Population Viability Analysis

What is PVA?

Population Viability Analysis

The use of quantitative methods to predict the likely future status of a population or collection of populations of conservation concern.

(Morris and Doak 2002)

History

First used by Shaffer (1983) to estimate the **minimum viable population** size in Yellowstone National Park

Now routine part of species assessments and recovery plans

Uses of PVA (from Morris and Doak (2002))

(1) Assessing the extinction risk of a single population
(2) Comparing relative risks of two or more populations
(3) Analyzing and synthesizing monitoring data
(4) Identifying key life stages or demographic processes as management targets (sensitivity analysis)
(5) Determining how large a reserve needs to be to achieve a desired level of protection from extinction
(6) Determining how many individuals to release to establish a new population
(7) Setting limits on the harvest or "take" from a population that are compatible with its continued existence
(8) Determining how many (and which) populations are needed to achieve a desired overall likelihood of species persistence

Steps of PVA

(1) Develop objectives
(2) Develop a set of competing models
(3) Design a study to collect necessary data
(4) Fit models to data and select the best model(s)
(5) Use model(s) to identify best management options
(6) Implement management option, monitor the consequences, and refine models
(7) Return to step **(4)**

Very similar to adaptive management

Types of PVA

(1) Count-based PVA
- All you have is estimates of abundance in each year
- This is the cheapest, but least-informative method

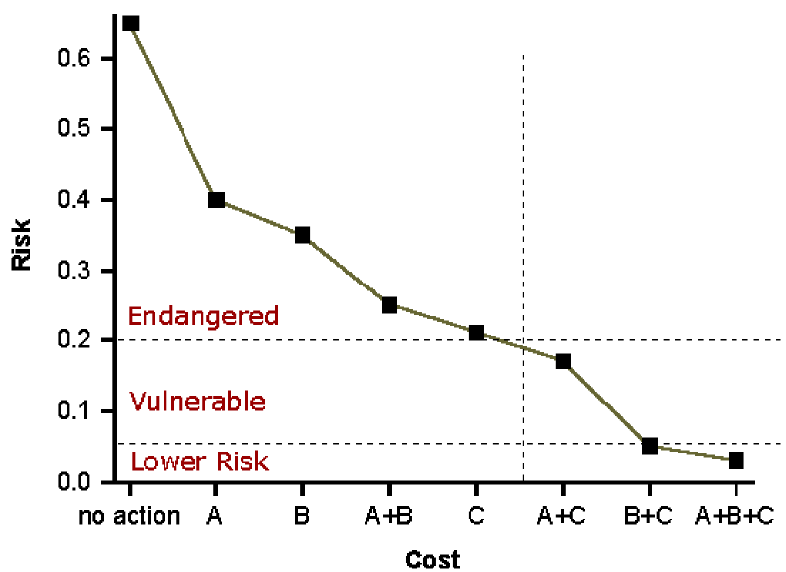
(2) Demographic PVA
- Requires estimates of vital rates
- Useful for identifying key demographic parameters

(3) Metapopulation viability analysis
- Useful in reserve design

(4) Spatially-explicit, individual-based PVA
- Most realistic, but hardest to parameterize

All methods require clear definition of time horizon and acceptable level of extinction risk

Products of PVA



Sensitivity analysis

A sensitivity analysis seeks to understand the degree to which λ is sensitive to changes in vital rates.

Usually applied to age- or stage-based population models.

The sensitivity of λ to a change in a population parameter θ (e.g., survival or fecundity), is:

$$\text{sensitivity} = \frac{\Delta\lambda}{\Delta\theta}$$

Sensitivities allow us to make statements such as:

"Increasing subadult fecundity by 1 unit increases λ by 0.01, whereas increasing adult fecundity by 1 unit increases λ by 0.02. Therefore, population growth is more sensitive to changes in adult fecundity."

Sensitivity example

Parameter	$\Delta\theta$	$\Delta\lambda$	Sensitivity
Fecundity of first age class (f_1)	0.05	0.010	0.20
Fecundity of second age class (f_2)	0.05	0.003	0.06
Survival of first age class (s_1)	0.05	0.040	0.80
Survival of second age class (s_2)	0.05	0.030	0.60

Sensitivies don't have to sum to 1

Elasticity

A problem with sensitivities is that it is hard to compare values for parameters on different scales, such as survival and fecundity. For this reason, it is usually better to report "elasticities" instead.

Elasticity: the proportional change in λ caused by proportional changes in vital rates.

Easier interpretation because:

- Standardized units
- Values sum to 1

Examples

"A 1% increase in f_1 increases λ by 0.01%."

"A 1% increase in s_1 increases λ by 0.05%."

R code for sensitivity analysis

Suppose we have the following stage-structured projection matrix:

```
A <- matrix(c(
    0.2, 0.8, 1.0, 0.9,
    0.4, 0.0, 0.0, 0.0,
    0.0, 0.6, 0.0, 0.0,
    0.0, 0.0, 0.8, 0.5), nrow=4, byrow=TRUE)
```

We can use eigenanalysis to compute λ, stable age distribution, and reproductive value.

```
eA <- eigen(A)
lam <- Re(eA$values[1])
lam                             ## Asymtotic growth rate

## [1] 1.034908

w <- Re(eA$vectors[,1])
w <- w/sum(w)                   ## Stable age distribution

v <- Re(eigen(t(A))$vectors[,1]) ## Reproductive value
```


R code for sensitivity analysis

The sensitivities are given by $z_{ij} = \frac{v_i w_j}{\mathbf{vw}}$

```
z <- outer(v,w)/c(v%*%w)
z ## Sensitivites

##           [,1]      [,2]       [,3]      [,4]
## [1,] 0.3473925 0.1342698 0.07784447 0.1164229
## [2,] 0.7251023 0.2802575 0.16248251 0.2430061
## [3,] 0.7875009 0.3043751 0.17646493 0.2639179
## [4,] 0.5844985 0.2259131 0.13097572 0.1958851
```

The elasticities are given by $e_{ij} = \frac{a_{ij} z_{ij}}{\lambda}$

```
e <- A*z/lam
e  ## Elasticities

##            [,1]      [,2]      [,3]       [,4]
## [1,] 0.06713492 0.1037926 0.0752187 0.10124623
## [2,] 0.28025755 0.0000000 0.0000000 0.00000000
## [3,] 0.00000000 0.1764649 0.0000000 0.00000000
## [4,] 0.00000000 0.0000000 0.1012462 0.09463883
```

Sensitivity and elasticity

Take-home points

Sensitivity measures the change in λ given an absolute change in a parameter.

Elasticity measures the proportional change in λ given a proportional change in a parameter.

Problems with PVA

Most PVA's are *"essentially games played with guesses."* (Caughley, G. 1994. Conservation Biology)

Many PVA's don't include multiple models corresponding to different hypotheses.

Some software encourages this.

Summary

Final thoughts

- People often say that PVA's require too much data.
- But what is the alternative?
- When data are limited (and they always are), you must decrease the time horizon and acknowledge uncertainty in decision process.