Genetic & Population Processes

1. Problem of small populations
2. Genetic processes
3. Uncertainty & extinction risk
4. Population viability analysis
5. Population dynamics in space
6. Checkerspot butterfly example
1. Problem of small populations

- Loss of genetic diversity
- Demographic variability
- Allee effects: extinction threshold
- Greater risk of extinction
2. Genetic processes

Why worry about genetics?

- rate evol. change $\propto$ genetic diversity
- fitness often correlates w/ heterozygosity
- potential to adapt to envt’l changes
- information value of genetic diversity

Conc: greater genetic diversity $\Rightarrow$ lower extinction risk
Basic concern:
small pops tend lose genetic variation over time

Main conclusion:
maintain genetic diversity
  – adapt future conditions
  – allow for evolution
Levels of Genetic Variation

• within individuals (heterozygosity)
• within populations (gene pool)
• among populations
Genetically Effective Pop. Size

\[ N_e = N \] of idealized pop. w/ same drift & inbreeding

Idealized pop:
- 1:1 sex ratio
- no selection
- even distribution of progeny

\[ N_e < N_{\text{census}} \] (usually)

e.g., grizzly bears (MT, WY, BC):

\[ N_e \approx \frac{1}{4N} \]
Loss of Genetic Diversity: Mechanisms

- Founder effects
  - few individuals establish population
- Demographic bottlenecks
  - temporary severe reduction in $N$
- Genetic drift
  - loss of alleles due to sampling error
- Inbreeding
  - mating of related individuals
Genetic Concerns: Summary

- Greatest concern in small isolated pops
  - endangered species
  - captive breeding programs
- Small pops lose genetic diversity
  \[ \sim \frac{1}{2N_e} \] per generation
- Small losses add up over generations
  \[ \rightarrow [1 - \frac{1}{2N_e}]^t \]
Exemptions & Caveats

N minima not always relevant

1. Spp needing large groups
   N >> genetic thresholds

2. Spp normally with:
   • low N
   • low genetic variation
   • frequent bottlenecks
Qualitative Guidelines
Meffe & Carroll, Table 6.10

1. \( N_e \): Large better than small (lose fewer alleles)
2. Avoid managing for small \( N \) (drift, inbreeding)
3. Manage for historical genetic processes
4. Avoid sudden or large losses of diversity
5. Avoid artificial selection in captivity
6. Avoid prolonged bottlenecks
7. Avoid outbreeding depression
8. Avoid introducing exotic alleles
9. Avoid selection in harvesting wild stocks
10. Genetic diversity: captive \( \neq \) wild
Limitations

1. Ecological management often cheapest & effective way to conserve genetic diversity
2. Genetic concerns usually after in critical danger
3. Expensive: usually only for charismatic spp

⇒ Address genetic concerns thru conservation @ higher levels
3. Uncertainty & extinction risk

4 Kinds of Uncertainty

1. Genetic
2. Demographic
3. Environmental
4. Catastrophic
Demographic Uncertainty

- Birth & death model (MacArthur & Wilson 1967)

\[
N_{t+1} = (B + b_t)N_t - (D + d_t)N_t
\]

\[
N_{t+1} = (R + r_t)N_t
\]

- Plot persistence time vs. \( N \)

\( \Rightarrow \) Large populations “immortal”
Catastrophic Uncertainty

- Extinction possible, even w/ exp. growth
- Shoulder of M-W model disappears
- Extinction times \( \approx \) exp. distributed
  \( \Rightarrow \) extinctions likely

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4. Population Viability Analysis

2 criteria:
• P{persistence}
• Persistence time

Process:
• Simulate demographic stochasticity
• Estimate demographic parameters (field data)
• Population simulations

Limitations:
• mostly large vertebrates
• rarely include envt’l variability, catastrophes
• rarely consider spatial structure or dispersal
## Estimated Extinction Times

<table>
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<tr>
<th>Species</th>
<th>$N_0$</th>
<th>Threshold</th>
<th>$\Delta t$ extinct</th>
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Evaluation of PVAs

- Appropriate time frame?
- Acceptable level of risk?
- Assumptions underlying simulations?
5. Population Dynamics in Space

- Source-sink structures
- Metapopulation dynamics
- Emerging principles
Source-Sink Structures

Definitions:  
- **source**: mean growth rate $> 0$
- **sink**: mean growth rate $< 0$

Source-sink system:

- source pop. grows to maximum density
- surplus individuals migrate to sink

Result:

- sink populations maintained by migration from sources
- if source reprod. surplus $> sink$ deficit, $N_{sink} > N_{source}$

  “Most individuals in local pop may exist in habitats that cannot maintain the population.”  – Pulliam 1988

Conclusion:

- Conservation should focus on source habitats
- ID sources from demographic data, not pop. density
Kinds of Patch Structure

- Classic metapopulation
- Isolated populations
- Single patchy population
- Mainland-island metapopulation

Symbols:
- Solid circle: occupied patch
- Empty circle: unoccupied patch
- Arrow: dispersal
Sea Surface Temperature, California coast, 5/93
Emerging Principles

1. Habitat thresholds for persistence
2. Connectivity; dispersal barriers → extinction
3. Extinction debt: habitat loss → delayed extinctions
4. Spatial heterogeneity → complex dynamics
5. Spatial structure can maintain spp diversity
development that simplifies or creates barriers
→ extinctions
6. Checkerspot Butterfly Example