*
Common names:	Ethiopian wolf, Abyssinian wolf Simien or Simenian fox, red fox Simien jackal, Simenian jackal Ethiopian jackal, red jackal
Indigenous names:	*ky kebero*, *walgie* (Amharic) *jedalla farda*, *arouayé* (Orominiac)

Conservation Status

The Ethiopian wolf has been rare since it was first recorded by science, and already in 1938 it was listed as requiring protection (Harper 1945). It is one of two canid species listed by the IUCN Red List of Threatened Animals as *endangered*; the other is the North American red wolf *Canis rufus*. Ginsberg and Macdonald (1990) recommended in their Action Plan for the Canidae that the status of the Ethiopian wolf should remain as *endangered* until population levels have stabilized and protection of the different areas where it occurs is secured.

Although the species is very rare and is endangered, it is not listed by CITES, the Convention on International Trade in Endangered Species, since no poaching or legal trade seem to affect it. Thus, the species should not be included in CITES unless it requires protection from trade in the future.

The IUCN has recently revised its Red List categories and provided quantitative criteria to classify each species accordingly (IUCN 1994). The continued decline of the Ethiopian wolf's largest population in the Bale Mountains National Park (BMNP) has prompted the IUCN Canid Specialist Group (CSG) to re-evaluate the species' status based upon the new categories and criteria (Table 1.1). Classification as *Endangered* did not reflect the current predicament of Ethiopian wolves, and therefore the CSG recommended that the species should be reclassified as *Critically Endangered*, in acknowledgement of its extremely high risk of extinction in the wild. This transfer to a yet more precarious status was effected with no delay. The justification for reclassification was as follows:

Based on direct observation there was a substantial reduction of the BMNP population; a 22–55% population reduction in three years, or 65–75% in five years (Table 1.1, *A.1.a*). Based on an index of abundance available from the Sanetti Plateau in BMNP (Chapter 2) the average number of wolves sighted has declined steadily for at least the last 10 years with the average number of wolves seen dropping from 8.6 in 1983/1984 to less than one wolf in 1995 (*A.1.b*). Similarly, the absolute BMNP wolf population size has been estimated six times since 1976. Hillman (1986) estimated 700 wolves. By 1995 the population had declined to 120–160 (Sillero-Zubiri 1995), or by about 80% in the last 10 years. The recent population decline in Bale has been partly due to pathogens (rabies and possibly distemper), human persecution (road kills and shooting) and the population is further threatened by hybridization with domestic dogs (*A.1.e*).

Table 1.1
IUCN Red List Categories

Critically Endangered (CR). A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the following criteria:

A. Population reduction in the form of either of the following:
   1. An observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is the longer, based on (and specifying any of the following:
      (a) direct observation
      (b) an index of abundance appropriate for the taxon
      (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
      (d) actual or potential levels of exploitation
      (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.
   2. A reduction of at least 80 %, projected or suspected to be met within the next ten years or ten generations, whichever is the longer, based on (and specifying) any of (b), (c), (d) or (e) above.

B. Extent of occurrence estimated to be less than 100 km or area of occupancy estimated to be less than 10 km, and estimates indicating any of the following:
   1. Severely fragmented distribution or known to exist at only a single location.
   2. Continuing decline, observed, inferred or projected, in any of the following:
      (a) extent of occurrence
      (b) area of occupancy
      (c) area, extent and/or quality of habitat
      (d) number of locations or subpopulations
      (e) number of mature individuals.
   3. Extreme fluctuations in any of the following:
      (a) extent of occurrence
      (b) area of occupancy
      (c) number of locations or subpopulations
      (d) number of mature individuals.

C. Population estimated to number less than 250 mature individuals and either:
   1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer or
   2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals and and population structure in the form of either:
      (a) severely fragmented (i.e. no subpopulation estimated to contain mare than 50 mature individuals)
      (b) all individuals are in a single subpopulation.

D. Population estimated to number less than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or 3 generations, whichever is the longer.

Source: IUCN. 1994. IUCN red list categories. IUCN Species Survival Commission, Gland, Switzerland, 21 pp.

Although the area of occurrence for the species is larger than 100 km² it is severely fragmented, with wolf populations known from only five small isolated mountain ranges (*B.1*). At least two other populations have become extinct in the last 100 years (*B.2.d*), and the number of mature animals in BMNP has declined (*B.2.e*).

While the global population is currently estimated at 400 adults, only a fraction, probably less than the IUCN stipulated 250, are breeders (*C*). The current total estimate indicates a decline of at least 25% in the last three years (*C.1*), distributed in 5–7 populations of less than 100 breeders each (*C.2.a*). Finally, Vortex (Lacy 1993) simulations for the Bale Mountains population when using population parameters from the 1988–1992 study, always led to population extinction, since the population growth rate was negative during that period (*E*; Chapter 6). However, more refined population viability analysis is required.

Legal Status

The Ethiopian wolf is officially protected in Ethiopia. The Wildlife Conservation (amendment) Regulations 1974, include the species in Schedule VI: This states that the species "may only be hunted with special permit for scientific purposes – only to be issued by the Minister of Agriculture" (Negarit Gazetta 1974). No such permits have been granted in the last 15 years. No poaching, sport hunting and/or trade of live animals has been reported, although concern existed in the past of occasional sport hunters shooting and killing wolves unlawfully (Sillero-Zubiri 1989, Gottelli and Sillero-Zubiri 1990). Sport hunting in Ethiopia has been banned since 1993.

Occurrence in Protected Areas

Wolf populations and suitable habitat in Bale and Simien mountains are directly protected by inclusion in the BMNP and Simien Mountains National Park (SMNP) respectively. Over 1,000 km² of afroalpine habitats are included within BMNP, which is the largest range of afroalpine habitat in the continent, and the current wolf population is almost entirely restricted to the National Park, where until recently there was little human persecution. A different situation applies to the smaller SMNP, only 180 km² in size, a third of the afroalpine habitats in the Simien massif (Chapter 2). The activities of cowherds and farmers within the SMNP boundaries had an adverse effect on the wolf population and prey base. Most of the remaining wolf population in Simien may occur outside the SMNP (Hurni 1995). There are plans to extend the park boundaries to include at least part of that range.

Populations in west Bale Region (Somkaro/Korduro range) and Arsi Mountains (Mount Kaka and Mount Chilalo) are included within Hunting Areas under the jurisdiction of EWCO, and at least in theory they are afforded some protection.

Wolves also occur in an area proposed for protection, the Guassa range in Menz, Shoa Region. The afroalpine grasslands in Menz has been traditionally protected by the local Amhara people for the sustainable use of *Festuca* tussock grass as a communal resource (Mateos and Leykun 1992, Sillero-Zubiri 1995, Zelealem Tefera 1995). Access to the range is monitored and restricted, resulting in an abundant resident wildlife.

Taxonomy

The Ethiopian wolf belongs to the Order Carnivora, Infraorder Canoidea, Family Canidae, Subfamily Caninae (Wozencraft 1989). One of four *Canis* species

Ethiopian wolves in the afroalpine habitat of Sanetti Plateau.

in Africa, it is readily distinguishable from jackals (*C. aureus*, *C. mesomelas*, *C. adustus*) by its larger size, relatively longer legs, distinctive reddish coat and white markings (Sillero-Zubiri and Gottelli 1994). Clutton-Brock *et al.* (1976) noted that the Ethiopian wolf was the most distinct of seven *Canis* species, but suggested close affinity with the side-striped jackal (*Canis adustus*) and some South American zorros (*Dusicyon spp.*).

Gray (1868) classified the species in a separate genus *Simenia*, a taxonomy followed by Allen (1939). A recent phylogenetic analysis using a mitochondrial DNA sequence suggested that *C. simensis* is a distinct species, more closely related to the grey wolf (*C. lupus*) and the coyote (*C. latrans*) than to any African canid (Gottelli *et al.* 1994; Chapter 5). The Ethiopian wolf may be an evolutionary relict of a grey wolf-like ancestor which invaded northern Africa from Eurasia where fossils of wolf-like canids are known from the late Pleistocene (Kurtén 1968).

The Ethiopian wolf is often called the Simien or Simenian fox but is not closely linked to the fox (*Vulpes* – subfamily Vulpinae) group (Clutton-Brock *et al.* 1976). Gervais (1855), Gray (1868) and Rothschild (1901) preferred to call it the Abyssinian wolf. Throughout Ethiopia it is known by its Amharic names, "*ky kebero*" or "*kebero*", which translate as red jackal or jackal. In southern Ethiopia it is also known by the Oromo names "jedalla farda", or horse's jackal in the Bale Mountains, and "arouayé", or reddish, in Arsi Mountains (J. Malcolm, pers. comm.). In Gojjam it may be known as "walgie", meaning trickster (von Heuglin 1863). Other vernacular English names include Simien jackal, simenian jackal, red fox and Ethiopian jackal (e.g. Clutton-Brock *et al.* 1976, Sheldon 1992). The French name is "loup d'Abyssinie" (Gervais 1855), the German "Abessinische wolf" or "Abessinischen fuchs" (Emmrich 1985) and the Italian "volpe rossa" (de Beaux 1922).

De Beaux (1922) considered populations from opposite sides of the Rift Valley to be taxonomically distinct, describing the southern subspecies *C. s. citernii* based on the bright red coloration of some specimens. The two subspecies are currently accepted, based not on coloration but on skull structure, with the nasal bones from wolves southeast of the Rift Valley consistently longer than those from the typical race northwest of the Rift (Yalden *et al.* 1980).

Morphology

The Ethiopian wolf has long legs and a long muzzle, resembling a coyote (*Canis latrans*) in conformation and size. It has an elongated skull with a slender protracted nose and small and widely spaced teeth, especially the premolars. The adult pelage is soft and short, of a distinctive bright tawny rufous colour with a dense whitish to pale ginger underfur. The coat is lighter in juveniles, and turns to yellowish in females during the breeding season.

The throat, chest, a band around the ventral part of the neck, the underparts and inside of limbs are white, with the outline between the red coat and the white markings sharp and well defined. The ears are pointed and broad, their dorsal surface red fringed with long white hairs growing inward from the edge. The tail is a thick black brush with the proximal third white underneath.

Male Ethiopian wolves are significantly larger than females. In BMNP males were 20% larger than females in body mass and 7% larger on body dimensions. Adult males have a mean mass of 16.2 kg (14.2–19.3 kg) and females 12.8 kg (11.2–14.15 kg). For a detailed description of the species' morphology and craniometry refer to Sillero-Zubiri and Gottelli (1994).

Habitat Requirements

The Ethiopian wolf is a very localised endemic species and is confined to some isolated pockets of afroalpine grasslands and heathlands (Chapter 2), where they prey on afroalpine rodents (Sillero-Zubiri and Gottelli 1995a). In BMNP rodent biomass varies several-fold between different habitats, and the abundance of these prey is closely correlated with that of wolves, which appear to utilize all suitable habitat (Sillero-Zubiri *et al.* 1995a, 1995b). Short vegetation is preferred, with afroalpine herbaceous communities providing the optimal habitat for the species. Wolves are also present in montane grasslands, ericaceous heathland and secondary Helichrysum dwarf-scrub. In BMNP wolves are occasionally seen on barren peaks and lava flows.

Biology

Diet and Foraging Behaviour

Although Ethiopian wolves live in close-knit territorial packs they forage and feed alone on small prey, contradicting the general association in larger carnivores between grouping and cooperative hunting. In BMNP the wolves feed almost exclusively upon diurnal small mammals of the high altitude afroalpine grassland community, such as the giant molerat (*Tacyoryctes macrocephalus.* 300–930 g), a rare root-rat endemic to Bale Mountains, and other endemic species such as grass rats *Arvicanthis blicki*, *Lophuromys melanonyx*, and Starck's hare *Lepus starcki* (Morris and Malcolm 1977, Yalden 1988, Yalden and Largen 1992, Sillero-Zubiri and Gottelli 1995a). Rodents accounted for nearly 96% of all prey occurrences in faeces, with 87% belonging to the first three species listed above. Other prey species included *Otomys typus*, *Lophuromys flavopunctatus*, and occasionally goslings and eggs, rock hyrax (*Procavia capensis*), and mountain nyala calf (*Tragelaphus buxtoni*). In locations where the giant molerat is absent it is replaced in the diet by the smaller common molerat, *Tachyoryctes splendens* (Sillero-Zubiri 1995, Malcolm in press). In the Simien mountains wolves feed upon *Arvicanthis abyssinicus* (Müller 1977). Undigested *Carex monostachya* leaves were found in 4% of the faeces, probably ingested to assist digestion or for parasite control.

Wolves are most active during the day; peaks of foraging activity suggest that they synchronize their

A giant molerat, a frequent item in the Ethiopian wolf's diet.

Starck's hare, an endemic mammal in the Bale Mountains preyed upon by Ethiopian wolves.

activity with that of rodents above the ground (Sillero-Zubiri *et al.* 1995a, 1995b). Digging prey out is common, and is the most favoured technique to catch giant molerats, with the effort varying from a few scratches at a rat hole to the total destruction of a set of burrows leaving conspicuous mounds of dirt (Morris and Malcolm 1977). Sometimes digging serves to reach a nest of grass-rats. Kills are often cached and later retrieved (Sillero-Zubiri and Gottelli 1995a).

Although the Ethiopian wolf is a pre-eminent rodent hunter it is also a facultative, cooperative hunter. Occasionally small packs have been seen chasing and killing young antelopes, lambs, and hares. Wolves will take carrion – a sheep carcass is the most successful bait for trapping (Sillero-Zubiri 1996). In areas of grazing in the Web Valley wolves are often seen foraging among herds of cattle, a tactic that may aid in ambushing rodents out of their holes, by using the herd as a mobile hide (Sillero-Zubiri and Gottelli 1995a).

Spatial Organization and Social Structure

Ethiopian wolves live in discrete and cohesive social packs that communally share and defend an exclusive territory. In optimal habitat packs consisted of 3–13 adults (mean = 6), containing 3–8 related adult males, 1–3 adult females, 1–6 yearlings and 1–6 pups (Sillero-Zubiri and Gottelli 1995b). Pack adult sex ratio was biased toward males 2.6:1. In an area of lower prey productivity wolves lived in pairs or small groups (mean = 2.7) and adult sex-ratio was 1:1. Wolves in Simien appeared to be less social. Only 22% of 38 wolf sightings reported were two animals (Müller 1973 in Nievergelt 1981).

Wolves congregate for social greetings and border patrols at dawn, noon and evenings, and rest together at night. They break up to forage individually in the morning and early afternoon. Wolves sleep in the open, curled up, with nose beneath the tail. Several animals may sleep close together. They do not use dens to rest at night, and during the breeding season only pups and nursing females use the den. In BMNP there is little nocturnal activity, with wolves seldom moving far from their evening resting site. They may become more crepuscular and nocturnal where human interference is severe (*e.g.* Simien: Brown 1964a, Somkaro and Kaka: pers. obs.).

During the breeding season social gatherings are more common and take place next to the den. Intense, energetic, and noisy greetings occur primarily when groups assemble or before tandem-marking patrols and seem to be an important component in keeping cohesion and friendly relations within the pack. Other common interactions are food sharing, allo-grooming, nibbling, and playing, which involves chasing, ambushing, and mock fighting. Strong affiliative ties are developed between siblings during the first months of their life. Vicious play-fighting during the first weeks outside the den may determine the establishment of rank between siblings. Hierarchies among pack members are well established with frequent displays of dominance and subordination. A dominance rank develops among adults of each sex; shifts in rank may occasionally take place in males but not among females.

Annual home ranges of eight packs in optimal habitat monitored for four years averaged 6.4 km² and home ranges in an area of lower prey biomass averaged 13.4 km², with some overlap between home ranges. An additional 4–7% of the population was composed of non-resident females, inhabiting larger ranges (mean 11.1 km²). Home ranges overlapped extensively between members of the same pack, whereas home ranges of neighbouring packs were largely discrete, forming a mosaic of packs occupying all available habitat. Pack home ranges were stable in time, drifting only during major pack readjustment after the disappearance of a pack or significant demographic changes (Sillero-Zubiri and Gottelli 1995b).

A pack patrolling and scent marking their territory border.

Scent marking of territory boundaries, via urine posts, scratching, and faeces, and vocalizations, are common and function in advertising and maintaining territories (Sillero-Zubiri 1994). Packs patrol and scent-mark their territory boundaries at dawn, evening, and often at noon. Tandem-marking trips are regularly carried out by the whole pack including subadults and juveniles but more often only adults of both sexes take part, led by one of the dominant pair, usually the female. All wolves, independent of social rank, scent-mark objects with raised leg urinations and scratches. Vocalizations and deposition of faeces on conspicuous sites (such as mounds, rocks, bushes) also play a role in territory defence. Aggressive interactions with neighbouring packs are common. They are highly vocal and always end with the smaller group fleeing from the larger. Home range overlap and aggressive encounters between packs are highest during the mating season.

Dispersal movements are tightly constrained by the scarcity of suitable unoccupied habitat. Males do not disperse and are recruited into multi-male philopatric packs; two-thirds of the females disperse at two years of age and become '*floaters*', occupying narrow ranges between pack territories until a breeding vacancy becomes available. Breeding females typically are replaced after death by a resident daughter, resulting in a high potential for inbreeding. Extra-pack copulations and resulting multiple-paternity may be the mechanism by which this problem is circumvented among Ethiopian wolves (Sillero-Zubiri *et al.* 1996b).

Mating System

Most matings in BMNP occur between August and November. The receptive period of females in any given area is synchronized to less than two weeks. Courtship may take place between adult members of a pack or with members of neighbouring packs. After a short courtship, which primarily involves the dominant male accompanying the female constantly, wolves copulate over a period of 3 to 5 days. Copulation involves a tie lasting up to 15 min. Other males may stand by a mating pair with no signs of aggression. Mate preference is shown, with the female discouraging attempts from all but the pack's dominant male, either by defensive snarls or by moving away. In contrast, she is receptive to any visiting male from neighbouring packs. Up to 70% of matings (n = 30) involved males from outside the pack (Sillero-Zubiri *et al.* 1996a).

A male Ethiopian wolf feeding a pup.

The dominant female of each pack may give birth once a year between October and December, with only about 60% of dominant females breeding successfully each year (Sillero-Zubiri *et al.* 1996a). Gestation lasts 60–62 days. Pups are born with their eyes closed and without teeth, in a den dug by the female in open ground, under a boulder or inside a rocky crevice. The pups natal coat is charcoal gray with a buff patch on the chest and inguinal regions. Two to six pups emerge from the den after 3 weeks. At this time, the dark natal coat begins to be replaced by the pelage typical of the species. Pups are regularly shifted between dens, up to 1,300 m apart (Sillero-Zubiri and Gottelli 1995b).

All pack members guard the den, chase potential predators, and regurgitate or carry rodent prey to feed the pups. Subordinate females may assist the dominant female in suckling the pups. At least 50% of extra nursing females showed signs of pregnancy and may have lost or deserted their own offspring before joining the dominant female's den (Sillero-Zubiri *et al.* submitted).

Development of the young is divisible into three stages: (1) early nesting (week 1 to week 4), when the young are entirely dependent on milk; (2) mixed nutritional dependency (week 5 to week 10), when milk is supplemented by solid foods regurgitated by all pack members until pups are completely weaned; and (3) post-weaning dependency (week 10 to 6 months), when the pups subsist almost entirely on solid foods supplied by helpers. Adults have been observed providing food to juveniles up to one year old. Juveniles will join adults in territorial patrols as early as 6 months of age, but will not urinate with raised leg until 11 months if male or eighteen months if female. Full adult appearance is attained at two years and both sexes become sexually mature during their second year.

Cultural and Economic Significance

The Ethiopian wolf does not play a major role in mankind's culture or economy. So far as we know, there is no mention of it in the culture or folklore of Ethiopia. Some indication of the interest that wolves may have held for indigenous people is to be found in their local names. For instance, the name ‘jedalla farda” given by the Oromo people in southern Ethiopia means ‘horse's jackal”, referring to the reported habit of wolves following mares and cows about to deliver and eating the afterbirth. However, the Ethiopian wolf has been recognized by Ethiopian peoples for a very long time. For example the earliest reference to the species uncovered dates to the 13th century or earlier, referring to "*Ethiopicis lupis*" as a docile carnivore that never attacks men (Barber 1993). More recently, the government has used the wolf and other endemic species as national symbols. For instance, the Ethiopian wolf has illustrated two series of postage stamps.

There is no indication of exploitation for furs or other purposes, although a report from Simien suggested that the wolf's liver is used as a medicament (Staheli 1975). No poaching or trade in live animals seem to involve the Ethiopian wolf. Similarly, we have found no mention or evidence of Ethiopian wolves being kept as pets. The only possible indication of a wolf ever being kept in captivity was the mention of a female ‘wolf” kept in a private collection by Harar's Postmaster and offered to the National Zoo in Washington (Anon. 1904), although it is not known whether it referred to an Ethiopian wolf or some other carnivore (many Ethiopians refer to African wild dogs *Lycaon pictus* as wolves).

Ethiopian commemorative stamps featuring the Ethiopian wolf.

Chapter 2
The Ethiopian wolf: Distribution and Population Status

J. R. Malcolm and C. Sillero-Zubiri

There have been three previous attempts to assess the range and status of the species. Yalden *et al.* (1980) collated all Ethiopian wolf locations known from the literature. This was followed by an assessment of the status of the species that estimated the world population at less than 1,000 animals (Malcolm 1984). Gottelli and Sillero-Zubiri (1990, 1992) summarized all information on the species' past and present distribution. This chapter will review the past and present habitat for the Ethiopian wolf and summarize historical and current populations.

With the exception of the Bale Mountains National Park (BMNP) it is difficult to arrive at wolf population estimates with any accuracy. Local ecological data on wolves' home ranges, social organisation, distribution and density are lacking. However, an attempt is made here to estimate the population of adult animals (> one year old) likely to exist in different locations on the basis of short visits and reports together with extrapolation from studies in the BMNP. Other factors such as the extent of suitable habitat remaining and human pressure are also taken into account.

Habitat

The Ethiopian wolf is restricted to the high montane ecosystem (Box 2.1). The species occurs in two main ecological zones in Ethiopia (following Hurni 1986), the afroalpine (approx. 3,700–4,400 m *asl*) and the subalpine (approx. 3,000–3,700 m). In the traditional Ethiopian classification these areas are *Wurch* (sometimes divided into *High Wurch* and *Moist Wurch*). No part of Ethiopia extends into the sub-nival zone found on the highest African mountains.

The Afroalpine Zone

Open areas above the treeline occur in ten parts of Ethiopia. Such afroalpine habitats have high diurnal temperature fluctuations with daytime temperatures on clear days in the 20s °C and regular nightly frosts. Rainfall data from high elevations in Ethiopia are scanty but indicate an annual range from 400–1,500 mm *p.a.*. Hail is common but snow occasional and short-lived. All areas have high levels of UV radiation. Soils tend to be shallow and gravelly and

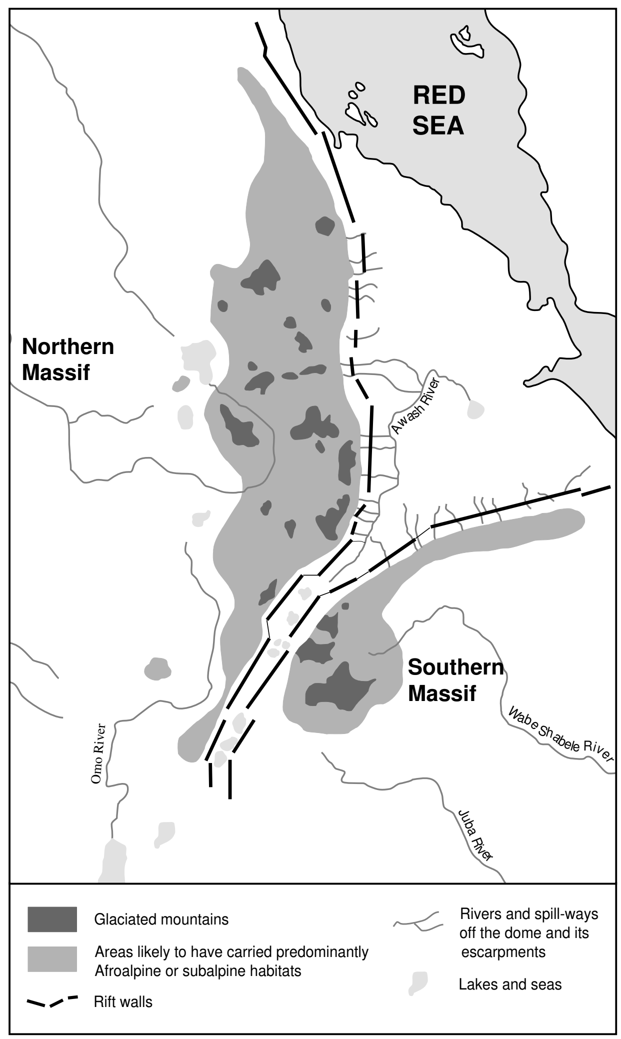


Figure 2.1. Probable range of afroalpine habitat during the major glacial periods (redrawn from Kingdon 1990).

Table 2.1
Past and present potential habitat for Ethiopian wolves

Altitudinal limits	Area of Habitat (km²)	Ecological Zone
Last glaciation		
2,300–3,300 m	150,000 km²	Afroalpine & subalpine
Present		
> 3,800 m	1,050 km²	Afroalpine
3,300–3,800 m	4,660 km²	Subalpine
Total	**5,710 km²**	

are recently derived from volcanic rocks exposed since glaciers retreated (Hedberg 1964).

The Ethiopian afroalpine vegetation is dominated by grass and low-growing shrubs from which the peculiar giant lobelias (*Lobelia rhynchopetalum*) emerge. Hedberg (1964), working on mountains in East Africa, identified five major afroalpine vegetation communities: *Dendrosenecio* woodlands, *Helichrysum* scrub, *Alchemilla* scrub, Tussock grassland, and Bogs and related communities. The last four, but not the first, are found on Ethiopian mountains. Variations in moisture and topography determine which community predominates. *Helichrysum* scrub (usually the small grey shrub *H. splendidum*) covers large areas of drier (<900 mm *p.a.*) and flatter land. *Alchemilla* scrub dominates in the wetter areas. Tussock grassland and bogs occur in any area of impeded drainage. The different vegetation communities support different rodent densities and as a result different numbers of Ethiopian wolves (Sillero-Zubiri *et al.* 1995a, 1995b) (see Bale Mountains below).

There is little permanent human settlement in the afroalpine zone and little cultivation. However, the area is used by livestock and sedges harvested for thatching.

The Subalpine Zone

In the absence of humans, the subalpine zone in Ethiopia would probably support two main vegetation types: heathlands in the areas of well drained soil and grasslands in the areas of poorly drained soil. These two zones will be discussed in the context of human disturbance.

Heathlands

Giant heathers of the genera *Erica* and *Phillipia* occur in their undisturbed form in a few areas of the Bale Mountains, where between 3,100–3,500 m, they can form closed canopy woodlands with a height of 5–15 m. Above 3,400 m the plants decrease in size and blend gradually with the afroalpine shrubs between 3,500–3,800 m. Below 3,300 m trees, mainly *Hypericum revolutum* and *Hagenia abyssinica*, occur in increasing numbers in the heather. Heathlands have been cut and burnt by humans in almost all areas. Burning reduces the size of the plants and opens up the canopy so that a community of grass and small dicots grows between the plants. With more intense burning only scattered heather plants, often growing from large, old boles are left and in extreme cases grassland or *Helichrysum* shrub occurs in regions where heather would appear to be the climatic climax.

The heather zone is exploited for fuelwood production and managed for grazing using fire in all areas.

Grasslands

Tussock grass and sedges occur in the bottoms of valleys throughout the subalpine zone. A ring of short grass and small shrubs often circles the boggy areas. Derived grasslands cover much of the subalpine.

Barley cultivation extends into the subalpine region in all areas. However the maximum height of ploughing varies from around 3,600 m in parts of the Simien to about 3,300 m in parts of Bale and Arsi.

Marginal Ethiopian wolf habitat: subalpine heathland.

Box 2.1
The High Montane Ecosystem of Ethiopia

The Ethiopian wolf is one of a remarkable collection of species living above 3,000 m on Ethiopian mountains. Conservation of the wolf and its habitat is the best way to ensure the survival of this considerable biological wealth. These communities are of interest for at least three reasons:

1. Endemism

An array of organisms that colonized Ethiopia in glacial times are now isolated at high elevations and in many cases have become new species. For mobile forms, notably birds, many of the same species tend to occur on different mountain ranges in Ethiopia while for small mammals and plants separate species are sometimes found on the different mountains within Ethiopia.

Nineteen of the thirty mammals currently known to be endemic to Ethiopia live in the high montane area. Of these nineteen, eleven are shrews or rodents. As small mammals have not been studied on several of the mountain ranges, other small mammal species may not yet be identified. Rodents are the dominant herbivores on the afroalpine grasslands with densities up to 25 kg/ha in parts of the Bale Mountains. In most areas the endemic Ethiopian wolf preys on endemic rodents.

Two large and critically endangered ungulates and one primate are also high altitude specialists. The walia ibex (*Capra ibex walie*) is a southern offshoot of the Nubian ibex. It is now restricted to a small number of escarpments in northern Ethiopia. As many as 250 survive in the Simien Mountains although less than half are found in the Simien Mountains National Park. The world population may not exceed 400.

South of the Rift Valley the mountain nyala (*Tragelaphus buxtoni*) survives only in the Bale and Arsi Mountains and in parts of the Chercher Mountains further East. This large and sturdy member of the kudu family weighs up to 300 kg. In the Bale Mountains National Park it is most numerous in montane forest and grasslands around 3,000 m. Humans keep it from occupying this habitat in most other places and the final refuges of the species are in the heathlands and afroalpine grasslands. The BMNP contains the largest population numbering perhaps 1,500. It is doubtful that the world population exceeds 3,000 although there has been little recent census work.

The gelada baboon (*Theropithecus gelada*) is mostly restricted to the Ethiopian plateau North of the Rift Valley where it remains quite widespread in grassland areas. A small population has been found south of the Rift Valley in the Wabi Shabelle gorge recently and it may constitute a distinct subspecies.

Fifteen of Ethiopia's 26 endemic bird species live at high elevations. Notable species include the blue-winged goose (*Cyanochen cyanoptera*), which appears to be related to South American species. It occurs throughout the Ethiopian Plateau including the afroalpine zone. The largest bird of high elevations is the northern wattled crane (*Grus carunculatus*). This is a distinctively marked and genetically isolated race of a species that occurs at low elevations in southern Africa. Other montane endemics include a monotypic rail (*Rougetius rougetii*) and several passerines.

There are estimated to be 24 amphibians endemic to Ethiopia of which nearly half are from high elevations. The invertebrates remain largely unstudied.

The higher plants of the Ethiopian mountains are still being catalogued, and some ranges have not been visited. Collections, mainly from Bale, Arsi and Simien, suggest that there are between 100–150 high altitude endemic species. The most conspicuous is the giant lobelia (*Lobelia rhynchopetalum*), whose sentinel forms dot the afroalpine landscape.

continued on next page

2. The Palearctic connection

The high mountains of Ethiopia form an important biogeographic link with the temperate lands of Eurasia. During the temperate winter the mountains provide habitat for an array of palearctic migrants. The most conspicuous at high elevations are the waterfowl living on the rich alpine tarns. Several thousand wigeon (*Anas penelope*) and shovelers (*Anas clypeata*) winter in the Bale Mountains together with waders including the ruff (*Philomachus pugnax*) and the greenshank (*Tringa nebularia*). Golden, imperial and booted eagles (*Aquila chrysaetos*, *A. heliaca*, *Hieraaetus pennatus)* together with harriers (*Circus pygargus* and *C. macrourus*) live off the high altitude rodent fauna. The forests below support large populations of songbirds.

Three paleartic species, the chough (*Pyrrhocorax pyrrhocorax*), the ruddy shelduck (*Tadorna ferruginea*) and the golden eagle have their only known breeding sites outside the north temperate zone in the afroalpine zone of Ethiopia.

3. Special adaptations

The tops of African mountains have environmental conditions that differ dramatically from the lowlands below. Plants and to a lesser degree animals have evolved some peculiar adaptations in response to the afroalpine climate. Plant gigantism is the most striking example. Giant lobelias, tree heather (*Erica arborea*) and giant Saint John's wort (*Hypericum revolutum*) are important elements of the high montane flora of Ethiopia. The everlasting flowers (*Helichrysum spp*) are conspicuous over large areas of the montane habitat. Their highly reflective silvery leaves and dry, papery flowers allow them to survive in the desiccating winds up to 4,300 m.

Among the animals, the most extreme adaptation may involve a small toad (*Nectophrynoides malcomi*) that lives in damp areas from 3,300–4,200 m. Fertilization is internal and eggs develop out of water in moist soil. The species belongs to a group that has evolved unusual mechanisms of viviparity and ovoviparity.

The most peculiar of the mammals is the giant molerat (*Tachyoryctes macrocephalus*). This animal is restricted to the afroalpine regions of the Bale Mountains where it is common. It is several times larger than the related common molerat (*T. splendens*) of lower elevations. It also takes its food from above ground vegetation. Its eyes have migrated to the top of its head so that it can scan for predators while exposing as little of its body as possible. The tube-like body allows the molerat to stretch itself across the surface while keeping its hind legs in the burrow. The extensive burrowing and mound building activities of the molerats are dominant ecological forces in the afroalpine grasslands of the Bale Mountains.

Past and Present Availability of Habitat

Until the recent end of the Pleistocene epoch the highlands of Ethiopia were widely covered with afroalpine heathland and grassland (Messerli et al. 1977). These habitats generally lacked the herds of large ungulates characteristic of the African plains, but smaller mammals were present in great abundance, particularly molerats (Rhizomyinae) and grass rats (Murinae). The Ethiopian wolf, a specialist rodent hunter (Sillero-Zubiri and Gottelli 1995a), almost certainly evolved in Ethiopia during the Pleistocene glacial periods (Chapter 5).

The habitat available to the species would have varied with the climate. Figure 2.1, redrawn from Kingdon (1990), shows the extent of subalpine and alpine habitat at the peak of the last glaciation. Table 1.1 shows the areas of land in subalpine and alpine zones at the present and at the height of the last glacial period assuming the vegetation zones were depressed by about 1,000 m (Flenley 1979). The current habitat represents less than 10% of the species'

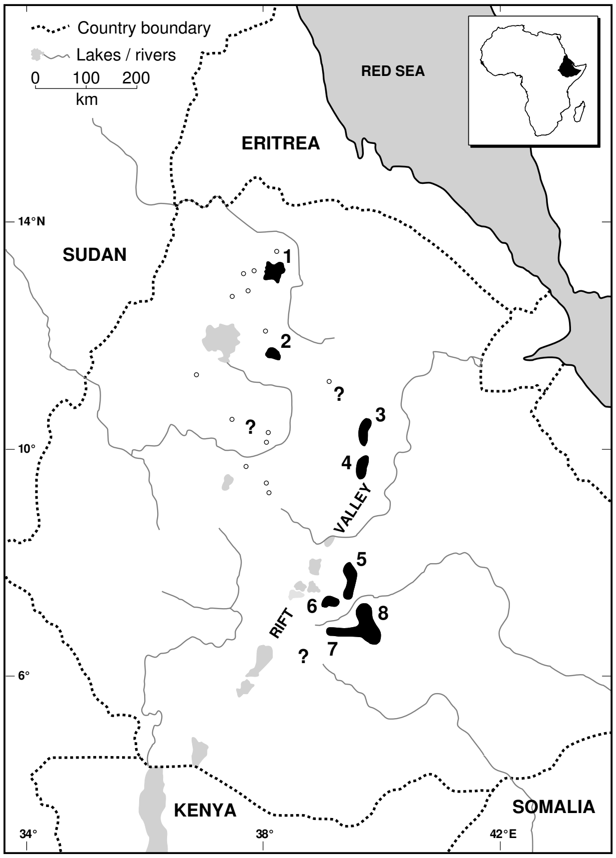


Figure 2.2. **Geographical distribution of the Ethiopian wolf. Current and historical range together with the 3,300 m contour, the lowest limit of the present subalpine zone.** Open circles indicate records prior to 1925 (from Yalden *et al.* 1980). Question marks indicate uncertain or unconfirmed records. **1**: Simien Mountains National Park; **2**: Mount Guna; **3**: Menz; **4**: Ankober; **5**: Arsi Mountains; **6**: Mount Kaka; **7**: Somkaro/Korduro Mountains; **8**: Bale Mountains National Park.

maximum range, and probably less than 20% of its average range over the last 500,000 years.

Figure 2.2 (modified from Yalden *et al.* 1980) shows the current and historical range of the species together with the 3,300 m contour, the lowest limit of the present subalpine zone. There are five areas where the species is now confirmed to occur and these are discussed below. One area around Mount Choke (4,154 m) in Gojjam (10° N, 38° E) has a number of historical sightings up to 1932 (Powell-Cotton 1902, Maydon 1925, Yalden *et al.* 1980) but has not been visited by naturalists for a long time. Early in 1996 however, the Important Bird Areas project visited Mount Choke and noted that they were very few rodents in the area, suggesting perhaps that it was unlikely that the wolves occurred there anymore (Yilma Delelegn pers. comm.). Von Heuglin (in Yalden *et al.* 1980) reported a sighting in 1862 from around Mount Abunie Josef (4,190 m) in Wollo (12° N, 39° E), but the area is not cited in any other faunal accounts since and has not been visited recently. Two other peaks in northern Shoa, Mount Amba Farit (3,975 m) (11° N, 39° E) and Mount Abuye Meda (4,000 m) (10° N, 39° E) and one in Gamo Gofa, Mount Guge (4,200 m) (6° N, 37° E) would appear on maps to have some area of wolf habitat but have neither historical nor recent sightings. Three of the records from before 1925 are from areas under 2,500 m, well below the current altitudinal limit of the species. They are probably unreliable (Yalden *et al.* 1980), as well as unconfirmed reports of the species occurring in Hararge and in Eritrea.

Simien Mountains

The Simien mountains (13° N, 38° E) lie 120 km northeast of the town of Gondar and include Ras Dashan, the highest peak in Ethiopia at 4,543 m. There is 1,350 km² of land above 3,000 m. The Simien Mountains National Park (SMNP), established in 1969, lies in the western part of the range and covers 190 km². The park was established to preserve the high altitude biota including the gelada baboon (*Theropithecus gelada*) and the walia ibex (*Capra ibex walie*) as well as some of the spectacular gorges and escarpments in the region. Information on the park can be found in the Management Plan (Hurni 1986) and Nievergelt (1981).

Afroalpine vegetation available to wolves extends from about 3,700 m and covers approximately 180 km². The flatter areas support mainly tussock grassland with abundant giant lobelias. Steep slopes and extensive cultivation provide little wolf habitat in the subalpine zone.

Wolves have been reported in the Simien mountains since the species was first described from the area in 1835 (Rüppell 1835). The species is regularly seen in three separate areas, each separated by about 8 km of lower ground from the other two (Fig. 2.3). Approximately two thirds of the wolf habitat lies outside the boundaries of the National Park. While Nicol (1971) and Müller (1977) reported a basic diet of grass rats (predominantly *Arvicanthis abyssinicus*), the species is seen most often in the tussock grasslands and boggy habitats where it is presumed to be eating swamp rats (*Otomys*) (Ato Gelay, pers. comm. 1994).

Sightings of wolves in Simien have always been scattered and irregular. Bailey in 1927 spent three weeks in the high altitude areas but did not mention the species (Bailey 1932). Brown (1964*a*, 1964*b*) recorded eleven wolf sightings in 12 days. Nicol (1971) feared an

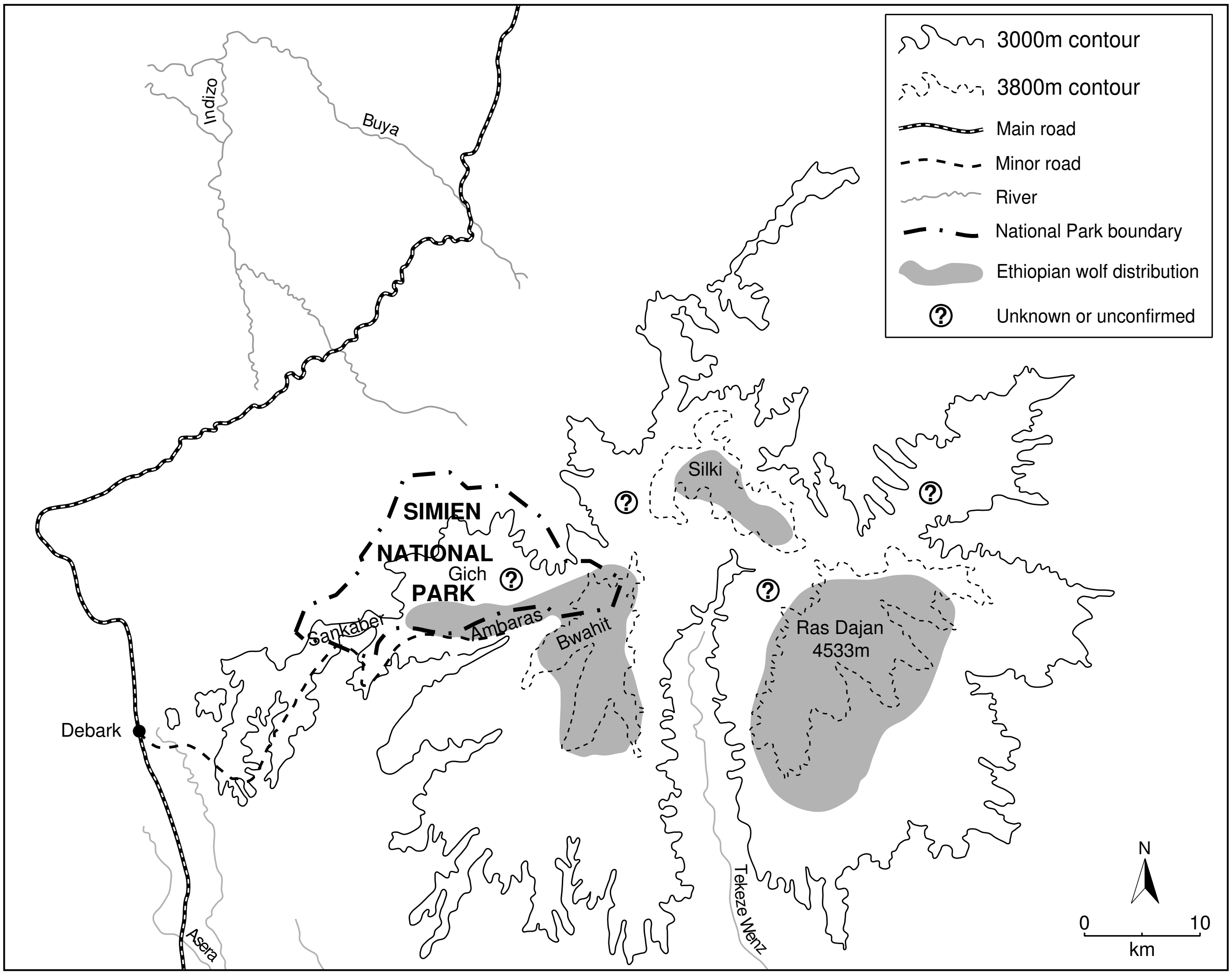


Figure 2.3. Probable distribution of Ethiopian wolves in the Simien Mountains.

imminent local extinction. Müller (1977) recorded 15 sightings of single wolves in Geech Plateau, SMNP, during one year. Hurni (1995, pers. comm.) saw wolves once in three months of field work in the SMNP in 1994. Guides working in the park expect to see wolves once every two or three days spent in the prime areas of afroalpine habitat (pers. comm. 1994). Professor Nievergelt, who worked in Simien between 1966–1973, in 1983, 1994 and 1996, indicated that while wolf sightings were never common the species seems rarer now than it was before (B. Nievergelt 1996, pers. comm.). It is possible that the low number of sightings reflects more secretive habits than in more southerly populations. However, human persecution is not evident, wolves appear to have about the same flight distance as in other areas and the low sightings probably indicate low numbers. The perceived population decline may be a consequence of the substantial increase on human activity on the Geech Plateau and the ensuing overgrazing of grasslands (Nievergelt 1996).

Biologists working in the Simien Mountains National Park since 1975 have estimated the number of wolves between 5–15 (Stäehli 1975, Hurni 1986, pers. comm. 1995). The numbers inside the whole mountain range are estimated from 20–40 (Hurni 1995, pers. comm., Park Wardens' reports 1975–1995).

Using a habitat area of 200 km² and a low wolf density as suggested from all sources, the population in the area may number as few as 20–40 wolves.

Mount Guna

The isolated peak of Mount Guna (11° 45´ N, 38° 15´ E) rises to 4,231 m approximately 150 km south of the Simien mountains. There are 110 km² of land above 3,400 m, but no more than 40 km² above the 3,800 m contour which may provide good habitat for the species. Following reports of wolves in the area, staff from the Ethiopian Wildlife Conservation Organisation (EWCO) visited Guna in June 1982. They confirmed the presence of the species (Yilma Delelegn pers. comm.). A limited area of afroalpine habitat remains (Malcolm 1995). A recent expedition to Mount Guna reported seeing an adult female near the summit and talked to several shepherds that had seen them recently (Andrew Pierce pers. comm.).

It is unlikely that more than 20 Ethiopian wolves survive in this small area.

Northeastern Shoa

The eastern wall of the Great Rift Valley in northern Shoa, central Ethiopia, provides a strip of potential wolf habitat. The area above 3,000 m extends for about 100 km from a point 20 km northeast of the town of Mehal Meda in Menz (10° 35´ N, 39° 45´ E) in the north to a point 15 km northwest of the town of Ankober (9° 35´ N, 39° 45´ E) in the south. It is bounded on the east by the 1,500 m escarpment of the Rift wall and on the west by the central Ethiopian plateau dissected in places by deep gorges. The area over 3,000 m is approximately 1,400 km² with peaks rising to 3,564 m in the northern area and to 3,730 m in the south. Over the last 20 years wolves have been reported at either ends of this linear piece of habitat with a gap between the northern and southern sightings of about 50 km (Tyler 1975, Groce and Groce 1977).

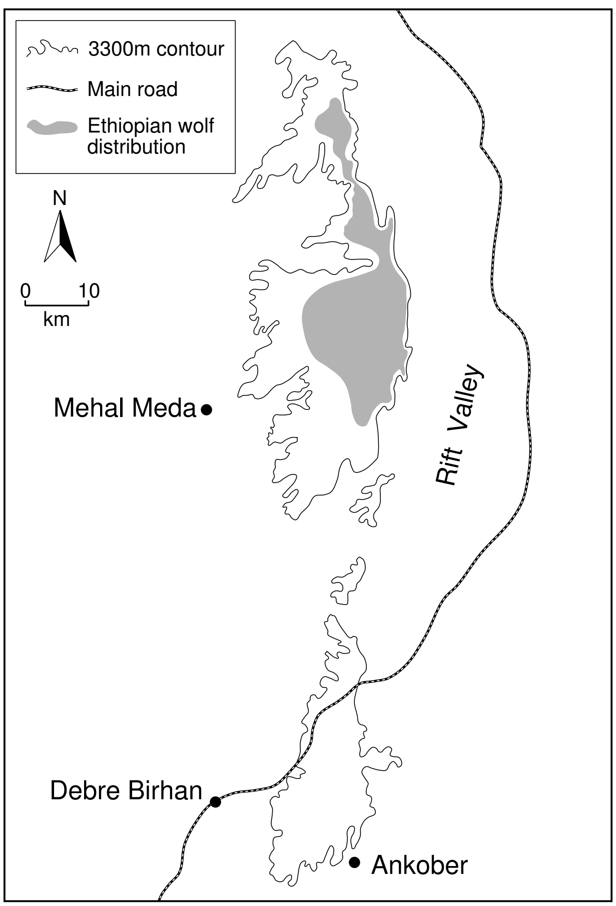


Figure 2.4. Distribution of the Ethiopian wolf in Northern Shoa.

The ridge area is dominated by tussock grassland (*Festuca spp*) known as *Guassa* in Amharic and used for thatch and basket work (Zelealem Tefera 1995). The valley bottoms have sedges and tall grasses. On steep slopes and in areas of thin soil, especially above 3,300 m, *Festuca* is increasingly replaced with *Helichrysum* and *Alchemilla* scrub. Short grass is common in these areas. Remnant heather plants occur along the edge of the escarpment, often with boles much larger than those of the current plants, suggesting that *Erica* would be more extensive in the absence of human-caused fires.

The status of Ethiopian wolves was assessed for both northern and southern areas by the authors (southern area in 1989 by CSZ and in 1994 by JRM; the northern area in 1994 by JRM and 1995 and 1996 by CSZ). Zelealem Tefera has observed wolves in the area in 1994 and 1995 (Zelealem Tefera 1995) and wolves were also reported by a EWCO mission that visited the northern area in 1992 (Mateos Ersado and Leykun Abunie 1992).

Northern Area – Menz

Almost 100 km² of suitable habitat remains in the northern area, traditionally known as *Guassa* (Fig. 2.4). The communal management of the *Festuca* grasslands (Zelealem Tefera 1995) has limited the impact of both grazing and cultivation (see Chapter 7). Currently barley fields extend to about 3,200 m.

Ethiopian wolves are seen regularly along the road from Tarmaber to Mehal Meda in the Gera area, southern end of the range, and were sighted by biologists in Asabo, at the northern part of the range. Indirect evidence of Ethiopian wolves, in the form of droppings and diggings, is as common in this area as in parts of the Bale Mountains rated as ‘good’ habitat (see Bale Mountains below). Prey populations of grass rats (*Arvicanthis spp*) and swamp rats (*Otomys*) could be seen and heard and the diggings of the common molerat (*Tachyoryctes splendens*) were conspicuous. Dissection of nine droppings confirmed that all three species occurred in the diet (Sillero-Zubiri 1995).

Using a habitat area of 100 km² and extrapolating from data on wolf densities from Bale, the population in the area could number from 50–75.

Southern Area – Ankober

There is only a narrow strip of afroalpine and subalpine vegetation at the southern end of the ridge and in some places (*e.g.* Gosh Meda) the cultivation extends to the escarpment.

Ethiopian wolves were reported from this area in 1974 by Tyler (1975) and in 1988 by J.C. Hillman (pers. comm.). The area was visited in both 1989 and 1994 by the authors and all but 5 km of the ridge was walked. No wolves were seen or heard and no indirect sign was found. Some of the local people, particularly from the older generation, knew the animal. A night-watchman protecting a microwave tower in an area of apparently suitable habitat reported sightings from as recently as 1992.

We do not think that a population survives in the area and suspect that transients that have moved south down the ridge from the Menz area may account for recent sightings.

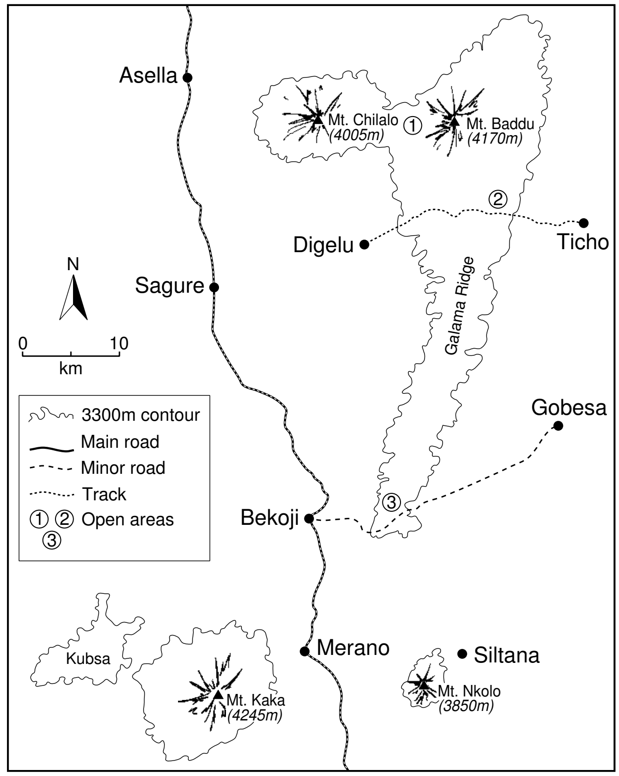


Figure 2.5. Distribution of afroalpine range in Arsi where Ethiopian wolves are known to occur.

Arsi Mountains

An area of high ground in former Arsi Region south of the Rift Valley wall has been known to support Ethiopian wolves since the turn of the century. The species has been sighted and collected at intervals *(e.g.* Fuertes and Osgood 1936, Brown 1966) from at least three locations of the Arsi range Mount Kaka, Galama ridge and Chilalo Mountains. Mount Kaka was visited by CSZ in 1990 (Gottelli and Sillero-Zubiri 1990) and the Galama ridge area by JRM in 1995 (Malcolm 1995). The whole area was studied on a Landsat transparency (Scene 167/055) dating from 1987 (Malcolm 1995).

Figure 2.5 outlines the five regions above 3,300 m in Arsi, and Table 2.2 shows their respective areas. This contour is close to the limit of human cultivation and heathlands predominate above it, covering over 90% of the area (from the satellite image). The heather is burnt regularly and varies from 0.5–2.5 m depending on the time since the last fire. Recently burnt areas have short grass and small dicots between the *Erica*. Areas close to the peaks, mainly above 3,900 m, are extremely rocky with *Helichrysum* and short grass. Areas of impeded drainage have tussock grass and are often surrounded by a zone of *Helichrysum* scrub.

The whole area is grazed, although there are few

Table 2.2
Estimated Ethiopian wolf numbers in Arsi (June 1995)

Region	Area of Habitat (km)	Wolf Density (min) 0.1/km²	0.15/km²	(max) 0.2/km²
Nkolo	18	2	3	4
Kaka/Kubsa	196	20	29	38
Chilalo/Galama	572	57	86	114
Total	**786**	**79**	**118**	**156**

Tullu Deemtu.

permanent settlements above the zone of cultivation. Livestock are herded up each day. Burnt heather sticks are an important source of fuelwood for the lower lying areas and people walk up each day to collect the wood. Mountain nyala (*Tragelaphus buxtoni*) occur in the heather and remnant montane forest on the east of the main ridge. Sport hunting of mountain nyala and other species was permitted until 1993.

Two wolves were seen and several others heard during two days spent by CSZ on Mount Kaka (4,180 m) in 1990. Wolf droppings and diggings were present above 3,600 m and common above 3,860 m. Local people interviewed reported wolves in the smaller Kubsa mountain, some 15 km west of Mount Kaka. An Ethiopian wolf was seen in eastern Arsi, at the south end of the Galama ridge, by JRM in June 1995. Interviews with local people revealed that Ethiopian wolves are seen, at least occasionally, in all areas above 3,300 m. Sightings are rare in areas of continuous heather.

The species is seen regularly in the open and more swampy areas throughout most of the Arsi range. Grass rats, swamp rats and common molerats occur throughout the area. The satellite image showed at least 90% of the area was covered with heathlands. Extrapolating from data on wolves in the heathlands of the Bale Mountains, a density of between 0.1–0.2/km² over much of the area seems likely (Table 2.2). It is possible that the small areas of open and swampy habitat are important centers for the species and population densities appeared higher in them.

Migration of Ethiopian wolves between the five pieces of habitat has not been reported. However, the greatest distance between areas of suitable habitat does not exceed 20 km and some movement seems likely, thus all five areas could be treated as a single population.

The total wolf population in Arsi was estimated at 80–160 with a best guess at 120 in nearly 800 km of suitable habitat. It is the largest population outside the Bale Mountains.

Bale Mountains

The Bale Mountains, lying southeast of the Rift Valley and south of Arsi include the largest area of afroalpine habitat on the continent and over 4,000 km above 3,000 m. Little was published about the area until recently. Smeds (1959) was the first to record Ethiopian wolves in the range and Mooney (1963) confirmed their presence on the highest peak in southern Ethiopia (Tullu Deemtu, 4,377 m) in the Bale Mountains. Leslie Brown (1964c, 1966) did extensive surveys and established that the largest existing populations of both Ethiopian wolves and mountain nyala survived in the area. As a result, the BMNP was proposed and its boundaries drawn up in 1969. The area has received protection from the EWCO since then (although BMNP has never been officially gazetted). Information on the National Park is available from the Management Plan (Hillman 1986).

Wolf habitat occurs along an east/west ridge about 100 km long with the main areas of high ground at its eastern end (Fig. 2.6). The ridge falls away steeply on its southern side and slopes more gently on the northern side towards the Wabe Shebelle river drainage. Areas below 3,200 m on the northern side are heavily cultivated with remnant Juniper forests. To the south large areas of closed canopy montane forest persist. *Hagenia*/*Hypericum* woodland occurs close to the treeline in all areas (3,200–3,500 m) and this grades into subalpine heathlands from about 3,400–3,800 m. Afroalpine habitat extends to the summits. It is possible that the heathlands extended into the current afroalpine in the past but have been reduced by fire (Miehe and Miehe 1994).

The vegetation along the Web Valley, which drains a large area in the north eastern part of the range, is exceptional. A wide valley in the upper part of the drainage at 3,500 m is covered with afroalpine habitat. Lower down, at 3,000 m, an area of edaphic grasslands

The Web Valley.

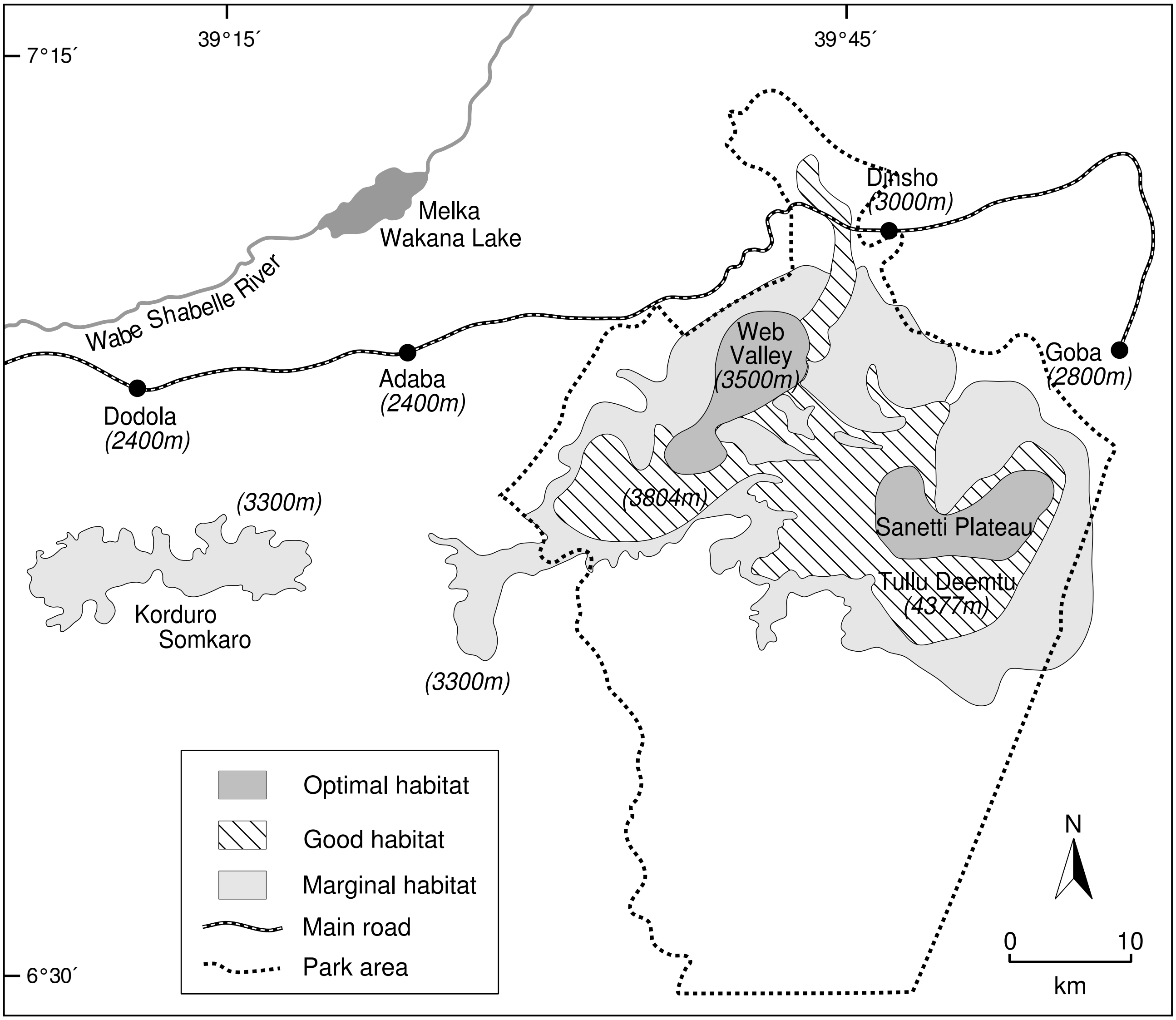


Figure 2.6. Bale Mountains National Park.
Different habitat types, and concurrent value for Ethiopian wolves, are indicated.

(Gaysay Valley) in the forest zone provides wolf habitat at an unusually low elevation.

Oromo people and their livestock occupy the whole area. Cultivation on all but the steepest slopes has been attempted in most areas up to 3,500 m. Ploughing has been tried in parts of the upper Web Valley but has not persisted. There are permanent settlements of pastoralists in the Web Valley and a few houses as high as 4,000 m in other areas. People and livestock travel across the mountains and many domestic animals are driven into the high area to mineral rich springs (called *horas*).

Mountain nyala occur throughout the afroalpine and subalpine zones and are particularly common in and around the grassland area on the lower Web Valley. The Bale Mountains support populations of at least 17 mammals endemic to Ethiopia of which nine are characteristic of high-altitude grasslands and heathlands

The Gaysay Valley.

Table 2.3
Endemic mammal species found in the Bale Mountains, indicating those characteristic of high–altitude grasslands and heathlands

Myotis scotti	Scott's hairy bat	
Crocidura baylei	shrew	✓
Crocidura bottegoides	shrew	
Crocidura harenna	shrew	
Crocidura thalia	shrew	
Dendromus lovati	Lovat's mouse	✓
Megadendromus nikolausi	Nikolaus' mouse	
Mus mahomet	Mahomet's mouse	
Praomys albipes	white–footed rat	
Stenocephalemys albocaudata	white–tailed rat	✓
Stenocephalemys griseicauda	grey–tailed rat	✓
Arvicanthis blicki	Blick's grass rat	✓
Lophuromys melanonyx	black–clawed mouse	✓
Tachyoryctes macrocephalus	giant molerat	✓
Lepus starki	Stark's hare	✓
Canis simensis	Ethiopian wolf	✓
Tragelaphus buxtoni	mountain nyala	

(Hillman 1993, Yalden and Largen 1992) (Table 2.3). There are 16 Ethiopian endemic birds recorded from the mountains and several rare endemic amphibians (Hillman 1993).

Information on Ethiopian wolves in Bale comes almost exclusively from areas within BMNP. The park includes about 90% of the available habitat. Data from the small areas of habitat to the west and north of the park will be mentioned at the end of this section. We have surveyed the population of Ethiopian wolves periodically since 1976. JRM attempted censuses in Dec/Jan 1975/6, Dec/Jan 1976/7 and Sept/Oct 1987 (Malcolm 1976, 1977, 1987). He attempted a direct count in one area and estimated wolf abundance by indirect evidence (droppings and diggings) and vegetation over the rest of the range. In 1982 an Ethiopian wolf monitoring program was established by J.C. Hillman. Sightings and sighting distance are recorded for all wolves seen from a vehicle along 32 km of road that crosses the Sanetti Plateau, one of the prime pieces of afroalpine habitat. CSZ, with D. Gottelli, studied the species intensively from 1988–1992. They made exact counts of known individual wolves in three areas of good habitat, together with estimates of prey abundance from rodent trapping. Rodent trapping in other areas combined with other indirect evidence provided a basis for extrapolation.

The best estimate for the number of Ethiopian wolves in the Bale Mountains at any given time comes from the work of CSZ and D. Gottelli in 1988/90 (Gottelli and Sillero-Zubiri 1990, 1992). They identified areas of marginal, good and optimum wolf habitat (Table 2.4).

Table 2.4
Estimate of Ethiopian wolf numbers in 1990 and 1992 for different habitat types in the Bale Mountains National Park

	Area	Density (adults/km²)		
Habitat	**km²**	**1990**	**1992**	**Habitat characterized by:**
Optimal	253	1.0/1.2	0.35/0.5	Afroalpine grasslands with short grass and herbs. Rodent biomass estimate 27–29 kg/ha.
Good	267	0.25/0.35	0.2/0.3	Uniform *Helichrysum* dwarf–scrub. Rodent biomass less than 1/5 of optimal habitat.
	62	0.25/0.35	0.2/0.3	Northern grasslands: 1/2 of optimal habitat.
Marginal	360	0.1/0.2	0.1	Ericaceous belt. Rodent biomass less than 1/10 of optimal habitat.
	137	0.1	<0.1	Barren peaks and lava flows.
Total	**1,079**			

These corresponded broadly but not exactly with vegetation communities. The total population in BMNP at that time was estimated at 440–470.

The highest wolf concentrations in BMNP (1–1.2 adult/km²) were found in extensive rolling short grasslands and valley meadows typified by the Sanetti Plateau and Web Valley (Fig. 2.7). The open landscape of the Sanetti Plateau is dominated by the activity of rodents and by frost-induced soil movements. The burrowing of the giant molerat and cryoturbation keeps the vegetation in permanent pioneer stages, dominated by short herbs and grasses (less than 0.25 m high), such as *Alchemilla abyssinica*, *Polygonum plebejum*, *Trifolium acaule*, *Anthemis tigrensis*, *Artemisia schimperi* and *Poa muhavurensis* (Miehe and Miehe 1993). In the Web Valley livestock grazing and molerat activity are the main vegetational disturbances, and the primary vegetation is a short herb community, dominated by *Alchemilla spp.* and specked by *Helichrysum* and *Artemesia* shrubs. These open grasslands supported a high biomass of rodents, in the order of 2,000–3,000 kilograms per km² (Sillero-Zubiri *et al.* 1995b).

Secondary *Helichrysum* dwarf-scrub is the dominant plant formation in the drier southern declivity of the Bale Mountains and was classified as good habitat,

Photo of the Sanetti Plateau.

represented by the Tullu Deemtu area and southern central parts of the Bale massif above 3,600 m. Spherically shaped *H. splendidum shrubs*, 30 to 50 cm tall, dominate, but leave open space to tussock grasses such as *Agrostis quinqueseta* and *Festuca richardii* (Miehe and Miehe 1993). Diurnal rodent biomass in the southern plateau was only one sixth of that on Web and Sanetti (Sillero-Zubiri *et al.* 1995b) and sustained a lower wolf density (0.2 adult/km²). A small area of montane grassland and scrubland dominated by sage brush (*Artemesia afra*) in the northern area of BMNP (Gaysay Valley) at 3,000 m supported a similar wolf density (<0.5 adult/km²).

The afroalpine range of optimal Ethiopian wolf habitat in BMNP is surrounded by a belt of heathland (*Erica trimera* secondary scrub and *Phillippia spp.*). Giant molerats are virtually absent from the ericaceous belt and other diurnal rodent are scarce. Barren rocky peaks and lava covered areas above 3,600 m were marginal for the species, with an estimated density of 0.1–0.2/km².

In 1989 CSZ surveyed wolf habitat in the west of the mountain range outside BMNP, in the Somkaro and Korduro areas. Heavily burnt heather interspersed with small marshy areas and rocky plateaux provide about 100 km² of suitable habitat. Rodent trapping revealed densities similar to good wolf habitat in BMNP and common molerat signs were widespread. Wolves were heard but not seen in three days spent in the area. A population of 15–20 adults was estimated (Gottelli and Sillero-Zubiri 1992, Sillero-Zubiri 1989). Large heather-covered mountains extend north from the BMNP over an area of about 120 km², known as the Lajo spur. It is possible that a few wolves survive there but the area has not been surveyed.

In summary between 460 and 510 adult Ethiopian wolves were estimated living in the Bale Mountains in 1990 with less than 10% of the population outside the boundaries of the National Park.

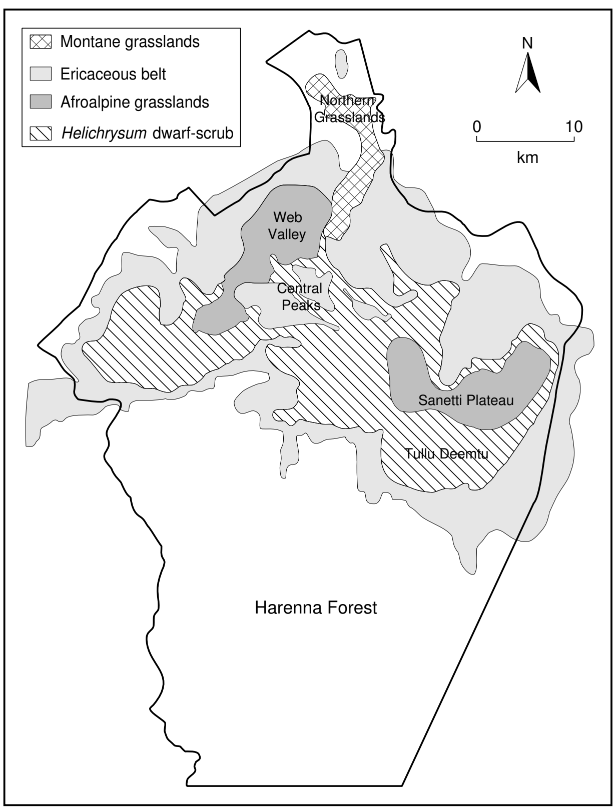


Figure 2.7. Vegetation types in the Bale Mountains National Park (modified from Hillman 1986).

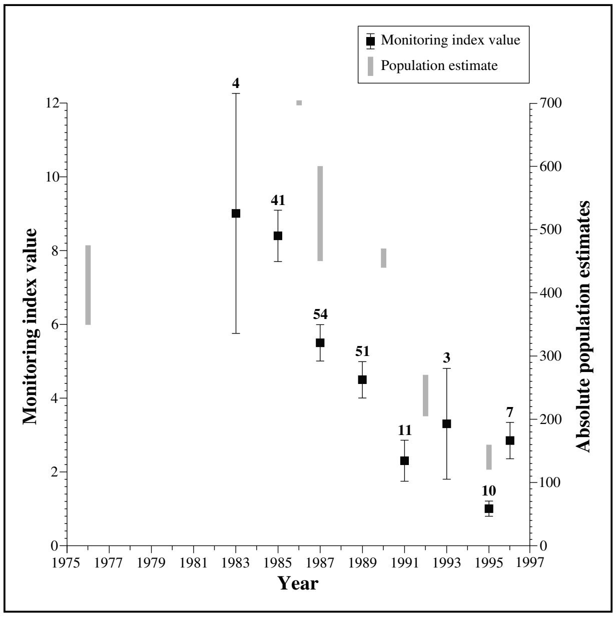


Figure 2.8. Number of Ethiopian wolves sighted on Sanetti Plateau during transects, with grey bars showing the various population estimates as explained in the text.

The population of Ethiopian wolves in the Bale Mountains has fluctuated over the last 25 years and is now considerably lower than the figure for 1990. Figure 2.8 shows the number of wolves sighted on the Sanetti Plateau since 1976 together with six estimates of absolute abundance for the same area. Estimates of absolute numbers (from small areas of known density) correlate well with the monitoring data. It appears that the numbers were at a maximum in the mid-1980s and have declined steadily since then. Figures from the mid-1970s corresponded well with those from the late 1980s and from 200–250 wolves appeared to have lived on the Sanetti Plateau at those times. The factors responsible for the changes in numbers are discussed in Chapter 3 below.

The numbers in the whole of the Bale Mountains appear to have followed closely the numbers on the Sanetti Plateau. Declines in the early 1990s on Sanetti were recorded in other parts of the habitat and the wolf population was estimated at 205–270 in 1992 (Gottelli and Sillero-Zubiri 1992). JRM and CSZ visited BMNP in 1994–1995. Ethiopian wolves occurred throughout their former range but at greatly reduced numbers in all areas (Malcolm *et al.* 1994, Sillero-Zubiri 1995). This continuous population decline is closely associated with outbreaks of disease from 1990–1992 (Chapter 4). Some reproduction occurred in the 1994 breeding season but the survival of these young is unknown. Karen Laurenson visited BMNP in early 1996 (Laurenson 1996) and Claudio Sillero-Zubiri in late 1996. Extrapolating from the monitoring data and current surveys it is likely that the population of Ethiopian wolves in the Bale Mountains 1996 (December 1996) is less than 200.

The current population in Bale is estimated at less than 200.

Discussion

Habitat Requirements

The species is most abundant in open and moist areas above 3,300 m. It is less common in the drier areas of the afroalpine zone and uncommon in continuous heathlands. However, small areas of grassy and boggy habitat in the subalpine zone may be important. The distribution closely follows that of its primary prey species, rat-sized rodents and molerats. The lower altitudinal limit of the species is not clear as the primary prey species occur at lower elevations. In many areas it is restricted by human cultivation. In the BMNP it survives in a grassland area at 3,000 m where it is sympatric with golden jackals (*Canis aureus*). In Shoa an area of apparently suitable uncultivated grassland at 2,800 m and only 10 km from where Ethiopian wolves lived was occupied by common jackals but not wolves.

Total Population Estimate for 1996

Table 2.5 summarizes information on Ethiopian wolf populations. The species is known to survive in five areas, may occur in two other areas and has been recently extirpated from an eighth area. The three small known populations from north of the rift valley (*C. simensis simensis*) may number 100 adult wolves. The two populations south of the rift valley (*C. simensis citernii*) are estimated at 295.

We therefore estimate a world total close to 400.

Table 2.5
Summary of known and possible Ethiopian wolf populations from north to south in 1995

Location	Habitat available Total[1]	Habitat available Afroalpine	Population estimate	Notes
NW of Rift Valley				
Gondar				
Simien Mountains	680	180	20–40	
Mount Guna	110	<25	10–20	
Gojjam				
Mount Choke	?	?	?	Historical records
Wollo				
Mount Abunie Josef	?	?	?	Suitable habitat, no records
Shoa				
Mount Amba Farit	?	?	?	Potential habitat
Mount Abuye Meda	?	?	?	Potential habitat
Mehal Meda	95	20?	50–75	
Ankober	46	10?	0	Recently extirpated
Sub-total	***> 930***	***> 245***	***80–135***	
SE of Rift Valley				
Arsi				
Arsi Mountains	786	20?	80–150	
Bale				
Bale Mountains NP	1,209	646	120–180	
Somkaro/Korduro Mts2	155	?	15–20	
Lajo Spur	121	0	<10	
Gamo Gofa				
Mount Guge	?	?	?	Habitat, no records
Sub-total	***> 2,270***	***> 666***	***225–360***	
Total	**> 3,200**	**> 911**	**305–495**	

[1] Afroalpine and sub–Afroalpine habitat potentially available to Ethiopian wolf, in km^2.

Chapter 3
Endangering Processes

The previous chapter has shown that in the recent past Ethiopian wolves have declined throughout their range. The main threats facing Ethiopian wolves are essentially those encountered by most wildlife today: habitat loss and fragmentation and human interference. The recent decline in the numbers of wolves in Bale seems to be due to a combination of factors that result, directly or indirectly, from the above causes and include: road kills, shooting, disease epizootics, hybridization with domestic dogs and possibly loss of genetic variability. Most of these threats are exacerbated by the Ethiopian wolf's specialization to life in the afroalpine ecosystem of Ethiopia (Gottelli and Sillero-Zubiri 1992, Sillero-Zubiri and Gottelli 1994, 1995a. See also Kingdon 1990, Yalden and Largen 1992).

The relevance of each of these endangering factors and their interaction need to be seen in the context of how rarity and population fragmentation affects a species' survival.

Rarity and Endangerment

Why is the Ethiopian wolf endangered? To understand this we must address the questions of why some species are rare, why populations and species become extinct, and what makes a population vulnerable.

Species may be rare in two senses: they may occur in very restrictive ranges or may not be common even in suitable habitat. There are several reasons why species confined to real or ecological islands show high rates of extinction. Their restricted distribution may limit population size, and allow adverse factors to operate on the entire population. Island species are less likely to receive immigration or be recolonized from neighbouring populations. They may also have evolved adaptations that render them vulnerable to predation or competition from humans, introduced species or their pathogens. Most of the 491 species reported extinct in the last 400 years (WCMC 1992) had restricted distributions, 96% were endemic to single countries and 75% were restricted to islands (Magin *et al.* 1994).

Most rare canids occur at low density, their total population divided into many populations. Examples of rare, low density canids are grey wolves (*Canis lupus* – 0.01–0.001 per km²), African wild dogs (*Lycaon pictus* – one pack per 500/2,000 km²), Asian dhole (*Cuon alpinus*) and bush dogs (*Speothos venaticus* – ca. one per 20 km²). They share other natural history features: all are communal hunters, live in packs, are cooperative breeders, but as a rule only the dominant male and female breed once a year, producing large litters (an important implication of this is that in good years populations can recover quickly). As a consequence, large areas and many populations are required to conserve them.

In contrast, Ethiopian wolves have a narrow ecological niche, living at high density as a strict rodent predator in a few populations scattered in the Ethiopian highlands. The extinction chances of mammal species living on mountain tops are negatively affected by two traits: large body size and habitat specialization (Brown 1971), both characteristics apply to the Ethiopian wolf. A medium-sized canid, its distribution is limited to isolated pockets of afroalpine habitat.

In closed populations *(i.e.* without immigration) such that of the Ethiopian wolf, the reproductive monopoly of only a small number of individuals, sustained over several generations, will lead to the depletion of genetic variation. Genetic variation is a pre-requisite for evolutionary adaptation to a changing environment. Fluctuating populations reach certain minima, known as population bottlenecks, which also have significance in determining the rate at which variability is lost, and occasionally result in biased sex ratios that may affect overall population reproductive success.

Extinction is a natural process, and all species become extinct sooner or latter, simply as a result of variation in population numbers. Adaptive, environmental and stochastic factors operate over populations making them more or less susceptible to extinction. Small populations are more susceptible to local extinction. Large populations may be decimated by catastrophes such as epidemics, cyclones or droughts, and then recover, but small populations are likely to be extirpated by the same catastrophes. Even less dramatic effects, such as a decline in the food resource affecting overall condition, survival and reproductive success over a few years may reduce a small population to a handful of animals, at which point stochastic effects (such as biased sex ratio or heavy mortality) may lead to local extinction.

Furthermore, in a small population the frequency of mating between close relatives may increase, which can increase random genetic drift and inbreeding depression. Reduced heterozygosity may expose recessive alleles which can reduce fecundity and increase mortality (Templeton 1986), driving a declining population to extinction. The fragmentation of a population and its reduction in size, may also increase the risk of genetic introgression. This may be of particular importance with closely related, sympatric carnivores with small population sizes that are the result of ecological and anthropogenic factors (Brownlow 1996). Members of small populations may become less able to find an appropriate mate, and mate instead with a closely-related species (Hubbard *et al.* 1992, Jenks and Wayne 1992).

Thus the biggest threat for the long-term survival of Ethiopian wolves, and other rare species, is the small size of their remaining populations (Chapters 2 and 6).

Threats to Ethiopian wolves

Habitat Loss and Fragmentation

The specialized Ethiopian wolf's niche as the prime afroalpine rodent predator has resulted in the species' restricted distribution. Afroalpine habitats were geographically widespread during the Pleistocene (Yalden 1983, Kingdon 1990). However, during the last 15,000 years these habitats became increasingly rare and fragmented due to a gradual warming of the African continent that pushed upwards the lower boundaries of the afroalpine grasslands. This process has reduced the habitat available to the Ethiopian wolf by at least one order of magnitude (Gottelli and Sillero-Zubiri 1992, Chapter 2).

Habitat loss and fragmentation are further worsened by increasing high-altitude subsistence agriculture and grazing. The highlands of Ethiopia are among the most densely populated agricultural areas within Africa today: rural densities of 47 people/km² are typical (Mesfin Wolde-Mariam 1972). The problems of habitat destruction, soil degradation and high population pressure are persistent and, although concentrated in the north of the country, are spreading south rapidly. Remnants of afroalpine ecosystems increasingly resemble islands hemmed in by degraded or lowland areas that act as ecological boundaries (Hurni 1986). The risk of local extinctions of many endemic species is increased by this process of insularization (Kingdon 1990), and the resulting susceptibility to human persecution, hybridization, inbreeding, disease and natural catastrophes.

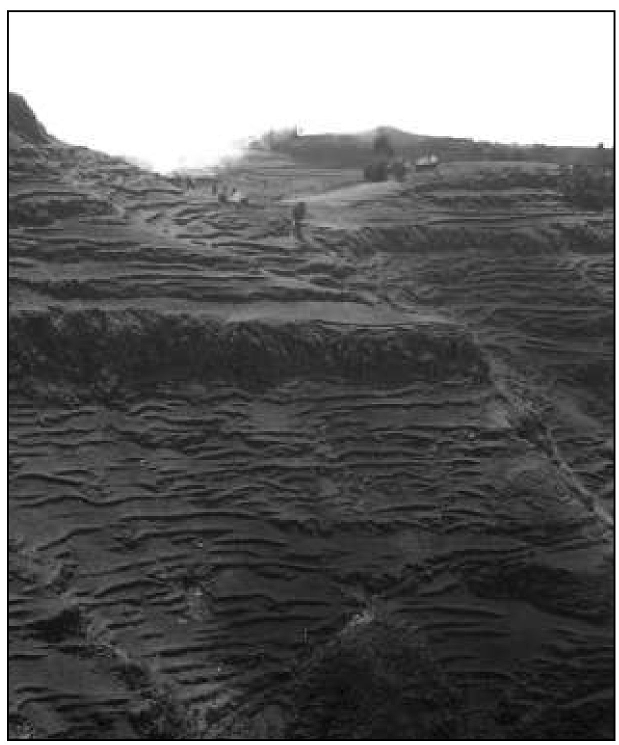
Loss of habitat can affect the survival of Ethiopian wolves in two ways:

i) by decreasing the total area of habitat available and therefore placing an upper limit on the global population, and

ii) through habitat fragmentation.

Much of the Ethiopian wolf's decline during the last few decades is the result of habitat destruction, particularly in northern Ethiopia. Heather and grasslands have been cleared and ploughed to grow cereal crops and provide grazing. The immediate consequences are diminished rodent prey populations and increased conflict with human interests. At least two wolf populations in Gojjam and Shoa have been extirpated due to habitat degradation, and the ranges of other wolf populations have been reduced.

Habitat fragmentation is a complex phenomenon which, at its extreme, causes isolation and therefore increasing vulnerability to demographic stochasticity and the consequent damaging loss of genetic variability (Chapter 5). The fragmentation of the wolf's range is worrying: only two of the five areas the species now inhabits hold more than 100 animals. Even when habitat fragmentation does not result in total isolation, its influence on range geometry (*i.e.* decreasing area and increased fragmentation result in areas with



Habitat degradation in Menz.

relatively larger perimeters) eventually result in increasing contact with humans, roads, livestock and domestic dogs.

In summary habitat loss and fragmentation result in:

- population isolation, increasing the rate at which genetic variability is lost,
- smaller populations, increasing rates of demographic and other stochasticity,
- juxtaposition with human interests, increasing contact with people, livestock and domestic dogs.
- All these factors result in increased risks of local extinction.

Human Factors

In addition to the habitat degradation and loss caused by people, there are other derived threats, such as:

- increased exposure of livestock to wild carnivores, conceivably resulting in stock losses and escalation of human-wildlife conflict,
- increased contact of domestic dogs and wolves, resulting in potential for hybridization and disease transmission,
- increased road kills.

Most canid species have been implicated in predation on livestock. Twenty-one of 34 species of canid have been reported to kill domestic animals (Ginsberg and Macdonald 1990), although for only a few species could this predation be considered economically significant. Although Ethiopian wolves are very rare, they occur locally in fairly high densities and may conflict with people whose livestock share their foraging grounds. This is especially obvious in northern Ethiopia, where the human population is one of the highest in Africa. Predation on livestock may be an indication of the destruction of the Ethiopian wolves' natural habitat, forcing them to turn to prey upon small stock in areas where agricultural practices and overgrazing have diminished the availability of rodent prey. This possibility however, remains to be substantiated.

Unlike the northern highlands, the Bale Mountains have never been heavily populated. In 1984, permanent settlement in BMNP was estimated by an aerial survey to be 2,500 people, approximately one person per km² (Hillman 1986), of which about one third live in wolf habitat. More recently the 1992 census indicated at least 7,000 living within the BMNP boundaries. These people are Oromo pastoralists, depending for their livelihood on cattle and smaller stock which they graze in the mountain grasslands and heathlands. In areas below 3,500 m raising livestock is combined with the cultivation of barley. Within BMNP, the Oromo have hitherto coexisted peacefully with wolves and other wildlife, although this is quickly changing (see below).

Overgrazing

Extensive overgrazing by cattle may have a significantly unfavourable impact on rodent populations. For example, in Uganda's Queen Elizabeth National Park, highest populations of rodents occurred where large mammals were least numerous, whereas areas heavily grazed had fewer rodents (Delany 1972). However in areas of BMNP moderate grazing may not have a negative influence on rodent populations. In west BMNP the Web Valley meadows seem to be maintained by grazing and carried similar biomass of rodent species to ungrazed areas. Similarly, heath stands kept open by grazing and/or fire may sustain higher rodent densities. Furthermore, vegetation height may have an influence on wolf foraging success, with higher wolf densities occurring in areas of short grass (Sillero-Zubiri *et al.* 1995b).

Regular livestock censuses in the Web Valley indicated a combined average of 22 head of cattle, horses and donkeys per km², with a maximum of 46 heads per km². Sheep and goats forage on the steep valley sides and ridges. Livestock numbers are highest during the late wet season when the herds are kept away from the extensive wheat crops in the lowlands and lowest in the dry season, as the herds are then taken to feed on the fields which have been left fallow. Traditionally, people from all around BMNP regularly take their cattle to the high altitude mineral springs, but the recent prolonged stays of livestock by the springs suggests that their use is becoming the excuse for grazing at high altitudes (Hillman 1986, Kemp-McCarthy 1990). A perception of wild carnivores as

Increasing domestic cattle pose two problems for the remaining Ethiopian wolves: reduction of rodent prey through overgrazing, and increasing contact with the local people's dogs.

predators of livestock may develop with these protracted grazing periods inside wildlife areas.

Persecution by Humans

Local people's attitudes towards Ethiopian wolves vary from indifferent to negative, always in direct relation to their need for farming and grazing land. While wolves in Arsi, Bale and May are tolerated, they are persecuted in the other northern populations. Conflict is likely where there are shepherds, and in some areas Ethiopian wolves have been accused of taking small domestic stock and are persecuted.

Persecution has been notable in Simien (Brown 1964a) where in the past even park staff perceived wolves as vermin (Nicol 1971). Brown (1964a) suggested that wolves may be more nocturnal in locations where they are persecuted. The flight distance of wolves in Simien, however, is not significantly greater than elsewhere, suggesting perhaps that persecution is not the actual cause of the wolves' decline (B. Nievergelt pers. comm., J. Malcolm pers. obs.). A small number of interviews in Menz and Gosh Meda, north Shoa, suggested that wolves are tolerated, although they are perceived as killers of small stock (Sillero-Zubiri 1995).

Until recently the Oromo people were remarkably tolerant of wolves in the Bale Mountains. Four years of close observations on wolf-human interactions showed that wolves and pastoralists interacted very little and coexisted peacefully. The pastoralists did not regard the wolf as a threat to their stock and even occasionally left their sheep unattended during the day. Sixty percent of 40 heads of family interviewed in areas of high wolf density claimed to have lost at least one lamb from their flock to wolves within the last three years, but dismissed such losses when compared to damage by spotted hyaenas (*Crocuta crocuta*) (Gottelli and Sillero-Zubiri 1990). Only two cases of predation on sheep were observed in Bale in more than 3,900 hours of observations, including 946 hours of foraging observations (Sillero-Zubiri and Gottelli 1995a).

Children looking after sheep and goats in BMNP keep any inquisitive wolves away from their herds by shouting and throwing stones, but this was an unusual occurrence. With the exception of rare attacks by children, people were indifferent to wolves. Similarly, wolves did not avoid human habitation and were oblivious to people walking or riding across their range. Wolves drifted cautiously away only if people came within 100 metres or showed interest in them. Wolves seemed to be more aware of approaching tourists than of the Oromo residents (Gottelli and Sillero-Zubiri 1990).

An additional source of wolf persecution in the past came from sport hunters seeking trophies in afroalpine habitat. Sport hunters reputedly shot and killed wolves in West Bale and Arsi on two separate occasions in the 1980s (Gottelli and Sillero-Zubiri 1990). Sport hunting is currently banned in Ethiopia.

Warfare

Ethiopia has suffered the ravages of war between government forces and guerrilla movements for several decades, and only recently has the fighting stopped. War affects wildlife conservation directly through destruction of the environment and shooting of wildlife, and indirectly due to the repercussions on national policy and people. The impact of war is manifested in policy changes, blocking conservation activities, deterring outside funding for projects, and diverting funds from social to military activity. For instance, in the late 1980s up to half of the Ethiopian budget was allocated to defence, reducing the funds available for other activities including education and wildlife conservation. As a consequence of the war most afroalpine ranges in northern Ethiopia were out of bounds for wildlife conservation and surveys. Simien Mountains National Park was closed for at least six years and Park staff became targets of guerrilla activity. In addition to indiscriminate killing of wildlife, the effects of war may linger: land mines may restrict access to conservation areas and kill people and wildlife, and displaced people may be forced to exploit the environment. Much of SMNP was opened for settlement when it was outside EWCO control.

Even areas outside the direct influence of war may suffer increased availability of weapons. Wildlife conservation and park management in BMNP deteriorated quickly following the end of the war and change of government in May 1991. Following the overthrow of Mengistu's government, peaceful coexistence between people and wildlife turned into persecution. Automatic weapons sold by run-away soldiers became widely available, and Ethiopian wolves and other wildlife became shooting targets. The killing seemed to be part of the '*retribution*' being carried out by local people against all elements of government, probably fuelled by grudges against the Park administration (Sillero-Zubiri and Gottelli 1993). At least six known adult wolves were shot in late 1991. The shooting of a breeding female led to the death of her 3-week old litter. In another instance, two pups perished after their den was plugged with the corpse of a shot wolf. The slaughter subsided after lengthy discussions with the local elders, but the threat is likely to persist until some sort of gun control is imposed.

Trucks cross the Sanetti Plateau on an all-weather road.

Road Kills

With an ever-expanding human population, increased development and habitat loss, Ethiopian wolves and other afroalpine wildlife are increasingly exposed to death on new roads. As the habitat available to wildlife declines, and contact with man increases, the shooting of wolves from cars or killed by cars may also increase. There is concern that increasing use of roads over the next few years as a consequence of economic growth and increased transport will exacerbate this trend.

The Ethiopian wolves in BMNP are particularly vulnerable to traffic kills because they regularly cross busy roads in Gaysay near Dinsho, and on the Sanetti Plateau, where an all-weather road runs across 40 kilometres of prime wolf habitat. Between 1988–1991 an average of 26 vehicles (mostly trucks) used the road every day (Gottelli and Sillero-Zubiri 1990). The wolves are unafraid of vehicles and ignore them even at close proximity. They may den and rear pups within one hundred metres of the road.

At least two animals were killed on the Sanetti road between 1984–1986 (Hillman 1986). Another four car kills were reported between 1988–1991. Two other animals have been shot from the road and another two were left permanently lame from collisions with vehicles. Some accidents may have been caused by fast driving or heavy mist, but we suspect that some drivers deliberately drive at wolves. A local superstitious belief associates wild canids crossing somebody's path with bad luck (Hillman 1986) and leads some drivers to shoot or run over wolves and other wild canids.

The existence of the road across Sanetti Plateau, and the fearless wolves beside it, are great assets for the development of tourism in BMNP. However, immediate measures should be taken to educate drivers and the local administration to avoid unnecessary wolf deaths.

Road kills may also be a mortality factor elsewhere. A juvenile wolf was killed in 1988 in a road traffic accident between Tarmaber and Mehal Meda in Menz, north Shoa (M. Melloni, pers. comm.). Similar accidents could occur on other roads across wolf habitat such as the Debre Birhan – Ankober road in Gosh Meda, north Shoa, the Bekoji – Gobesa and Ticho roads in Arsi.

Domestic Dogs

Even when people tolerate wolves human presence may have secondary effects on the survival of the species through the presence of domestic dogs. Wild canids may be affected by domestic dogs in three different ways:

i) by direct competition and aggression;
ii) by dogs acting as vectors of disease;
iii) by introgression and outbreeding depression.

Cases of negative impact of domestic dogs on wild carnivores abound, but a typical one is that of grey wolves and dogs in Italy (Boitani 1983).

Domestic dogs, kept by shepherds to guard livestock from predators, are present throughout BMNP. Very few dogs are fed or looked after, rather they are effectively independent, living on offal and carrion. Dogs pose a threat to wildlife in the northern areas of BMNP, where they reputedly kill antelopes. Dogs are also known to have killed sheep and are a threat to the human population as vectors of rabies, a common disease in Bale Region (Chapter 4).

Every settlement in the Web Valley, has several dogs with an estimated 0.7 dogs per km² in the survey area, at an average of 11 dogs per settlement (Gottelli and Sillero-Zubiri 1990). The presence of large numbers of domestic dogs in prime wolf habitat has been considered the most immediate threat faced by the species in BMNP (Gottelli and Sillero-Zubiri 1992, Gottelli *et al.* 1994).

Domestic dogs accompany the Oromos people living in the Bale Mountains.

In BMNP, dogs roam across wide areas of wolf range and forage on rodents, potentially competing with the wolves for the same food resource. Additionally, all ungulate carcasses that may become available to carnivores, including those of livestock, are quickly monopolized by dogs. Thus a potential source of food is denied to the wolves. Dogs travel regularly with their owners in and out of the Bale Mountains and are then in contact with many other dogs which are attracted to garbage and carrion in villages. These dogs may provide the vehicle for pathogens to reach their wild relatives (Mebatsion *et al.* 1992b, Sillero-Zubiri *et al.* 1996a, Chapter 4).

Wolves normally avoid direct contact with dogs. In all 34 agonistic dog-wolf interactions observed in BMNP dogs always chased away wolves, which were faster than dogs and escaped easily (Sillero-Zubiri 1994). No information is available on wolf-dog interactions in other Ethiopian wolf populations. However, contact between both species is greater at the lower limits of the species' altitudinal range, and thus is likely to increase with increases in human density and habitat fragmentation. Ethiopian wolf packs located at the periphery of a restricted population would therefore have more contact with domestic dogs. A comparable phenomena was observed in Simien where wolves were seen together with sympatric golden jackals (*Canis aureus*) at least four times (Nicol 1971, Nievergelt 1981). Non-resident female wolves dispersing away from centres of high wolf density will face increasing chances of meeting domestic dogs or jackals instead of another wolf.

Hybridization

The Ethiopian wolf is closely related to the grey wolf and coyote and can hybridize with domestic dogs (Gottelli et al. 1994, Chapter 5). Following hybridization, a population may be affected by a reduction in fitness (in either fertility or viability) known as outbreeding depression (Templeton 1986). Concern was raised of the possibility that the wolves in BMNP may hybridize with sympatric domestic dogs (Sillero-Zubiri and Gottelli 1991). Some animals in the Web Valley population had an unusual appearance, characterized by shorter muzzles, heavier-built bodies and differences in coat patterns. A study of interspecific hybridization and genetic variability indicated that hybridization of wolves and their domestic relatives had indeed occurred (Gottelli et al. 1994, Chapter 5).

An Ethiopian wolf-dog hybrid.

Disease

As a species becomes more endangered, their last remaining individuals are likely to be concentrated in a few relict populations. Any of these populations could be eradicated by the sudden outbreak of disease. Rabies poses a serious risk for populations of rare carnivores and is possibly the most dangerous disease that may affect the Ethiopian wolf. For instance, rabies was confirmed as the cause for one, and possibly two, epizootics in BMNP, which killed whole wolf packs in 1990 and 1991 and accounted for most of the recorded population decline (Sillero-Zubiri *et al.* 1996a, Chapter 4).

Recent cases of rabies in rare and endangered canids (*i.e.* Ethiopian wolf, Blanford's fox *Vulpes cana*, African wild dog), all surviving in small, fragmented populations, have given a new dimension to concerns about the control of rabies (Macdonald 1993). Epidemiologists must now consider wild carnivores not only as rabies reservoirs but also as casualties of the disease, and efforts should focus not only on control but also on the protection of endangered species.

Due to the importance of the threats posed by hybridization and disease to the survival of Ethiopian wolves these topics are dealt separately in the following two sections (Chapters 4 and 5).

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

K. Laurenson, Fekadu Shiferaw and C. Sillero-Zubiri

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.

Chapter 5
Systematics, Population Genetics and Genetic Management of the Ethiopian Wolf

R.W. Wayne and D. Gottelli

Introduction

Molecular genetic techniques can be used to address several questions of interest to conservation biologists. Significantly, recent advances in DNA technology have allowed a finer precision to investigations. DNA techniques can now potentially be used to identify parents, offspring, and close relatives in a single group or population, to quantify the genetic variability of present and past populations, to reconstruct the phylogenetic relationships of taxa now very rare or extinct and to match samples of individuals to each other and to species or populations for forensic purposes. Moreover, the quantity of material required for DNA analyses may be minute, for example, single hairs, serum, or archaeological or museum samples of pelts and bone. Because of the recency of these techniques, they have yet to be widely applied to significant problems involving the management and conservation of small populations. In this review, we will address several genetic issues important to the conservation of Ethiopian wolves (*Canis simensis*) that span ever finer levels of evolutionary divergence. At the highest level are questions about the uniqueness of species relative to other species within the same genus or higher taxonomic unit, and at the lowest level, questions concerning the parentage and reproductive success of individuals.

Systematics and Phylogenetic Distinction

The phylogenetic position of the Ethiopian wolf is uncertain as some researchers have suggested relationship to African jackals rather than wolves (see Sillero-Zubiri and Gottelli 1994). In general, the systematics and phylogenetic distinction of endangered species is an important concern for conservation biologists (*e.g.* May 1990). Phylogenetic analysis based on morphological or molecular methods allows a ranking of species on a scale reflecting the distinctiveness of their evolutionary heritage. For example, we might consider a giant panda (*Ailuropoda melanoleuca*) more distinct in a phylogenetic sense relative to other bears, because it is the only living representative of an entire subfamily. In contrast, a single genus of beetle may encompass hundreds of genetically similar species. Therefore, because each species of such beetles contains less distinct genetic information than would the sole representative of a higher taxon, it might be accorded a lower priority for conservation measures. Of course, other characteristics such as overall endangerment, the role in the ecosystem of each species and their value as flagship species, need to be considered as well. Comprehensive discussion of molecular techniques as applied to systematic questions may be found in Hillis and Moritz (1990) and discussion of schemes which rank species according to their position in a phylogenetic network are discussed by Vane-Wright *et al.* (1990) and Faith (1994).

Hybridization

An important genetic concern in Ethiopian wolves is the degree of interbreeding with domestic dogs (Sillero-Zubiri *et al.* 1993, Chapter 3). Interbreeding among individuals from closely related species and among individuals from distinct populations of the same species is a common natural phenomenon (Barton and Hewitt 1985, 1989, O'Brien and Mayr 1991). However, in the Ethiopian wolf, interbreeding is not a natural phenomenon but is due to the recent introduction of domestic dogs. Human activities have led to hybridization between other species, for example coyotes (*Canis latrans*), grey wolves (*C. lupus*) and domestic dogs in North America and Europe (Lehman *et al.* 1991, Wayne and Jenks 1991), the Florida puma (*Felis concolor coryi*) and a non-native subspecies of puma (O'Brien *et al.* 1990), and native fish populations and hatchery raised fish (Waples and Teel 1990). Similarly, captive breeding stocks may often represent a blend of subspecies through unintentional interbreeding. An example is the Asiatic lion (*Panthera* *leo persica*), for which breeding stocks at many zoos have been found to contain genes from the African subspecies (O'Brien *et al.* 1987). This discovery caused a dramatic change in the captive breeding program of the Asiatic lion. Genetic screening of wild, endangered populations or captive stocks suspected of such artificial hybridization may provide essential data for on-site conservation or captive breeding programs.

Population Genetic Units

The Ethiopian wolf had a historic distribution throughout the Ethiopian highlands and given the presence of topographic and environmental barriers to dispersal, some populations may have acquired important genetic differences that should be preserved by captive breeding and *in situ* genetic management. Two subspecies are currently recognized, one from either side of the Ethiopian Rift Valley, based on craniological differences (Yalden *et al.* 1980, Chapter 1). Molecular genetic analysis can be used to document the genetic distinctiveness of subspecies and other population genetic units that existed within species. In addition, molecular genetic techniques can be used to trace corridors of dispersal among populations and to identify populations that might provide the source material for re-stocking or reintroduction programs. Re-stocking of an endangered population may be necessary if inbreeding has significantly affected viability. Given this condition, re-stocking with individuals from a similar environment and with a similar genetic constitution to that of the source population may be desirable.

Genetic Variability

The small population size of Ethiopian wolves suggests that genetic variability may be limited and will continue to decline unless numbers increase. Genetic variability generally comprises two components, allelic diversity (or the number of alleles at a given locus), and genetic heterozygosity (or the expected proportion of genes in the heterozygous state in the average individual). In small populations, genetic variability may be rapidly reduced; initially allelic diversity decreases followed by reduced heterozygosity levels (Allendorf 1986). Such decreases in heterozygosity, especially in association with breeding among close relatives, may correspond with decreases in viability and increased juvenile mortality (Allendorf and Leary 1986, Ralls and Ballou 1983, Ralls *et al.* 1988, Quattro and Vrijenhoek 1989). Genetic variability is thought to be essential to the long-term persistence and adaptability of populations and thus management of captive and wild populations of endangered species should be designed to minimize the loss of genetic variability. Both morphologic and molecular techniques can be used to compare variability among populations and to follow the decline of variability in small populations (*e.g.* Wayne *et al.* 1991a, 1991b). The discovery of hyper-variable mini- and micro-satellite loci may potentially increase the sensitivity of genetic variability measurements (*e.g.* Taylor *et al.* 1994).

Genetic Management

Finally, there are several genetic questions important to the establishment and genetic maintenance of captive populations of Ethiopian wolves and to their reintroduction or the genetic augmentation of populations in the wild. In wild and captive populations, there may be great asymmetries in reproductive success among individuals and sexes such that the effective population size is reduced and breeding among close relatives occurs. To reduce the loss of genetic variability in small populations, the genetic relationships of individuals and breeding structure need to be understood so that the number of breeders and their genetic dissimilarity is maximized. Moreover, the founders of a captive population should be chosen such that they are unrelated and best represent the genetic diversity within the source population. Animals of hybrid ancestry should also be excluded if hybridization is not part of the evolutionary history of the population (*e.g.* De Marais *et al.* 1992). Molecular genetic techniques can effectively be used to deduce parentage in wild and captive populations, to identify individuals that are close relatives, and that have population specific polymorphisms (Avise 1994). Even in populations for which little information is available, inferences can be made about the breeding structure from molecular genetic data (*e.g.* Packer *et al.* 1991, Lehman *et al.* 1992).

Molecular-genetic Techniques

Within species, canids generally show only low levels of allozyme polymorphism (*e.g.* Wayne *et al.* 1991*b*, Kennedy *et al.* 1991). Consequently, population genetic studies focused on the mitochondrial genome because in mammals its sequence generally evolves much faster than most nuclear genes (Brown 1986). Moreover, because the mitochondrial genome is maternally inherited in a clonal fashion without recombination, analysis of mitochondrial DNA (mtDNA) sequences in populations provides a history of maternal lineages that avoids the reticulation caused by recombination and may allow for a precise reconstruction of colonization events, gene flow and hybridization (Avise 1994). Initially, we characterized mtDNA variation using a restriction fragment analysis approach (*e.g.* Lehman *et al.* 1991, Wayne *et al.* 1992). More recently, with the advent of the polymerase chain reaction and the identification of universal primers, we have begun to compare directly hyper-variable mitochondrial sequences in large population samples (Wayne and Jenks 1991; Girman *et al.* 1993; Mercure *et al.* 1993; Maldonado *et al.* 1995). Such techniques can be used on samples obtained through non-invasive sampling, which include samples of hair and faeces (*e.g.* Hoss *et al.* 1992; Morin *et al.* 1994).

However, mitochondrial (mtDNA) analysis provides only one perspective on genetic variation. Levels of mtDNA variation are more severely affected than nuclear loci by changes in population size and phylogenetic trees based on mtDNA sequence data record the history of only a single linked set of genes. Formerly nuclear genes with equivalent evolutionary rates had not been identified or were difficult to survey in large population samples. Recently, hyper-variable nuclear loci have been characterized in a diverse array of taxa that are composed of tandem repeats of very short sequences, 2–5 base pairs (bp) in length. These simple sequence repeat or micro-satellite loci can easily be amplified by the polymerase chain reaction and separated on acrylamide gels. This procedure allows an assay of individual loci that are highly polymorphic in large population samples and, as above, allows the use of degraded material including bones, hair and faecal material (Hagelberg *et al.* 1991; Hoss *et al.* 1992; Roy *et al.* 1994*a*; Morin *et al.* 1994). A panel of only a dozen or fewer micro-satellite loci may be sufficient to quantify components of variation within and among populations and to study individual relatedness within social groups (*e.g.* Amos *et al.* 1993; Roy *et al.* 1994*b*). We have assessed variation for about 10 highly polymorphic micro-satellite loci in several canid species and find they provide an extremely useful contrast to past surveys of mtDNA variability (see below).

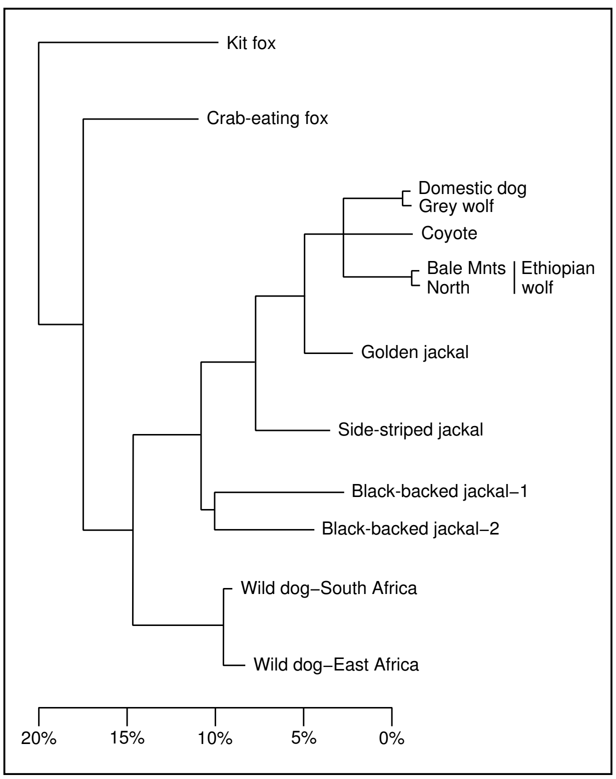


Figure 5.1. A strict consensus tree of the two most parsimonious trees obtained from phylogenetic analysis of 2001 base pairs of mitochondrial DNA sequence (Gottelli et al. 1994).
Two individuals were sequenced for each species. The two east African black-backed jackal sequences (1 and 2) are representatives of the two divergence mtDNA genotypes found there (Wayne et al. 1990). The grey fox sequence was used to root the tree. Nodes supported in over 50% of 1000 bootstrap trees are indicated.

Results and Discussion

Systematics and Phylogenetic Distinction – a Wolf in Africa

Our phylogenetic analysis of the sequence of 2001 base pairs of mtDNA showed conclusively that the Ethiopian wolf is a close relative of grey wolves, domestic dogs, and coyotes (Fig. 5.1, Gottelli *et al.* 1994). This association was our motivation to use Ethiopian wolf as a common name instead of the more frequently used Simien jackal or Simien fox (Chapter 1). The phylogenetic tree provides an evolutionary yardstick to measure the distinction of Ethiopian wolves; they are a distinct species, as different from grey wolves and coyotes as each of these species is from each other. As the only close relative of grey wolves and coyotes in Africa, they are clearly a unique taxon worthy of conservation and are phylogenetically distinct from the African wild dog (*Lycaon pictus*) and the three species of African jackals.

The phylogenetic relationships of Ethiopian wolves and their restriction to afroalpine grasslands above 3,000 m suggests an unusual history. We hypothesized that Ethiopian wolves are a relict species resulting from a Pleistocene invasion of a wolf-like canid into the once more extensive Afroalpine ecosystem. This species has become remarkably well adapted to existence in the high altitude grasslands and heathlands. Its social behaviour, feeding ecology and morphology differ from other wolf-like canids (Chapter 1) and contrast with those of the savanna-living, African wild dog. The unique attributes of the Ethiopian wolf and its distinct evolutionary history, highlight the urgent need for its conservation.

Population Genetic Units

The two populations we studied in detail from the Bale Mountains National Park were located in the Sanetti Plateau and the Web Valley, two areas separated by 20 kilometres of inhospitable rocky peaks, crossed by narrow corridors of suitable habitat (see Fig. 2.6). We found that both populations had the same mtDNA sequence. More significantly, micro-satellite allele frequencies differed little between the two populations. A measure of population differentiation, F_{st}, was 0.057 indicating that only about 6% of the genetic variation was distributed between populations. The Nei's genetic distance between the two populations is only 0.025 which contrasts with the average value of 0.55 between them and grey wolves or 0.47 between them and domestic dogs. Migration rates based on this value of F_{st} are large, about 4.3 migrations per generation. Because, more than two migrants per generation are sufficient to confound genetic divergence due to drift in finite populations (Slatkin 1987), and given the absence of genetic distinctiveness, the two localities may be considered as not genetically isolated.

The molecular techniques we used can also be applied to museum pelt specimens. We analyzed a small highly variable segment of the mtDNA control region in two museum skins from an extinct northern population (Fig. 2.2, Roy *et al.* 1994a). We found these skin samples had identical sequences but that both were different in two of 134 base pairs from wolves in the Bale Mountains to the South. This amount of sequence divergence (about 1.5%) is relatively small for this hyper-variable region of mtDNA (called the control region), and may be the effect of recent isolation since the last glaciation 10,000–70,000 years ago. In contrast, Ethiopian wolves differ from domestic dogs and grey wolves by about 11% of the control region sequence. Consequently, although Northern populations may be genetically isolated from those in the Bale Mountains, the amount of genetic differentiation is minimal compared to that which exists between species or long-isolated subspecies (*e.g.* Wenink *et al.* 1993; Maldonado *et al.* 1995). If the population of Ethiopian wolves from the North was large, separate captive breeding plans might be considered. However, because most populations from the North are extinct, large number of individuals cannot be obtained from either northern or southern locations to establish captive breeding populations. We suggest that concern for preserving this limited degree of population differentiation should not override concerns about inbreeding depression in small separately maintained captive populations.

Genetic Variability

The demographic history of Ethiopian wolves is marked by both long term and recent range reductions. The current limited fragmented distribution of the Ethiopian high altitude afroalpine habitats is only 5% of the area existing after the last Ice Age (see Gottelli *et al.* 1994). Consequently, the geographic range and numerical abundance of Ethiopian wolves has been progressively decreasing during the Holocene. Recently, a more rapid decline in habitat has occurred as habitat loss and fragmentation was accelerated by human population growth and agriculture (Gottelli and Sillero-Zubiri 1992, Chapter 2).

Mitochondrial DNA sequence and restriction site analysis showed that the two populations that we surveyed in the Bale Mountains had a single mitochondrial genotype, the most limited population variability of any extant canid, except those populations isolated on islands (Table 5.1, Gottelli et al. 1994). Similarly, average variability of micro-satellite loci was also dramatically reduced to 46% of the heterozygosity and 38% of the allelic diversity of an average population of wolf-like canids (Table 5.1). All of the genotype distributions fit Hardy-Weinberg expectations as determined by chi-square tests ($p < 0.05$). Overall heterozygosity and allelic diversity appeared lower on the Sanetti Plateau; only six of nine loci were polymorphic and average levels of heterozygosity were significantly lower (Fig. 5.2, Gottelli et al. 1994). In general, such low values of heterozygosity are consistent with an equilibrium effective population size of only a few hundred individuals. Moreover, recent habitat fragmentation has likely decreased the effective population size to a value much lower than this. Consequently, levels of genetic variation will rapidly decline in both populations, especially in more slowly evolving loci of the kind that might influence continued adaptive change within the population. In fact, recent theoretical analysis suggests that at least five thousand individuals are needed in order to prevent drift from fixing mildly deleterious genes, and causing the population to be less fit (Lande 1995). Similarly, in the other still remaining isolated populations of Ethiopian wolves, loss of genetic variation and inbreeding will occur, increasing the immediate probability of population extinction. In sum, our results show that Ethiopian wolves have already lost substantial genetic variation. This loss will accelerate given the present extent of habitat fragmentation and will be a negative influence on the survival of populations in the short and long term.

Hybridization

The close relationship of Ethiopian wolves to domestic dogs suggests that they may be able to hybridize with them just as dogs, coyotes and grey wolves hybridize with each other (Gray 1954, Lehman *et al.* 1991). Although as discussed above, loss of variation and inbreeding is a concern, a more pressing issue with Ethiopian wolves is hybridization with domestic dogs. Domestic dogs are abundant in the Web Valley and are often only loosely associated with humans (Chapter 3). In contrast, domestic dogs are nearly absent from the Sanetti Plateau. Field researchers observed that many Ethiopian wolves in Web Valley had unusual coat coloration and morphology and suspected hybridization because of local reports of dogs mating with wolves

Table 5.1
Number of mtDNA restriction site genotypes, maximum percent mtDNA sequence divergence within a species, and the mean number of microsatellite alleles per locus and their mean heterozygosity for ten canid species. References for these data are indicated.

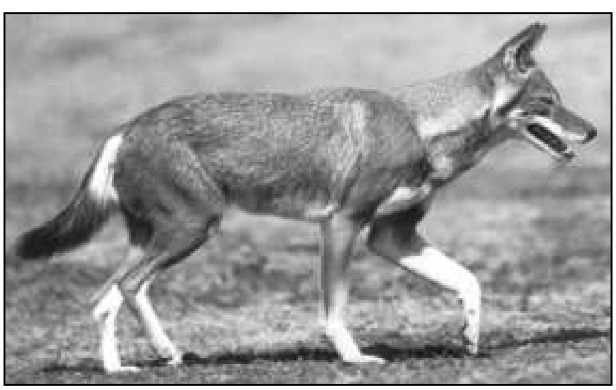
Species	Number of genotypes	% Sequence divergence	Alleles per locus	Heterozygosity	Reference
Ethiopian wolf *(Canis simensis)*	1	0.0	2.4	0.24	a
Black-backed jackal *(Canis mesomelas)*	4	8.4	5.0	0.67	b
Golden jackal *(Canis aureus)*	2	0.1	4.8	0.52	b
Side-striped jackal *(Canis adustus)*	2	0.2	ND	ND	b
Coyote *(Canis latrans)*	32	2.5	5.9	0.68	c
Gray wolf *(Canis lupus)*	9	0.8	4.5	0.62	d
Kit fox *(Vulpes macrotis)*	24	1.5	ND	ND	e
Channel Island fox *(Urocyon littoralis)*	5	1.8	2.1	0.24	f
African wild dog *(Lycaon pictus)*	6	0.9	3.5	0.56	g

a) Gottelli *et al.* 1994; b) Wayne *et al.* 1990; c) Lehman and Wayne 1991, Roy *et al.* 1994a; d) Wayne *et al.* 1992, Roy *et al.* 1994a; d) Mercure *et al.* 1993; e) Geffen *et al.* 1992; f) Wayne *et al.* 1991a, Wayne *et al.* 1995; h) Girman *et al.* 1993.

(Sillero-Zubiri *et al.* 1993). Our initial mtDNA analysis showed suspected hybrid individuals to have genotypes identical to those in '*pure*' Ethiopian wolves from Sanetti. However, based on observation of dog-wolf interactions and the Ethiopian wolf mating system (Chapter 3, Sillero-Zubiri *et al.* 1996b) interspecific matings would be expected between male domestic dogs and female wolves, and not the other way round. Therefore an Ethiopian wolf mitochondrial genotype would be expected in dog-wolf hybrids because of the maternal inheritance of mitochondrial DNA. Consequently, we analyzed pure wolves and suspected hybrids for variation in 10 micro-satellite loci. This analysis showed that all the suspected hybrid wolves had one or more diagnostic dog marker alleles (*e.g.* Fig. 5.2). The presence of several dog marker alleles in phenotypically abnormal wolves confirmed that hybridization was occurring and provided an important justification for dog control. Sympatric dogs threaten Ethiopian wolves in other ways as well; they not only hybridize with them, but are reservoirs of canine diseases and compete with them for food (see Chapter 4).

Patterns of Reproduction within Populations

We had limited data on reproduction patterns in Ethiopian wolves. In one pack, we found that the alpha female had bred with at least two males, neither of which was the alpha male in the pack. One of these males must have carried dog alleles and was likely a dog-wolf hybrid or a domestic dog. This instance of multiple paternity is the first confirmed for a wild canid. In another pack offspring of the alpha female also had dog alleles not found in the alpha male. However, multiple paternity was not necessarily occurring because a single paternal genotype could be constructed that would satisfy the distribution of alleles in this litter. These very preliminary results suggests a more open reproductive system than exists in grey wolf packs which are thought to consist of a monogamous pair and their offspring (Mech 1970). The genetic results indicate that female Ethiopian wolves have multiple mates that may not be an established member of their pack supporting direct observation of mating patterns that report 70% of all matings (n = 70) taking place with extra-pack males (Sillero-Zubiri *et al.* 1996b). This open reproductive system may make the threat of hybridization with roaming dogs more severe, and suggests that captive breeding schemes should allow for multiple matings with males outside the pack.



Genetic Management

No Ethiopian wolves are kept or bred in zoos. A great concern for the survival of Ethiopian wolves is the vulnerability of the remaining populations to stochastic demographic effects and to increased inbreeding and loss of genetic variability. Rabies is thought to have eliminated about half of the Bale Mountains population since 1990 (Sillero-Zubiri *et al.* 1996a) and human persecution and further agricultural development threaten all populations (see Chapters 2–4). Thus, in addition to immediately halting the decline of wild wolves there is an urgent need to establish a captive population as a hedge against further cataclysmic population declines. Unfortunately, progress in establishing a captive population has been slow. The primary difficulty has been obtaining permission to capture and breed individuals from the wild, the construction of breeding facilities in Ethiopia and other prerequisites for exporting wolves to breeding facilities outside the country.

Given these problems can be solved, several genetic considerations need to be addressed. A first concern is the number and selection of individuals from the wild. Clearly, if wolves were more abundant, a large founding stock of 50 or more individuals would be desirable to represent and preserve the diversity of the wild population (*e.g.* Lacy 1987). However, captive populations have been founded with fewer individuals and succeeded although some inbreeding depression may occur. A living model is provided by the captive programme for the red wolf (*Canis rufus*), where only 14 individuals were selected from the wild but rapid expansion of the captive population and careful genetic management keep inbreeding to a minimum. Our own analysis of the red wolf population has shown them to have high levels of allelic diversity and heterozygosity (Roy *et al.* 1994b). The important concern here is that the founder population should be managed to reduce inbreeding and the loss of variability and should be expanded rapidly. To accomplish this, computer-based pedigree management is needed (*e.g.* large scale breeding facilities should be considered that involves the cooperation of many zoos. For the red wolf, a breeding facility was constructed near Seattle that can accommodate about 200 wolves and in addition over a dozen zoos participate in the programme.

Having secured permission to capture 14 or more individuals for captive breeding, they should be selected to represent the genetic diversity of wild populations before the introduction of domestic dogs.

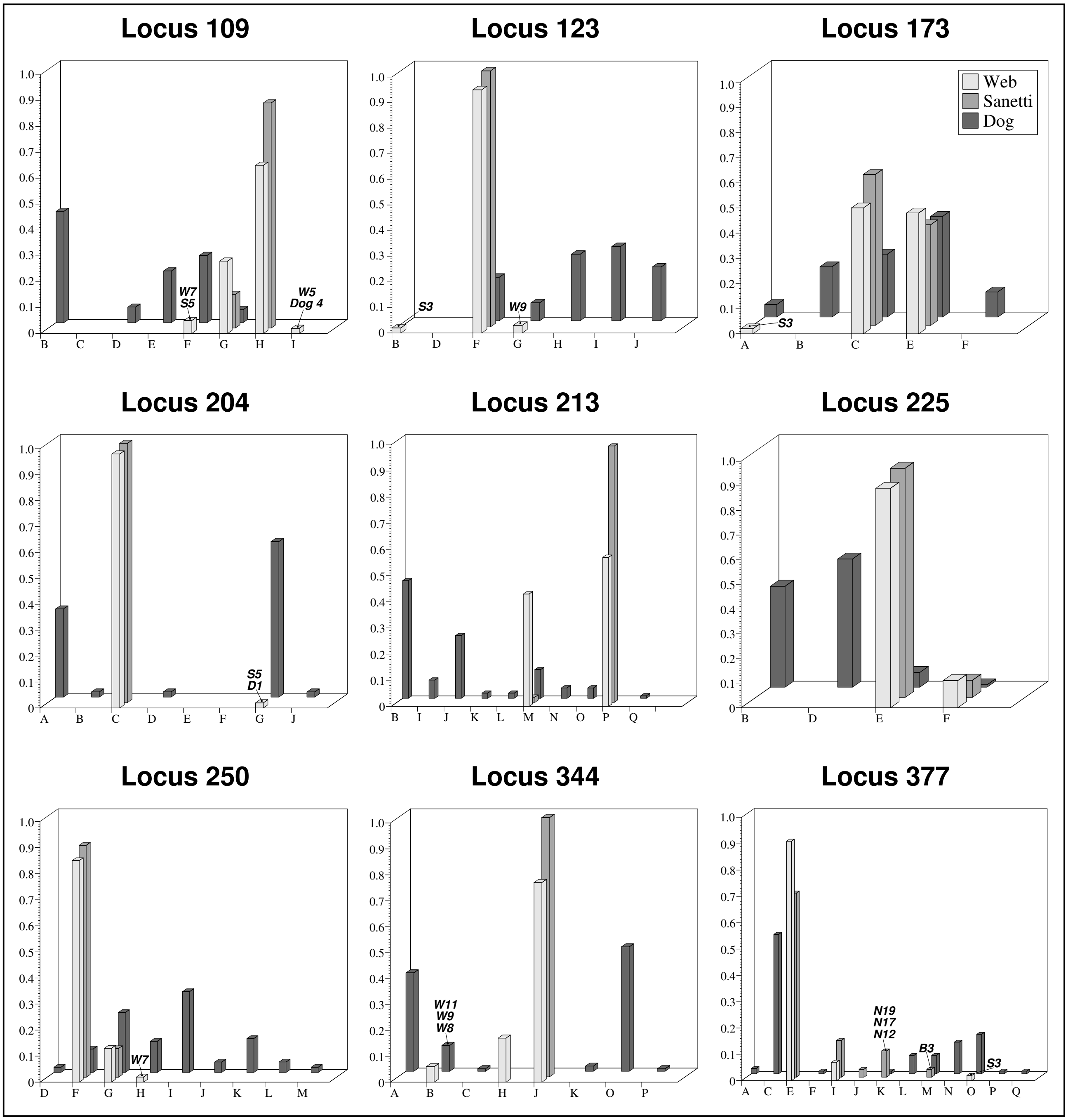


Figure 5.2. Allele frequency histograms for nine microsatellite loci in Ethiopian wolves from the Web Valley and Sanetti and in a sample of 32 domestic dogs.
Consecutive letters differ by a single two base pair repeat unit. Ethiopian wolves that were suspected to be hybrids based on phenotypic criteria are indicated by their ID. All suspected hybrids have one or more alleles that are otherwise found in domestic dogs but absent from Sanetti wolves where domestic dogs are not common.

This might involve the selection of individuals from different packs that appear phenotypically normal and have them tested using genetic methods that might detect dog ancestry. Moreover, the genetic relatedness between potential founders can be estimated using molecular techniques and the selection of closely related individuals avoided. Finally, if multiple paternity is common in the wild, captive breeding plans may wish to consider multiple insemination of females by different males to maximise the chance that they may become pregnant and at the same time allow genetic contributions from an increased number of males to be included in the next generation. This genetic strategy may also better mimic the pattern that occurs in the wild.

Finally, an urgent need is the development of specific protocols for the collection of viable sperm and eggs from wild wolves that could be frozen for future use in captive breeding. It is now possible in some exotic carnivores to collect sperm through electro-ejaculation of wild males who are then released and use the sperm as a source for artificial insemination or to fertilize harvested eggs in vitro (*e.g.* Donoghue *et al.* 1992a, 1992b). Similarly, eggs could potentially be flushed from wild caught females, viably frozen and matured at later date for fertilization and implantation in captive wolves (*e.g.* Johnston *et al.* 1991, 1994). Such fertilized eggs could potentially be brought to term in surrogate mothers from a related species, such as domestic dogs. A genetic bank of eggs and sperm from wild caught wolves could be used to enrich the genetic diversity of captive wolves once the breeding program is started and in the meantime, would provide a hedge against the very real possibility of dramatic population declines and even extinction in the wild.

Summary

The Ethiopian wolf is a phylogenetically distinct African canid endemic to the Ethiopian highlands that is closely related to grey wolves, domestic dogs and coyotes. The species has a more distant relationship to African jackals. A primary threat to the persistence of the Ethiopian wolf is the presence of domestic dogs who hybridize with them, compete with them for food and act a reservoir of canine diseases. Hybridization between Ethiopian wolves and domestic dogs is widespread in the Web Valley. Hybrid offspring are incorporated into Ethiopian wolf packs and with the continued persistence of dogs in this population, and their spread to others as well, the species could be threatened with genetic extinction. The population of domestic dogs co-existing with Ethiopian wolves needs to be immediately reduced and better controlled. The genetic variability of the Ethiopian wolf is lower than that of any other wolf-like canid and will continue to decline unless measures are taken to stabilize wild populations. A captive breeding program should be initiated immediately in Ethiopia with genetically certified Ethiopian wolves. A captive population would provide a reserve in the event of a cataclysmic decline in the wild population and a source for reintroduction to areas where the species has gone extinct.

Chapter 6
A Preliminary Population Viability Analysis for the Ethiopian Wolf

G. Mace and C. Sillero-Zubiri

Introduction

Conservation biology has emphasized, since its inception, that the conservation of endangered species cannot be based only on protecting species and their habitats. It will also require careful analyses of their needs, and sometimes direct management to overcome the effects of threatening processes (Caughley and Gunn 1996)

The examination and analysis of the interacting factors that place a population or a species at risk has been termed population viability analysis, or PVA (Burgman *et al.* 1993, Lacy 1993). PVA is an aid to the management of threatened species and its use has grown significantly over the last decade or so. PVA allows a systematic analysis of a species' life history and ecology, to identify conditions that a population or species requires to remain viable in the long term (Shaffer 1981, Soulé 1987).

The term PVA is widely used, and interpreted to mean different things by different people. To some it simply describes the use of a population simulation model. To others it signifies a process, whereby all individuals and authorities concerned with the conservation of a species are involved in problem-solving and consensus-building exercises (including the population models) to develop a management plan to which all will subscribe (Seal *et al.* 1994).

In this chapter we introduce the use of PVA on the Ethiopian wolf. This exercise should not be regarded as definitive in any sense since it was undertaken after evaluating only some of the threatening processes, without details of habitat change, and without the involvement of users and managers of the habitat. In addition, we were restricted in the species data on which to base the analysis, and were not able to model satisfactorily either of two major threatening processes: disease and hybridization (Chapter 3). However, we include this preliminary analysis since, even in this form, it does give some clues as to the relative impor-tance of different threats, and indicates approaches that could be very useful for developing management strategies, once fully explored. We hope that this will act as a stimulus for the development of a more com-plete PVA for the species in the near future.

Population Processes

PVA is based upon the recognition that extinction processes in natural populations are influenced by four different kinds of processes. Simulation modelling allows these variables to be incorporated (Shaffer 1981):

1. ***The basic life history of the species***, (its ecology, breeding system, birth rate, mortality pattern, social system) sets the context upon which other processes act, and determines how and whether a population can respond to changing circumstances. However, chance processes play an important part in determining the fate of populations, especially small populations, and deterministic population models may fail to reflect this.

2) ***Demographic stochasticity***. This is random variation in population size as a consequence of chance variations in birth or survival rates. This process is entirely intrinsic to the population and can lead to population extinction even when average population growth rates are positive. The importance of demographic stochasticity is negligible in all but the smallest of populations and it is unlikely to be significant when population sizes are greater than about 50 to 100 individuals.

3) ***Genetic variation.*** In small populations genetic variation is lost rapidly. Inputs from mutation are negligible, and so if there are limited opportunities for exchange of individuals with neighbouring populations, this lost variation is unlikely to be regained. This can lead to reduced fitness both through loss of adaptive potential and through the

deleterious effects of inbreeding. Genetic factors are most problematic for the smallest populations and accumulate over generations, so that in most cases they are not a short term problem. Over the long term they can become significant, especially for species that are facing new environmental challenges, or that have survived through small population bottlenecks.

4) Environmental variation and catastrophes. These are the external forces acting on populations. Natural populations experience continuing variation, and often progressive deterioration in their habitat. These have significant impacts on viability both through restricting the total amount of habitat and through increasing fragmentation. In addition, outside the normal year to year changes in habitat quality, there may be periodic rare events with major effect which substantially reduce survival or fecundity. These so-called catastrophes may have evident causes such as disease epizootics, a storm, drought, etc. This kind of variation can affect even the largest of populations.

Traditional methods of population analysis, based on predictions from large (infinite) analytical population models, fail to incorporate the above factors, at least in any useful way, and may therefore lead to optimistic predictions about small populations. The effects of multiple interacting variables, as well as chance varia-tions in their values, are best modelled by stochastic simulation and this is the approach that is generally described as population viability analysis.

PVA is a useful tool for gaining insight into the dynamics of a particular system, but not generally for making predictions about future outcomes. Specific questions are much more likely to be usefully answered by PVA than are the very general ones. For example, PVA has been most successfully applied to evaluating the effects of various alternative management schemes, assessing the likely impacts of different threats or assessing the reliability of different census methods, rather than for general predictions about future population sizes or extinction probabilities (Durant and Harwood 1992, Durant and Mace 1994, Lacy and Clark 1993, Lindenmayer and Possingham 1996).

This is the context in which we present here some analysis on the likely impact of two canid related diseases and how significant each may be in determin-ing long term viability of the Bale population under different assumptions about their rate, their impact on the population and the size and structure of the wolf population. We also look at the likely impact of similar processes on a smaller population, likely to be representative of at least two wild populations in Shoa and Arsi (Chapter 2). The possible management option of supplementing populations with young females is also considered. The outcome product is not definitive, but permits those people trying to manage/conserve the species to see a range of outcomes and the factors that affect them.

Methods

The Model

We used the population viability model VORTEX v 7, a program developed by R. Lacy and colleagues at the Chicago Zoological Society (Lacy 1993, Lacy *et al.* 1995). This is a stochastic individual-based population simulation that models demographic events (mating, birth, death, immigration), environmental and stochastic variation in the frequency of these events, genetic variation within individuals and one way it may influence survival, as well as periodic catastrophic events that influence breeding and survival rates. A variety of model scenarios were developed to examine the relative importance of the different threatening processes. Each model was run for 50 years and iterated between 200 and 1,000 times.

Input to the Basic Model

All data used as input for the model were based on a field study carried out in the Bale Mountains between 1988–91. Details are provided in condensed form in the PVA Data Form (Box 6.1). The original data are available from various publications (Gottelli and Sillero-Zubiri 1992, Sillero-Zubiri and Gottelli 1994, Sillero-Zubiri *et al.* 1996a).

Breeding rates of Ethiopian wolves are influenced by complex social behaviour. Individuals live in multi-male packs of up to 13 adults (mean about six) in which only the dominant female breeds. Pack size may be smaller in disturbed or marginal habitats or at very low density, in which case pairs may even form. The proportion of adult females breeding is therefore related inversely to population density, and this may be the major determinant of breeding rate within a population. During 1988–1991 at a high wolf density in Web and Sanetti, 32.2% of females bred. In order to reflect as closely as possible the influence of density we allowed breeding rates in the model to be density dependent. In

Box 6.1
Ethiopian Wolf
Population Viability Analysis Data Form

Species: *Canis simensis.*

Species distribution: Ethiopian highlands.

Metapopulation: Two subspecies (northwest and southeast of Rift Valley), totalling 5–7 populations, between which dispersal of individuals is not occurring at a substantial rate or may not be occurring at all.

Population estimate: 340–520 adults (1992), in 5–7 populations.

Specialized requirements (trophic, ecological): Carnivore. Eat predominantly rodents.

Age of first reproduction for each sex: Approximately, females 2 years; males 2–3 years.

Gestation period: 60–62 days.

Litter size: 1–6, mean 4.1 at emergence.

Birth season: October–January.

Birth frequency: Annually.

Reproductive life-span: 8 years?

Maximum longevity: Unknown; probably 10 years in the wild; 6 known animals ≥ 7 years old.

Adult sex ratio: population 1.8M:1F; packs 2.6M:1F.

Adult body weight: females 11–14 kg; males 14–19 kg.

Breeding structure: Multi-male packs of up to 13 adults (mean 6 adults); only one female in each pack breeds. Pairs or small groups in areas of lower prey productivity.

Proportion of adult females breeding each year: 56% of packs (19 of 34 pack-years) breed each year; 32.2% of adult females breed successfully each year.

Dispersal: Males do not disperse; only one known case an adult male dispersed > 20 km after pack collapsed due to rabies epizootic; 75% of females disperse. 60–70% dispersing females become floaters nearby; rest disperse further (up to 7.5 km reported).

Age of dispersal: females disperse at 15–40 months old.

Migrations: no.

Territoriality: scent-mark and defend home ranges, averaging 6.0 km²; 13.4 km² at a low-density site.

Population sex and age structure prior to breeding season (pups, yearlings, adults):

	Male	Female	Sex ratio
Juvenile (< 1yr):	10%	9%	1:1
Subadult (< 2):	9%	6%	1.3:1
Adult (> 2):	43%	16% (21%)	2.6:1 (1.8:1)

Pup mortality rate: 53% (3 weeks to 1 year; *n* = 14 litters)

Sources of mortality: Disease (rabies and possibly canine distemper), illegal deliberate shooting, road kills.

Mayor threats to survival: Hybridization with domestic dogs, disease epidemics, fragmentation and destruction of habitat, loss of genetic variability.

Population density estimates: Highest densities found in Afro-alpine grasslands, up to 1 adult/km²; lower in *Helichrysum* dwarf-scrub (0.2/km²) and in ericaceous heathland and barren peaks (0.1/km).

Habitat capacity trends: Human encroachment and livestock grazing in afroalpine habitats increasing, subsistence high altitude agriculture in the north increasing; human persecution may persist in most populations.

Projected carrying capacity: 800–1,000 adults would approach existing carrying capacity

in 3,000 km² of afroalpine habitat across range.

Present habitat status: Simien Mountains National Park and Bale Mountains National Park protect the two largest populations. Include 180 km² and 640 km² of afroalpine habitat respectively.

Projected habitat status: Possible creation of a new conservation area in Shoa region and another in Gojjam region.

Environmental variation affecting reproduction and mortality: Availability of rodent prey remains quite stable between seasons and years; prevalence of disease difficult to assess; potentially epidemics have a heavy impact on demography.

Pedigree information?: No captive population exist.

VORTEX the form of the density dependence can be specified by the following function (Lacy *et al.* 1995):

$$P(N) \quad = \quad \left(P(0) - P(K)\frac{N}{K}B\right) \cdot \left(\frac{N}{N+A}\right)$$

where *P(N)* is the percentage of females that breed when the population is at size *N*, *P(K)* is the percentage of females that breed when the population is at carrying capacity *(K)*, *P(0)* is the percent breeding when the population is close to 0, and *A* and *B* are constants defining the shape of the curve at low and high density. We set the parameters to maximize breeding rate up to about 40% of the estimated carrying capacity of the habitat, after which breeding rate declines to about 15% of adult females breeding. In VORTEX this was achieved by setting *p(0)* to 100, *p(K)* to 15, *B* as 4, and *A* as 0 (Fig. 6.1).

Males and females start breeding at about two years of age and continue throughout their adult lifespan. Maximum age is probably about 10 years in the wild and this was set as the individual lifespan in the model.

The litter size distribution used was based on field observations of 19 litters which showed the following distribution: 1(1.7%); 2(5.1%); 3(6.8%); 4(5.1%); 5(5.1%); 6(8.5%). Sex ratio was recorded in litters at close to 1 male:1 female, and this was assumed to be the birth sex ratio in the model. Since females disperse at 15–40 months and males do not, adult sex ratios become strongly biased toward males and a population sex ratio of 1.8 male:1 female was recorded in the Bale population. The rate is 2.6 males:1 female when only territorial packs are considered and floater females excluded (Sillero-Zubiri and Gottelli 1995a).

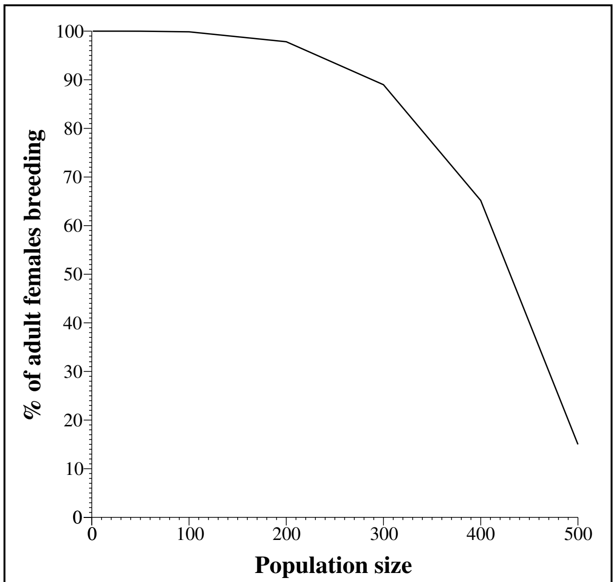


Figure 6.1. Density dependent relationship between population size and the percentage of adults breeding that was implemented in the VORTEX model to reflect changes in breeding patterns as the population changes in size.

Table 6.1
Mortality rates for age/sex classes set in the VORTEX model. Values shown are the percentage mortality rates and the standard deviation due to environmental variation in parentheses.

Age (years)	Female	Male
0	55.0 (10)	45.0 (10)
1	20.0 (10)	10.0 (3)
2–10	15.0 (5)	10.0 (3)

In the model mortality rates were set as shown in Table 6.1 to reflect the higher female mortality, and led to populations with appropriately biased adult sex ratios. The breeding system was set with all males being breeders and a polygynous breeding system. Genetic effects through inbreeding depression were not incorporated in the model.

Model Scenarios

We chose to investigate the relative significance of two kinds of factors in the population: disease processes and population reduction and fragmentation. We also explored a third factor, hybridization with domestic dogs. We tried various methods to approximate the effects of hybridization on the population, but each of these had problems and therefore we concluded that VORTEX was not an appropriate model for examining the influence of hybridization.

Population Size and Structure

We based the model on the Bale Mountains population, and set the current population at about 150 (Chapter 2) with a carrying capacity of around 500. However, to investigate the extent to which small population size effects might increase in importance if the population were reduced by further habitat loss, and to model the other, smaller, populations, we also investigated the viability of a smaller population of 50 individuals living in an area with an estimated carrying capacity of about

80. These parameters may reflect those in other known wolf populations such as those in Arsi and Shoa (Chapter 2).

For the larger population (Bale) we also investigated the effect on persistence of recognizing two major sub-units to the population between which there is little migration, and upon which threats such as disease risks might operate independently. In this case there were assumed to be two sub-populations, the Web Valley and Sanetti Plateau of 65 individuals and 85 individuals respectively, with proportional carrying capacity. Migration rates between the two under normal circumstances were set quite low reflecting field observations that few dispersing females travel further than about 7–8 km (Sillero-Zubiri and Gottelli 1995b). Normal migration rates resulted in 7% of 2–3 year old females moving between sub-populations. A higher migration rate involving both sexes was also modelled, to reflect the effect of a disease such as rabies which alters normal behaviour patterns, Sillero-Zubiri *et al.* 1996b). In this case 10% of 2–6 year old males and females moved between the sub-populations each year.

Disease

We modelled two diseases, canine distemper virus (CDV) and rabies, both of which have been recorded in Bale in recent years, and used estimates for the incidence and impact from Laurenson (pers. comm. 1996). Rabies has a major effect upon survival, reducing survival rates by about 70–75% (Sillero-Zubiri *et al.* 1996b). CDV has a smaller effect, reducing survival rates by about 15%. The incidence of disease outbreaks is harder to estimate. Based on observations in recent years, we modelled rabies at two different rates of one in every seven years on average (14.3% – low rabies) and two in every seven years on average (28.6% – high rabies). CDV was modelled at an incidence of 15%.

Supplementation

Finally, we examined the consequences of one potential management option: that of supplementing the population with young (two year old) females. Here we ran the standard rabies models, but introduced one two year old female either every year ('high supplementation') or every second year ('low supplementation'). The effects of supplementation on persistence were compared between 'high rabies' and 'low rabies' incidence models.

Results

The results from running all the model scenarios are summarized in Table 6.2. This gives the VORTEX estimates after 20 years and 50 years for the probability of extinction, estimated population size and percentage of starting genetic variation retained (measured as heterozygosity) for each model scenario.

The basic model for Bale, with no catastrophes, gave a population that was growing deterministically, *lambda* was calculated for this population as 1.35, *r* (the intrinsic rate of increase) is 0.313. There was negligible risk of extinction in the control model and population size stabilized at close to 500 after about seven years. The basic model for the smaller population with no catastrophes also showed negligible extinction risks.

The figures in Table 6.2 are accumulated over up to 1,000 simulations and mask a great deal of fluctuation between years that occurs in any one population, particularly when catastrophes occur. For example, Figure 6.2 shows six sample runs from a low rabies model for the larger population. In any one run, population sizes can change dramatically between years, declining as a result of disease outbreaks, and increas-ing rapidly as a result of the high reproductive rate that is characteristic of the species.

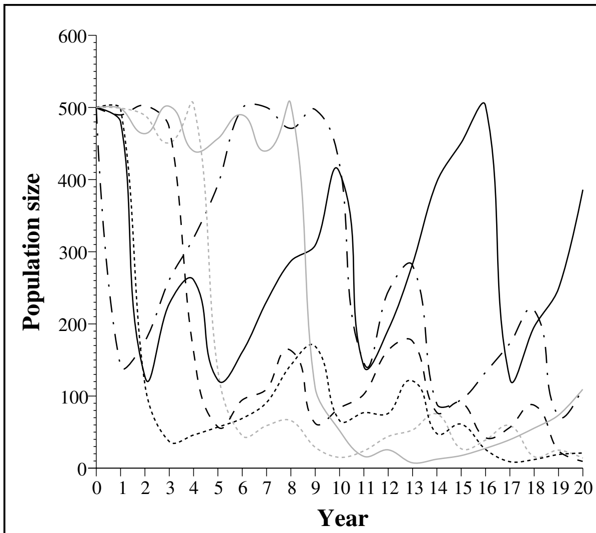


Figure 6.2. Example set of 6 runs from a VORTEX simulation. The figure illustrates the large amount of underlying variation masked by average values in the model output statistics, and also the ability of the population to recover rapidly from small numbers.

Table 6.2
Summary of results from VORTEX models. The results of simulation runs under each of the scenarios listed are shown after 20 years and 50 years. *p(S)* is the frequency with which the population was still extant in 1,000 simulations, *N* is the average population size of extant populations and *se* is the standard error of these estimates.

Input Parameters						Results									
N	K	Subpops	Migration rate	Supplementation	Disease	20 years					50 years				
						p(E)	N	se	heteroz.	se	p(E)	N	se	heteroz.	se
150	500	1	–	–	none	1.00	464.13	3.42	0.99	0.00	1.00	471.08	3.26	0.97	0.00
150	500	1	–	–	low rabies	0.97	267.21	*16.67*	0.95	*0.01*	0.94	277.07	*17.27*	*0.90*	*0.01*
150	500	1	–	–	high rabies	0.75	117.61	*17.41*	0.88	*0.01*	0.27	112.33	*27.55*	*0.72*	*0.04*
150	500	1	–	–	cdv	1.00	454.90	*4.99*	0.98	*0.00*	1.00	461.44	*4.19*	*0.97*	*0.00*
150	500	1	–	–	cdv+low rabies	0.96	257.93	*17.86*	0.94	*0.01*	0.81	275.31	*18.57*	*0.87*	*0.01*
150	500	1	–	–	cdv+high rabies	0.66	92.52	*14.70*	0.88	*0.01*	0.14	56.21	*21.75*	*0.76*	*0.03*
50	80	1	–	–	none	1.00	74.74	*0.63*	0.93	*0.00*	1.00	73.75	*0.77*	*0.83*	*0.01*
50	80	1	–	–	low rabies	0.87	50.82	*2.91*	0.84	*0.01*	0.62	51.55	*3.29*	*0.64*	*0.02*
50	80	1	–	–	high rabies	0.39	28.79	*4.21*	0.71	*0.03*	0.04	19.50	*4.66*	*0.37*	*0.06*
50	80	1	–	–	cdv	1.00	71.63	*0.87*	0.92	*0.00*	1.00	71.31	*0.79*	*0.82*	*0.01*
50	80	1	–	–	cdv+low rabies	0.84	44.27	*2.87*	0.83	*0.01*	0.45	46.80	*3.63*	*0.64*	*0.03*
50	80	1	–	–	cdv+high rabies	0.29	28.21	*3.26*	0.74	*0.03*	0.04	18.50	*5.42*	*0.52*	*0.06*
150	500	2	normal	–	low rabies	1.00	328.11	*11.58*	0.96	*0.00*	1.00	319.60	*12.99*	0.91	*0.01*
150	500	2	normal	–	high rabies	0.84	126.65	*12.43*	0.89	*0.01*	0.37	109.62	*18.96*	0.75	*0.02*
150	500	2	normal	–	cdv	1.00	456.87	*3.18*	0.98	*0.00*	1.00	458.41	*3.05*	0.97	*0.00*
150	500	2	high	–	low rabies	1.00	335.04	*11.82*	0.97		1.00	333.54	*12.84*	0.93	
150	500	2	high	–	high rabies	0.90	160.83	*14.06*	0.91		0.62	143.69	*18.40*	0.81	
150	500	2	high	–	cdv	1.00	454.36	*2.97*	0.98		1.00	461.0	93.00	0.97	
150	500	1	–	0.5 fem/year	low rabies	0.99	307.18	*16.89*	0.96	*0.01*	0.97	272.62	*17.17*	0.92	*0.01*
150	500	1	–	0.5 fem/year	high rabies	0.85	88.02	*12.17*	0.88	*0.01*	0.53	114.42	*20.25*	0.84	*0.01*
150	500	1	–	1 fem/year	low rabies	1.00	303.05	*16.57*	0.96	*0.00*	1.00	318.18	*17.45*	0.93	*0.00*
150	500	1	–	1 fem/year	high rabies	0.87	145.62	*16.78*	0.92	*0.01*	0.69	137.65	*19.12*	0.88	*0.01*
50	80	1	–	0.5 fem/year	low rabies	0.93	50.85	*2.74*	0.88	*0.01*	0.82	32.00	*3.06*	0.83	*0.01*
50	80	1	–	0.5 fem/year	high rabies	0.66	49.59	*2.99*	0.81	*0.01*	0.27	39.70	*5.85*	0.78	*0.02*
50	80	1	–	1 fem/year	low rabies	0.95	54.52	*2.44*	0.91	*0.00*	0.90	58.27	*2.57*	0.89	*0.00*
50	80	1	–	1 fem/year	high rabies	0.72	37.17	*3.18*	0.88	*0.00*	0.46	37.30	*3.66*	0.88	*0.01*

Disease

Figures 6.3a and 6.3b show persistence rates and average population size in Bale under each of the disease scenarios compared to the control model. CDV has little effect on population persistence or size. After 50 years there were no significant differences between the CDV affected simulations and the control simula-tions. Rabies had a more significant effect, especially at the high (two in seven years) incidence. Under high rabies incidence the likelihood of extinction of the Bale population after 50 years is about 75% (Fig. 6.3a), and the surviving populations only comprise about 100 individuals, with a high variance (Fig. 6.3b, Table 6.2). This has consequences for the amount of genetic variation maintained in the population which is always lowest under high rabies incidence (Table 6.2). At lower incidence, rabies has a less marked effect although still leads to unacceptably high extinction rates, especially if CDV is also present.

When the population size is smaller, the influence of disease has the same qualitative pattern (Figs. 6.4a and 6.4b), although the extinction risks are much higher. Under high rabies incidence, the likelihood of the population surviving for 50 years is less than 5%. However, even in these smaller populations, CDV alone appears to offer little threat to population viability, except in combination with rabies, where it increases the threats posed by rabies.

Metapopulation Model

The division of the entire population into smaller units which experience disasters independently was examined under various levels of inter-population migration. Higher migration rates increase the survival of the metapopulation, so that, for example under the high incidence rabies scenario the probability that the population will still persist after 50 years is estimated to be 27% with no subdivision, 37% with subdivision and normal migration rates and 62% with subdivision and high migration rates (Fig. 6.5; Table 6.2). These results suggest that population subdivisions will be advantageous, although it is important to emphasize here that this model does not reflect the increased disease transmission that will result in a metapopulation with higher migration rates

Supplementation

Supplementation had, as expected a beneficial influence upon population persistence, although the supplementation had to be at quite a high rate, and sustained over the entire simulation period if it was to be effective. Figures 6.6a and 6.6b show consequences of supplementation at high or low rates on larger (Fig. 6.6a, $N = 500$) or smaller (Fig. 6.6b, $N = 80$) populations. At high rabies incidences, high supplementation rates of

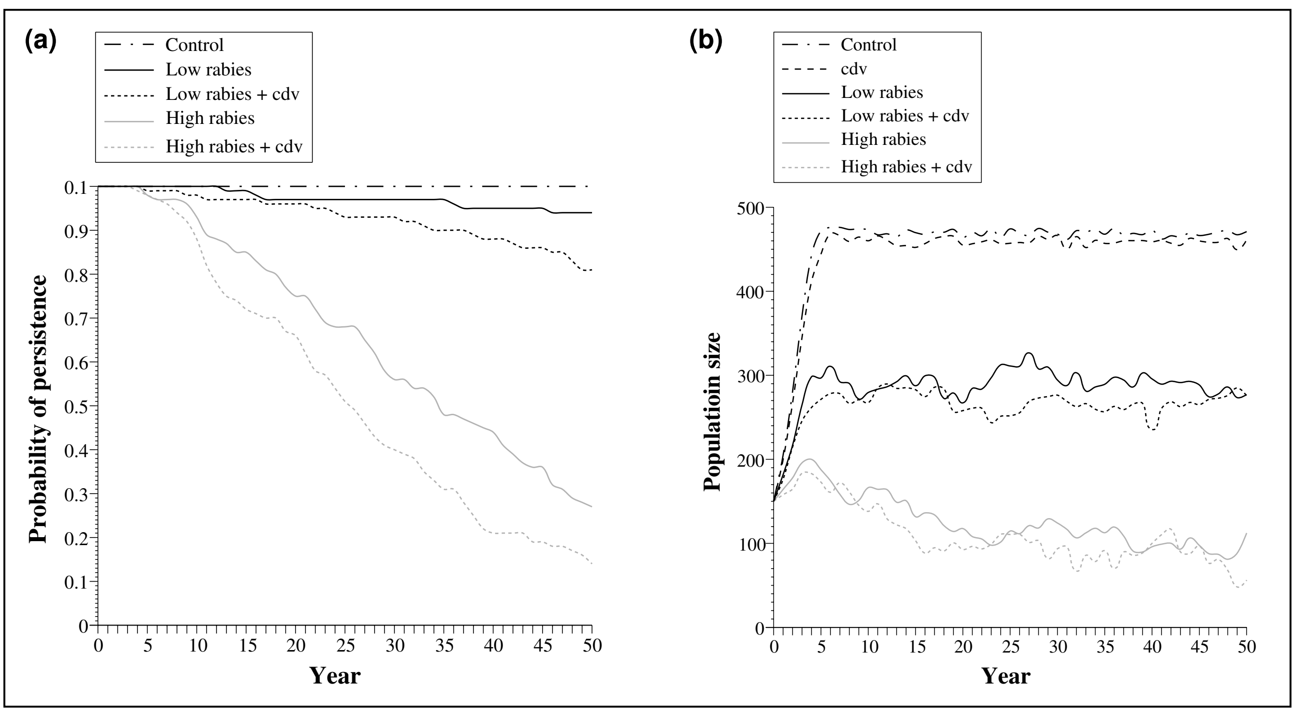


Figure 6.3. (a) Persistence rates and (b) average population size over time under different disease threats in a population of size 150 and carrying capacity of 500.

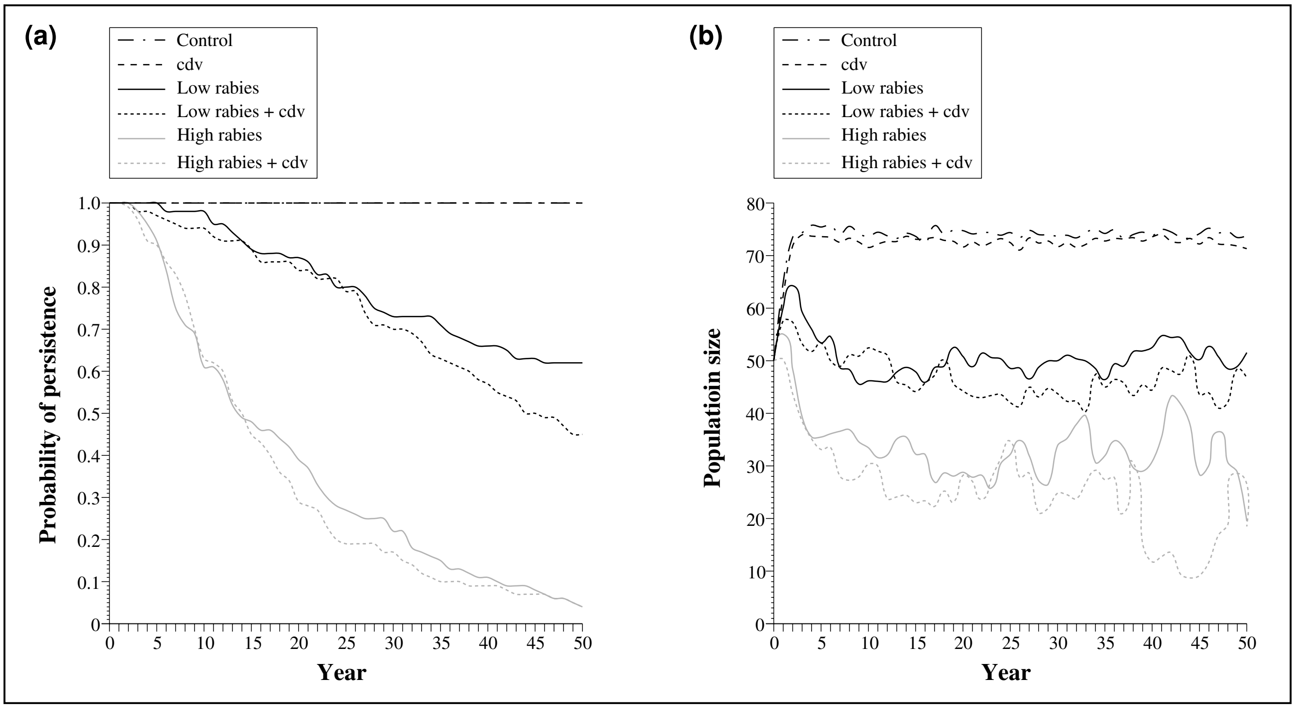


Figure 6.4. (a) Persistence rates and (b) average population size over time under different disease threats in a population of size 50 and carrying capacity of 80.

one two year old female per year were able to increase persistence rates from 27% to 69% for the larger (Bale) populations, and from 4% to 27% for the smaller population. Despite improving persistence, supplemen-tation did not allow these high rabies populations to achieve acceptable persistence rates. Under low rabies, however, persistence rates with supplementation were at 97% or 100% for the larger population, and 82% to 90% for the smaller populations. Supplementation therefore may be a useful option to be applied alongside disease control.

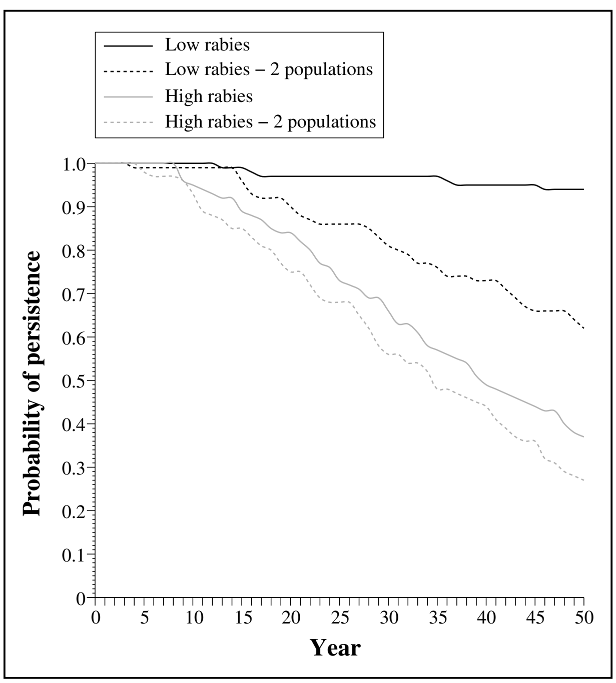


Figure 6.5. The effect of subdivision on a population of size 150 and carrying capacity of 500 under different disease threats.

Discussion

The work presented here is a preliminary application of the current methodology on PVA to the Ethiopian wolf . It is not intended to be a complete analysis, since we have not considered many possible scenarios in the simulations, and many population parameters necessary for PVA modelling were not available to us. Addition-ally, we recognize that the modelling needs input from other scientists and land managers if it is to reflect likely patterns of changing threats over coming years with accuracy. So our intention is that this analysis will act is a spur to further PVA work aimed at evaluating alternative conservation strategies, and this should be undertaken within Ethiopia.

We also recognize another kind of limitation of the current analysis, that VORTEX does not adequately incorporate some critical components of Ethiopian wolf biology. In particular, the social structure of Ethiopian wolves is pack-based, and rates of breeding depend more on pack size and structure than upon population parameters. Also, all individuals are equally likely to breed in any one year in the model, whereas there are known fixed differences between individuals in the wild. Even with density dependence set as discussed earlier, we suspect that the model may be too pessimistic about demographic rates, and too optimistic about the preservation of genetic diversity within the population. Secondly, we were unable to model two significant threats with any precision. The threats from hybridization with domestic dogs was impossible to model using VORTEX, so we have omitted it here. The threats from disease we have approximated by setting disease outbreaks as a catastrophe, and then looking at the impact of the increased mortality rate upon population viability. One problem is that disease modelled in this way only has an effect within years: there is no consequence of the disease outbreak on subsequent breeding and survival rates. In addition, and perhaps more seriously, we have not included any kind of disease transmission in our model so that, for example, the consequences of increased migration rates appear to be beneficial, whereas they may in reality be detrimen-tal. Further PVA modelling on the Ethiopian wolf will require the use of a model that can effectively reflect the consequences of social structure, disease epidemiol-ogy and interspecific hybridization. Also, as recent reviews of PVA modelling has shown, model outputs need to be validated and checked for reality before any conclusions are implemented (Brook *et al.* in press, Mills *et al.* 1996).

Despite these reservations, the results obtained using VORTEX were included here as there are some interesting conclusions which could influence conservation planning. First, the basic population data indicate that in the absence of specific threats from disease and hybridization the population has a positive growth rate. Therefore, over the longer term, even the smaller populations (numbering fewer than 100 individuals), can be viable if threats are managed or controlled. In fact, the population growth rate is high ($r = 0.313$) and this high reproductive rate can enable the population to recover from small numbers caused by threats, so long as they strike the population relatively infrequently.

Under the conditions modelled here CDV alone did not appear to be a major threat to population persistence. In fact there was little difference between the persistence rates of CDV affected populations and disease free populations in our models. This results from the small increase in mortality from CDV used in our models.

In contrast, rabies is a major threat, especially if the incidence is high. At low incidence (an outbreak every seven years on average), and with some population substructure, the population could recover. Low incidence of rabies alone gave a 94% chance of population survival.

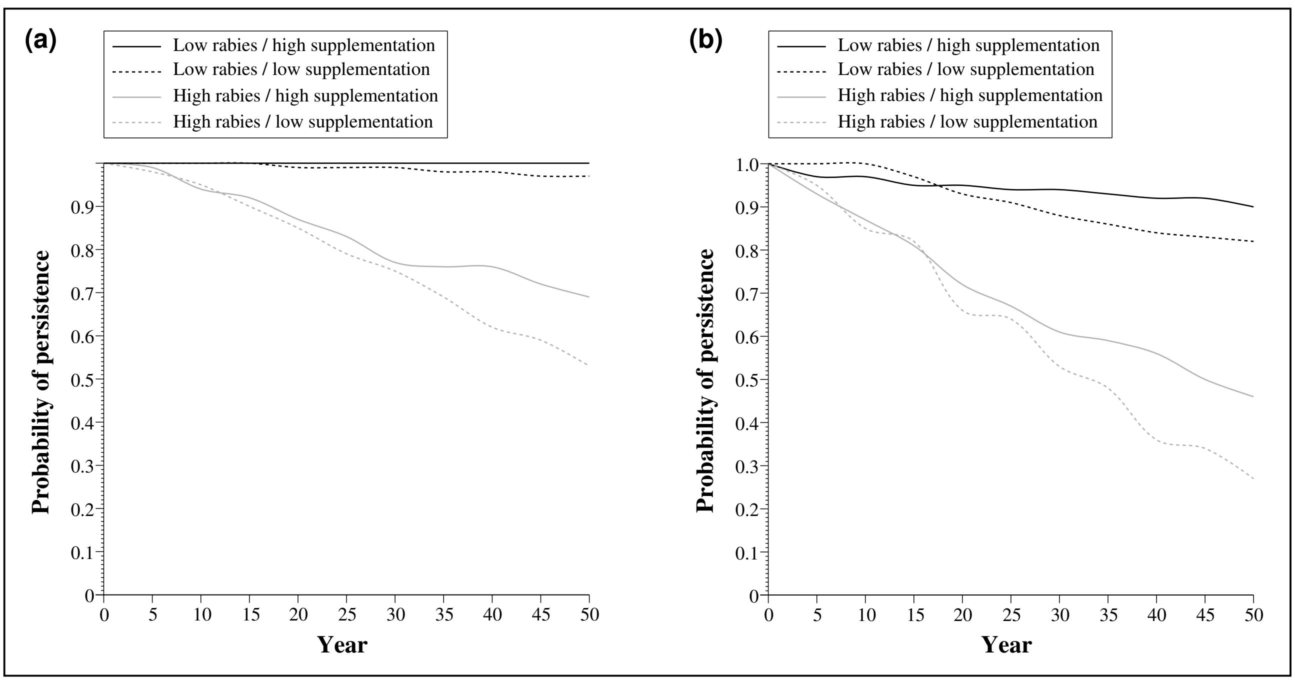


Figure 6.6. (a) The effect of supplementation of a 2 year old female once per year (high supplementation) or once every two years (low supplementation) on a population of size 150 and carrying capacity of 500 under different rabies incidence. (b) The effect of supplementation of a 2 year old female once per year (high supplementation) or once every two years (low supplementation) on a population of size 50 and carrying capacity of 80 under different rabies incidence.

However, this is compromised when CDV is also present.

The effect of substructure on population viability is generally beneficial. When a population such as Bale is divided into two units between which there is limited migration, persistence of the metapopulation improved, especially when catastrophes occur independently in the two sub-units. Under these circumstances, one subpopulation may go extinct, but can be re-established by incoming migrants from the other subpopulations. This finding is likely to hold, even with a more elaborate and accurate model for disease transmission. However, in the case modelled here the subpopulations were still relatively large (at least 65 individuals at the start of the simulation). It is likely that the benefits of population subdivision would disappear if subpopulation size becomes smaller, since the added risks of small populations would become more significant (Shaffer 1981, Soulé 1987).

Population supplementation with translocated or captive bred females is one potential management option. Our models show that this could have a benefi-cial influence on population persistence, although the strategy needs to be maintained over the long term, and translocations need to occur at a reasonably high rate.

Conclusions

PVA modelling is a potentially useful tool for examining the conservation status of the Ethiopian wolf. In particular, once an appropriate model is developed, it will provide information about the relative benefits of alternative management strategies, about the relative importance of different kinds of threatening processes, and about when and where interventive management is appropriate. We believe that this will be a useful tool in conservation planning.

Chapter 7
Conservation of Afroalpine Habitats

J.R. Malcolm and Zelealem Tefera

The Ethiopian wolf is only one of an array of plants and animals restricted to high elevations in Ethiopia (Box 2.1) and these species are only some of the important resources of the alpine zones. Other resources include agricultural land, catchment areas and places of historical and cultural significance. The Ethiopian wolf may play an important role as a flagship species but its conservation will only be successful if attention is paid to the wise management of all the resources occurring in its range.

Afroalpine grasslands and ericaceous heathlands form the afroalpine zone. They extend above 3,400 m and cover about 5,000 km² (Chapter 2). Sixty percent of this habitat occurs in three mountain ranges (Arsi, Simien and Bale) with the remainder scattered in as many as 20 smaller areas over the rest of the highlands. Three primary mountain ranges receive some recognition as protected areas under the EWCO. About 750 km² of land above 3,400 m in the Arsi mountains is in a Controlled Hunting Area. However, the Wildlife Organisation has only a minimal presence. There are 680 km² of afroalpine and subalpine habitat in the Simien Mountains of which 180 km² fall within the Simien Mountains National Park and the remainder in the Buffer Zone drawn around the Park. The largest area of protected high elevation habitat is in the Bale Mountains. Of 1,485 km² above 3,400 m, 1209 km² lie inside the Bale Mountains National Park. Outside the areas recognised by EWCO, there is one area of afroalpine habitat in Menz (Amhara Regional State – South Zone) that is managed by a committee of the community (Chapter 3). For the other small areas of afroalpine habitat scattered across the country there is no information.

This discussion of the resources of the afroalpine and their management will focus on Bale and Simien. Management Plans for both areas were completed in 1986 (Hillman 1986, Hurni 1986). This analysis draws on the 'Guidelines for Mountain Protected Areas' (Poore 1992).

The Physical and Cultural Setting

The highlands of Ethiopia are a massive volcanic dome formed from eruptions between 70 and 5 million years ago. The Great Rift Valley divides the lava massif into a larger northern area and a smaller southeastern area. During the Pleistocene the high areas were glaciated. The most recent glaciers retreated within the last 10,000 years and extended down to about 3,700 m with a periglacial zone extending to 3,300 m.

Most of the land above 3,400 m is steep and soil formation is limited. Above 3,700 m thin soils have developed after the glacial retreat. Deeper soils are present in the flatter areas in the periglacial zone. Below 3,300 m most of the natural forests and their soils has been lost to 2,000 years of cultivation. Rainfall in the high altitude zones varies from 1,000–2,000 mm/year with one period of drought extending from December to February or March.

The Habasha people have ruled the northern highlands for most of the last millennium. They are mixed agriculturalists growing barley at high elevations as well as keeping cattle, sheep and goats. Up to the 1970s, land tenure in many places was feudal. Peasant tenants contributed part of their produce to the landowner.

The southeastern highlands were conquered in the 17th and 18th centuries by Oromo pastoralists. This culture recognises clan based communal grazing lands. Cultivation of barley is also integral to their subsistence in the highlands. The southeast was incorporated into the Habasha (Amhara) empire in the 1890s and is now re-emerging as a political force with the end of the Amhara regime.

The Resources

Management of the subalpine and alpine ecosystems must balance the value of the natural resources used by humans with the intrinsic value of the biological heritage of the area. A diverse array of resources is present.

Wild Species

The plants and animals restricted to high Ethiopian mountains were described in Chapter 2. Conservation of these species and particularly the endemics is of paramount importance. In addition some species have immediate economic value. Grass of the genus *Festuca* is used for thatch and basket making. It grows up to about 3,600 m on good soils. As described above, areas of this grass have been set aside by some communities with limited harvest periods.

Menassie (1991) recorded 42 species used in the Bale Mountains as medicines and a further 10 that were used for food or drinks. A wild thyme (*Thymus serrulatus*), used to make a tea, is harvested by people living close to the town of Dinsho and near Menz. It is dried, put in plastic bags and sold to travellers on buses. The potential value of the wild plants for medicines has not been assessed.

Agricultural Resources

Barley cultivation occurs almost continuously below 3,300 m and may extend up to 3,600 m depending on soils, slope and frost. Recently abandoned fields indicate areas where cultivation has failed. Pressure to find agricultural land is strong. Land at about 3,600 m in the Simien Mountains has recently been ploughed and even the steeper parts of the Bale Mountains up to 3,300 m have been cleared.

Domestic animals use the entire alpine habitat. There are large seasonal movements of stock as animals are removed from the areas of cultivation during the growing season. The effects of domestic stock on the populations of herbivorous rodents are unknown. Areas where the herds are corralled at night have high levels of nitrogen and specialized plants.

Firewood and Fuel

The ericaceous heathlands are or have been an important source of firewood in some areas. Typically the wood is collected a year or two after a fire has killed the above ground growth. Bundles of heather twigs are collected and carried to lower elevation. In most areas this fuel is for local use. However, in the large heather areas of Arsi, the wood is gathered on a commercial scale. Large boles of heather plants in many areas suggest that ericaceous heathlands were both more extensive and of larger stature a generation or two ago.

Water Resources

The high ground in the mountains catches more rain than the surrounding lowlands. This is marked in the Simien where the lowlands less than 35 km east of the peaks receive only one third of the rainfall (500 vs 1,500 mm/yr) (Hurni 1986). In the south, all three of the major rivers that provide water to southeastern Ethiopia have their headwaters in the Bale Mountains. Maintenance of these high elevation watersheds is important. The potential for hydroelectric power on many of the fast flowing streams has hardly been tapped.

Tourist Values

The spectacular scenery and unusual animal life offer great opportunities for tourism. Many of the areas are accessible only on foot or horseback and the number of large wild animals will never rival the great African savannah parks. However, there is plenty of room to develop trekking and camping tours together with more specialised interest groups such as bird watchers, rock climbers and even fly fishing in Bale. The Simien is also within easy reach of some of the famous historic sites of Ethiopia.

Sport Hunting

Sport hunting occurred in the ericaceous zone of the Arsi Mountains until August 1993 when it was banned. Mountain nyala (*Tragelaphus buxtoni*) were the main trophy, although warthog (*Phacochoerus aethiopicus*) and bushbuck (*T. scriptus*) were taken occasionally.

Cultural Resources

The high mountain areas are important in the social and ritual life of the people who live there. In Bale, there are as many as 30 burial grounds in the park (Regassa 1992) which also operate as prayer sites. A small hill close to the headquarters of BMNP is the site of an annual religious celebration.

Obsidian tool fragments are common in the Web Valley in the BMNP but most of the area has not been surveyed archaeologically.

Other Resources

Mineral Springs. In the Bale Mountains, most domestic stock is taken to natural mineral springs at approximately monthly intervals (Kemp-McCarthy 1990). The waters appear to be an important nutritional supplement although their exact action is unknown. Five of the larger and more valued springs occur above 3,400 m. These high elevation springs are communal property.

Roads. The high mountains are criss-crossed with trails reflecting the important lines of communication for people and their herds over the high passes. The well used drove roads are marked by multiple cattle tracks often deeply eroded.

This inventory of resources is probably not complete and it is likely that other elements of the mountain environment will acquire value in the future in ways that we cannot anticipate. However, it may provide a perspective on the range of values that need to be integrated into a successful programme of development.

Management

In the Ethiopian Mountains, as elsewhere, the interactions between people in search of subsistence and the natural communities are complex. For example the Oromo people in Bale and Arsi are remarkably tolerant of the large endangered species with which they share their land. They are reported to take wounded mountain nyala into their huts to treat them (Regassa 1992) but the evidence suggests that mountain nyala avoid areas grazed by cattle. Despite their tolerance an expansion of the Oromo pastoralists will lead to a decline in the numbers of mountain nyala. Similarly, the Ethiopian wolves are not persecuted by the Oromo and wolves have been seen to use the grazing herds of cows as camouflage to approach their rodent prey (Sillero-Zubiri and Gottelli 1995a). However, we now know that it is the herders' dogs that threaten the wolves with both disease and hybridization (Chapter 4).

Probably the most pervasive impact of people involves the regular burning and cutting of the heathlands which cover, or used to cover, most of the subalpine zone. The closed canopy heather thickets or small forests are replaced in most places by grasslands. These derived grasslands have been shown to have greater species diversity and provide more grazing than the original heathlands (Miehe and Miehe, 1994). However, these advantages are offset by the fact that clearing the heather removes the tall cover necessary for the native ungulates, particularly the mountain nyala.

Two trends will inevitably impinge on any of the ecological relationships now operating. First, human populations will continue to expand and second, human standards of living must increase. Some of the mechanisms to cope with these changes seem to be in place. There are two national parks with management plans and each has a buffer zone drawn around its boundaries. The challenge is to translate these areas marked on maps into programs of development that benefit human and non-human resources.

Some of the steps seem clear. First and foremost, any management must involve the local people. Liaison committees now operate between the park's authorities and the local administrative districts in both Bale and Simien. This communication is vital but projects that benefit the local people and involve them in the development of the park will be important. The development of tourism has great potential. The guides in Simien are organised into a cooperative and at least one hotel caters mainly to tourist traffic. More visitors are needed before similar facilities in Bale would be profitable but this is unlikely to occur before all-weather roads and reliable sources of fuel are available in the area.

Many other forms of development such as the provision of veterinary services, herd improvement with artificial insemination, and provision of mineral supplements could help the local people. By reducing the number of domestic animals needed to secure a livelihood, such programs could possibly reduce the impact of stock on the afroalpine ecosystems. Negotiations over stocking rates are more likely to succeed if the wildlife authorities can provide some help to the pastoralists.

The wildlife authorities are in a position to initiate these changes and to dispel their old authoritarian image. A large grant from UN for rehabilitation in the Gondar region which includes the Simien Park provides a stimulus for integrative planning.

Similarly, a three year project has started in Menz, funded by the Darwin Initiative of Great Britain. Its aims are to integrate biodiversity conservation with the sustainable management of Afroalpine resources.

Chapter 8
Does the Ethiopian Wolf Need Captive Breeding?

Introduction

The pace of wildlife habitat destruction and species extinctions has increased worldwide. During the last 400 years nearly 500 described species have become extinct and the rate of extinction is escalating. An increasing number of species, particularly those occurring in small, isolated populations, now require conservation action. Wildlife management measures used by species' recovery programmes include captive breeding, or a combination of *ex situ* and *in situ* efforts. *Ex situ* efforts can be defined as occurring outside the species' natural range, whereas *in situ* conservation occurs within the species' natural range.

In addition to the captive breeding of endangered species for their eventual reintroduction to the wild, translocation of surplus animals between populations may be used to reestablish the species after a local extinction or to supplement small populations. In this section we review the literature available on the merits of captive breeding, reintroduction and translocation in wildlife conservation, with particular emphasis on canid species. In the following section we will consider metapopulation management and examine how these complementary approaches may be applied in an Ethiopian Wolf Recovery Programme.

The following definitions are used in the context of these two chapters (after Wilson and Stanley Price 1994, Kleiman *et al.* 1994): 'captive breeding' concerns the preservation in captivity of species at risk of extinction in the wild, to eventually supply animals for reintroduction. A 'reintroduction' is an attempt to re-establish a species (or subspecies) in an area which was once part of its historical range, but from which it has disappeared. An 'extirpation' refers to the disappearance of a species from a limited part of its range. A 'translocation' involves movement of wild-born individuals or populations from one part of the range to another. Thus a translocation to an area from which the species has been extirpated is a reintroduction. 'Restocking' involves the release of either captive-born or wild-born animals into an already occupied habitat, with the intention of building up population numbers and/or increasing genetic variation.

Captive Breeding

The aims of breeding rare and endangered species in captivity are to maintain genetically viable populations safe from the threats faced by wild populations and to produce founder populations for eventual release into the wild in reintroduction programmes (Seal 1986, Kleiman 1989). This captive population may help to preserve genetic variability and, in some cases, to protect the species' gene-pool from hybridization with related species. This may be of particular importance for large carnivores whose small population sizes make them susceptible to hybridization with closely related, sympatric species (Jenks and Wayne 1992, Hubbard *et al.* 1992, Gottelli *et al.* 1994).

In terms of species conservation the maintenance of viable populations of rare species is important for the following two purposes (IUCN 1987a): a) as an insurance population for the survival of an endangered species regardless of crises in its natural habitat, and b) as a source of new genetic material to infuse diversity into depleted wild populations. Captive populations can also serve as latter-day 'arks' (gene banks) if wild populations become extinct (Ginsberg 1993). However, Snyder *et al.* (1996) have warned that this ark paradigm is built on a misconception and may result in domesticated forms with low re-establishment potential. Critics point to the cost of captive breeding *(ex situ* conservation), and the potential diversion of funds and attention away from the *in situ* conservation of habitats.

The World Conservation Union (IUCN) has recognized the potential contribution of zoos that keep endangered animals in captivity and recommends that vertebrate taxa numbering less than 1,000 individuals in the wild should be considered for captive breeding (IUCN 1987a). Obviously, captive breeding specialists and field conservationists need to integrate their efforts, with the ultimate goal of recreating a self-sustaining wild population.

Most current captive breeding programmes are done *ex situ*, particularly in western zoos. *In situ* captive breeding would have the benefits of access to appropriate habitat and environmental conditions, and reduced exposure to exotic diseases (Ginsberg 1993). Therefore support for local captive breeding facilities in range countries should be increased, possibly within the framework of global captive breeding programmes.

Captive breeding programmes need to be established before species are reduced to critically low numbers or substantial genetic variability is lost, and, thereafter, need to be coordinated internationally (IUCN 1987a). Captive breeding for conservation should be a step in the following sequence:

- planning a conservation strategy;
- captive breeding;
- reintroduction to the wild;
- management of metapopulation.

Limitations of Captive Breeding in Recovery Programmes

The use of captive breeding for recovering endangered species has grown enormously in recent years. However, until recently its limitations tend to have been underestimated. Balmford *et al.* (1996) questioned the criteria used by zoos to decide which endangered taxa to breed; while reintroduction should be the ultimate aim of captive breeding, zoos show no tendency towards those species for which continued availability of habitat makes reintroduction a realistic prospect. Snyder *et al.* (1996) listed the following problems affecting captive breeding as a species recovery measure:

- difficulty in establishing self-sufficient captive populations;
- poor success in reintroductions;
- high costs;
- domestication;
- preemption of other recovery techniques;
- disease outbreaks;
- maintaining administrative continuity.

Ex-situ captive breeding programmes have now lost much of their appeal for the above reasons, so much so that the Noah's Ark Paradigm is now widely questioned. Additional criteria to be considered have been suggested by the Born Free Foundation:

- loss of natural immunity;
- psychological effects of captivity;
- unnatural selection process;
- potential weakening of cultural importance.

In summary, a distinction should be drawn between captive breeding in the *ex-situ* zoo based model and specialized *in-situ* captive breeding programmes which may significantly negate many of the effects and problems cited by Balmford, Snyder and Born Free Foundation.

With these difficulties in mind, careful evaluation of the costs and benefits of all alternatives available for the recovery of a species is necessary before launching into captive breeding. Furthermore, the decision to pursue a programme of captive breeding should generally be taken as a last resort in species recovery and not viewed as a long-term solution – not least because of the dramatic genetic and phenotypic changes that can occur in captivity (Snyder *et al.* 1996). On the other hand, captive breeding may prove crucial when effective alternatives are unavailable in the short-term.

Captive breeding should run in parallel with ecosystem protection, not as an alternative, and is doubtfully useful in the absence of efforts to maintain or restore populations in the wild. In addition to breeding efforts, zoological institutions can help support *in situ* conservation, and indeed there is a trend in the zoo community toward becoming more closely involved with *in situ* wildlife conservation. They recognize captive populations as a support, rather than a substitute, for wild populations. While breeding centres are important to maintain viable captive populations, refine reproduction technology and provide animals for reintroduction, they have a more immediate role to play by increasing their role in field research, professional training, and most importantly, public education and direct financial support.

Reintroduction

The ultimate objective of a reintroduction is the establishment of a viable, self-sustaining population. For each species, reintroduction poses unique problems. For most taxa, release strategies and post-release monitoring techniques are still being refined (Wilson and Stanley Price 1994). The IUCN has produced guidelines for reintroductions (IUCN 1992), providing a practical framework.

Mammals constituted 31% of 126 species reintroduced from captive-bred stock reviewed by Beck *et al.* (1994). Of these, 26% of all mammal reintroduction projects involved Carnivora. Captive breeding of endangered species, followed by reintroduction, has mostly been undertaken in reaction to imminent extinction in the wild. For instance, the black-footed ferret (*Mustela nigripes*), North America's rarest mammal, was reduced to 18 individuals before action was taken. The surviving animals were captured, have been breeding well in captivity and are now being reintroduced (Miller *et al.* 1994).

Correlates of Reintroduction Success

Reintroducing an endangered species is a long-term, expensive, and very often impractical operation (Kleiman 1989, Stanley Price 1989). Economic factors or political problems in the intended country of release have resulted in several reintroduction projects being suspended (Wilson and Stanley Price 1994). There is an argument that reintroductions stand a higher chance of success if made into a country with a relatively high standard of living and political stability. Beck *et al.* (1994) reviewed some characteristics of 145 reintroduction projects, including five mammal species, of which 16 were considered successful. A proportion of the remaining 129 projects were at too early a stage to judge definitively their success. The following are abstracts from the review by Beck *et al.* (1994), highlighting the features of each stage of the reintroduction process relevant to carnivores:

Pre-release training: Includes searching for hidden and spatially dispersed food and experience in finding and killing prey in large outdoor enclosures. Prior to release animals may be harassed by humans or trained dogs, presumably teaching fear and avoidance of potential predators.

Acclimatization: Reintroduction candidates are held at or near the release site in a cage, pen or man-made enclosure for a period of time, in order to allow the animal to become familiar with climatic conditions, landmarks, natural foods or other features of the environment.

Medical screening: Is the choice of reintroduction candidates based at least in part on veterinary considerations? It may include certification of freedom from certain infectious diseases, quarantine, vaccination, deparasitization, freedom from debilitating injury or deformity, reproductive viability. Vaccination of canids could include rabies, distemper, canine parvovirus, hepatitis, leptospirosis, corona-virus and parainfluenza, but the vaccine virulence for other species in the range should be considered (Woodford and Rossiter 1994).

Genetic screening: Is the choice of reintroduction candidates based on genetic or pedigree considerations? Potential founders should preferably be chosen from the geographically closest population to the release site.

Post-release training: May consist of active presentation of natural foods or inducing the animals to approach suitable shelter or denning sites.

Provisioning: Released animals may be given food, water, shelter or nest-boxes.

Monitoring: An active attempt to determine the size of the reintroduced population, the occurrence of births and cause of deaths, observation of behaviour and formation of social groups. Monitoring may involve direct visual contact with the animals, radio-telemetry or indirect evidence such as faeces, footprints and dens (Appendix 3).

Local employment: Involves providing salaries to local people in the release site in exchange for working in the project. This may include building enclosures or participating in guarding or community education projects.

Professional training: A project may offer training opportunities to field assistants and graduate students.

Community education: Project personnel may present lectures, provide posters, leaflets, T-shirts, hats, participate in community meetings, cultural events, visit schools or households, or help to prepare releases for radio, television or newspapers.

Release year: The number of years in which the project released animals to the wild. Excludes time of preparation or captive breeding or years when no releases took place.

Success: The reintroduction project is considered successful if the wild population subsequently reaches a population that will be self-sustainable.

According to Beck *et al.*'s (1994) study, successful projects received more pre-release training, acclimatization, and post-release monitoring than unsuccessful projects. Medical screening and post-release provisioning did not seem essential for success. Successful projects were of longer duration and released more animals than did unsuccessful programmes. They also more frequently provided local employment and community programmes. When attempting the reintroduction of captive animals, these correlates must be taken into account. Additionally, staggered releases seem to be more successful than single ones, a reasonable number of potential founder animals and subsequent supplementation will improve the probability of establishing a self-sustaining population (Stanley Price 1989).

We also acknowledge the possibility of indirect benefits of reintroduction even where a self-sustaining population may never be established, insofar as the exercise resulted in increased public awareness and support for conservation, professional training, enhanced habitat protection, and increased scientific knowledge (Kleiman *et al.* 1994).

Any reintroduction project should do everything possible to foster a good relationship between GOs, NGOs and the local people. To a large extent this may be done by giving employment to people living in or near the range, so that these people can appreciate that it is in their interest to protect the animals and their habitat.

Translocation

The IUCN (1987b) definition of 'translocation' is the movement of living organisms from one area with free release in another, and includes both reintroductions and restocking. It does not however, distinguish between the provenance of animals for release, although this is likely to have a major impact on the outcome (Kleiman *et al.* 1994). Here we restrict the definition of translocation to the movement of wild-bred animals used to restock depleted wild populations or for reintroduction into areas where the species has been extirpated. However, with populations in very fragmented habitat it may be effectively impossible to distinguish between restocking and reintroduction.

Wild-to-wild translocations have historically been more successful than releases of captive-bred animals. Similarly, the method of release, hard or soft, may affect survival. Soft release techniques involve a period of acclimatization to the environment into which the animals will eventually be released, and there is a degree of food provisioning. In hard release the animals are introduced straight into the wild with no transitional phase. Carbyn *et al.* (1994) studied the survivorship of reintroduced swift foxes (*Vulpes velox*) in Canada and found that wild-caught, hard-released animals survived better than captive-bred hard-released ones. Overall soft released animals were slightly less successful than hard released ones.

Similar examples come from African wild dogs (*Lycaon pictus*) and grey wolves (*Canis lupus*) where translocation of wild animals away from 'problem' areas and into reserves proved more successful than reintroduction of captive-bred animals (Scheepers in Ginsberg *et al.* in press, Fritts *et al.* 1985). Therefore it seems probable that wild-to-wild translocations would be a more successful management measure than the reintroduction of captive-bred animals. On the other hand the use of captive-bred animals is preferable insofar as it avoids interference with the wild stock.

Wild-born animals may be taken into captivity and bred with captive-born animals. For the Canadian swift fox, notable differences have been observed in the behaviour of such offspring with one wild-born parent compared with offspring from both captive-born parents. For example, the former showed greater tendencies towards denning in their enclosures and greater aversive behaviour towards potential predators (C. d'Sa, pers. comm.). Such behaviour would be advantageous following release into the wild.

Wildlife Reintroductions and Disease

Insufficient attention has been given to the role of infectious disease in conservation biology (Thorne and Williams 1988, Chapter 4). Diseases are important when considering the conservation of endangered species (Macdonald 1993, 1996) and the impact on wildlife of infectious diseases introduced by animal translocations have been largely neglected (Woodford and Rossiter 1994, Cunningham 1996). While disease is a component of the maintenance of biodiversity and natural selection (Chapter 4), disease transmission through translocations may nullify or have an overall negative effect on wildlife conservation (Cunningham 1996).

Captive Breeding and the Conservation of Canids

For canid species in particular, captive populations provide a temporary safe haven from human persecution, disease or genetic introgression with closely related species. Previous attempts to breed and reintroduce canid species have been reviewed by Ginsberg (1994). Thirty-two of the 34 canid species have been bred in captivity at some time during the last three decades. There are no records of the Tibetan fox (*Vulpes ferrilata*) and the Ethiopian wolf ever breeding in captivity. To our knowledge the latter has never been kept in captivity. Most of those species bred in captivity are relatively common and most of the breeding effort has concentrated in three very common species, the grey wolf, the dingo (*Canis familiaris dingo*) and the red fox (*Vulpes vulpes*). The IUCN Canid Action Plan lists 18 canid species as threatened, only two of these, the African wild dog and the maned wolf (*Chrysocyon brachyurus*), are among those species frequently breeding in captivity (Ginsberg and Macdonald 1990). Four species were recommended in the Action Plan for reintroductions (maned wolf, Ethiopian wolf, grey wolf and red wolf (*Canis rufus*)).

Attempts to reintroduce or translocate endangered canids are uncommon; four species have been involved in at least six separate projects (Wilson and Stanley Price 1994). Relative success has been achieved in reintroducing captive-bred canids to the wild (red wolf, grey wolf, swift fox). Given adequate funds, appropriate habitat and adequate numbers of potential founder animals reintroduction could be a useful tool for the conservation of endangered canids (Ginsberg 1994). However, public and government support are vital for the success of any reintroduction. The successful reintroduction of the red wolf in southeastern USA is a pioneer in the reintroduction of canids (Cohn 1987, Phillips and Parker 1988), but was accompanied by extensive public relations exercises. Encouraged by that achievement the grey wolf is now being reintroduced in Yellowstone, and there are plans to reintroduce the Mexican wolf (an endangered subspecies) to New Mexico. The Yellowstone reintroduction however, has met fierce opposition from sheep and cattle ranchers even though it has strong support from the general public.

Projects to reintroduce captive-bred African wild dogs in southern Africa has met with little success (Woodroffe *et al.* 1997). While relatively successful in the Umfolozi Game Reserve in South Africa, it failed in Namibia (Ginsberg 1994). However, the success of the reintroduction of wild-born, translocated swift foxes in Canada, and subsequent modelling of survival data from the study, suggest that reintroduction of once relatively common canid species to areas where they have been extirpated can be effective, at least in the short term.

Several lessons emerge from Ginsberg's (1994) review. First, a large number of animals for release are required to attain long-term success. Second, reduced mortality of wild-caught canids suggests that translocation from wild populations may be preferable to reintroduction of captive-bred animals. Finally, the reintroduction of social canids is far from simple. Their need to acquire hunting skills and more complex social behaviour may explain the difficulties observed in earlier canid reintroduction programmes. Furthermore, confirmation of the success of a reintroduction programme will take many years. Whether these reintroductions are to succeed remains to be seen; ultimately this depends on whether sufficient suitable habitat remains and on the public goodwill and government support.

Does the Ethiopian Wolf Need Captive Breeding and Population Management?

Each of the remaining Ethiopian wolf populations could swiftly be extirpated due to further destruction of habitat, inbreeding, hybridization, a disease epizootic or any combination of these threats (Chapters 3, 4 and 5). Ethiopia and the world stand in extreme likelihood of losing the species if action for its recovery is not taken swiftly. Detailed information on the status of some wild populations, Ethiopian wolf biology, habitat requirements and genetics is now available (Gottelli and Sillero-Zubiri 1992, Gottelli *et al.* 1994, Sillero-Zubiri and Gottelli 1994). Based upon recommendations arising from these studies, a captive breeding programme was proposed in 1992 (Sillero-Zubiri *et al.* 1992). A resolution supporting a captive breeding programme for the Ethiopian wolf was signed by IUCN/SSC and the AAZPA members during the Canid, Hyena and Aardwolf Conservation Assessment and Management Plan (CAMP) meeting held in 1992 (Appendix 5), and a captive programme of level 90/100 I recommended (Grisham *et al.*1994). Technically, a 90/100 I level requires a captive population sufficient to preserve a minimum of 90% of the average heterozygosity of the wild gene pool for 100 years developed within 1–5 years (Grisham *et al.* 1994). Subsequently, the New York Zoological Society submitted proposals to establish a breeding nucleus in the USA (Doherty *et al.* 1992), but neither initiative prospered. The major obstacle met by both proposals was the reluctance shown by the Ethiopian authorities to allow the export of breeding specimens to start the captive nucleus.

In view of the persisting human impact on the overall distribution of the Ethiopian wolf in Ethiopia and the species' vulnerability to extinction, a metapopulation management strategy should be considered (Chapter 9) within which a captive breeding programme is essential. However, assurance of long-term government support and funding is crucial if this programme is to succeed. Experience from captive breeding and reintroduction programmes elsewhere shows that the most effective and successful have all been comprehensive efforts involving a large team and considerable resources.

Captive breeding with the aim of reintroduction is feasible only when accompanied by an analysis of causes of the species' decline and steps to reduce continued threats to its survival (Kleiman 1989, IUCN 1987b). Even when the forces driving extinction can be reversed, appropriate habitat for reintroduction must be available. Few areas within the Ethiopian wolf's former range, excluding BMNP, offer sufficient undisturbed habitat, limited human influence, and few or no domestic dogs. Conservation of BMNP and Simien Mountains National Park areas is under the responsibility of EWCO and the Regional Governments. EWCO is sporadically supported by several international NGOs. A new afroalpine conservation area has been proposed for the Menz Highlands in north-east Shoa where a Darwin Initiative (UK) programme has just begun.

After evaluating the costs and benefits of all conservation alternatives available for the recovery of the Ethiopian wolf we conclude that population management is essential, with a captive breeding operation one of the measures required. This captive population is essential to a) develop a genetically pure wolf population as a last resort against extinction, safe from the threats faced by the wild populations, and b) produce potential founder individuals for the eventual release into the wild in reintroduction and restocking programmes. While we anticipate that a full-scale reintroduction will not be feasible in the foreseeable future (see Chapter 9), a limited captive population would help save a representative sample of the existing genetic variability in the wild, currently being lost as a result of small population sizes and genetic introgression.

Grisham *et al.* (1994) recommended a captive programme of level 90/100 I for the species. This objective would require a large-scale operation and we doubt its usefulness in the light of the current low reintroduction potential. Furthermore, such a large scheme would require substantial funding, and thus might result in competition for resources with *in situ* conservation. Pragmatically, therefore, we favour a more modest captive program of level Nucleus I. This would serve the purpose of an insurance programme to allow the continuity of the endangered species regardless of crises in its natural habitat. A level Nucleus I captive population requires a captive nucleus (50–100) individuals to represent always a minimum of 98% of the wild gene pool. This type of programme requires periodic, but in most cases modest, immigration of individuals from the wild population to maintain the high level of genetic diversity (Grisham *et al.* 1994). A detailed proposal for this approach is given in Chapter 9.

With the support of the Born Free Foundation, a proposal is being developed to set up and manage an *in-situ* long-term naturalistic captive breeding facility or facilities within Ethiopia dedicated to the Ethiopian wolf. The initial proposal will cover construction and a two year operating plan together with budget. Ongoing costs will also be identified.

Approval will be sought from the Ethiopian authorities for the construction of such a facility within Ethiopia, which is the preferred option.

Chapter 9
Metapopulation Conservation: Captive Breeding, Reintroduction, Translocation and Population Management

Introduction

In the previous chapter we considered those intensive management options available to the Ethiopian Wolf Recovery Programme. Wildlife management measures used by species' recovery programmes include captive breeding, or a combination of *ex situ* and *in situ* metapopulation management.

A few conclusions emerge from previous chapters. The Ethiopian wolf embodies the two paradigms of conservation biology (Caughley 1994): the small-population and the declining-population. The first only raises the question of how long a population will persist, and concerns the consequences of smallness and rareness. The second deals with the cause of smallness and its cure, and involves research effort to determine why a population is declining and what might be done about it. We now know that the species is rarer than it ever was, and that those populations which remain are fewer and smaller than before (Chapter 2). These remaining populations are being increasingly exposed to detrimental extrinsic factors, such as increased contact with humans resulting in persecution and road kills (Chapter 3), and contact with domestic dogs with ensuing disease epizootics and hybridization (Chapters 4 and 5). Regardless of the causes of their decline, these populations are also vulnerable due to their smallness, they are more exposed to demographic and environmental stochasticity, genetic drift and inbreeding, resulting in loss of heterozygocity and fitness, inbreeding depression and eventual local extinction. Furthermore, dramatic declines in numbers in short intervals of time – catastrophes (either physical or biological) – have an important effect in populations' persistence. Recent theoretical work suggests that local extinctions are likely to be more common than short-term studies would lead us to believe (Mangel and Tier 1994). Since extinctions are likely events, we should expect extinctions even of protected and larger populations.

Against this background we conclude that in order to halt the decline and enable the eventual recovery of the Ethiopian wolf, vigorous conservation is required. We need to assure the continuation of afroalpine habitat conservation within protected areas, monitoring the demography of the different wolf populations, and through education, reduce the impact of human activities and livestock on their survival.

In order to conserve this species in the long-term we need to address the small-population concern as well. Chapter 8 concluded that captive breeding was not a sufficient answer to this problem, although it is potentially a stepping stone in efforts to assure the survival of the Ethiopian wolf. We emphasized the need to treat the remaining populations as a metapopulation for management purposes.

Metapopulations

A metapopulation is a population of populations. It refers to the range of a species composed of geographically isolated patches, interconnected through patterns of gene flow, extinction and recolonization (Lande and Barrowclough 1987). Several smaller populations occurring in separate ranges may be more viable than a single larger one, provided that the environmental variation influencing each different segment is at least partially independent. It is also important that there is at least some recolonization, natural or managed, of ranges that experience local extinction (Soulé 1987). Captive populations should be encompassed by conservation strategies and action plans as an integral part of metapopulations.

With the aid of suitable techniques we can associate all wolf populations into a single one, and manage it as such. We have now concluded that while captive breeding is imperative to establish a nucleus of 'pure' wolves as a last defence against extinction, a full-scale reintroduction will not be feasible in the foreseeable future. This fails to fulfil the main objective of modern captive breeding, that is to produce animals for reintroduction (IUCN 1987a), but on the other hand such a programme would allow the preservation of a sample of the existing genetic variability. In addition to the captive breeding of endangered species for their eventual reintroduction to the wild, translocation of a limited number of surplus animals, either captive-bred or wild-born, between populations emerges as a potentially important metapopulation management option available to future Ethiopian wolf conservation (see below).

There usually is great urgency to address the issues posed by conservation crises, but rarely enough time to assess a situation exhaustively before one must act. Our suggestions, in the Action Plan, may be superseded as more information on the species and on suitable management techniques becomes available. However, our intention has been to establish a clear framework for the conservation of the Ethiopian wolf that at least enables a start to be made. In this section we examine how the complementary approaches of captive breeding, reintroduction, translocation and metapopulation management may be applied in an Ethiopian Wolf Recovery Programme.

Management of Ethiopian Wolf Populations

The following captive breeding and metapopulation management programme is proposed for the Ethiopian wolf:

- establishment of a captive breeding facility in Ethiopia, preferably in or close to wolf habitat;
- captive breeding at international captive breeding facilities with experienced curatorial and veterinary staff;
- provide protection for afroalpine habitat and the wolves and progress towards metapopulation management.

Captive Breeding

The Ethiopian wolf is one of only two canid species which have never been kept or bred in zoos, and therefore the species lacks that last "insurance policy" against extinction. Thus, in addition to reversing the decline of wild wolf populations there is a strong argument for establishing a captive population as a hedge against further cataclysmic population declines. However, without reintroduction as the subsequent outcome of captive breeding, captive animals will be in danger of becoming decreasingly suitable for reintroduction, should it eventually occur. Captive conditions over generations may increase the animals' degree of domestication, decrease their natural ability to deal with stress, and their natural behaviour may become suppressed or inhibited.

Both captive breeding approaches, *ex situ* and *in situ*, provide different advantages and are mutually supporting. Indispensable to the whole programme is the continued maintenance of the species' natural habitat and linking population management into a single metapopulation. The latter may be achieved through reintroduction of captive-bred animals and/or translocation of wild-bred animals. This includes restocking of existing populations and/or reintroduction in areas where the species was extirpated. Figure 9.1 shows a diagram of the proposed metapopulation management programme, including *ex situ* and *in situ* captive breeding and eventual reintroductions and restocking.

The goals of this programme will be:

- to develop captive programmes for Ethiopian wolf conservation with the primary purpose of contributing to the survival and recovery of the species in the wild;
- to provide animals to re-establish or restock wild populations when the need and opportunity arises;
- to conduct problem-oriented research that will contribute to manage wolves both in the wild and in captivity;
- to channel financial and technical support from the zoological institutions responsible for captive breeding towards *in situ* conservation, possibly through Adopt-A-Park programmes;
- to use the Ethiopian wolf as a *flagship* species for conservation education and public relations for all Ethiopian wildlife.

Ex Situ Captive Breeding

A pilot captive population could be immediately established in an existing facility (*ex situ* option), with a nucleus of animals on '*breeding loan*' from the Ethiopian Government. Similarly, expertise from existing facilities around the world could be brought in to help establish a pilot captive population within a specifically constructed Ethiopian facility. Captive breeding is a highly sophisticated procedure and there are several advanced institutions around the world willing to become involved in such a programme. Hitherto, progress in establishing a captive population has been slow due to the difficulty of obtaining permission to capture and breed individuals from the wild and other prerequisites for exporting wolves to

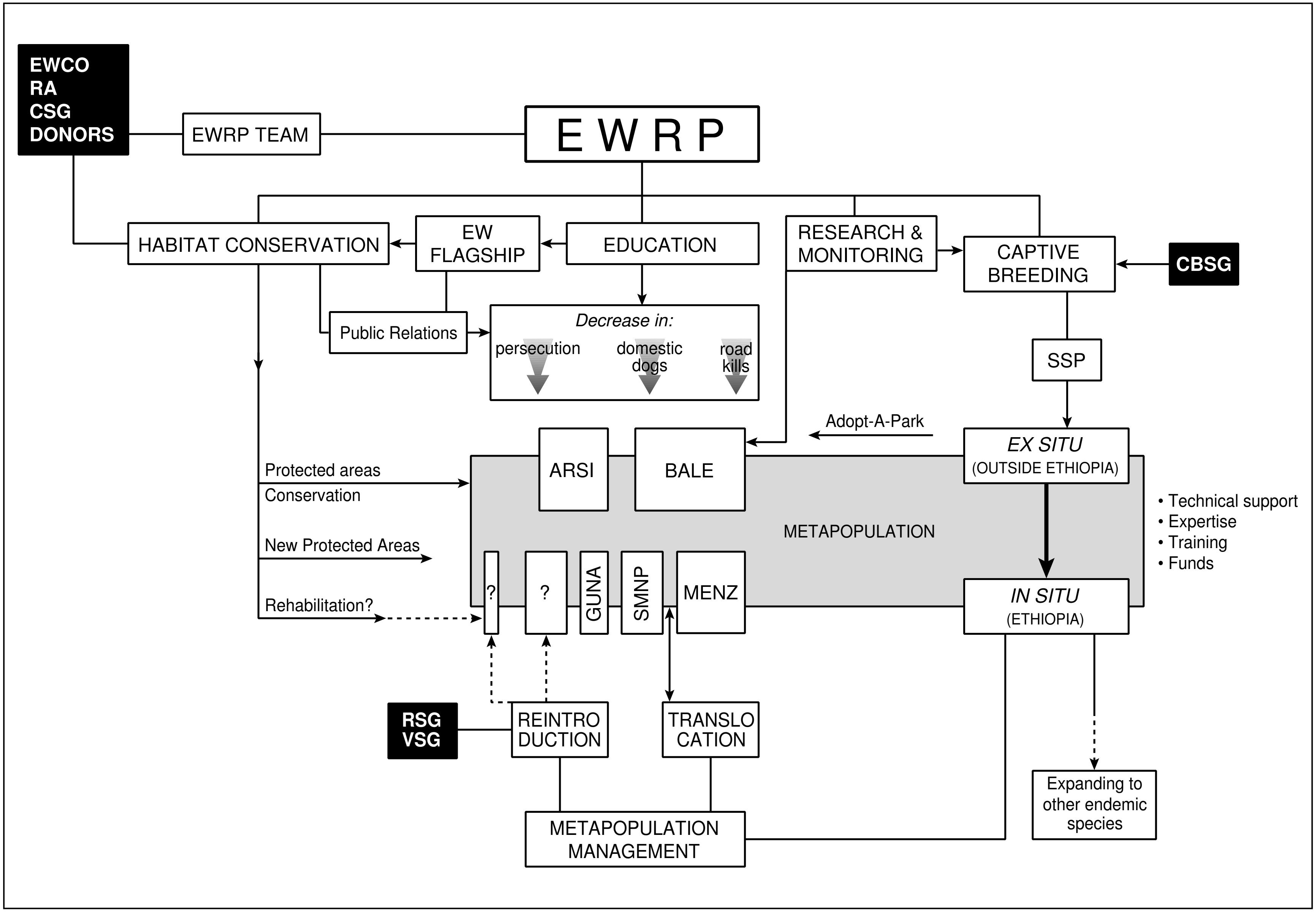


Figure 9.1. Flow chart summarizing the various components of the Ethiopian Wolf Recovery Programme, indicating relationships between them and the different agencies involved. Agencies are shown as white text on black backgrounds, and the acronyms used are listed in Chapter 10.

breeding facilities outside the country.

The main advantages of an *ex situ* breeding programme for the Ethiopian wolf are:
- availability of extensive experience on keeping and breeding of closely-related species;
- minimal start-up and running costs;
- the ready availability of advanced technology (such as genetic screening, embryo-transplants, hormonal monitoring);
- advanced veterinary medical care;
- potential to breed more animals faster with lower mortality;
- potential for fund raising, including the exhibition of this rare and unfamiliar species.

The disadvantages include:
- unfamiliar conditions in terms of habitat, prey types and climate;
- exposure to unfamiliar diseases;
- costs of transport and possible quarantine.

Funds raised by the different zoological institutions involved should be channelled to the *in situ* Ethiopian Wolf Recovery Programme and for the conservation of the afroalpine ecosystem, possibly through an Adopt-A-Park system similar to that in practice with the tiger (*Panthera tigris*) in India and Malaysia.

Captive breeding at existing international facilities outside Ethiopia should be governed by a strict international loan agreement. Animals for breeding outside Ethiopia would be supplied on breeding loan; and thus would never be out of Ethiopia's possession and control. Ownership of all the wolves, including potential founders and all successive generations, and participation in management by Ethiopia should be part of such an agreement.

In Situ Captive Breeding

The main aims of *in situ* captive breeding are to create a new population safe from the threats faced by wild populations, and to produce a founder population for release into the wild in reintroduction programmes. It should be possible to breed the species in large semi-natural enclosures in a suitable afroalpine location, and to develop a large captive population intended to supply stock for restocking or reintroduction to areas from which the species has been extirpated but which are again suitable.

The obvious advantages of breeding Ethiopian wolves within their range in Ethiopia are:
- the establishment of semi-natural enclosures in terms of habitat type;
- the availability of natural food;
- exposure to natural climatic conditions;
- the reduction of exposure to unfamiliar diseases;
- development of local wildlife management expertise;
- practical demonstration of national concern;
- local publicity.

Disadvantages of a captive breeding in Ethiopia may include:
- no captive facility currently exists;
- the high expense of initiating and running a new breeding facility;
- lack of assured financial support for a long-term programme, given Ethiopia's many other pressing priorities;
- no experienced curatorial and veterinary staff available to deal with the onset of critical health, reproductive and management situations;
- lack of sophisticated support infrastructure;
- exposure to local diseases.

A modest captive breeding facility could be built in a suitable location in Ethiopia. The local breeding facility should consist of suitable wolf enclosures, a simple clinic and food preparation room and staff accommodation at an appropriate site. The original facility may eventually be enlarged. Experience acquired by programme staff in captive breeding techniques could be transferred in the future to an education facility and to accommodate the breeding of other endangered highland wildlife, for example walia (*Capra walie*), mountain nyala (*Tragelaphus buxtoni*), Prince Ruspoli's turaco (*Tauraco ruspolii*) and wattled crane (*Bugeranus carunculatus*).

Guidelines for a Captive Breeding Programme

Based on proposals submitted in 1992 (Sillero-Zubiri *et al.* 1992), the main tasks involved in the design, coordination and funding of the programme are presented in loose chronological order:

First Phase
- Establishment of an international captive breeding programme;
- Coordination of captive breeding effort;
- Signature of ownership agreement between breeding institutions and government agencies;

- Selection, capture and transport of potential founder animals;
- Establishment of a breeding nucleus: the preferred option is to begin with a facility in Ethiopia if funding can be made available quickly;
- Develop husbandry research;
- Investigate potential for the use of electro-ejaculation and cryo-preservation of semen;
- Secure funding for Ethiopian facility;
- Development of educational programme in Ethiopia.

Second Phase
- Establish and consolidate an Ethiopian captive breeding programme (plans are already being drawn up);
- Select suitable location(s);
- Determine facilities required;
- Build facility;
- Establishment of breeding nucleus;
- Organize management of the facility;
- Develop technical and scientific cooperation;
- Training of Ethiopian nationals;
- Implementation of educational programme.

Based on the above considerations a captive breeding programme in Ethiopia must be considered a long-term operation, with resources and planning available for at least 10 years. The institution(s) responsible for the project must provide their continued support until, at least, conditions for reintroduction in the wild are suitable.

Coordination of Captive Breeding Programmes

The proposed breeding programme would be biologically safe through drawing on the wealth of existing practical knowledge collated by CSG, the Conservation Breeding Specialist Group (CBSG) and programmes on captive breeding of other related species, and our recent knowledge of the species' ecology, demography and mating system in the wild. Details of the proposed programme have to be agreed by all participating GOs and NGOs and are dependant upon developments in funding, possible locations, government approval and other factors.

It is vital to establish a managerial structure to coordinate and oversee the future captive breeding programme. Participating zoos should cooperate to manage individual animals within the different breeding facilities involved as a single population. The overall programme should be coordinated between the CSG, CBSG, experts from captive breeding centres involved and relevant Ethiopian agencies.

A master plan should include demographic and genetic analysis of the captive population, including which animals should breed and with whom, which ones should not breed, which ones should be removed from the population, and which ones should be used for research, reintroduction or genome banking. The master plan should follow the format adopted by the American Zoo and Aquarium Association (AZA) for its Species Survival Plans (SSP).

Studbooks are indispensable to track the degree of relatedness between individuals (Dathe 1990). Detailed information on the location, whether from different populations or subspecies, and genetic relatedness of potential founder animals should be compiled in a studbook and used to manage the captive population and optimize outbreeding.

Genetic Considerations

Chapter 5 outlined several genetic questions important to the establishment and genetic maintenance of captive populations of Ethiopian wolves. These also apply to their eventual reintroduction or the genetic supplementation of populations in the wild through restocking. In naturally occurring populations there are great inequalities in reproductive success among individuals and sexes such that the effective population size is reduced. Furthermore, a high degree of philopatry risks potential inbreeding. This risk, however, seems to be circumvented through extra-pack mating (Sillero-Zubiri *et al.* 1996b).

Several genetic considerations would need to be assessed:

Number of potential founder individuals. In theory, a large stock of 50 or more individual potential founders would be recommended to start a captive nucleus, in order to represent and preserve the diversity of the wild population. However, captive populations have been founded with fewer individuals and succeeded although some inbreeding depression may occur (Chapter 5). In practice, and view of the small number of wolves surviving, it may be possible to start a captive nucleus with as few as 10–15 animals. Rapid expansion of the initial population and careful genetic management would keep inbreeding to a minimum.

Selection of potential founders. Having secured permission to capture 10–15 individuals for captive breeding, they should be selected to represent the genetic diversity of wild populations before the introduction of domestic dogs into the afroalpine range. This requires first the choice of source population(s) for the potential founders. We recommend BMNP as the preferred source for the majority of the potential founders, this being the larger wolf population as well as the one with the largest carrying capacity (and therefore least likely to be altered by the temporary population reduction caused by the potential founders' removal). Additional animals may be drawn from Arsi and perhaps Menz populations, to optimize the captive population's initial genetic diversity. Molecular genetic techniques can effectively be used to deduce population-specific polymorphisms and determine whether it is advisable to interbreed individuals from different populations (Avise 1994, but see Chapter 5).

The potential founder animals should be chosen such that they are unrelated and best represent the genetic diversity within the source population. Established molecular genetic protocols should be used to detect the genetic relatedness between potential founders and the selection of closely related individuals should be avoided (Gottelli *et al.* 1994). Animals of hybrid ancestry should be excluded. This may be achieved by the selection of individuals from different packs that appear phenotypically normal, such as those in Sanetti Plateau and Tullu Deemtu in BMNP. Captured animals should be tested for genetic evidence of dog ancestry (Gottelli *et al.* 1994, Chapter 5).

In order to reduce the impact the capture of potential founder animals might have on the source population, subadult animals, which have not yet been recruited into the breeding population, should be targeted. Young males may be removed from the larger packs in the source population (preferably those packs with at least 4−5 males), ideally from packs that have breed successfully the previous year. Young females that have left their natal packs and became floaters (Sillero-Zubiri *et al.* 1996b) constitute ideal candidates, since their removal would not affect breeding dynamics in established packs. Alternatively, subadult females from packs with at least three females may be chosen. On no account should either adult females that have bred or dominant adult males be removed. An alternative strategy would be to target animals in the fringes of a wolf population, since they would probably be dispersing animals, with lower survival expectancy. This would be a suitable strategy when collecting a few potential founders from smaller, less well known populations.

Husbandry. Husbandry. Once in captivity, the founder population should be managed to reduce inbreeding and the loss of variability and should be expanded rapidly. In addition to the preservation of genetic variability, husbandry practices need to address the preservation of wild-adapted behaviour (Tudge 1991, Badridze *et al.* 1992). This may be achieved in large semi-natural enclosures, with wolves kept in stable groups (*e.g.* breeding pair with offspring of the previous year). It will be necessary to consider a feeding regime that insures that captive bred individuals destined for release have appropriate survival skills; in due course this will necessitate evaluation of topics such as the feeding of live rodent prey (perhaps established in naturalistic colonies with escape terrain). We acknowledge that this is an ethically complicated issue, and flag it as one that may have to be addressed.

To reduce the loss of genetic variability in a small, captive population, the genetic relationships of individuals need to be understood and the breeding structure manipulated so that the number of breeders and their genetic dissimilarity is maximized. Multiple mating and paternity occurs in Ethiopian wolves (Gottelli *et al.* 1994). In order to mimic the pattern that occurs in the wild, husbandry practices may include multiple insemination of females by different males to maximise the chance that they may become pregnant and at the same time allow genetic contributions from an increased number of males to be included in the next generation. This might be achieved by placing the oestrous female in a separate enclosure and allowing males other than her partner access to her cage in succession.

Reproduction technology. The establishment of a captive population will permit species-specific husbandry research, in order to optimize future metapopulation management. An obvious path is the development of specific protocols for the collection of viable sperm and eggs from wild wolves that could be frozen for future use in captive breeding (Chapter 5). Sperm from wild males may be collected through electro-ejaculation. The sperm may be used later for artificial insemination or to fertilize harvested eggs *in vitro*. Similarly, eggs could potentially be flushed from wild caught females, viably frozen and matured at a later date for fertilization and implantation in captive wolves. Such fertilized eggs could potentially be brought to term in surrogate mothers from a related species, such as domestic dogs. A genetic bank of eggs and sperm from wild caught wolves could be used to enrich the genetic diversity of captive wolves once the breeding program is started and, in the meantime,

Table 9.1
Reintroduction of Ethiopian wolves. Is it supported by the reintroduction criteria proposed by Kleiman *et al.* (1994). Scale 5 = best.

Condition of species	
1. Need to augment wild population	Yes
2. Available stock	No
3. No jeopardy to wild population	?
Environmental conditions	
4. Causes of decline removed	No
5. Sufficient protected habitat	No
6. Unsaturated habitat	No
Biopolitical conditions	
7. Negative impact for locals	No
8. Community support exists	2
9. GOs/NGOs supportive/involved	Yes?
10. Conformity with all laws/regulations	?
Biological and other resources	
11. Reintroduction technology known/in development	3
12. Knowledge of species' biology	4
13. Sufficient resources exists for programme	No
Recommended reintroduction/translocation	**No**

would provide a hedge against the very real possibility of dramatic population declines and even extinction in the wild.

Reintroduction and Translocation

There have been a few attempts at reintroducing canid species in the past, and these were reviewed in Chapter 8. With the increased sophistication of captive breeding in the last decade, reintroduction may become a more frequent recovery technique in the future. However, with regard to the Ethiopian wolf, no reintroduction programmes should be considered until human influences are controlled and the threat from domestic dogs is totally removed from potential release sites, or until new natural reserves are created to conserve more habitat suitable for the species.

The benefits of intervention should be carefully weighed against its possible negative effects (such as disturbance and accidental disease introduction) before deciding whether or not such an intervention can be justified. Because of the conservation significance of animal translocations, the implementation and interpretation of risk assessment should be evaluated by regular reviews by outside specialists.

Kleiman *et al.* (1994) presented 13 criteria that should be considered prior to implementing a reintroduction. These criteria can be used in decision making, especially regarding proposals to use captive-bred animals for a reintroduction, and are grouped into four discrete categories: condition of the species; environmental conditions; biopolitical conditions; and biological and other resources. We applied these criteria to the Ethiopian wolf. Table 9.1 presents the criteria and indicates where the species lies with respect to the recommendation to initiate or carry out a reintroduction programme. In some cases we have insufficient data to determine whether a criterion is met.

Overall, consideration of the proposed criteria lead us to the conclusion that it would be premature to recommend a reintroduction of Ethiopian wolves into a new area at this stage. However, conditions may change in the near future and reintroduction may become a feasible management option.

Translocation as a means of restocking small populations and boosting genetic variability remains an option more likely to be of use for the management of Ethiopian wolf populations. This method is less expensive than captive breeding and reintroduction, but will require a high degree of planning and implementation. Wayne and Gottelli (Chapter 5) showed that the BMNP wolf population exhibited significantly less genetic variation than expected. Supplementing a population with as little as one or two individuals per generation may be enough for genetic variability to be maintained. Behavioural and demographic arguments need to be considered in the selection of individuals for wild-to-wild translocations. The age and sex category of those animals targeted is important for two reasons. First, as suggested above, removal of individuals from the wild should not affect the reproductive dynamics of the source population. Second, Ethiopian wolves show a high degree of philopatry, and only females would disperse under normal conditions. Similarly, only relatively young (1.5–4 year old) females were seen to immigrate into an established wolf pack and breed (Sillero-Zubiri *et al.* 1996b). Both findings point at young females as the best choice for translocation purposes. However, while it has been shown that wild-born individuals perform better than captive-born ones in translocation operations (Chapter 8), the potential impact of removing animals from a relatively small wild population should not be overlooked, and careful consideration should be given to the use of captive-born individuals in spite of their potentially lower success rate, bearing in mind that they would be more ‘expendable’ that wild ones. An additional precaution when moving individuals between wild or captive populations is the risk of transmitting disease.

Translocation Guidelines

In order to minimize disease risks due to the transfer of animals between different wild and/or captive populations Cunningham (1996) suggested the following guidelines:

- Before a translocation assess disease risks and take precautions to minimize these risks.
- Maintain the animals in captivity as near to the site of capture/release as possible (preferably in the region of origin).
- Maintain the animals in captivity for as short a time as possible.
- Prevent contact between the animals in question and those from a different source or of a different species.
- Keep and handle the animals under hygienic conditions to minimize the risk of parasites being passed from the keepers to the animals.
- Avoid the transfer of parasites from foodstuff to the animals.
- Clinically healthy animals should not be regarded as parasite free and therefore should be treated with caution.
- Translocation to areas devoid of related species helps decrease the risk of interspecific transmission of disease.

Metapopulation Management

Gottelli *et al.* (1994) showed that the genetic variability of wild populations of Ethiopian wolves in BMNP was low in comparison to that of other related canids, suggesting long-term effective population sizes of less than a few hundred individuals. The role of genetics in the future management of wild and captive Ethiopian wolf populations is discussed earlier in this volume (Chapter 5).

Metapopulation management will be required to avoid further loss of genetic variability. In order to keep isolated and small populations genetically viable, captive born animals may have to be released into established wild groups, and some wild-born animals may have to be caught for use in captive breeding. Additionally direct wild-to-wild translocations may be used. Such exchanges must be accompanied by intensive medical checks to avoid the possibility that disease might be exchanged between populations.

The whole programme should be dynamic, making use of genetic records of the captive animals as well as information from wild populations. Metapopulation management should integrate the management of wild and captive populations, population genetic management, conservation and management of habitat and eventual reintroductions to areas where the species has been extirpated. Information from both wild and captive populations and their habitat should be used to elaborate a Population and Habitat Viability Assessment (PHVA) in order to coordinate all aspects of the programme, and to optimize the management of all remaining Ethiopian wolf populations. This recovery programme needs careful design and supervision by a steering group of experts.

Conclusions

Ethiopia experiences unique environmental conditions, which have resulted in the evolution of a plethora of endemic animal and plant species. The future of several of these larger Ethiopian wildlife species is in question due to continuing and insidious pressures on the habitats and the species themselves. To insure the continuity of these species until more benign conditions prevail in their environment, captive breeding and population management are crucial for some of the species. Arguably the most endangered of these, due to persecution, critical genetic circumstances and habitat modification, is the Ethiopian wolf.

The Ethiopian wolf population in the Bale Mountains apparently increased since the BMNP was established in the 1970s and into the 1980s, illustrating the importance of conservation areas to ensure the survival of this species. However, the dramatic decline that the Bale population has suffered since 1990, together with the small numbers remaining elsewhere and the fragmentation of its population, highlight the vulnerability of these wolves. Reduced levels of genetic variability are further compounded by the dilution of the species' gene pool from cross-species breeding (Gottelli *et al.* 1994). The Ethiopian wolf is now more endangered than ever. Ethiopia and the world stand in extreme likelihood of losing the species if action is not taken soon. In view of the persisting human impact on its overall distribution and its vulnerability to extinction, the establishment of a captive breeding and population management programme must be undertaken.

A captive breeding programme has already been proposed for Ethiopia, with the Ethiopian wolf as a flagship species, but one view expressed in Ethiopia was the concern about removing any of the world's remaining Ethiopian wolves from the wild. However, information from the wild and recent events involving hybridization and disease epizootics have made captive breeding a priority to enhance the survival of the species. Establishing a captive population could forestall the possibility of a natural disaster wiping out a whole wild wolf population, or of genetic extinction through hybridization.

In summary, the Ethiopian wolf would benefit from a captive breeding operation in order to halt the loss of genetic variability sustained by its remaining small populations, and protect some stock from introgression with domestic dog genes. *In situ* captive breeding is the preferred technique and there are already proposals and funding pledged for the establishment of such a facility in the near future. The surplus wolves from the captive nucleus and some wild caught animals could be used for restocking. Reintroduction may become an option in the future if the species becomes extirpated from a protected area with sufficient habitat available to make such an operation viable. Reintroduction to small islands of afroalpine habitat where the species has been extirpated is another attractive possibility, although a technical problem with this exercise is the limited scope for expansion of the reintroduced population, so that even at carrying capacity, population sizes may not strictly be viable.

We know that a successful reintroduction project will have to be extended over many years and may necessitate the release of a large number of animals. To succeed, the project will have to invest heavily in the involvement of local people through employment opportunities and community education. This calls for long-term commitment, a large recovery team, clear protocols and guidelines for population management and most importantly, institutional support. All of these characteristics are resource-intensive, suggesting that prospects for adequate, long-term funding must be good if captive breeding and/or reintroduction are to be undertaken responsibly. Captive breeding, both *in situ* and *ex situ*, must be carried out in collaboration with field research into the wild-living populations. The captive breeding facilities will greatly benefit from new information about Ethiopian wolf ecology and behaviour.

This programme should be coordinated between the Canid Specialist Group (CSG), the Conservation Breeding Specialist Group (CBSG), the Veterinary Specialist Group (VSG), the Re-introduction Specialist Group (RSG), experts from existing captive breeding centres and the most up-to-date information from the wild in Ethiopia. Such a programme would be biologically safe through drawing on the wealth of existing practical knowledge collated by CSG, CBSG and programmes on captive breeding of other related species, and our extensive recent knowledge of the species' ecology, demography and mating system in the wild. Details of the proposed programme have to be agreed by all participating GOs and NGOs and are dependant upon developments in funding, possible locations, Government approval and other factors.

Chapter 10
An Action Plan for the Ethiopian Wolf

Introduction

The previous chapters have described what action is needed to safeguard the Ethiopian wolf from extinction. The selection of priorities, and projects proposed to address them, has developed from those chapters. Here we suggest a programme which emphasises the need for immediate and pragmatic conservation action. At the core of our approach is the conviction that effective conservation must embrace four fields of endeavour. Referred to collectively as the Conservation Quartet, these are research, education, community involvement and implementation. Clearly, many conservation problems cannot be solved until they are understood, hence the need for research. The resulting understand-ing is the basis for education, and is unlikely to lead to effective use unless it involves the local community. Finally, the major task is to blend the results of research, and the enthusiasm cultivated by education and community involvement to produce effective implementation of a workable plan. Our suggestions are intended to create a framework for the operation of this Conservation Quartet to save the Ethiopian wolf.

Primary Objectives

The main goal of this action plan is to assist with the recovery of Ethiopian wolf populations and conserve their habitat in order to achieve the minimum population level required to ensure their long-term survival.

The objectives of this recovery plan for the Ethiopian wolf are:

- To secure the conservation of areas of afroalpine ecosystem, their biodiversity and ecological processes.
- To address, and counteract, the main threats to the survival of Ethiopian wolves, such as those arising from coexistence with domestic dogs, human persecution and fragmented populations.
- To preserve at least 90% of the existing genetic diversity of the species for 100 years.
- To establish a Nucleus I captive breeding population, preferably in Ethiopia, required to maintain genetic variability and supply individuals for meta-population management.

Primary Assumptions

Thanks to the studies carried out since 1988 we now know enough about this species to focus conservation efforts effectively. Several assertions concerning the Ethiopian wolf's conservation in the wild can be made with confidence:

1. The species will only survive if its needs, and those of the local people inhabiting the afroalpine ecosystem, are brought into harmony.
2. The Ethiopian wolf is widely accepted by the Ethiopian people as a symbol of the country's unique fauna. In recent years the conservation needs of the species have attracted a high level of public concern, both nationally and internationally. This should be capitalized on as a vehicle for comprehensive afroalpine conservation programmes. The conservation of the wolves and of their afroalpine habitats are inseparable.
3. The survival of the Ethiopian wolf is closely linked to the existence (or establishment) of well-managed, protected areas that have the support of the local

human populations. Such protected areas, both existing or proposed, should ideally be located so as to provide protection to other threatened/endemic mammals, such as the mountain nyala, giant molerat, walia ibex, numerous endemic birds (notably the northern wattled crane, white-collared pigeon and blue-winged goose) and rare plants like giant lobelias.
4. Public education campaigns will be needed in the regions where the Ethiopian wolf occurs, stressing the uniqueness of the species and its importance within the afroalpine ecosystem.
5. Due to small population sizes and the nature of the endangering factors (hybridization and disease) threatening the Ethiopian wolf it will be necessary to manage the species (both in the wild and captivity) in perpetuity.
6. A captive breeding population is a vital part of the population management approach. This will provide an additional wolf population free from domestic dog hybridization. It will serve as a backup in case wild populations become extinct, and eventually provide stock for metapopulation management and reintroduction programmes.

In Situ or *Ex Situ* Conservation?

Saving the Ethiopian wolf means saving the species in its natural habitat, with a full range of genetic variation. This goal has two main components: saving the Ethiopian wolf's habitat and saving the species' gene pool. It might be possible to save the species by protecting it and its habitat together through the application of standard *in situ* conservation procedures, such as improvement of protected area management (Chapter 7), increased wolf range patrols, population monitoring and community education. Of particular importance for the Ethiopian wolf would be the control of sympatric domestic dogs to curtail the risk of hybridization and disease transmission (Chapters 4 and 5). However, in view of the very low number of wolves remaining, the small size and isolation of their populations and the lack of long-term security over much of the species' distribution, there is a strong possibility that the Ethiopian wolves cannot be afforded sufficient protection to allow their numbers to recover in the wild. *Ex situ* conservation in the form of a limited captive breeding population therefore may need to be contemplated as well (Chapter 8). In this context, the first preference is specialized *in situ* facilities in Ethiopia; if funding is not available sufficiently swiftly to implement this, then the second option would be *ex situ* facilities elsewhere. For management purposes, all remaining populations, including the proposed captive one, should be treated as a single metapopulation (Chapter 9).

The Action Plan Summary

A conservation programme for Ethiopian wolf survival, or the Ethiopian Wolf Recovery Programme (EWRP), is presented in three sections, each dealt with in the previous chapters, namely: (1) ecosystem conservation; (2) population conservation; and (3) metapopulation conservation. A fourth (4) part deals with the organizational aspects of the programme. A step-down outline of action needed in each of these areas is listed below, followed by specific projects required to advance these goals.

1. Actions that Focus on Conserving the Afroalpine Ecosystem

1.1 Encourage Support and Assist with Management of Bale Mountains National Park.

1.1.1 Seek actively official ratification that BMNP is gazetted and request its listing as a UNESCO World Heritage Site.
1.1.2 Attract funding for development of BMNP infrastructure.
1.1.3 Extend management and staff presence to the afroalpine sectors of BMNP, including the construction of outposts in Sanetti Plateau and Web Valley.
1.1.4 Establish a system of staffed outposts and regular park patrols covering all afroalpine areas of BMNP.
1.1.5 Work with local communities and local government to foster coexistence between BMNP staff and park residents. Invite residents to participate in development of conservation programmes.
1.1.6 Consider the feasibility of a zoning system within BMNP, with a core area excluding all human settlement or activity, and buffer areas permitting limited human settlement and exploitation activities.

1.2 Encourage Support and Assist with Management of Simien Mountains National Park

1.2.1 Promote the expansion of SMNP boundaries or a buffer zone to include remaining afroalpine habitats in the Simien range.

1.2.2 Refurbish infrastructure and staff presence throughout SMNP.
1.2.3 Encourage resumption of park management including staffed outposts and regular park patrols.
1.2.4 Liaise with organizations currently involved with conservation and rural development programmes in SMNP.

1.3 Promote Conservation and Integrated Management of Afroalpine Habitats Elsewhere in Ethiopia

1.3.1 Establish a regional conservation area in Menz, northern Shoa.
1.3.2 Explore potential for the creation of regional conservation areas in Arsi, Gojjam and Wollo.

1.4 Promote the Ethiopian Wolf as a Flagship Species for Ethiopian Fauna and the Afroalpine Ecosystem

1.5 Contribute Towards the Advancement of a National Syllabus for Wildlife Conservation Education in Ethiopia's Primary and Secondary Schools, Assuring Appropriate Coverage of Afroalpine Conservation Issues.

2.Actions Needed for the Recovery of Ethiopian Wolf Populations *In Situ*

2.1 Change IUCN Category of Threatened to Critically Endangered

2.2 Confirm the Present Status and Distribution of Ethiopian wolf populations

2.2.1 Design a systematic approach for compiling data on population, habitat availability, prey abundance and human/livestock conflict on all wolf populations. Develop a quantitative wolf population evaluation technique (Appendix 3).
2.2.2 Designate EWCO personnel in SMNP to collate and forward wolf sighting reports from Simien.
2.2.3 Identify local government personnel in Shoa to collate and forward wolf sighting reports from Menz.
2.2.4 Conduct wolf surveys in other areas of consistent wolf reports to verify their relative abundance and status (*e.g.* Arsi Mountains, West Bale Mountains, Mount Guna).
2.2.5 Conduct wolf surveys in other areas of historical range (*e.g.* Wollo and Gojjam) to verify the presence of wolf populations and determine habitat available.
2.2.6 Estimate habitat available, current wolf population and wolf carrying capacity for each area.
2.2.7 Determine the taxonomic status of Ethiopian wolf sub-species and the degree of genetic differentiation between populations.
2.2.8 Determine the degree of genetic variability within populations (inbreeding), and the extent of wolf hybridization with domestic dogs.

2.3 Initiate a Programme of Ethiopian Wolf Management in BMNP

2.3.1 Monitor BMNP wolf demography, reproductive success and population trends from observation of known wolf packs.
2.3.2 Monitor human activity within wolf range.
2.3.3 Determine degree of interaction and conflict between wolves, domestic dogs and wild carnivores.
2.3.4 Collect information on the health status and causes of wolf mortality.
2.3.5 Assess the prevalence of canid pathogens in the wolf population, particularly rabies and canine distemper, and the role of sympatric domestic dogs in their epidemiology.
2.3.6 Test the effectiveness, feasibility and acceptability of control and/or vaccination of domestic dogs as a management strategy.
2.3.7 Investigate the feasibility of preventing disease transmission through vaccination of wolves and other wild carnivores.
2.3.8 Quantify the extent of wolf-dog hybridization, and assess levels of population genetic variability and rate of variability loss.
2.3.9 Carry out a dog vaccination campaign in BMNP and surrounding areas.
2.3.10 Implement a programme of domestic dog control in BMNP.
2.3.11 Expand demographic and disease monitoring and management practices implemented in BMNP to other wolf populations.

2.4 Develop and Initiate Education and Development Programmes to Protect Ethiopian Wolves

2.4.1 Involve BMNP residents in the protection of afroalpine wildlife through a community education and extension programme.
2.4.2 Design, produce and deploy road-signs on roads and tracks crossing Ethiopian wolf range.
2.4.3 Produce and distribute educational materials on

afroalpine wildlife and its conservation.

2.4.4 Provide factual information on Ethiopian wolf biology and conservation requirements to government organizations and interested groups.

2.4.5 Publish data available in relevant technical journals, wildlife conservation magazines and other popular written media to promote the plight of the species.

2.4.6 Provide film, graphic and written information on Ethiopian wolves to television and broadcast media in Ethiopia.

3. Actions Required for Metapopulation Conservation for the Ethiopian Wolf

3.1 Devise a Long-term Programme for Meta-population Conservation

3.1.1 Investigate the role of population genetics and small population sizes in the management of the Ethiopian wolf leading to a Population and Habitat Viability Analysis for the species.

3.1.2 Implement a plan of active metapopulation management.

3.2 Institute a Global Ethiopian Wolf Breeding Programme to Safeguard the Species' Genetic Integrity as well as Providing Animals for Eventual Reintroduction

3.2.1 Identify and contact reputable captive breeding institutions with an interest and know-how for breeding Ethiopian wolves.

3.2.2 Facilitate an agreement between the government of Ethiopia and breeding institutions to regulate future breeding and movement of animals between breeding partners.

3.2.3 Monitor the time-scales on which *in situ* and, if necessary, *ex situ* captive breeding can be initiated, to insure that no time is lost.

3.3 Create a Captive Breeding Facility in Ethiopia

3.3.1 Identify sponsors and collaboration with international breeding facilities.

3.3.2 Determine administrative and legal position of facility.

3.3.3 Select suitable site for facility and secure land and planning permission.

3.3.4 Contract construction of breeding centre.

3.3.5 Develop structure for managing the facility.

3.4 Develop and Maintain Captive-breeding Capability to Accommodate a Nucleus I Captive Programme

3.4.1 Determine source and number of initial founders required.

3.4.2 List captive facilities and space available and prepare the space for first breeding nucleus. Ideally the Ethiopian facility would be ready in time for this, otherwise overseas options will have to be explored.

3.4.3 Prepare a detailed plan for the capture, holding, transport and breeding of wolves.

3.4.4 Build holding pen in BMNP.

3.5 Plan and Carry Out Limited Restocking of Existing Populations to Boost Genetic Viability

3.5.1 Determine population for reintroduction and number and source (wild or captive) of reintroduced animals.

3.5.2 Construct necessary acclimation pens in selected area.

3.5.3 Monitor the survival, spatial use and interaction of released animals with resident wolves.

3.5.4 Assess success of reintroduction.

3.6 Evaluate Potential for Eventual Reintroduction to Areas within Historical Range where now Extirpated

3.6.1 Identify potential reintroduction sites.

3.6.2 Examine site for essential biological parameters (prey density, habitat types, competition) and socio-economic factors (human density, husbandry practices, domestic dogs, proximity to large settlements).

3.6.3 Measure potential public response to a wolf reintroduction.

3.6.4 Conduct public meetings and evaluate public concern about the project.

3.6.5 Decide nature of reintroduction (hard vs soft; captive-bred vs wild-bred), number, age and sex of founders.
3.6.6 Construct necessary acclimation pens.
3.6.7 Introduce and acclimatise wolves to pen for settling period and release.
3.6.8 Monitor the survival, spatial use and reproduction success of released wolves.
3.6.9 Assess success of reintroduction.

3.7 Develop a Strategy for the Cryogenic Preservation of Ethiopian Wolf Sperm and Embryo Banking

3.7.1 Develop protocols for collection of semen from wild male wolves.
3.7.2 Liaise with a research organization with capabilities to evaluate suitability of techniques and to carry out pilot project.

4. Coordination of the Ethiopian Wolf Recovery Programme

4.1 Full-time Recovery Programme Coordinator

4.2 Designate and Maintain an Ethiopian Wolf Recovery Team

4.3 Set up a Consortium of Donor Agencies

List of Conservation Projects Needed

A list of projects considered as priorities for Ethiopian wolf conservation over the coming decade are presented here in summary form. They serve simply as broad guidelines for eventual implementation of various components of the EWRP – we do not intend this list to be considered as a rigid structure for either funding or implementation. The different projects suggested here provide different levels of detail, that will almost certainly need to be adapted to the funds that become available. We offer our judgement of project priority, a category on the nature of the project, a link to one or various tasks in the Action Plan Summary, a categorization of approximate budget and a time frame:

A priority rank is assigned to each proposed project as follow:

P1. **Priority 1.** An action that must be taken to prevent extinction or to prevent irreversible decline (or loss of variability) in the foreseeable future.
P2. **Priority 2.** An action that must be taken to prevent a significant decline in numbers or habitat quality or some other significant negative impact short of extinction.
P3. **Priority 3.** All other actions necessary to meet the recovery objective.

Proposed actions are categorized as:

A Administration
C Captive breeding
E Education
F Facilitation (liaison/agreements)
L Enforcement
M Management
R Research

Acronyms used in the list of proposed projects:

EWRP Ethiopian Wolf Recovery Programme
EWCO Ethiopian Wildlife Conservation Organization
RA Regional Authorities
BMNP Bale Mountains National Park
CSG IUCN/SSC Canid Specialist Group
CBSG IUCN/SSC Conservation Breeding Specialist Group
VSG IUCN/SSC Veterinary Specialist Group

Budgetary needs are considered, but the cost information provided here is for planning purposes only. This aspect of the action plan will be refined as funding or management constraints dictate. Separate funding efforts will address different projects, although central coordination will lie with the EWRP Coordinator in consultation with EWCO and the consortium of donors. Projects are categorized as follows in terms of approximate annual budget (all figures in 1996 US $):

I. $ 10,000 or less.
II. $ 10,000 – $ 20,000
III. $ 20,000 – $ 50,000
IV. Over $ 50,000
? Not known

Establishment and initiation of some projects is dependent on the completion and/or results of others. Negotiations and planning for captive breeding related projects, involving EWCO, breeding partners and the EWRP Team may involve considerable time and effort. Reintroduction projects remain a possibility for the future but their budget, implementation and tentative dates cannot be anticipated and are beyond the scope of this plan.

There are two categories of projects included in the Action Plan. The first consists of existing or proposed projects which already have received varying proportions of their required funding. These projects are identified by an asterisk *. A contact address is pro-vided. The second category of projects is those proposed by this Action Plan. These projects will need detailed proposals, funding, and workers. Donors and interested parties should contact the Canid Specialist Group directly for details, through the following personnel:

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and
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Afroalpine Ecosystem Conservation

1. Promote Support and Funding for Established Afroalpine Conservation Areas

Objectives: Ensure long-term conservation of the afroalpine ecosystem in BMNP and SMNP; promote conservation and research projects; assist EWCO in obtaining additional funding to support protected areas infrastructure.

Background: The Ethiopian afroalpine range is a unique reservoir of biodiversity and endemism. It is also of climatological and water-cycle importance to human activities beyond the range. There are two existing protected areas: BMNP and SMNP, established with the priority of conserving biological processes, diversity of habitats and all species. Detailed management plans have been produced to guide their enforcement (Hillman 1986, Hurni 1986). Overall, a large proportion of afroalpine habitats in Ethiopia have protected status. However, current management is insufficient and stops short of achieving minimum management objectives (Chapter 7). Current support includes a UNESCO emergency grant to SMNP for park rehabilitation, support from UNDCF and assis-tance from Pro-Simen Fund (Switzerland) and WWF-International.

Activities:
- Promote afroalpine habitat conservation by providing incentives for the development of conservation and research projects in both protected areas.
- Seek additional funding to implement management recommendations provided for each park by existing management plans.
- Liaise with other conservation and community projects to seek alternative sources of income for local people and reduce negative effects on protected areas.
- Lobby Ethiopian authorities and national and international organizations for the following causes: (a) official gazetting of BMNP; (b) listing of BMNP as a UNESCO World Heritage Site; (c) inclusion of additional afroalpine habitats in the Simien range (embracing Bwahit, Silki and Ras Dejen areas) into SMNP or adjoining protected zone.

Output: Assist EWCO by promoting afroalpine conservation activities and lobbying for the implementation of existing recommendations.

Use of output: Upgrade protected areas legal status; lobby and fund raising; improvement of management; increase local employment.

Priority: P1
Category: A & F
Links: 1.1.1, 1.1.2, 1.2.1, 1.2.2
Annual budget: IV
Time frame: long-term

2. Strengthen Management of Conservation Areas

Objectives: Improve wildlife conservation in SMNP and BMNP, including relationship with local communities and effective park surveillance.

Background: Both national parks have existed for a long time. However, current management is restricted to only a fraction of their total areas. Furthermore, past management practices in both parks have generated conflicts between park staff and local villagers living in the park or using its resources (Chapter 7).

Activities:

- Encourage authorities to establish a system of regular patrolling by park scouts, covering all afroalpine areas in both parks. These patrols should monitor wildlife populations and enforce park regulations concerning resource use (*e.g.* firewood and thatch grass extraction, grazing).
- Increase the number of field staff, preferably recruiting scouts from the local community.
- Work with local communities and other conservation and development projects to evolve a pattern of coexistence between park staff and residents.
- Consider the feasibility of a zoning system within BMNP, with a core area excluding human habitation and/or activity and buffer areas permitting limited human activities (*e.g.* grazing, use of mineral springs, firewood and thatch grass collection).
- Similar approach in SMNP, incorporating additional mountain ranges under protection.

Output: Assist EWCO and regional governments with the management of protected afroalpine areas; encourage recovery of existing infrastructure and improvement of management practices.

Use of output: Enhance wildlife conservation inside protected areas; mitigate the conflict existing between the parks and the local people; create local employment.

Priority: P
Category: E, F, L & M
Links: 1.1.3, 1.1.4, 1.1.5, 1.1.6, 1.2.3, 1.2.4
Annual budget: III–IV
Time frame: long-term

3. Promote Conservation of Afroalpine Habitats Outside Existing Conservation Areas *

Objectives: Help to develop and manage an additional afroalpine conservation area in Menz, North Shoa, incorporating land use practices compatible with wildlife conservation.

Background: The afroalpine range in Ethiopia is fragmented, resembling small islands with little or no biotic exchange between them. While two national parks protect this ecosystem additional areas are required to safeguard afroalpine biodiversity. These areas could be multi-purpose protected areas, involving controlled extractive practices, such as harvesting thatch grass, collection of firewood and grazing. A system of this kind already operates in the Gwassa community management scheme in Menz. The Gwassa Biodiversity Project, funded by Darwin Initiative, started in 1996 and will facilitate a system of sustain-able resource utilization, including regulated grazing, collection of grass, wood fuel and building materials and eco-tourism.

Activities:

- Gwassa Biodiversity Project in Menz working with the local community to manage the afroalpine range sustainably. Realize potential for local weekend tourism.
- Explore potential for the creation of additional regional conservation areas in Arsi, Gojjam and Wollo.
- Encourage Regional governments to establish those small conservation areas.
- Work with local communities and other conservation and community development projects to achieve coexistence between wildlife and local resident interests.

Output: Assistance with wildlife surveys and protected area planning; lobby regional governments to set up new protected areas for afroalpine habitats and implement simple management practices.

Use of output: Improve conservation of afroalpine habitats and wildlife outside protected areas; facilitate sustainable use of natural resources.

Priority: P2
Category: F, M & R
Links: 1.3.1, 1.3.2
Annual budget: IV
Time frame: ongoing, 3 years
Contact: Claire Bensham, Conservation and Consultancy, Zoological Society of London, Regent's Park, London, NW1 4RY, UK.

4. Reconciling Local Needs and Biodiversity Conservation

Objectives: To understand better the mechanisms of Ethiopia's montane ecosystems and to develop sustainable strategies for the management of threatened resources; to reconcile human needs and conservation of biological resources.

Background: The need to manage ecosystems rather than individual populations of endangered species is widely accepted. However, not enough is known of

African montane ecosystems to manage them appropriately. There is a need for research on ecosystem processes as well as the socio-political and economic factors which influence exploitation and conservation of natural resources. Resulting recommendations would make the economic value of the area more evident to local people and policy-makers.

Activities:
- Interdisciplinary practical research in the Bale Mountains needed to identify critical ecological features of the system, involving biologists, modellers, economists and social scientists.
- Identify mechanisms that could enhance the sustainability of the Bale Mountains through an Integrated Protected Area system.

Output: A multifaceted appraisal of the ecosystem and human ecology of the area; recommendations on how local people and conservation areas can benefit and be supported i*n situ;* development of a model to enhance sustainable management and development in Bale Mountains.

Use of output: Resolution of conflicts which arise out of uncertainty about the functioning of fragile ecosystems and their use as resources; sustainable management of Bale Mountains montane ecosystems; generate among the people an interest in the protection and conservation of the protected area through a com-munity approach; potential application of model elsewhere.

Priority: P3
Category: E, M & R
Links: 1.1.1, 1.1.2
Annual budget: IV
Time frame: 3–5 years
Contact: Project proposed by a consortium of academic institutions coordinated by Professor Nils Chr. Stenseth, Department of Biology, Faculty of Maths and Natural Sciences, University of Oslo, P.O.Box 1050 Blindern, N–0316 Oslo, Norway

5. Establish Ethiopian Wolves as Flagship Species for the Afroalpine Ecosystem

Objectives: Use the Ethiopian wolf as a flagship to develop interest in, and improve upon, wildlife conservation practices throughout the afroalpine ecosystem.

Background: The term 'flagship species' is used to describe an animal that stands for or promotes conservation in a general or regional sense. The Ethiopian wolf has tremendous potential as a species around which to stimulate conservation interest and action in Ethiopia. It fulfils the three proposed criteria for a flagship: geographical location, ecological role and the potential for attracting local support. A high profile for wolf conservation will help conserve the afroalpine habitats with the wolves and other endangered wildlife benefiting from it.

Activities:
- Conservation projects should focus attention on this species by the production of posters, booklets and other materials for distribution in Ethiopia; these should detail a description of the species, its behaviour, and its habitat, accompanied by attractive pictures of the species and its habitat.
- Write popular articles and promote production of films on the plight of Ethiopian wolves.

Output: Publicize the predicament of the Ethiopian wolf and its habitat.

Use of output: In school and community education programmes; boost appeal for fund raising.

Priority: P2
Category: E & F
Links: 1.1, 1.2, 1.3, 1.4, 1.5, 2.4
Annual budget: I
Time frame: 3–5 years

6. Contribute to Wildlife Conservation Education at all Levels

Objectives: Contribute towards the advancement of wildlife conservation education for Ethiopian public; assure appropriate coverage of wildlife conservation issues in the State's educational syllabus for primary and secondary schools.

Background: The school system has long been recognized as the best vehicle for educational campaigns. Children are the most receptive component of society in this respect, and targeting elementary grades can be particularly effective. Instructional documents should be written in user-friendly language and describe the afroalpine ecosystem, its wildlife and interactions between human and wildlife interests. Text should be accompanied by attractive and clear pictures of wildlife. Production of wildlife films should be encouraged and shown in national television.

Activities:
- Develop and prepare educational packages centred on Ethiopian wolf conservation for national, regional

and community education programmes.
- Educational programmes in schools near Ethiopian wolf range should coincide with a responsible pet ownership campaign.
- Provide film, graphic and written material on Ethiopian wolves to television and radio broadcast media in Ethiopia.

Output: Agreement with Ethiopian authorities to include wildlife conservation in their education syllabuses; education materials; expanded coverage of conservation issues by Ethiopian media.

Use of output: Environmental and wildlife conservation education at all primary and secondary schools.

Priority: P3
Category: E & F
Links: 1.4, 1.5, 2.4.3, 2.4.6
Annual budget: III
Time frame: 3–5 years

In Situ Conservation of Ethiopian Wolf Populations

7. Transfer Ethiopian wolf to Highest IUCN Category of Threat *

Objectives: Classify the Ethiopian wolf as *Critically Endangered*.

Background: Data on population trends reported for the Bale Mountains show clearly that the Ethiopian wolf is declining, its largest and best known population having plummeted to half in the last five years, while little is known of the population trends of other smaller populations. Extinction is probable if not certain, unless efforts to reverse this decline are continued and expanded. Trade is not a threat to the species and for this reason it is not listed by CITES.

Action:
- Application of the IUCN new criteria for the listing of threatened species supports the transfer of the species to the category of Critically Endangered.
- No CITES listing is required.

Output: Upgrade of the species' IUCN category.

Use of output: The upgraded listing will highlight the Ethiopian wolves' risk of extinction and focus attention on conservation measures designed to protect them; increase the likelihood of proposals for the species' conservation to access limited conservation funds available for endangered species, thus improving fund raising.

Priority: P3
Category: A, F & L
Links: 2.1
Annual budget: none
Time frame: ongoing

8. Determine the Distribution, Numbers and Status of All Ethiopian Wolf Populations *

Objectives: Determine distribution, numbers and current status of all Ethiopian wolf populations.

Background: All known Ethiopian wolves are found in only five or six relatively small areas of afroalpine habitat. However, much of the potential habitat of the species, including four of those populations, has not been adequately surveyed. The viability of all known populations depend critically on their number and potential level of exchange between adjacent popula-tions. Detailed information on the habitat available to the species, population numbers and status is essential for future conservation action, including area conserva-tion and eventual meta-population management.

Activities:
- Develop standard methodology for estimating abundance of wolves, and provide baseline date for population monitoring (Appendix 3).
- Conduct field surveys to determine wolf abundance and status in all known populations; assess other factors relevant to wolf survival, including habitat availability, prey abundance and conflict with human interests.
- Set up a system for regular reporting of wolf sightings for those populations within protected areas.
- Carry out field surveys to determine wolf presence and habitat available of other areas of afroalpine habitats within wolf historical range.
- Collate and compile all data available in a central database; estimate potential wolf carrying capacity for all areas.

Output: Information on the status and trends of wolf populations; centralized reports of observed data; demographic data for population and habitat viability analysis and metapopulation management.

Use of output: Estimate overall population size; provide basis for assessing priority sites for conservation measures, habitat protection and population management.

Priority: P2
Category: F & R
Links: 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 3.1.1, 3.1.2
Annual budget: II (partially funded)
Time frame: Ongoing, 3 years
Contact: CSG

9. Taxonomy and Inter-population Variability of Ethiopian Wolves *

Objectives: Determine whether wolf populations on both sides of the Rift Valley deserve subspecific status and quantify variation across populations.

Background: All remaining wolf populations are effectively isolated from each other, but it is not known whether this separation is a consequence of relatively recent habitat degradation factors or a natural biogeographical process. It is important to define taxa for conservation decisions. For instance, when determining whether wild populations need to be managed as independent units; which wild populations should contribute founders for a captive breeding program; and whether distinct subspecies require separate captive programs (Chapter 5).

Using canine microsatellite markers already developed and adapted for use in Ethiopian wolves, samples from different locations can be compared to determine genetic distinctiveness between populations. In addition to tissue and blood, it may be possible to obtain DNA from faecal samples, allowing for a broad collection of samples. Furthermore, the methodology is now available to extract DNA samples from museum skins collected during the last 100 years, potentially allowing comparison with other extinct populations and determining rates of genetic change.

Activities:

- Collect tissue or blood samples from different wild populations, as well as from skin specimens kept in various museums.
- Analyse microsatellite DNA from samples using single-locus probes and determine the degree of genetic differentiation between putative sub-species and between populations.

Output: Report; scientific papers.
Use of output: Further understanding of evolutionary history of the species; provide input into the assessment of suitable captive breeding founders.

Priority: P3
Category: C, R & M
Links: 2.2.7, 2.3.8, 3.1.2
Annual budget: I–II (funding pending)
Time frame: 3 years
Contact: Dada Gottelli and Michael Bruford, Institute of Zoology, Regent's Park, London, NW1 4RY, UK.

10. Study Dog/Wolf Hybridization and Genetic Variability in the BMNP Ethiopian Wolf Population *

Objectives: To quantify the degree of wolf-dog hybridization; determine levels of genetic variability within populations; quantify rate of genetic loss.

Background: Most Ethiopian wolf populations are now reduced to very low numbers and as a result may have reduced genetic variability and may therefore have limited ability to adapt to environmental change. Information on genetic variability within populations is therefore essential to determine genetic variability loss rates (Chapter 5). Together with demographic data, information on genetic diversity available will allow for the formulation of a Population and Habitat Viability Analysis (PHVA) for the Ethiopian wolf (Chapter 6). Analysis of paternity within known packs are needed to assess the importance of extra-pack mating as a mechanism to maintain intra-population genetic vari-ability and minimise inbreeding. Since there is data available for BMNP wolf's genetic variability from before 1992 a direct comparison will assess quantita-tively the rate at which variability is being lost.

In some parts of BMNP wolves have bred with do-

mestic dogs and produced fertile offspring. The degree of interspecific hybridization and its overall effect on population dynamics need to be established. Furthermore, screening of hybrid individuals is required to identify them for management decisions.

Activities:
- Collect blood and tissue samples from wolves in BMNP.
- Using single-locus microsatellite DNA techniques analyse samples and quantify changes in the levels of genetic variation within the BMNP population (degree of inbreeding).
- Determine the rate of genetic variability loss through population bottlenecks; compare this with variation present in other remaining populations.
- Assess extent of hybridization between wolves and domestic dogs in BMNP; identify hybrid individuals; determine occurrence of hybridization in other populations.
- Investigate the importance of extra-pack mating and multiple paternity in the social organisation and mating system of the species.

Output: Report on prevalence of dog/wolf hybrids; quantify intra-population genetic variability levels.

Use of output: Assessment and improved understanding of the impact small population sizes and hybridization have on inbreeding and survival; impli-cations for future management of wild and captive wolf populations; potential tool for selection of suitable captive breeding founders.

Priority: P2
Category: C, M & R
Links: 2.2.8, 2.3.8, 3.4.1
Annual budget: III (funding pending)
Time frame: 3 years
Contact: Dada Gottelli and Michael Bruford, Institute of Zoology, Regent's Park, London, NW1 4RY, UK.

11. Monitor Demography and Dynamics of BMNP Ethiopian Wolf Population *

Objectives: To monitor the demographic trends of the wolf population in BMNP.

Background: The largest Ethiopian wolf population is that in BMNP and previous research there has provided baseline data for population monitoring. The BMNP population has been declining steadily in the last decade and has now reached its lowest recorded level. On the other hand, BMNP harbours the largest range of suitable habitat for the species, providing the greatest chance of a population recovery. Continued monitoring of the BMNP wolf population dynamics and habitat quality are required to decide conservation priorities and measure recovery. Furthermore, variation in pack size, home range size and position influences the risk contact rates and disease transmission rates between wolves and other carnivores and might determine the levels of disease threat to individuals. In addition, behavioural and demographic correlates will help to examine rates of hybridization and changes in genetic variation.

Activities:
- Determine wolf population numbers, pack number, size and structure, breeding success, mortality rate and dispersal patterns; locate dens and determine pup survival and reproductive success (Appendix 3).
- Based on these parameters calculate population trends over time and the population growth rate.
- Determine interactions with other carnivores and their effects on wolf reproduction and survival.
- Monitor prey abundance, assess changes in the availability of food resources.
- Determine the influence of humans on habitat quality and species' survival and whether there is a relationship between wolf abundance and human activity.
- Field work will combine the input of at least one full-time field assistant and regular visits by a senior researcher.

Output: Demographic trends and dynamics of the wolf population and its habitat; determine primary population parameters and calculate the population growth rate.

Use of output: Provide early warning of further population decline to allow immediate intervention if required; contribute to model contact rates and the risk of disease transmission; provide demographic correlates to rates of hybridization and changes in genetic variation.

Priority: P1
Category: M & R
Links: 2.3.1, 2.3.2, 2.3.3
Annual budget: II
Time frame: 3–5 years
Contact: CSG

12. Monitor the Prevalence of Disease in Domestic Dog and Wolf Populations *

Objectives: Determine and monitor the incidence of diseases in Ethiopian wolves and sympatric domestic dogs; obtain information on the health status, diseases and causes of mortality on wolves to assess the prevalence and threat of canid pathogens to the population.

Background: Populations of wild carnivores often fluctuate, and numbers increase or decrease widely. Disease is often suggested as a possible factor in such declines, and may have been responsible for local extinctions in several carnivore species. Disease vectors and evidence of exposure to disease are often reported, but their influence is sometimes unclear, as are the interspecific pathogen dynamics involving both domestic and wild carnivore species (Chapter 4).

An epidemiological study in Ethiopian wolves will establish the role of rabies, canine distemper and other pathogens in the conflict between domestic dogs and wolves in BMNP. The demographic characteristics of the domestic dog population and the spatial and temporal dynamics of these canine diseases needs to be studied both inside the protected area and in surrounding rural and urban areas.

Activities:
- Obtain blood samples from domestic and wild carnivores for serological analysis.
- Establish the incidence of canid disease and patterns of spread by vertical and cross-sectional serological analysis of domestic dogs and wolves.
- Investigate the epidemiology of canine pathogens, particularly rabies and canine distemper, both in BMNP and in surrounding rural areas.
- Examine dog demographics, establishing current population size, reproductive and mortality rates, turnover rate, movement patterns of dogs in rural areas within and outside the BMNP and nearby urban areas.
- Determine the distribution and density of wild carnivores and the frequency of interactions between domestic and wild carnivores and other behavioural correlates of disease transmission.
- Survey other wolf populations for prevalence of disease.

Output: Information on prevalence of disease and vectors in BMNP; determine which species are affected by which pathogens, the prevalence and incidence of infection, geographical and seasonal patterns of infec-tion and host population dynamics and behaviour.

Use of output: Target local disease control programmes effectively.

Priority: P1
Category: R
Links: 2.3.3, 2.3.4, 2.3.5
Annual budget: II
Time frame: 2–3 years
Contact: Karen Laurenson, Institute of Zoology, Regent's Park, London, NW1 4RY, UK

13. Test Methods to Prevent Disease Transmission in Domestic and Wild Carnivores *

Objectives: Investigate the feasibility, effectiveness and sustainability of a vaccination scheme to protect Ethiopian wolves in BMNP from disease transmission. Improve disease monitoring practices in Ethiopia.

Background: Management practices need to be established in order to reduce the impact of infectious diseases on the survival of Ethiopian wolves. The vaccination of dogs and/or wild carnivores is a possibil-ity that needs to be explored (Chapter 4). Training of Ethiopian veterinarians must also be carried out so that local personnel are able to sustain the required manage-ment solutions.

Activities:
- Survey local community attitude towards plans to vaccinate/control domestic dogs
- Test and select a method of delivering vaccine.
- Determine vaccine and administration to be used (mass oral, individual oral or parenteral).
- Implement a trial vaccination programme.
- Test effectiveness.
- Establish a veterinary surveillance committee and reporting structure.
- Train local personnel on vaccination practices.
- Establish improved laboratory diagnostic techniques in Ethiopia.

Output: Evaluation of vaccination as a management alternative.

Use of output: Vaccination of domestic and/or wild carnivores.

Priority: P1
Category: M & R
Links: 2.3.6, 2.3.7, 2.3.9, 2.3.10
Annual budget: II–III
Time frame: ongoing, 3 years
Contact: Karen Laurenson, Institute of Zoology, Regent's Park, London, NW1 4RY, UK.

14. Test Methods to Control Domestic Dog Populations

Objectives: Investigate the feasibility, acceptability, effectiveness and sustainability of limiting the growth of the domestic dog population in wolf range to prevent dog-wolf hybridization and disease transmission.

Background: Conservation management strategies practices need to be established in BMNP in order to reduce the impact of domestic dogs on the survival of Ethiopian wolves. Alternative management strategies in addition to vaccination, including reproductive control of domestic dogs or selective culling, need to be tested. However, strategies must be devised and tested locally to be acceptable and feasible given economic importance for dogs and local cultural practices.

Activities:
- Set up a register of all dogs found in BMNP.
- Selective culling of unowned dogs.
- Devise non-lethal control methods by chemical, surgical or immunological means.
- Implementation of a trial sterilization campaign.
- Education on responsible pet ownership.
- Consider zonation of dog removal/control to protect core area.

Output: Recommendations and protocol for a dog control campaign.

Use of output: Control of domestic dog populations within protected areas.

Priority: P2
Category: M & R
Links: 2.3.6, 2.3.7, 2.3.9, 2.3.10
Annual budget: II
Time frame: 2 years
Contact: Karen Laurenson, Institute of Zoology, Regent's Park, London, NW1 4RY, UK.

15. Community Education and Extension in the Bale Mountains *

Objectives: Involve BMNP settlers in the protection of afroalpine wildlife; develop a conservation education and extension campaign at community level.

Background: Most people living in close contact with wildlife have an utilitarian perception of wildlife, animals are seen as either beneficial or harmful to them; often they find themselves in conflict with wildlife conservation managers. It is imperative that this perception changes where local people's interests conflict with those of wildlife such as in BMNP. A public outreach campaign targeted at educating those people on the value of wildlife and potential benefits accrued to the local community may help to reconcile the interests of conservationists and others. If the decline of wildlife is to be prevented, the community needs to be informed of the causes and solutions, and local people should be involved in the recovery operations. Community education should concentrate on developing an attitude of responsible dog ownership among residents in and adjacent to Ethiopian wolf range.

Activities:
- Production of educational packages to target adults and children, that include simple educational leaflets in Orominia language, posters and educational toys.
- Develop an extension team to reach all communities living inside Ethiopian wolf range.
- Set up a programme of regular visits to all local settlements within BMNP.
- Set up a system of responsible dog ownership. Distribute veterinary medicines and dog chains/leashes to assist them with better management of their dogs.

Output: Develop trust of local communities towards extension work; community education packages; curb detrimental effect of domestic dogs on wildlife.

Use of output: Develop residents' tolerance of wildlife conservation practices; reduce dog/wolf contact.

Priority: P2
Category: E & M
Links: 2.4.1
Annual budget: II (partially funded)
Time frame: 3–5 years
Contact: CSG

16. Produce and Install Signs on Roads Across Ethiopian Wolf Range *

Objectives: To design, produce and install road signs warning drivers of the presence of wolves and other wildlife and their responsibility to avoid traffic accidents.

Background: Road kills are a recurrent cause of wolf mortality in BMNP and perhaps elsewhere. Additionally wolves and other wildlife are occasionally shot from vehicles. Wildlife exposure to road accidents is likely to increase with development and construction of new roads and increasing volume and speed of traffic.

Activities:
- Produce and install road signs along roads across wolf range in BMNP, Arsi, Menz and Simien.

Output: Road signs.

Use of output: Prevent road kills; education of general public.

Priority: P3
Category: A, E & M
Links: 2.4.2
Annual budget: I
Time frame: 1 year
Contact: CSG

17. Explore Role of Population Genetics and Devise a Programme for Ethiopian Wolf Population Management

Objectives: Carry out a Population and Habitat Viability Analysis; plan conservation techniques such as genetic population management and captive breeding needed to ensure Ethiopian wolf long-term survival.

Background: Small isolated populations such as those of the Ethiopian wolf generally require active management to ensure survival and maintenance of genetic variability in the long term (Chapter 5 and 9). As a rule small populations stand a higher risk of extinction, and lose variability at a higher rate, than do larger ones. But all wild and captive populations may be treated as a metapopulation with some genetic flow among them. Genetic variability may be boosted through the translo-cation of a small number of animals among different populations.

Activities:
- Using demographic data, model the probability of survival of different wolf populations in varying circumstances.
- Devise a management plan for limited translocation of breeding animals between different populations.

Output: PHVA; metapopulation management guidelines.

Use of output: Manage all remaining wolf populations as a single metapopulation.

Priority: P2
Category: M & R
Links: 2.5.1, 2.5.2, 2.5.3
Annual budget: I–II
Time frame: 1 year

Captive Breeding and Reintroduction of Ethiopian wolves

18. Institute a Global Ethiopian Wolf Captive Breeding Programme

Objectives: Establish, develop and fund a global effort to breed Ethiopian wolves in captivity through an internationally concerted effort.

Background: Currently there are no Ethiopian wolves in captivity. The development of an Ethiopian wolf breeding population is required for protection from genetic introgression (hybridization) and conservation of genetic variability. Such a captive population will be supplementary to those in the wild and will provide additional protection from local extinctions (Chapter 8). Captive breeding will require the support and cooperation of the international captive breeding community and the Ethiopian government.

Activities:
- Identify institutions interested in participating and funding the programme and form a consortium of breeding facilities.
- Set up a steering committee with biological, veterinarian and legal expertise.
- Formalize an agreement with the Ethiopian authorities regarding supply and ownership of founder animals.
- Establish a captive breeding plan.
- Ensure that participating zoos and facilities adhere strictly to established regulations and protocols.
- Develop and maintain an Ethiopian wolf studbook.

Output: Establishment of a captive breeding programme for the species.

Use of output: Outline facility and funding requirements to establish breeding programme in existing breeding facilities and eventually in Ethiopia.

Priority: P1
Category: F & M
Links: 3.1.1, 3.1.2
Annual budget: II
Time frame: one year

19. Establish a Global Captive Breeding Population of Ethiopian Wolves

Objectives: Establish a Nucleus I captive wolf population as an insurance programme for the endangered Ethiopian wolf regardless of crises in its natural habitat.

Background: A level Nucleus I captive population requires a captive nucleus to represent always a minimum of 98% of the wild gene pool. This type of programme requires periodic, but in most cases modest, immigration of individuals from the wild population to maintain the high level of genetic diversity, and may be started with a modest founder population. Closely related canid species such as red and grey wolves have a good record of captive breeding and existing hus-bandry and reproductive techniques should be easily adapted to the Ethiopian wolf. While Ethiopia should remain the sole owner of all Ethiopian wolves born in captivity, a consortium of breeding partners will ensure the capability and funding required to attain and main-tain population levels required for a Nucleus I captive programme (50–100 individuals).

Activities: Capture, transport and housing of founder animals. Achieve reproduction and establish breeding nucleus. Rapidly build up captive population to required levels.

Output: Creation of a captive breeding nucleus.

Use of output: Captive population to supplement wild populations; additional animals for population management and/or eventual reintroduction.

Priority: P2
Category: F & M
Links: 3.2
Annual budget: ? (Expensive to start, moderate to maintain)
Time frame: long-term

20. Establishment of a Captive Breeding Facility in Ethiopia

Objectives: To participate in global breeding effort; act as holding facility in a population management and reintroduction programme.

Background: *In situ* captive breeding (*i.e.* within the species' natural range) would have the benefits of access to appropriate habitat and environmental conditions, and reduced exposure to exotic diseases. Such a local breeding facility would accommodate animals in large (0.2–0.5 hectare), semi-natural enclosures, and could use natural prey to supplement the wolves' diet. Operating within the framework of a global captive breeding programme this local facility would be instrumental in supplying animals for eventual reintroduction, serve as an education centre and provide training to Ethiopian nationals.

Activities:
- Develop with Ethiopian authorities necessary permission and support to establish facility.
- Secure international expertise and identify funding sources.
- Identify suitable site.
- Design facility.
- Build installations.
- Acquire and establish a breeding nucleus.
- Train Ethiopian nationals to run facility.

Output: A captive breeding centre in Ethiopia; a captive population of Ethiopian wolves.

Use of output: Provide animals for eventual population management and reintroduction purposes; education; facilities and technology available to breed other endangered Ethiopian fauna.

Priority: P2
Category: A, C, E & M
Links: 3.1, 3.3, 3.5
Annual budget: ? (Very expensive to start, quite expensive to maintain)
Time frame: long term.

21. Restocking and Reintroduction of Ethiopian Wolf Populations

Objectives: Implementation of metapopulation management; regular restocking of existing populations to preserve genetic variability; eventual reintroduction to areas within historical range where now extinct. Reestablish, secure and maintain a minimum of five breeding pairs for a minimum of three successive years.

Background: Reintroductions are a future conservation option, but subject to successful conservation of afroalpine habitat and positive public opinion in the area. Balance with economic advantages to the area in terms of tourism or employment of local people as wildlife scouts.

Activities:
- Implement metapopulation management strategy.
- Identify and prioritize potential reintroduction sites.
- Evaluate potential sites for essential biological parameters (prey abundance, habitat types, competition with other carnivores) and socio-economic factors (human density, land use, livestock husbandry practices, domestic dogs, proximity to large settlements).
- Measure potential public response to a wolf reintroduction through contacts at local government and community levels.
- Conduct public meetings and listen to public concerns about the project.
- Develop reintroduction plan.
- Secure funding.
- Construct necessary acclimation pens.
- Introduce and acclimatise wolves to pen for approximately 6 months and release. Monitor the survival, spatial use and reproduction success of released wolves.
- Reintroduce additional animals to achieve minimum population desired.
- Assess success of reintroduction.

Output: Produce a detailed reintroduction technical proposal and carry out operation.

Use of output: Increases global population and genetic variability. Creates additional populations.

Priority: P2
Category: M
Links: 3.1, 3.4, 3.5, 3.6.
Annual budget: ? (Relatively expensive)
Time frame: long-term

22. Develop a Strategy for the Cryogenic Preservation of Ethiopian Wolf Sperm and Embryo Banking

Objectives: Investigate suitability of reproductive techniques such as long-term storage of sperm and embryos for application to Ethiopian wolves.

Background: Significant advances have been accomplished in recent years for the storage of sperm and embryos in felids and bovids. Existing techniques could be adopted and refined to ensure the preservation of critical Ethiopian wolf genetic variability.

Activities: Develop a collaboration with a reproduction research institution and investigate suitability of these techniques for use with Ethiopian wolves.

Output: Protocol for field collection of wolf sperm, in-vitro fertilization and long-term storage of sperm and embryos.

Use of output: Useful in an eventual population genetic management aimed at increasing levels of genetic variability. In captivity possible application for (surro-gate mother) reproduction.

Priority: P3
Category: R, F & M
Links: 3.6
Annual budget: ?
Time frame: 2–3 years?

Coordination and Administration of Recovery Programme

23. Coordination of the Ethiopian Wolf Recovery Programme *

Objectives: To support a full-time coordinator for the EWRP.

Background: A coordinator is essential to oversee progress of the different tasks in the EWRP and to assure continuity of various objectives.

Activities: The coordinator will be responsible for implementing different tasks of the EWRP, liaise between different institutions and personnel involved, seek sources of funding and promote the conservation needs of the Ethiopian wolf and the afroalpine eco-system. Also will provide leadership, establish annual objectives and goals, develop budgets, administrate programme funds, present annual reports to the EWRP Team, publish technical and popular accounts and serve as the spokesperson for the programme.

Priority: P3
Category: A & F
Links: 4.1
Annual budget: III
Time frame: ongoing, 5 years or more
Contact: CSG

24. Establishment of an Ethiopian Wolf Recovery Team

Objectives: To organize a coordinating committee, the EWRP Team. The Recovery Team will be a multi-disciplinary group to review the EWRP progress in regular meetings and address special biological and logistic needs.

Background: An important feature of research and management of endangered species is the high level of cooperation between different organizations and individuals involved. The Recovery Team should be composed by individuals with special skills and exper-tise applicable to the various objectives of the programme, and include representatives of the relevant Ethiopian wildlife agencies (EWCO and RA), conser-vation area managers and EWRP scientific personnel, as well as IUCN/SSC Specialist Groups (CSG, CBSG, VSG). Donor agencies should also be represented in the Recovery Team.

Activities: The Recovery Team should meet annually to review progress on the implementation of the programme, recommend increased efforts where necessary and deal with logistical problems and/or special circumstances. By inviting relevant field managers to the Recovery Team meetings, those responsible for implementation of the plan at the local level can have input and be advised, encouraged and stimulated to greater efforts. Technical advisers on different topic may also be invited to address the Recovery Team on relevant technical issues.

Priority: P3
Category: A
Links: 4.2
Annual budget: II
Time frame: 5 or more years

25. Foster Establishment of a Consortium of Donor Agencies

Objectives: Coordinate the funds and facilities made available to the EWRP in order to optimize its output.

Background: Close cooperation and flow of information between various donors is vital to plan long-term funding requirements, and to avoid misunderstandings and/or duplication of efforts.

Activities: Periodic contact between agencies to co-ordinate current and future funding to the EWRP. Attendance to EWRP Team meetings.

Priority: P3
Category: A
Links: 4.3
Annual budget: none
Time frame: long-term

26. Produce and Disseminate Information on the EWRP

Objectives: Provide accurate information on all programme conservation efforts to all government officers and entities involved with the programme.

Background: Education of the general public and government officers involved is of extreme importance for the success of any conservation effort. It is impor-tant to ensure that consistent information is provided to all of the involved agencies, having identified the direct relevance on each sector of the readership of that information.

Activities:
- Produce regular reports of programme progress.
- Publish data available in relevant technical journals, wildlife conservation magazines and other popular written media to promote the plight of the species.

Output: Written and graphic information. Channelled through the CSG Actioner.

Use of output: Conservation education; keep all players in this conservation effort informed of programme progress and shortfalls.

Priority: P3
Category: A
Links: 2.4.3, 2.4.4, 2.4.5, 2.4.6
Annual budget: I
Time frame: long term

Appendix: Ethiopian Wolf Literature

Including those mentioned in text

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Appendix 3
Population and Habitat Assessment Techniques

In order to assess the impact of current threats (Chapter 3) and conservation action needed to allow the recovery of the Ethiopian wolf (Chapter 10) it is important to determine the status and distribution of all remaining wolf populations. These data could then form the basis for any subsequent population monitoring and to assist with future management decisions.

Information on suitable habitat available to the species is also important to calculate the carrying capacity for wolves of different areas. For example, it will be necessary to evaluate the availability and suitability of sites for eventual reintroduction of wolves. The structure and biomass of the rodent community will play an essential part in the assessment of the areas.

Difficulties in accurate censusing have hampered many carnivore studies (Mills 1996). Indeed, most studies of carnivore distribution have been based on the use of signs, in particular faeces, footprints and kill remains. While these indirect methods do not quantify the number of animals present in a given area, they are particularly useful as a quick means of assessing the status of little known populations. Information of a quantitative nature, however, is needed to establish valid baseline data to monitor changes in numbers and distribution.

Techniques for Surveying Ethiopian Wolf Populations

Presence/Absence

Surveying techniques useful for short field visits to ranges of afroalpine habitats where Ethiopian wolf might be present.

Historical records. Collate previous wolf sightings for the area from the bibliography, and from interviews with wildlife officials, hunting guides, naturalists, tourists and aid workers that work or have worked in the area.

Interviews with local people. Interviews can provide confirmation of wolf presence in a given area. With the assistance of a local interpreter visit local settlements and interview shepherds living in the area using a standard questionnaire (Box. A3.1). Always use the most suitable local name(s) for the species. Present respondent with a photograph of a wolf. If any respondents report a wolf sighting, record the approximate location on a detailed map, and the date, time of day, habitat type, number of wolves and name of the observer in a data-sheet.

Reports of opportunistic sightings. When visiting suitable afroalpine areas carry out wolf searches either on foot, horseback or by car during trips across range, or scan range with binoculars from vantage points such as hills or cliffs. Record details of every individual sighting in customized data-sheets, including date, time, observation time, location, coordinates, altitude, group size, habitat type and name of the observer. Include information on age, sex and breeding whenever possible. Darker coat of males makes it easy to sex them. The large penile sheath, testis and the raised-leg urination position also help to identify males. Lactating females can be detected by their swollen teats and lighter coats. Animals under eight months old are considerably smaller than adults and therefore easily classified as young of the year. Pups (< 4 month old) are easily recognizable by size and dark brown coats.

Vocalizations. While camping in afroalpine habitat listen carefully for vocalizations at dusk, night and dawn. Communal call may give away clues on the number of packs in the vicinity, pack size, and position.

Calls can be grouped into two categories: alarm calls, given at the scent or sight of man, dogs, or unfamiliar wolves, start with a "huff", followed by a quick succession of high-pitched "yelps" and "barks". "Yelps" and "barks" can be also given as contact calls, and often attract nearby pack mates. Greeting calls include intense "group yip-howls", given at the reunion of pack members and to muster pack members before a border patrol. A lone howl and a group howl are long-distance calls used to contact separate pack members and can be heard up to 5 km away. Howling by one pack of wolves may stimulate howling in adjacent packs.

Box A3.1
Ethiopian Wolf Status and Distribution

QUESTIONNAIRE/INTERVIEW

Addressed to: People living within historical / present Ethiopian wolf range.
Subject: Presence and status of Ethiopian wolves in your area. Conflict with human interests.

Ethiopian wolves are one of Africa's most endangered animals and are unique to Ethiopia. Ethiopian wolves occurred originally in most Ethiopian mountains, where they inhabit Afroalpine heathlands and grasslands (wurch and high wurch). Today, they have disappeared from most places. We would appreciate your help in answering the following questions. We want to know whether Ethiopian wolves are still found in your area. Additionally, we would appreciate your views on Ethiopian wolves and other wildlife. Thank you for your assistance.

QUESTIONS

Personal details

1 – What is your **name**?
2 – Your **occupation**?
3 – Name of this **area**?
4 – Name of your **village**?
5 – **How long** have you lived here? (months/years)
6 – Do you live here all **year round**? (months/seasons)

Occurrence/Abundance

7 – Have you **personally** ever seen wolves in this area? (Y / N)
8 – Have you heard if **anybody else** has seen wolves in this area? (Y / N)
9 – How many **times** have you seen them within the **past five years**? (*n* times)
10 – How many times have you seen wolves within the **past 12 months**? (*n* times)
11 – **How many** wolves do you think are present? (*n* wolves)
12 – What is the **largest group** of wolves you have seen?
13 – What **time of the day** you are more likely to see wolves?
14 – Have you ever seen wolves in **any other area**? Where? When?

Reproduction

15 – Have you ever seen wolf **pups**? (Y / N)
16 – Do you remember **how many** pups you saw together? (*n* pups)
17 – At what **time of the year**?
18 – Have you ever seen wolves **mating**? (Y / N)

continued on next page

Population trends

19 – Do you think the wolf population in your area is **increasing**, **stable**, or **declining**?
20 – Please give your reasons for thinking so.

Mortality/Disease/Competition

21 – Have you ever found **dead** wolves? (Y / N)
22 – If so, **where**, **when**, **how many**, and what was the **cause** of death?
23 – Do you keep/own **domestic dogs**? (Y / N)
24 – **How many** dogs do you have?
25 – Have any of your dogs **died** recently? (Y / N)
– If so, **where**, **when** and what was the **cause** of death?
26 – What year, to the best of your knowledge, were these diseases last documented to occur in your area? **Anthrax**, **Rabies**, **Canine distemper**.
27 – On average **how often** do you see (how many days passes between you seeing) **Ethiopian wolves**? **hyaenas**? **common jackals**? **lions**? (everyday, every *n* days, every *n* weeks, not seen).
28 – Have you ever seen **wolves and dogs together**?
29 – What were they doing?

Public perception/Livestock losses

30 – **What do you think** of Ethiopian wolves?
31 – Do you feel their presence in this area is **bad** for people and their animals?
32 – In your opinion, can wolves live harmoniously in the same area with people? (Y / N)
33 – What is the attitude of local people towards wolves? **Positive**, **Indifferent**, **Negative** (dislike wild dogs), **Very negative** (will kill wild dogs)
34 – Has any livestock, to the best of your knowledge, been **killed by wolves** in or close to your area within the **past five years**? (Y / N) – Within the **past 12 months**? (Y / N)
35 – Have you ever seen wolves taking sheep, goat or calves out of **your** herd? (Y / N)
36 – Please give details.
37 – Has any livestock been **killed by other predators** (lions, hyaenas, leopards)? (Y / N)
38 – Please give details.
39 – Is there anything else you would like to tell us about the wildlife of this area?

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*Many thanks for your help. Please report to the Ministry of Agriculture, Forestry Project, or local Administration any sighting of Ethiopian wolves, den (breeding hole), dead wolf and any livestock carcass **killed** by Ethiopian wolves.*

PLEASE DO NOT DISTURB ETHIOPIAN WOLVES. KEEP YOUR DOGS FROM HARASSING THEM

Wolf Abundance

The abundance and distribution of wolves in a particular mountain range may be assessed if the researcher can spend a longer period (weeks or months) in the area. There are several census methods, both direct and indirect, that might be used. The main methods used to study Ethiopian wolves in Bale have been survey transects of wolves, their signs and their prey, direct observation from vantage points of known animals, trapping, and radio-tagging.

Survey transects. Standardized walking transects may be used to assess wolf abundance, prey and habitat availability (see below). Walk or ride in roughly straight transects across range. Record in customized datasheets location, date, name of the observer, starting time, finish time and approximate distance covered. Observers may take advantage of any road traversing the range to do a road count. Counts may be stratified to take account of the representation in the area of main habitat types. For every individual sighting record time, distance to the transect in a perpendicular angle, group size, habitat type, age, sex and breeding status if possible. For survey design and data analysis follow standard line sampling methodology reviewed by Buckland *et al.* (1993). Line transect data may be analyzed using the software Distance described by these authors, although the sample sizes will almost certainly be low for Ethiopian wolves. Roads are often unsuitable as transect lines as they seldom sample the habitat well.

Extrapolation of wolf density. For large scale analysis of wolf density it is possible to rely on the availability of different vegetation types in a particular range. The estimated density of wolves in different plant communities may be extrapolated to the area of the plant communities calculated using detailed maps or remote sensing techniques. These may be either aerial photographs or satellite images used to see major plant communities. This technique was applied by J. Malcolm in Arsi (Chapter 2) and by Gottelli and Sillero-Zubiri (1990) to calculate the total wolf population and the potential carrying capacity of different mountain ranges.

Systematic sign surveys. If sample sizes are large and adequately stratified, by selecting plots or transects proportionately to habitat availability, it may be possible to estimate wolf abundance from indirect signs such as footprints, droppings and diggings.

In each plot or along transects search for wolf evidence. Look for droppings on top of earth mounds, rocks, bushes and edge of swamps or streams. It is important to determine whether the observer can discriminate wolf droppings from those of domestic dogs. Record other specific wolf signs (dens, prey remains and signs of digging) and evidence of rodent prey (see below).

Observation of known animals. For accurate estimates of population density more intensive methods are required. This requires knowing individual animals and usually involves catching and marking some individuals with radio tags, ear tags or ear notches. Alternatively, individuals may be identifiable by coat pattern differences and be censused through photographic methods. All known animals should be placed into four age categories: pups, up to four months old; juveniles, up to one year of age; subadults, up to two years of age; and adults.

The afroalpine landscape is typically fairly flat with short vegetation and most home ranges could be monitored from slopes, cliffs and rocky hills. Most travel within a study area can be accomplished on foot or horse-back. Scanning and observations can be made from vantage points during daylight (06:30 to 18:30 hrs). In most places the wolves are tolerant of human presence and detailed observations could usually be made from 20–500 metres. Whenever possible the wolf observed should be plotted to the nearest 100 m every 15 min. A hand-held GPS (global positioning system) is invaluable for this.

The Lincoln Index. The Lincoln index is a useful method to estimate animals' abundance and has been used widely (Seber 1973). A modified Lincoln index has been used in a number of large carnivore studies. It is a mark-recapture method relying on two important assumptions, that marked and unmarked animals have the same probability of being caught in the second sample and that the population must be closed, with no mortality or recruitment during the sampling period. In the modified version the total population is derived from the proportion of marked to unmarked animals resighted during a given observation period, making unnecessary to continue to capture animals.

Another modification to the Lincoln index relies on marked droppings and the rate of marked and unmarked droppings retrieved. For this purpose a small sample of animals need to be captured and injected with a Zn isotope (Kruuk *et al.* 1980). Alternatively coloured plastic beads may be fed to a sample of animals, and then compared the rate at which marked droppings are retrieved. Both methods only provide approximate population estimates.

Radio-telemetry studies. This technique is widely available today and has revolutionized studies of free-ranging vertebrates. With it it is possible to locate and monitor the movements and habits of elusive animals on a regular and predictable basis. Small (< 200 g), long-lasting transmitters (life span up to two years) should be favoured. In the BMNP Ethiopian wolf study radio-transmitters were predominantly used to locate the wolves for direct observations, but the radio-tagging data was also invaluable to quantify wolf movements and home range size.

Home range size and overlap may be evaluated using minimum convex polygons, or restricted polygons. The merits of these techniques and data analysis have been widely reviewed (*i.e.* Kenward 1987, White and Garrot 1990). Home range analyses may be carried out using one of the standard analysis packages such as Wildtrak for Macintosh (Todd 1992) or Range V for PC (Kenward *et al.* 1996).

Capture methods. If setting up a research programme it may be possible to capture wolves for fitting radio-transmitters, collect blood samples and morphological data. Be aware that any plans to trap wildlife in Ethiopia will require a formal application to EWCO and/or the regional authorities. In addition to confirming their presence trapping would allow collection of biological samples for genetic and epidemiological studies.

Ethiopian wolves may be trapped using rubber-jawed leg-hold Soft-catch ™ traps (N° 1½ and N° 3, Woodstream Corporation, Lititz, Pennsylvania, USA). Two to five traps set concealed in a circle around a dead bait of locally-caught rodents or a small lamb and laced with long distance call lure 600 and coyote & wolf gland lure No 100 (Stanley Hawbaker and Sons, Fort Loudon, Pennsylvania, USA). Traps need to be checked every two hours. On approaching the trap wolves should be covered with a blanket and immobilized with a hand injection of 3–4 ml/kg of Telazol (50 mg/ml), and individually marked with plastic ear tags (Rototag, Henley, U.K.). The trapping and handling methodology is discussed in detail by Sillero-Zubiri (1996).

Population Changes

In addition to quantifying wolf populations it may be possible to evaluate population trends.

Interviews. Properly conducted interviews can provide important data concerning the distribution and change in wolf numbers in addition to confirming wolf presence in a given area. The interviews also help to appraise public attitude towards Ethiopian wolves and other wildlife. Visit villages occurring within wolf range and talk to the village elders. Also talk to women and children, they spend more time out guarding livestock. Using a standard questionnaire (see Box A3.1) ask respondents for wolf occurrence in their area, abundance trends and evidence of mortality, occurrence of disease, breeding and/or evidence of hybridization with domestic dogs. Query about any large fluctuation in wolf sightings in the past and/or in the mortality of wolves and domestic dogs. Also enquire about livestock losses to predation by wolves or other predators.

Long-term systematic censuses. In conservation areas such as BMNP and SMNP wolves can be counted regularly along an established route. In the Sanetti Plateau of BMNP for example, records have been kept since 1983 by a regular animal count from a vehicle traversing the 32 km of road across the plateau (Chapter 2). Another count has taken place in the Web Valley since 1989, where all wolves, other wildlife and livestock are counted regularly on a circular horse-back census lasting approximately five hours.

Demographic modelling. Population Viability Analysis is a useful tool for gaining insight into the dynamics of a particular system, but not generally for making predictions about future outcomes. One such model is VORTEX (Lacy 1993). Using known population parameters (including reproductive and survival rates) and carrying capacity for an area VORTEX analyses the likely impact of the different threats to the population and how significant each may be in determining long term viability of the population under different assumptions about their rate, their impact on the population and the size and structure of the wolf population (Chapter 6). Similar models may be used to determine the loss of genetic variability of the population of survival under different levels of exploitation (such as hunting or culling).

Food-habits Studies

Knowledge of the food habits of a carnivore species is central to understanding many aspects of its behaviour and ecology. This may be achieved through direct

observations, and this should be the preferred method, provided that the observer does not disturb predator or prey in the process. A disciplined approach to data collection is important if direct observations are to yield good results. Alternatively faecal analysis may be used, this is the most common method for analysing carnivore food habits. For a discussion of both approaches for the Ethiopian wolf refer to Sillero-Zubiri and Gottelli (1995a).

Habitat Quality Assessment

Development of Predictors of Ethiopian Wolf Density

The role of the afroalpine rodent community in limiting the distribution of the Ethiopian wolves can be seen by the relationship between wolf density and diurnal rodent biomass index (Fig. A3.1). Independent observations of the density of wolves and a knowledge of the abundance and distribution of small mammal signs in a field study in the Bale Mountains established a significant correlation between wolf density and small mammal biomass in four study areas (Sillero-Zubiri *et al.* 1995a, 1995b). Areas with low rodent biomass index supported lowest wolf densities and vice versa.

Wolf density was positively correlated with giant molerat (*Tachyoryctes macrocephalus*) abundance measured from direct observation ($r = 0.996$, $df = 2$, $p < 0.002$), suggesting that the species was vital in determining the presence of the wolf. Because they are roughly six times the weight of any other rodent, hunting molerats is likely to be considerably more efficient than hunting a smaller species, and indeed, where they are present, they constitute 37% of the wolves' diet (Sillero-Zubiri and Gottelli 1995a). In areas where the giant molerat is rare or absent, the common molerat (*Tachyoryctes splendens*) may replace the giant molerat in the wolves' diet.

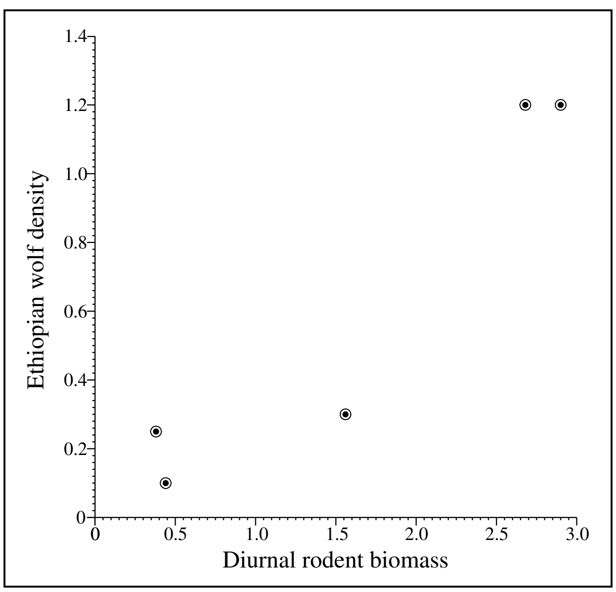

Figure A3.1. Relationship between wolf density and diurnal rodent biomass.

There was also a positive correlation between rodent signs and wolf signs, droppings or diggings, along habitat assessment transects. The percentage of transect points at which wolf signs were found correlated positively with the average number of rodent burrows per transect point ($r = 0.666$, $n = 83$, $P < 0.001$), the percentage of transect points including rodent burrows ($r = 0.62$, $n = 83$, $P < 0.001$), and the percentage of transect points at which rodent alarm calls were recorded ($r = 0.585$, $n = 83$, $P < 0.001$). A similar correlation was found between wolf signs and average fresh giant molerat signs ($r = 0.383$, $n = 83$, $P < 0.001$)

From direct observations the relationship between molerat signs and density was extrapolated. Molerat numbers were estimated during day-long watches (see below) in 50 m x 50 m plots. In the late afternoon after observation the number of open plus freshly plugged molerat holes within the plot (henceforth called 'fresh signs') were counted. Fresh signs correlated significantly with minimum ($r = 0.882$, $df = 34$, $p < 0.001$) and maximum ($r = 0.863$, $df = 34$, $p < 0.001$) estimates of molerat abundance and could therefore be used as an index of relative molerat abundance along transects.

Another molerat sign bearing correlation with rodent and wolf abundance is the mima mound, distinctive mounds found in afroalpine grassland probably as a result of long-term giant molerat activity. The density of mima mounds varied widely between habitats. In swamp shore, for instance, 82% of all transect samples included at least part of a mima mound. Other grassy sub-habitats in Web and Sanetti had mima mounds represented in 18–44% of the samples. Mounds were more sparse in *Helichrysum* dwarf-scrub, concentrating along drainage lines (7.8% versus 4% away from drains), and almost absent in the ericaceous zone (0.6%). The presence of mima mounds was strongly correlated with the mean number of fresh signs per transect point ($r = 0.946$, $df = 8$, $p < 0.001$).

Habitat Assessment Transects

Diurnal rodent species compose up to 97% of prey volume in the wolves' diet in Bale (Sillero-Zubiri and Gottelli 1995a). These rodents are therefore of vital importance in maintaining wolf populations, and an understanding of rodent distribution, abundance and biomass in each one of the Ethiopian wolf populations is essential in planning for their future conservation.

The presence of giant and common molerats, and the biomass contributed by smaller rodents, may be used as an index of the suitability of a habitat or particular mountain range for wolves. Simple, inexpensive field techniques, such as transect sampling for molerat fresh signs and abundance of rodent burrows can be used for such an evaluation. Based on the correlations presented above we developed a quick method of sampling habitat quality by counting the abundance of rodent signs along transects (Sillero-Zubiri *et al.* 1995a, 1995b).

Line transects, of 20 sampling points at 25 m intervals, were surveyed on foot to assess the numbers of rodent burrows, rodent alarm calls and wolf signs (droppings and signs of wolf diggings) within a 5 m radius of each transect point. At each transect point percentage plant cover was estimated by eye. Using a pin and a 5 m string we walked a full circumference recording the number of fresh signs within each circular sample point. Transects were walked in the late afternoon to standardize for the fresh signs and calls of diurnal rodents.

The line transects were stratified to cover all habitat types. An index of molerat abundance was calculated for each major vegetation zone; the indices for each habitat subdivision were weighted by their relative abundance. In areas where the common molerat replaces giant molerat their sign abundance along transects may be assessed in a similar fashion, although it will be necessary to calculate a suitable ratio of molerat abundance and their signs similar to the index presented above for giant molerats.

We also examined the role of soil depth in limiting the distribution of molerats and studied the daily patterns of molerat emergence and wolf foraging behaviour to investigate the temporal availability of molerats to wolves. Soil depth was measured using an iron probe at a subsample of transect points for each habitat subdivision.

Estimating Rodent Prey Abundance

When some time (weeks or months) can be spent in a particular area other more intensive methods may be applied to estimate the abundance and distribution of rodent prey. In Bale the relative abundance of different rodent species and their habitat preference were assessed by direct observation, live-trapping or snap-trapping. From these data total prey biomass was estimated. These methods worked well in Bale and are presented here as guidance for similar studies elsewhere.

Direct Observation. The abundance of diurnal rodents may be assessed by direct counts in a demarcated plot. This technique was particularly useful for molerats because live-trapping them has proved impossible (Bayene 1986), ruling out capture-mark-recapture studies. Unfortunately it cannot be applied to common molerats since they seldom emerge to the surface.

50 m x 50 m plots were marked with pegs and string in the area to be sampled. The plot was then scanned with binoculars from a vantage point every 10 minutes throughout the day (08:00–18:00 hs), and the number of individual molerats and other rodents present on the surface each time counted.

Individual molerats can be identified from hole use patterns as, generally, only one individual occupies a burrow system (Yalden 1975). For each plot observation day, minimum and maximum numbers of individuals were estimated. These were based, respectively, on the largest number of individuals surfacing simultaneously, and on numbers inferred from mapping activity throughout the day. For grass rats the largest number of individuals surfacing simultaneously was used as the minimum population estimate. Where a plot is watched more than once the largest estimate may be used.

Live-trapping. Grass rat densities were estimated using a 0.16 ha grid of 50 collapsible aluminium Sherman traps (Sherman, Tallahassee, Fl., USA) set at 10 metre intervals, with two traps per point. Traps were pre-baited for two days with peanut butter/flour bait and then set at dawn and cleared at noon and dusk for three consecutive days. Different habitat types were sampled in consecutive trapping sessions.

Population sizes on trap grids were estimated by Capture Mark Recapture techniques using numbers of individuals and the Bailey Triple Catch estimate (Begon 1979). In order to obtain an estimate of absolute density for each species a boundary strip equivalent to half the average distance moved between traps by individuals captured on consecutive nights was added. In Bale half of the average distance moved by consecutively captured L. melanonyx, using data from both sites combined, was 10.8 m, giving a trap area of 0.38 ha. On average, half the nightly distance moved by A. blicki was 8 m, giving an effective trap area of 0.314 ha (Sillero-Zubiri et al. 1995b).

Snap-Trapping. The relative abundance of rodents in all habitat types, sub-habitats and seasons was assessed using transects of twenty metal snap traps (20 cm by 10 cm) set 10 m apart. Traps were baited with a paste of peanut butter and wheat/barley flour, and checked in the early morning, at noon and in the evening for three consecutive days.

Snap-trapping were carried out opportunistically, making it a good quick method to assess species composition and relative abundance in a new area. Relative rodent abundance was expressed as percentage trap success, that is, the number of animals caught per 100 trap days or nights.

Rodents caught in snap-traps were sexed, weighed and identified with reference to a collection of specimens, available from the BMNP or Addis Ababa Museum (Sillero-Zubiri et al. 1995c). Reproductive condition (signs of lactation, pregnancy or hymen perforation; testes size and position) were recorded for all rodents caught in snap traps. The proportion of captured adult females which were pregnant were assessed by determining pregnancy using macroscopic detection of foetuses in the uterus (Hanny 1964) in order to assess the breeding seasonality of each species. This method however overlooks foetuses in the first third of pregnancy and therefore underestimates total reproductive output. Mean numbers of implanted foetuses was calculated by dissection of sub-samples of females.

Prey biomass. The absolute biomass (kg/ha) provided by the main wolf prey species may be estimated by multiplying the mean weight of trapped animals by an estimate of species density. If enough trapping data is available this calculation may be carried out monthly or seasonally. Species density values for grass rats may originate from the mean number of individuals live-trapped per hectare; and for molerats as the mean minimum number of individuals observed per hectare.

A biomass index, incorporating all snap-trapped species and weighted for sub-habitats, was calculated in Bale by multiplying transect snap-trap success by the mean weight for each species; this effectively gave an estimate of the biomass contributed per 100 snap-traps per night. This crude biomass index was intended only for general comparisons of habitat zones relative to each other.

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