Ecology Theory:

Minimum viable population size

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A minimum viable population (MVP) size is an estimate of the number of individuals required for a high probability of survival of a population over a given period of time. A commonly used, but somewhat arbitrary definition is > 95% probability of persistence over 100 years. The increasing conflict between people and wildlife initiated the theoretical development of MVP and has motivated the use of estimates by conservation biologists over the past three decades. MVP has seen practical application in conservation management and species recovery programs, and is relevant to the IUCN's Red List criteria regarding small and range-restricted populations. The quantitative estimation of MVP allows biologists to link finite resources to a target figure or range, assuming that the persistence of a population will be assured thereafter (or for a period of time). MVP also allows further assessment of species habitat requirements and determination of reserve size and population corridors.

MVPs can be estimated using a number of mathematical techniques. Most commonly, population viability analyses (PVA) are used. These are computer-based simulation models which project changes in initial population abundance over a set time period and account for processes such as inbreeding depression, density dependence, catastrophes and environmental and demographic stochasticity, i.e., random variation (these variables are discussed below). If, for example, an initial population N becomes extinct in only 10 out of 100 simulated projections into the future (100 years), then that population can be said to have a 90% chance of persisting for 100 years, and the starting population size N is used as the MVP size within this temporal context. Usually, thousands of simulation replicates are run to estimate these probabilities reliably.

Time periods for PVAs are typically 20, 50, 100, 200, or sometimes 1000 years. The number of generations (usually 40) has been used as a more appropriate measure of time scale, especially when comparing MVP across taxonomic groups. A PVA for African elephant *Loxodonta africana*, for example, is of limited use over 20 years when the average generation length is about 15 years (taking generation length as age at sexual maturity). Conservation practitioners may find calendar years more easily interpretable, however, given the ease of transfer into management plans.

PVAs typically account for factors that may limit a population over a projected time period. These are commonly inbreeding depression, natural catastrophes, environmental and demographic stochasticity, density dependence, and the Allee effect. Inbreeding depression refers to the reduction of genetic fitness within a population as a result of breeding between closely-related individuals. Catastrophes are natural events that may result in a sudden and dramatic population decline. These include disease outbreaks, floods, fires, drought or even socio-political upheaval that affects species' habitats and survival rates. Environmental and demographic stochasticity are random fluctuations in environmental conditions or population numbers that detrimentally affect small populations. Density dependence is the process by which average demographic rates (e.g., survival, fertility) fluctuate with population density. The Allee effect is a type of inverse density dependence that occurs when declining populations reach a point where per capita birth rate drops to a point where population growth rate becomes negative, often as a result of increasing difficulty of individuals finding mates, the breakdown of social structure in cooperatively breeding species, or inbreeding depression. These factors can act independently, but usually concomitantly, in driving a population to extinction.

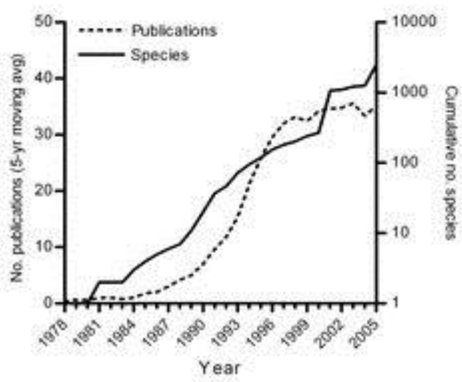

Figure 1. Publication trends for minimum viable population size (MVP), 1974-2005. The cumulative number of species in studies related to population viability and extinction (log10 scale, solid line), and a five-year moving-average of the number MVP-related peer-reviewed and unpublished literature sources (dotted line). A large increase in species studied since 2001 marked the advent of freely-accessible online population databases. (Source: Reprinted from*Biological Conservation*, 139(1), Traill LW, Bradshaw CJA and Brook BW, Minimum viable population size: A meta-analysis of 30 years of published estimates, Pages 159-166, Copyright (2007), with permission from Elsevier)

MVP estimates may also be derived from population censuses or genetic analyses. Long-term population census data are generally rare in ecology, but studies have shown the persistence of (sometimes small) populations over periods of 50, 75 and 100 years. Genetic analyses typically involve the estimation of loss of genetic diversity and fitness and projection to extinction. Some studies indicate that inbreeding depression alone can lead to extinction, even among wild populations. Thus, when considering the viability of a given population, one should consider whether the population is large enough to avoid inbreeding depression, if there is sufficient genetic diversity for adaptive change to occur, and if the population is large enough to avoid accumulating new deleterious mutations. Following Frankham et al., estimates of the population numbers required to overcome these effects (known as the effective population, Ne) are 50 to avoid inbreeding depression, 500-5000 to retain evolutionary potential, and 12 to 1000 to avoid the accumulation of deleterious mutations. Franklin proposed the 50/500 rule used by conservation practitioners, whereby an Ne of 50 is required to prevent an unacceptable rate of inbreeding, while a long-term Ne of 500 is required to ensure overall genetic variability. Given that the average Ne /N ratio is roughly 0.10 these rules of thumb translate to census sizes of 500 to 50,000 individuals.

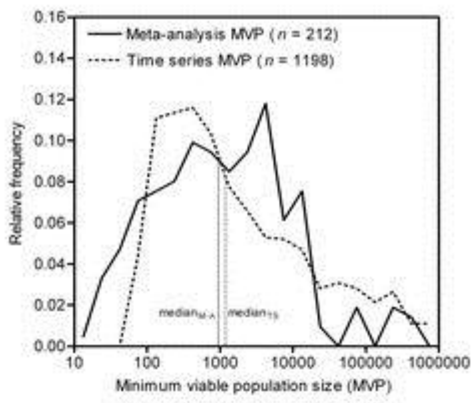

Figure 2. Relative frequency distribution of minimum viable population (MVP) estimates (log_{10} scale). Standardized MVPs from the meta-analysis of 212 species examined since 1976 (solid line) are compared to MVP estimates derived independently from models fitted to 1198 species' time series of abundance data (dotted line) ((Brook et al. 2006)). Median values are represented by vertical lines for each distribution. (Source: Reprinted from *Biological Conservation*, 139(1), Traill LW, Bradshaw CJA and Brook BW, Minimum viable population size: A meta-analysis of 30 years of published estimates, Pages 159-166, Copyright (2007), with permission from Elsevier)

Criticism of the MVP concept hinge mainly on the precision and accuracy of the estimates, and its real-world applicability, especially given long-term projections into an uncertain future. A survey of the current scientific literature shows that MVPs have been applied to an increasing number of species, but there has been a gradual decline in the rate at which MVP-related scientific papers are published (Figure 1). There are no robust rules of thumb for estimating MVP sizes for species lacking population models or other detailed information on their demography or changes in abundance over time; Brook, Traill and Bradshaw found no evidence that well-known correlates of species extinction could be used to predict MVP size. The conclusion is that MVP size depends mostly on the population's immediate environmental and ecological context.

Where conservationists lack funds to obtain the essential information needed for population-specific MVP size estimates, a broad range of MVP from 100 – 10000 individuals may be cautiously used (see Figure 2). Published median MVPs across taxonomic groups, standardized to a definition of a > 99% probability of persistence for 40 generations, vary from 5,816 to 4,169 individuals and may be as low as 1,377 if density-dependent compensation is adequately considered.

Figure 3. African wild dogs *Lycaon pictus* in the Zimbabwean south-east Lowveld. The species are listed as Endangered on the IUCN Red List. (Source: Kim Wolhuter, Wildcast)

Conservation practitioners are commonly faced with a lack of resources, limited scientific knowledge on the system under management, and sometimes operate within a hostile socio-political environment. Oftentimes biologists require general MVP targets for species conservation but do not have the time, skills or resources to run viability analyses. MVP targets are used to allocate scarce resources toward the maintenance of populations, and for the derivation of minimum species habitat requirements, which may then be used as a demographic and genetic justification for reserve design or preservation, and the possible creation of corridors or trans-boundary national parks. The recommendations that biologists make, based on broad MVP targets, are usually serious, with legal and financial consequences. Where data and resources are scarce, MVP ranges may be cautiously used.

An example of a PVA-based study is that done by the IUCN Species Survival Commission (SSC) Canid Specialist Group for African wild dogs *Lycaon pictus* (Figure 3). It was found that populations of more than 100 individuals are likely to survive over 50 years with adequate protection from human persecution, while small populations (of 20 individuals) are unlikely to persist due to stochastic hazards. Wild dogs have been reduced to small, discrete populations throughout sub-Saharan Africa due to the direct and indirect pressures of human settlement, so their risk of local extinction is high.

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