

Chapter 6

A Preliminary Population Viability Analysis for the Ethiopian Wolf

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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 importance 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 complete 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 variations 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 determining 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 pro-

cesses 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/conservate 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 \geq 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.

Major 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/km²).

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):

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

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

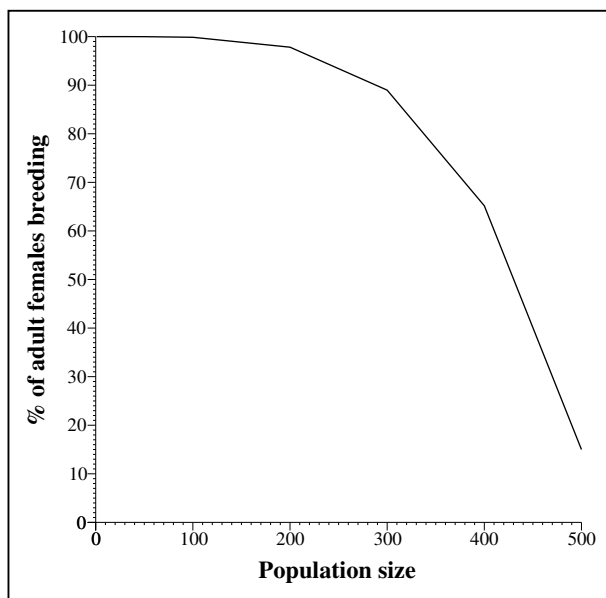


Figure 6.1. Density dependent relationship between population size and the percentage of adults breeding that was implemented in the VORTEX model to reflect changes in breeding patterns as the population changes in size.

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)

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).

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, λ 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 increasing rapidly as a result of the high reproductive rate that is characteristic of the species.

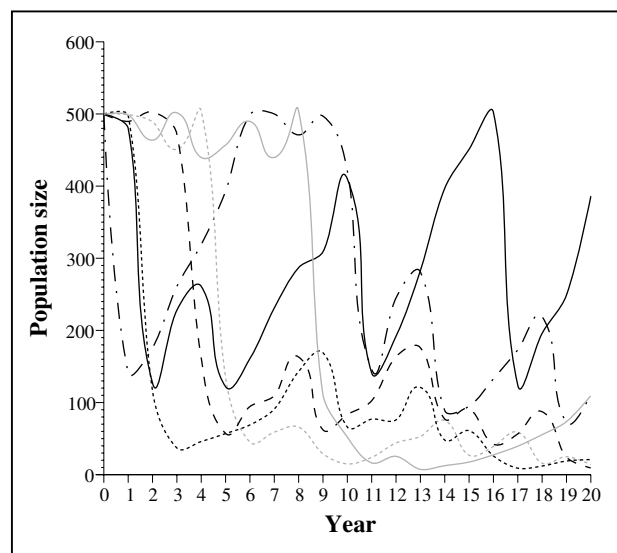


Figure 6.2. Example set of 6 runs from a VORTEX simulation. The figure illustrates the large amount of underlying variation masked by average values in the model output statistics, and also the ability of the population to recover rapidly from small numbers.

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	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	0.00	1.00	333.54	12.84	0.93	0.00
150	500	2	high	-	high rabies	0.90	160.83	14.06	0.91	0.00	0.62	143.69	18.40	0.81	0.01
150	500	2	high	-	cdv	1.00	454.36	2.97	0.98	0.00	1.00	461.0	93.00	0.97	0.00
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 simulations. 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

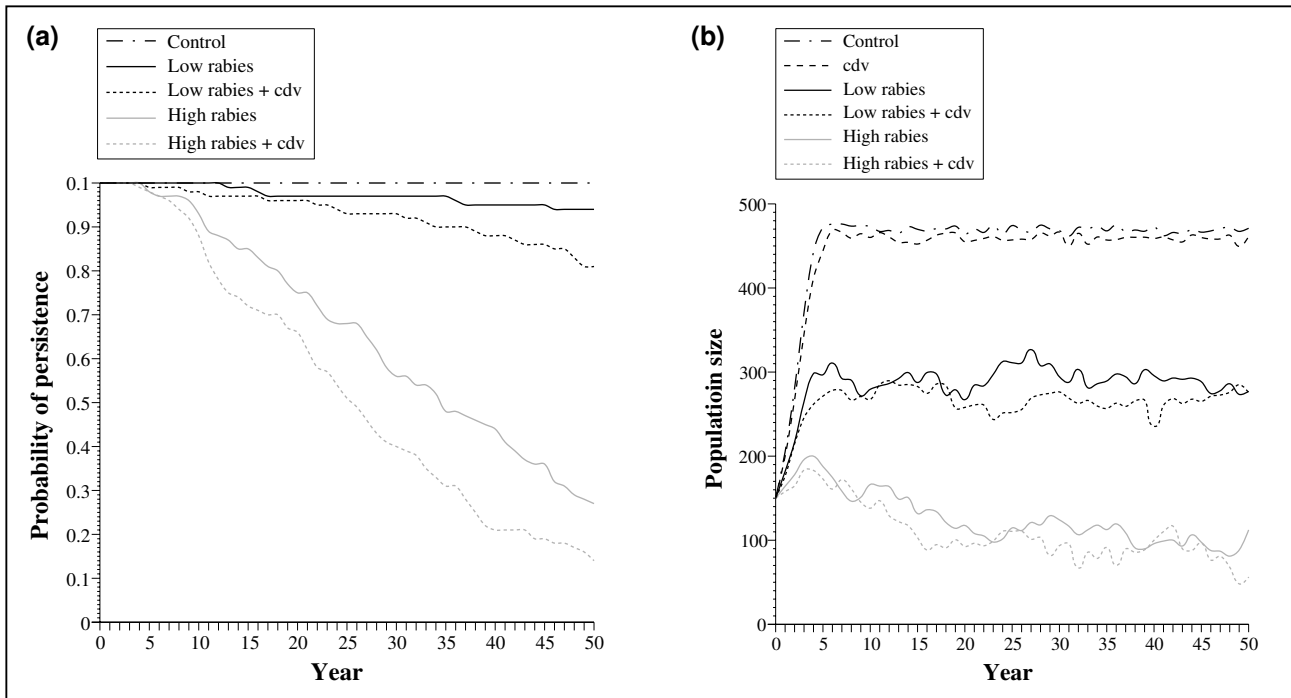


Figure 6.3. (a) Persistence rates and (b) average population size over time under different disease threats in a population of size 150 and carrying capacity of 500.

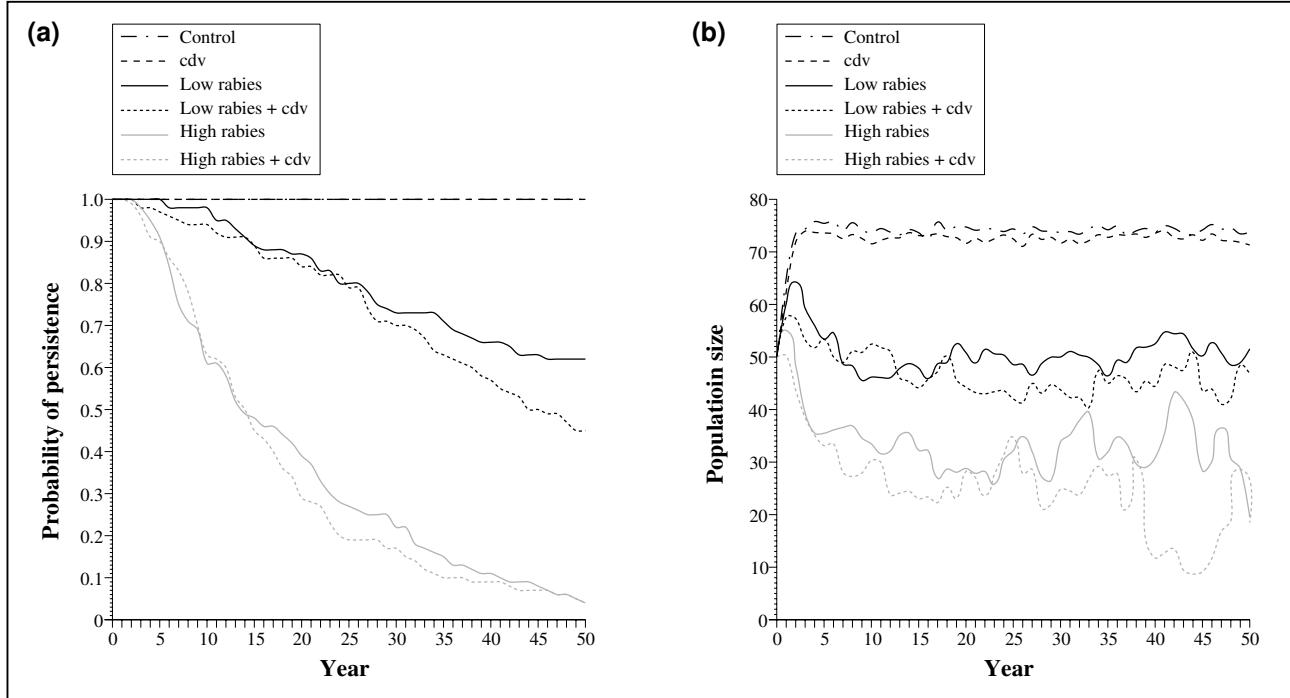


Figure 6.4. (a) Persistence rates and (b) average population size over time under different disease threats in a population of size 50 and carrying capacity of 80.

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, supplementation 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.

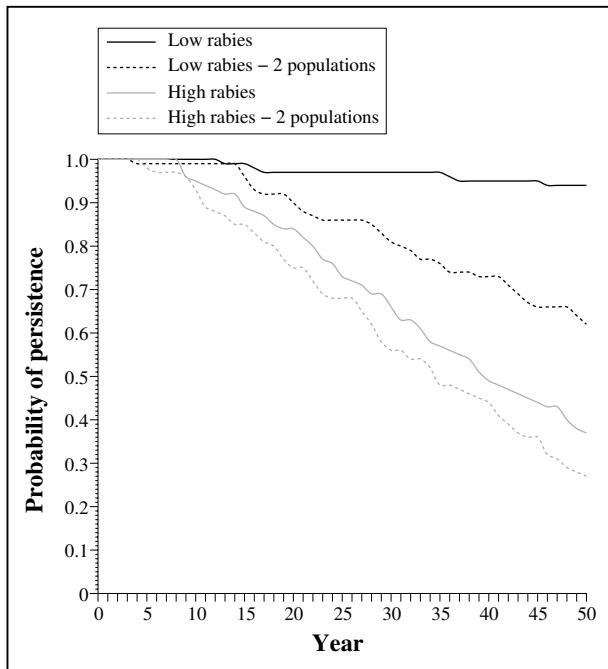


Figure 6.5. The effect of subdivision on a population of size 150 and carrying capacity of 500 under different disease threats.

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. Additionally, 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 as 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 detrimental. Further PVA modelling on the Ethiopian wolf will require the use of a model that can effectively reflect the consequences of social structure, disease epidemiology 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.

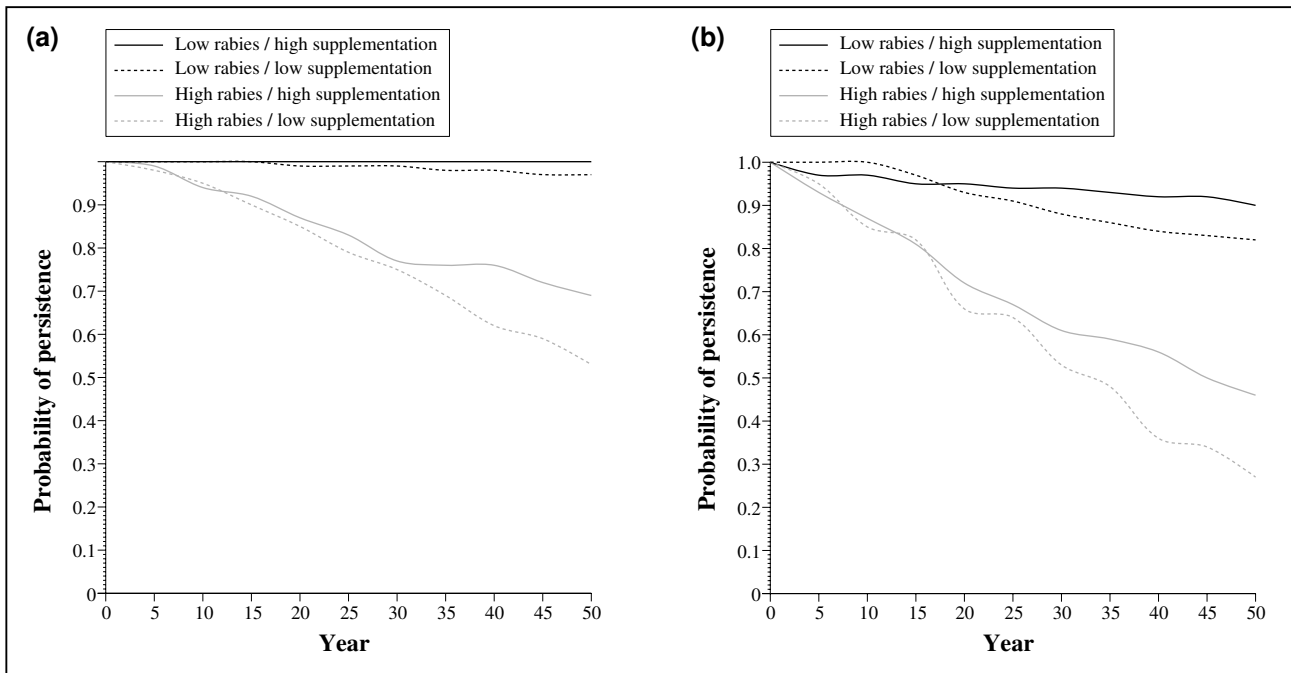


Figure 6.6. (a) The effect of supplementation of a 2 year old female once per year (high supplementation) or once every two years (low supplementation) on a population of size 150 and carrying capacity of 500 under different rabies incidence. (b) The effect of supplementation of a 2 year old female once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

tive bred females is one potential management option. Our models show that this could have a beneficial 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.