Population Viability I: Risks Faced by Small Populations

Motivation

Small populations are increasingly common due to population declines, habitat fragmentation, and habitat loss. Small populations are often more at risk of local extinction and it is imperative to develop a better understanding of population processes and management strategies.

Unfortunately, such populations are often mismanaged due to poor understanding and entrenched dogmas.

Objectives for Lecture and Discussion

1. Understand current thinking of the risks faced by small populations
   Small Population vs Declining Species Paradigms
2. Critically evaluate the two paradigms
3. Critically question if and how we have achieved the melding of the two approaches?
4. Introduce concept of population viability analyses
   and highlight the concept of process vs sampling variation

This will be followed by several labs related to PVA
and a final overview of the concept of PVA– its current “status”

Caughley’s Two Threads of Conservation Biology

Small-Population Paradigm

Year

The Enlightened Applied Ecologists

Great, that gives us S = 0.01 ± 0.02, just what I needed for my Individual-Based Model!

Drawings by John Megahan

Back to the Logistic Model

But if declining then logistic not proper conceptual model
Why Are Some Populations Small

The declining species vs the small population paradigms

Thread 1: Effect of Smallness on persistence
Thread 2: Cause of smallness and its cure

Multiple Factors Affect Local Dynamics

Habitat loss
Pesticides
Ground squirrel control
Increased predation
Isolation
Disturbance

Small Population Leads to “extinction vortex”

• Close relatives mate more frequently (inbreeding)
• This leads to lower heterozygosity in offspring
• This exposes effects of semi-lethal recessive alleles
• Causing reduced fecundity and increased mortality
• Leading to further decline in population decline
Probabilistic Nature of Extinction

“The tools of the trade”

1. Demographic stochasticity
   the chance event of age- and gender-specific survival and reproduction

2. Environmental stochasticity
   the year-to-year variation in environmental conditions

3. Genetic variance effects
   loss of alleles by chance during intergenerational transfer and inbreeding

Demographic Stochasticity

- coin flips: what do you expect if n=6 vs n=600?

Result of large number of probabilistic events is predictable; small number is not.

Same with “individual fortunes” of animals
- gender at birth
- reproductive rate
- survival rate

(contrast with individual heterogeneity)

Effects on Population:
• \( \text{variance in } r \rightarrow \text{erratic swings in pop size} \rightarrow \text{ext rate} \)
  \( \text{var}(r) \) increases as \( N \) decreases
• mean time to ext increases with \( r \)

At what \( N \) does all this matter?

Environmental Stochasticity

Effect of env. fluctuations on demographic parameters
- direct and indirect effects

Differs from demographic stochasticity by being independent of population size

leads to same proportional increase or decrease in numbers regardless of \( N \)

Includes fluctuations and catastrophes (think of pdf) separated by some

Can act in concert with demographic stochasticity

Example: Puerto Rican parrots and hurricane Hugo

Genetic Loss

Most voiced concern for small populations, probably inappropriate, but current dogma

Mechanisms of Genetic Loss

• Genetic drift
  Loss of alleles by chance during inter-generational transfer

• Inbreeding
  Loss of alleles by increase in homozygotes- freq of recessive phenotype increases in population
Genetic Loss

Genetic drift

Three rules:
1. The smaller the population (sample of gene freq), the greater the likely disparity in gene frequencies between the two generations.
2. The lower frequency of allele in parent generation, the more likely it is lost.
3. The higher frequency of a given allele the more likely it is to become fixed in the progeny generation.

Really only an issue at VERY SMALL N.

Role of immigration in countering drift?

Genetic Loss

Inbreeding

Production of offspring via matings of related individuals

Issue is inbreeding depression: production of inherited deleterious traits in progeny as a consequence of inbreeding

Shows up in fitness characteristics, by exposing recessive alleles.
Fitness characteristics include........??

Zoo vs studies of wild populations.
Relationship between inbreeding and inbreeding depression not clear.
An unfortunate dogma in conservation biology.

Genetic Loss

Some thoughts since Caughley’s paper.....

Inbreeding vs outbreeding: a dichotomy or a continuous trait?

Mechanisms of inbreeding depression

Inbreeding depression in wild populations

Role of supplementation

Loss of Social Structure:
A potentially critical aspect under-appreciated
Use of the Small-Population Paradigm on Wild Populations

Caughley argues few examples of “tools of the trade” of small population paradigm solving wild population declines

PVA: numerous attempts
• usually used when result is already known-popn at risk
• “Essentially games played with guesses…”
  •Primary value heuristic

Genetic effective population size invoked when demographic effective pop size more relevant

Some Thoughts from Caughley

“Temptation to focus on small population size as such carries the risk of missing the processes that reduced the size in the first place”

“It may not be logically possible to unite such disparate, messy and singular events within a neat and non-trivial theory. But the effort should be made even if ultimately unsuccessful. Even a negative result would be useful insight”

Some Thoughts from Caughley

“There is commonly a gap in the chain of logic stretching from a simple thought experiment to a management action. It skips at the point were a qualitative conclusion is applied in quantitative form to a specific problem....”

“The declining-population paradigm is urgently in need of more theory. The small-population paradigm needs more practice. Each has much to learn from the other. In combination they might enlarge our idea of what is possible.”

Population Viability Models

General principle

MVP

50/500 Rule

Exponential and Logistic Models

Structured Matrix Models

Individual-based Models
Sources of Variation

The importance of separating process and sampling variance from total variation