Minimum Viable Populations for elephant conservation

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Introduction and definitions:

It is well known that the smaller the size of a species population the higher the risk of it becoming extinct. This extinction need not be caused merely by deterministic ecological processes such as habitat destruction or hunting but also by chance factors operating on birth and death processes. Thus in a small population all the mature females may fail to reproduce in a given year or all the individuals may die within a short time span due to chance alone.

For small populations it is thus meaningless to talk of average birth, death or population growth rates. Deterministic models of population dynamics provide a reasonably robust approximation of average long - term demographic trends in large populations. These models are, however, quite inadequate for small population in which not only demographic stochasticity but also environmental and genetic stochasticity or catastrophes may drive the population to extinction, even though life table analysis may indicate that the population has on average a positive growth rate.

Small population biology is especially relevant to the conservation of Asian elephants. Loss and fragmentation of habitat, a process that still continues, has given rise to numerous small, isolated elephant populations in most Asian countries (Sukumar 1989, Santiapillai & Jackson 1990).

The crucial question is what is the minimum population size of elephants that should be maintained to prevent its extinction. Population viability analysis (PVA) could provide useful inputs to management decisions for these populations (see Soule 1987 for a review). At the outset we must understand that even for a single species the minimum viable population is not a magic number but varies according to various demographic traits and ecological pressures.

The continued survival of a population can be expressed only in probabilistic terms (Schaffer 1981). No population has a 100% probability of surviving for any given period of time. Thus, the minimum viable population (MVP) is usually expressed as that which has a 95% (or 99%) chance of surviving to 200 (or 1000) years.

The MVP thus varies from one species to another and from one population to another, depending on their peculiar demographic, environmental and genetic factors, and most important, on one's personal definition of MVP in probabilistic terms. A population ecologist may define MVP as one that has a 99% chance of surviving for 100 years (cf. Shaffer 1981); a reserve manger may deem it fit to continue *in situ* conservation measures for a population that has a 90% chance of surviving for 100 years.

Population viability analysis is thus a process that can yield different values of minimum viable population (Boyce 1992). The results reported here are based on a preliminary analysis and provides a first approximation of the MVP in Asian elephants. For this I used programme VORTEX developed by Robert Lacy (Chicago Zoological Society) who in turn used algorithms provided by James Greir (North Dakota State University).

Stochastic modelling

Most of the population parameters used in the modelling are based on data obtained

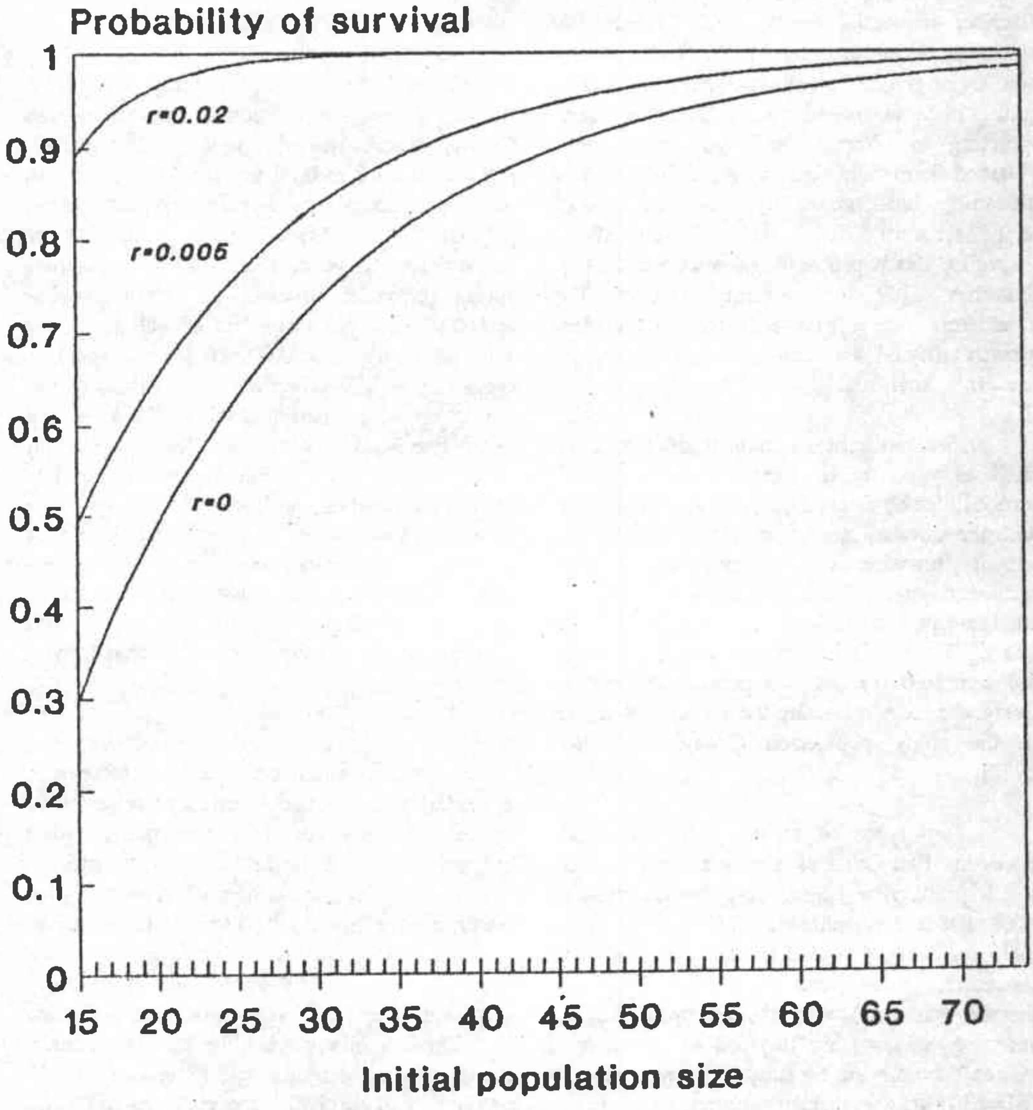

Fig. 1: Probability of survival of various initial population sizes

from a study of the Nilgiri-Eastern Ghats elephant population in southern India (Sukumar 1989).

Population processes are modelled as discrete, sequential events, with probabilistic outcomes determined by Monte Carlo simulation. Demographic stochasticity is modelled by taking birth and death probabilities as corresponding to observed average annual rates obtained from field data. In the First round of modelling, birth probability was taken as 0.20 to 0.22 / mature female / year, while annual age - specific death probabilities were varied (see Sukumar 1989 for mortality values). The parameters were adjusted so as to yield a desired growth rate and sex ratio under a deterministic life table analysis.

Environmental stochasticity is modelled as variation in annual birth and death probabilities by sampling binomial distributions, with the standard deviation (SD) specifying the annual fluctuations. Two populations were simulated, one with a SD equal to 20% and another equal to 40% of the average probabilities of death. SD in fertility was taken to be 5.0 and 10.0 for the two populations respectively, the latter reflecting the variance observed in the study population (Douglas-Hamilton 1972).

Two types of catastrophes were modelled, the first (such as a severe drought) with a 2% probability of reducing reproduction to 60% and survivorship to 80% (see Corfield 1973 for drought related mortality at Tsavo) of the normal values, and the second (such as a disease epidemic) with a 0.5% probability of reducing survivorship to 75% of the normal values.The carrying capacity (K) was set at 150 (SD=30); this was much higher than the initial size of simulated populations.

Age and sex - structure of the initial population were adjusted to begin with the stable age distribution. Adult sex ratios at stable age distribution under the first scenario were in the range of 1 adult male for every 3 -4 adult females, representative of a natural population not under any serious threat from ivory poaching. All simulations were run 1000 times for 100 years.

Fig. 1 shows the probability of survival for 100 years as a function of population size for populations with different intrinsic growth rates (r) from 0 to 0.02 as calculated from life table analysis of the female segment of the population. To ensure a 99% probability of survival for 100 years, the minimum population sizes required are about 25 - 30 for one growing at r=0.02 (2% per year) and 65 - 80 for those growing slowly at r=0.005 (0.5% per year) or remaining stable. When the probabilities of the two types of catastrophes are doubled for the population with potential r=0.02, a population of 45 animals has a 99% of surviving for 100 years.The survival probabilities for the two populations with low and moderate levels of environmental variance were hardly distinguishable. This implies that a long-lived K-selected mammal such as the elephant is relatively well buffered against environmental stochasticity.

For the population potentially increasing at r=0.02, the male mortality rates were increased so as to result in more skewed adult sex ratios (adult male: female ratio going from 1:4 to 1:16) at stable age distribution. This would reflect the trends seen in many Asian (Sukumar 1989) and African elephant populations (pool & Tomsen 1989) suffering from ivory poaching. The result is a significant reduction in probability of survival (Fig. 2). For instance, the population size needed to ensure a 99% probability of survival increases from 25 - 30 (at 1:4 sex ratio) to about 55 at 1:8 ratio. With a 1:16 sex ratio a starting population of 150 (at K=150) has only a 92% probability of surviving for 100 years. It is only when K is increased to 250 that a population of 120 elephants has a 99% probability of surviving for 100 years.

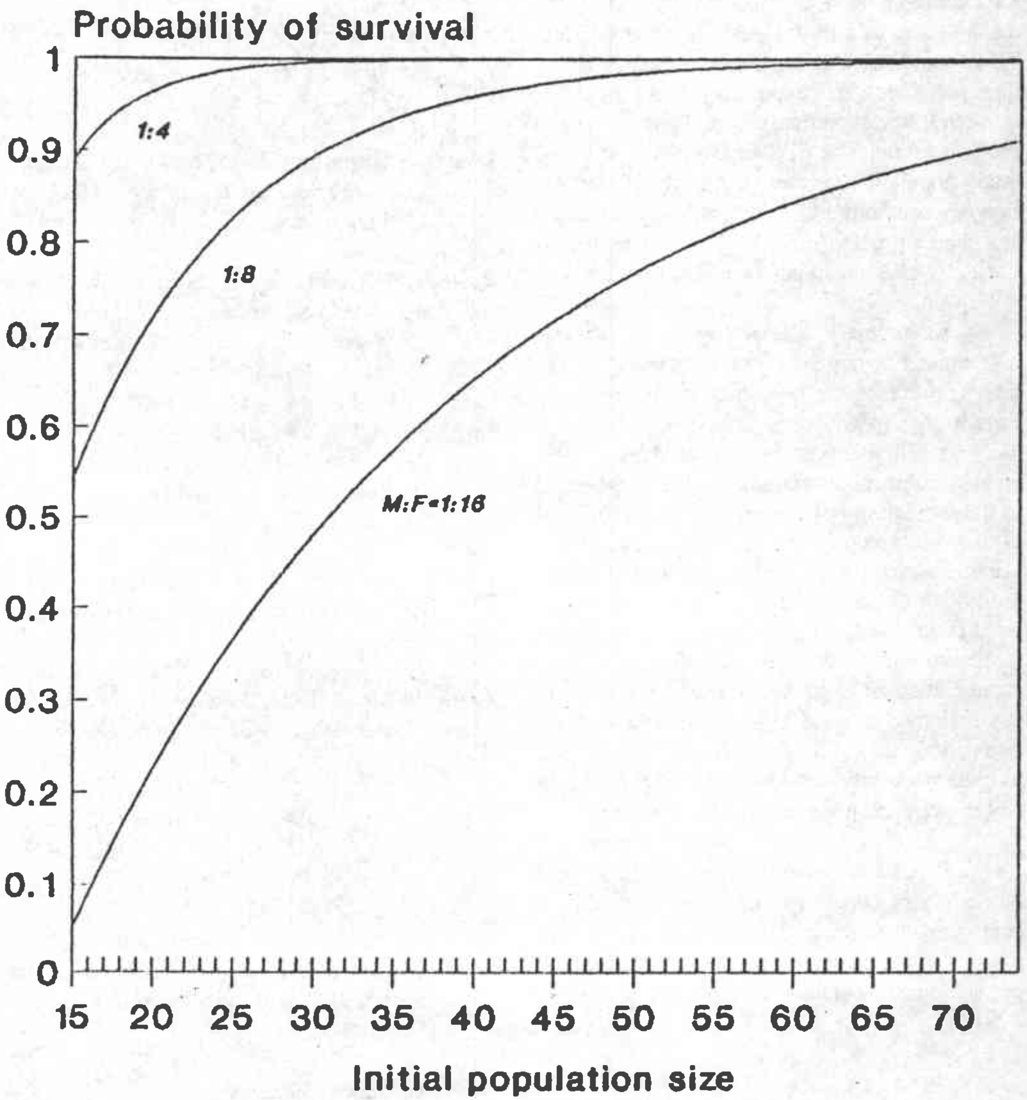

Fig. 2: Probability of survival of various initial population sizes

In the absence of specific data for elephants I did not model the deleterious effects of inbreeding on the population. The genetically effective population size (EPS) of 50 suggested as the minimum number needed to keep inbreeding below a tolerable 1% per generation can be taken as a useful guide for management. This would, of course, translate into a higher total population size depending on the adult sex ratio and the proportion of pre-reproductives in the population. The EPS as a percentage of the total population varies from about 8% in Periyar, southern India (where ivory poaching has been a problem) to 50% in southeastern Sri Lanka (where poaching is not a threat).

In summary, a total population of 100 - 200 elephants, depending on demography, sex ratio and ecological pressures, would not only have a high (>99%) probability of survival for the next 100 years in the face of demographic and environmental stochasticity, but also be safe in the short term from genetic erosion. The goal of managers could thus be to maintain these minimum sizes in isolated elephant populations until other options emerge in the future. Let me emphasize that the figures given above are the minimum sizes recommended for short-term conservation of populations that are not under any serious danger of losing their habitat. Such populations may still be unable to maintain their long-term evolutionary potential. For this much larger population sizes would be required.

Population viability analysis could also be usefully combined with other types of ecological analyses in deciding on management options as, for instance, in dealing with elephant populations in conflict with people (Sukumar, 1991).

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