Applied Population Biology

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Questions of Importance to Thorough Conservation Plans

- How should one determine if a specific conservation plan is likely to succeed?
- Given that natural populations generally fluctuate, how can additional disturbance caused by human activities be measured?
Answers Require Information of Many Sorts

- Environment
  - What habitat requirements exist?
  - How variable is the environment?
  - What human activities influence the environment?
Answers Require Information of Many Sorts

- Environment
- Distribution
  - How are individuals distributed within their habitat?
  - Is new habitat colonized?
  - Does movement or migration occur among habitat patches?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
  - What interspecific interactions exist?
  - How have human activities influenced interspecific interactions?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
  - What is the shape, size, color of body parts?
  - What is the function of body parts?
  - Is there geographic variation in morphology?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
- Physiology
  - What energy, water, and mineral requirements exist?
  - How is environmental stress managed?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
- Physiology
- Demography
  - What is the current population size, how has it changed in the past?
  - How might population size change in the future?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
- Physiology
- Demography
- Behavior
  - What behaviors of an individual allows it to survive and reproduce?
  - How do individuals interact with each other?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
- Physiology
- Demography
- Behavior
- Genetics

  - How much variation exists in morphological, physiological, and behavioral traits?
  - How much of that variation is influenced by genetic differences among individuals?
  - What fraction of the genome is variable and how variable is the variable component?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
- Physiology
- Demography
- Behavior
- Genetics
- Human interaction
  - How do human activities influence the species?
  - What is known by local people?
Answers Require Information of Many Sorts

- Environment
- Distribution
- Biotic interactions
- Morphology
- Physiology
- Demography
- Behavior
- Genetics
- Human interaction
Sources of Information

- Published scientific literature
- Agency and NGO reports
- Fieldwork and monitoring
  - inventories
    - count of individuals present
    - typically covers all individuals
  - surveys
    - repeatable sampling design to estimate population size
    - typically covers subset of individuals
  - demography
    - histories of known (e.g., marked) individuals
    - estimates of growth, survival, and reproduction
    - projections of population structure possible
Using Information to Improve Management: Population Viability Analysis (PVA)

Need: quantify outcome under “what if . . .” conditions

- Mathematical population model, including management-based parameters
- Exploration of parameter space: alternative management options
- Quantitative assessment of alternative management scenarios in terms of
  - mean time to an event
    - extinction
    - reach a management goal
  - probability of an event within $N$ years
    - extinction
    - population size above or below a threshold
PVA Example: *Caretta caretta*

- Declining loggerhead turtle (*Caretta caretta*) populations
- Major mortality of eggs and hatchlings
- Extensive effort managing nesting beaches
- Is this the right management strategy?
- Are there other management actions that would be better?
PVA Example: *Pedicularis furbishiae*
PVA Example: *Pedicularis furbishiae*

*Figure 1. Map showing range of Pedicularis furbishiae and locations of populations studied in detail from 1983 to 1986 (open circles).*
PVA Example: *Pedicularis furbishiae*

Table 1. Year-to-year variation in mean (and standard error) of demographic parameters representing survival and growth. Standard errors represent variation among populations (3 for 1983–84, 15 for other years).

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>1983–84</th>
<th>1984–85</th>
<th>1985–86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling</td>
<td>Juvenile</td>
<td>33.3 (7.3)</td>
<td>39.0 (2.7)</td>
<td>30.6 (3.5)</td>
</tr>
<tr>
<td>Juvenile</td>
<td>Vegetative</td>
<td>12.3 (3.1)</td>
<td>21.1 (1.6)</td>
<td>15.6 (1.6)</td>
</tr>
<tr>
<td>Juvenile</td>
<td>Small repro.</td>
<td>6.4 (0.9 )</td>
<td>10.9 (1.9)</td>
<td>3.4 (0.7 )</td>
</tr>
<tr>
<td>Vegetative</td>
<td>Small repro.</td>
<td>35.6 (2.9)</td>
<td>45.1 (2.8)</td>
<td>35.2 (4.1)</td>
</tr>
<tr>
<td>Vegetative</td>
<td>Medium repro.</td>
<td>8.3 (1.0 )</td>
<td>10.8 (1.9)</td>
<td>7.1 (1.8 )</td>
</tr>
<tr>
<td>Small repro.</td>
<td>Medium repro.</td>
<td>8.0 (2.0 )</td>
<td>21.3 (4.4)</td>
<td>16.3 (3.0)</td>
</tr>
</tbody>
</table>
Table 4. Transition matrix, 1984–85, all populations (lambda = 1.27). Values in parentheses are standard errors over 15 populations.

<table>
<thead>
<tr>
<th>TO:</th>
<th>Seedling</th>
<th>Juvenile</th>
<th>Vegetative</th>
<th>Reproductive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Juvenile</td>
<td>0.39</td>
<td>0.47</td>
<td>0.14</td>
<td>2.45</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(1.64)</td>
</tr>
<tr>
<td>Vegetative</td>
<td>0.01</td>
<td>0.21</td>
<td>0.24</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Small repro.</td>
<td>—</td>
<td>0.11</td>
<td>0.45</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Medium repro.</td>
<td>—</td>
<td>0.00</td>
<td>0.11</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Large repro.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.01)</td>
</tr>
</tbody>
</table>
PVA Example: *Pedicularis furbishiae*

Table 5. Population viability (finite rate of increase, lambda, at equilibrium), based on different years’ data. *P. furbishiae* populations are ordered by lambda based on 1984–85; note different ordering in other years.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferry Landing</td>
<td>—</td>
<td>1.81</td>
<td>1.67</td>
</tr>
<tr>
<td>Fox Brook South</td>
<td>—</td>
<td>1.71</td>
<td>1.00</td>
</tr>
<tr>
<td>Negro Brook</td>
<td>—</td>
<td>1.64</td>
<td>1.02</td>
</tr>
<tr>
<td>St. Paul</td>
<td>—</td>
<td>1.39</td>
<td>1.10</td>
</tr>
<tr>
<td>Jandrea</td>
<td>—</td>
<td>1.36</td>
<td>1.00</td>
</tr>
<tr>
<td>Fort Kent</td>
<td>0.68</td>
<td>1.27</td>
<td>0.94</td>
</tr>
<tr>
<td>Cono Burner</td>
<td>—</td>
<td>1.24</td>
<td>0.96</td>
</tr>
<tr>
<td>Fox Brook Ledges</td>
<td>—</td>
<td>1.16</td>
<td>1.18</td>
</tr>
<tr>
<td>Wesley Veratrum</td>
<td>—</td>
<td>1.05</td>
<td>0.88</td>
</tr>
<tr>
<td>Hamlin</td>
<td>—</td>
<td>1.05</td>
<td>1.12</td>
</tr>
<tr>
<td>Gardner’s New</td>
<td>—</td>
<td>1.04</td>
<td>0.95</td>
</tr>
<tr>
<td>Gardner’s Old</td>
<td>0.76</td>
<td>1.03</td>
<td>0.90</td>
</tr>
<tr>
<td>Wiggins</td>
<td>—</td>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td>St. Francis</td>
<td>0.64</td>
<td>0.98</td>
<td>0.58</td>
</tr>
<tr>
<td>Wesley Ledges</td>
<td>—</td>
<td>0.92</td>
<td>0.92</td>
</tr>
</tbody>
</table>

\(^a\)No analytical tests of significance are yet possible for lambda, because it is a derived, multivariate value. The method of Lande (1988) assumes independently varying matrix elements, patently unreasonable for this species. The data were not collected in a way to allow jackknifing and boot-strapping methods (H. Caswell, personal communication).
Table 7. Probabilities of individual population survival (using model protocol described under methods), adding various probabilities of natural catastrophe, for three cover classes. Simulations include within-population environmental stochasticity.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>6%</th>
<th>2%</th>
<th>0.5%</th>
<th>0.1%</th>
<th>0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983–86, all</td>
<td>0.00</td>
<td>0.09</td>
<td>0.57</td>
<td>0.92</td>
<td>1.00</td>
</tr>
<tr>
<td>1985–86,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low cover</td>
<td>0.00</td>
<td>0.16</td>
<td>0.53</td>
<td>0.93</td>
<td>1.00</td>
</tr>
<tr>
<td>Intermediate cover</td>
<td>0.00</td>
<td>0.06</td>
<td>0.34</td>
<td>0.42</td>
<td>0.66</td>
</tr>
<tr>
<td>High cover</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Metapopulations

- **Defining characteristic**
  - shifting mosaic of populations (≡ subpopulations)
  - linked to some degree by migration
  - locally extinct subpopulations are recolonized

- **Types of metapopulations**
  - equivalent, short-lived populations: e.g., *Pedicularis furbishiae*
  - source, sink populations with extinction
    - one of more large, persistent population(s)
    - remaining small, transient populations
    - recolonization of extinct transient populations by colonists from persistent population
  - source, sink populations with rescue: e.g., California peregrine falcons
    - one of more large, persistent population(s)
    - remaining small, not transient, but not self-sufficient populations
    - small populations rescued by colonists from large population