Population Viability Analysis Report

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Introduction

Population viability analysis (PVA) is a process of identifying the viability requirements of a species and evaluating the likelihood that the population(s) under study will persist for a given time into the future. Population viability analysis is often oriented towards the management of rare and threatened species, with two broad objectives. The short-term objective is to minimize the risk of extinction. The long-term objective is to promote conditions in which species retain their potential for evolutionary change without intensive management (Akçakaya and Sjögren-Gulve, 2000).

Environmental protection strategies often rely on environmental impact assessments. As part of the assessment process biologists are routinely asked to evaluate the effects of management actions on plants and animals. This evaluation often requires that biologists make judgements about the viability of affected populations. However, population viability analyses that are analytically comprehensive require extensive ecological data. Such data are usually unavailable and impossible for wildlife managers to collect given limitations of time and money (Ruggiero et al, 1994).

Broadly defined, the term "population viability analysis" refers to the use of quantitative methods to predict the likely future status of a population or collection of populations of conservation concern (Morris et al., 1999).

Models of PVA

There is a wide range of models used in PVA, differing in the amount of data they require, the factors they incorporate and their assumptions.

One extreme are occupancy models that describe each population as full (occupied) or empty (extinct), regardless of its location. One advantage of occupancy models is that they do not require detailed demographic data.

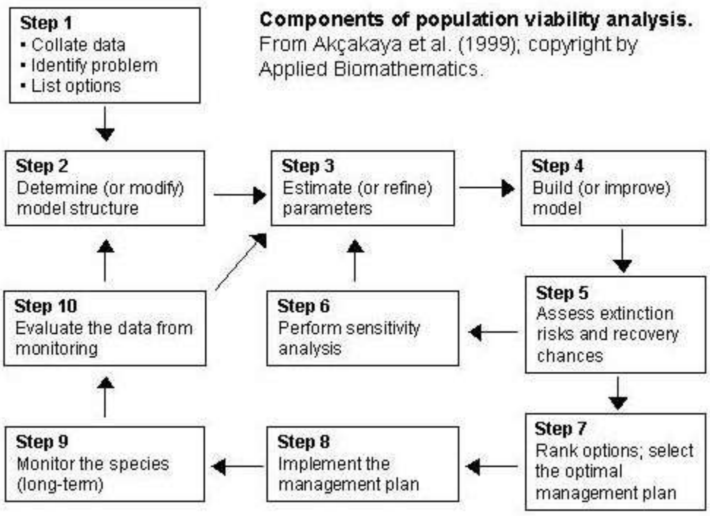
At the other extreme there are individual-based models which describe the spatial structure within the location of each individual in the population or the locations of territories or home ranges and are extremely data hungry (Reed et al, 2002). In addition to demographic data (survival rates and fecundities), these models require data on behaviour of individuals. Small errors in dispersal mortality, mobility and habitat suitability, result in large errors in predicting dispersal success. Often there not enough data to estimate the exact location and size of each territory and assumption lead to errors.

In between these, are odelling structured metapopulation (sets of populations of the same species in the same general geographic area) models, that describe the dynamics of each population with structured demographic models and incorporate spatial dynamics (Akçakaya, 2000). The main advantage of structured population models compared to occupancy models is their flexibility. In odelling the local population dynamics, they can in-corporate several biological factors and can represent spatial structure in various ways. The main disadvantage of structured models is that they require more data than occupancy models, including stage-specific survival and fecundity rates, and the temporal and spatial variation in these rates management (Akçakaya and Sjögren-Gulve, 2000).

Because species and their environments are dynamic, and our knowledge of future events and impacts is limited, it is not possible to say with certainty that a species will persist indefinitely. Also, it is not possible to determine a single, fixed population size above which a species is viable and below which it will be extirpated from an area. Consequently, recent viability assessments have expressed estimates of future viability as a likelihood, with associated measures of uncertainty.

However, we note that PVAs targeted at populations of dominant or characteristic species in a particular community type may serve as useful tools for evaluating the viability of community occurrences (Morris et al., 1999).

The following diagram gives an overview of the methodology of PVA.



(Adopted from Akçakaya et al., 1999)

Population dynamics in a random environment

Perhaps the simplest conceptual model of population growth is the equation :

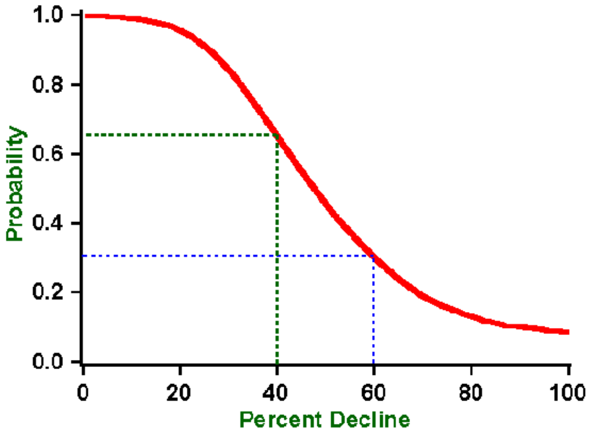
$N(t+1) = \lambda N(t)$

where N(t) is the number of individuals in the population in year t, and λ is the population growth rate, or the amount by which the population multiplies each year (the Greek symbol "lambda" is used here by tradition).

If there is no variation in the environment from year to year, then the population growth rate (λ) is a constant, and only three qualitative types of population growth are possible: if λ is greater than one, the population grows geometrically; if λ is less than one, the population declines geometrically to extinction; and if λ equals one, the population neither increases nor declines, but remains at its initial size in all subsequent years.

But when variation in the environment causes survival and reproduction to vary from year to year, λ must also be viewed as varying over some range of values. Moreover, if the environmental fluctuations driving changes in population growth include an element of unpredictability (as factors such as rainfall and temperature are likely to do), then we must face the fact that we cannot predict with certainty what the exact sequence of future population growth rates will be.

As a consequence, even if we know the current population size and both the average value and the degree of variation in the population growth rate, the best we can do is to make probabilistic statements about the number of individuals the population will include at some time in the future (Morris et al., 1999).



The above curve represents the probability of decline in a species population (Adopted from Akçakaya et al., 1999)

Limitations of Population Viability Analysis

Single species focus

The focus of a PVA is generally a population or multiple populations of a single species. Its focus on single species is a limitation in cases where the goal is the management and conservation of an ecosystem. In other cases, the single species focus is the strength of PVA: the dynamics of single species are much simpler (and thus better understood) than the dynamics of communities or ecosystems (Lawton 1999). Uncertainties in structure and parameters of single-species models are magnified when multiple species and their interactions are considered. However, it is important not to make the mistake of managing the landscape specifically for the indicator species without ascertaining that the enhancements benefit other species as well (Simberloff 1998).

Data needs

Incomplete information does not necessarily preclude meaningful results. First, PVAs can incorporate uncertainties in the data, and in some cases, these uncertainties do not effect the overall conclusion. Uncertainties in the data may not affect results when the goal of PVA is comparative, as in ranking management options.

Risk criteria

Some uses of PVA involve determining whether the risk faced by a particular species is acceptable. Such questions require a benchmark for “an acceptable level of risk” for the extinction of species.

Identifying causes of decline

It is important to remember that, as Caughley (1994) emphasized, no modelling effort by itself can determine why a population is declining or why it has declined in the past. For modelling to be used successfully to evaluate options for management of species, it must be part of a larger process and incorporate other methods, including study of natural history, field observations and experiments, analysis of historical and current data and long-term monitoring.

Advantages of Population Viability Analysis

Relevance to conservation of biodiversity

PVA has direct relevance to biodiversity conservation. An increasing number of species are presently threatened or endangered, and PVA results directly relate to the mandates of such laws as the Endangered Species Act. In addition, PVA can be applied to validated focal or umbrella species (Fleishman et al. 2000) to guide conservation efforts for entire nested species groups. Thus, PVAs of selected threatened species and sets of indicative species will be central for efficient conservation planning at local or regional levels, and for measures taken to comply with international treaties such as the UN Convention Biological Diversity (UNCED 1992).

Ability to use all available data and multiple data types

A PVA can use various types of data sets, including presence-absence data, habitat relationships, GIS data on landscape characteristics, mark-recapture data, surveys and censuses. Thus, it is possible to incorporate all available data into the assessment. Such an assessment is more reliable than one that ignores part of the available information.

Incorporating uncertainty

If data for a PVA are unavailable or uncertain, ranges of parameters are used. In addition, uncertainties in structure of the model can be incorporated by building multiple models. One of the simplest methods of propagating such uncertainties, is to build best-case and worst-case models (Akçakaya and Sjögren-Gulve, 2000). Combining the results of these two models gives a range of estimates of extinction risk and other assessment endpoints. This allows the users of the PVA results (managers, conservationists) to understand the effect of uncertain input, and to make decisions with full knowledge of the uncertainties.

Conservation planning with multiple objectives

Conservation and landscape management decisions often involve multiple objectives such as ecological and economic goals. Population viability analyses do not explicitly incorporate economic factors. However, because of the quantitative nature of PVA results, it is possible to consider ecological and economic objectives, for risk-based (and risk-weighted) decision-making.

Plant PVAs

Environmental variability is a problem in modeling plant populations. Despite patchy distribution many plant species are not appropriate for metapopulation modeling because either nothing is known of their immigration and emigration rates or because their dispersal distances are so short (Reed et al, 2002).

According to a review by E.Menges (2000), 95 plant PVAs can be found in the ecological literature. The earliest plant PVA calculated for age-structured data derived from a Scots pine *(Pinus sylvestris*) forest. Increasing numbers of studies have been published over time, with the peak years (through 1998) being 1997 and 1998, each with 13 articles.

This review of 95 plant population viability analyses (PVAs) reveals that most studies consider one species, only a few populations and are based on data collected for less than five years. Only five studies referred to themselves as PVAs. Plants offer numerous challenges, such as seed banks and periodic recruitment, but these can be answered with suitable data collection and modeling. New approaches, such as metapopulation models, inclusion of disturbance cycles, and integration of genetics and demography, are producing more realistic PVAs. Although exact solutions are fraught with limitations, plant PVAs can be useful in comparing management regimes, populations and microhabitats, and in using these results to guide conservation and management.

Characteristics of plant PVAs (n=95)

Characteristic	Alternative	% of studies
Classification method	Stage or size	80
	Age	68
	(Stage or size) and age	4
	Other	8
Length of study	1–5 years	70
	6–10 years	27
	>10 years	3
Number of species	1	84
	>1	16
Number of populations	0-5	82
	6-10	9
	>10	8
Calculated parameters	Finite rate of increase (l)	84
	Population size and/or structure	73
	Elasticities	45
Advanced modeling features	Environmental stochasticity	24
	Stochastic modeling of extinction	23
	Disturbance and/or catastrophe	16
	Density dependence	12
	Spatially explicit models	5
	Demographic stochasticity	3
	Genetics	3
	Metapopulation modeling	3

(Adopted from E.Menges, 2000)

A recent study by Pfab and Witkofski (2000), describes a population viability analysis (PVA) for Euphorbia clivicola R.A. Dyer, a threatened succulent confined to only two known populations in the Northern Province of South Africa, one of which is protected in a nature reserve. The PVA explicitly compared the relative effectiveness of four management scenarios in bringing about the recovery of the protected population that had shown a 91% decline over the decade during which the population was monitored. Demographic monitoring data as well as autecological data collected in 1996 were used to determine the temporal variation in observed demographic and reproductive parameters. The model parameters were allowed to vary randomly over the observed ranges in order to incorporate stochasticity of the environmental factors fire, herbivory and rainfall. If future management practices remain unchanged, the model predicted that there is an 88% probability of the protected population becoming extinct within the next 20 years. The population should recover under a management scenario involving a fire frequency of every 3 years, the exclusion of herbivores and augmentation. The model prediction for the 1999 population was 102 +/- 11 adult plants. It has been validated with data collected in 1999. Thus the total number of living adults in the 1999 population is 101, almost an exact match with the model prediction.

The explicit comparison of the relative effectiveness of different potential management actions to induce the recovery of the protected population of E. clivicola, which had shown a 91% decline from 1987 to 1996, is the greatest advantage of the PVA described in this paper.

Similarly another study (Quintana-Ascencio et al, 2003) explored extinction risks of Hypericum cumulicola, a fire-dependent plant endemic to the Lake Wales Ridge, in Florida. Stochastic and deterministic matrix population models based on six censuses (1994–1999) and data from several germination and seedling survival experiments were used to compare H.cumulicola demography and extinction probabilities under different fire regimes. Extinction probability declined as intervals between fires decreased. Fire intervals of 50 years resulted in an appreciable extinction probability after 200 years. Cycles of highly staggered short and long fire-return intervals caused slightly higher chances of extinction than regular fire-return intervals. The simulations were sensitive to estimates of survival in the seed bank. They concluded that active management will be required to restore favourable fire regimes in areas where fire has been suppressed.

In the event that co-operation is achieved with the natural resource manager, a PVA such as described in these papers could become an indispensable tool for the conservation of threatened species. The process of adaptive management could be successfully applied whereby the application of the proposed management actions could develop a better understanding of the dynamics of the population, while monitoring of the population could provide data to validate and/or refine the PVA model.

Discussion - Conclusions

A key goal of conservation biology is to maintain viable populations of rare species. Practical problems in conservation planning and wild-life management are increasingly phrased in terms of questions about the viability of threatened or indicator species. PVA provides a rigorous methodology that can use different types of data, a way to in-corporate uncertainties and natural variabilities and products or predictions that are relevant to conservation goals (Akçakaya and Sjögren-Gulve, 2000).

The disadvantages of PVA include its single-species focus and requirements for data that may not be available for many species. PVAs are most useful when they address a specific question involving a focal (e.g., threatened, indicator, sensitive, or umbrella) species, when their level of detail is consistent with the available data and when they focus on relative (i.e., comparative) rather than absolute results and risks of decline rather than extinction (Akçakaya and Sjögren-Gulve, 2000).

Viability assessments made with limited amounts of data will have wide confidence limits (i.e., low precision). Observation errors in the data used to construct a PVA will influence its predictions. Rare events (either good years or catastrophes), although usually omitted from viability analyses, will affect a population's extinction risk. Migration and environmental correlation among a set of populations will cause the extinction risk to differ from that of a suite of isolated, independent populations (Morris etal., 1999).

But PVA does not provide answers to all of the questions that will need to be addressed in designing ecoregional plans.

We will often lack sufficient data to avoid the simplifying assumptions discussed in the caveats above, and for many species, population-level data will be completely absent.

Nonetheless, PVA will help us to gain in-sight into the extinction risks faced by populations for which we do have data, and those analyses will help us to assess the viability of less well-studied populations and species.

Ongoing work in theoretical population biology is constantly leading to new tools for population viability analysis. By using the tools of population viability analysis when data are available, conservation practitioners might create a "demand" for new methods and techniques that would spur theoretical population biologist to improve existing approaches (Morris et al., 1999).

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