Population Dynamics

Previous chapter dealt with populations at any point in time – we are now ready to discuss the dynamics of population change over time

- Estimating Patterns of Survival – 3 ways
  
  - Most reliable is to count the number of individuals born at a given period of time and follow them until their death
    
    - Cohort – a group born at the same time
    
    - Cohort Life Table – a table produced from the data above, these are very easy to interpret but difficult to obtain the data (why?)
Population Dynamics

- Record the age a death (born at different times) – data used to produce a static life table – aging of individuals can be done in various ways
  - Tagging at birth
  - Teeth
  - Corpus albicans
  - Rings
    - Trees
    - Carapace
    - Horns and tusks

- Age Distribution – look at a total population and tally the number of individuals alive at each age group – calculational methods are used to estimate the chance of survival to the next age group (assumes a decrease in numbers is the result of mortality)
Population Dynamics

- High Survival Among the Young – Murie (1944) studied Dall sheep

To allow comparisons to other studies, number of Dall sheep surviving and dying within each year of life is converted to numbers per 1,000 births.

Subtracting number of deaths from number alive at the beginning of each year gives the number alive at the beginning of the next year.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Number of survivors at beginning of year</th>
<th>Number of deaths during year</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>1,000</td>
<td>199</td>
</tr>
<tr>
<td>1-2</td>
<td>801</td>
<td>12</td>
</tr>
<tr>
<td>2-3</td>
<td>789</td>
<td>13</td>
</tr>
<tr>
<td>3-4</td>
<td>776</td>
<td>12</td>
</tr>
<tr>
<td>4-5</td>
<td>764</td>
<td>30</td>
</tr>
<tr>
<td>5-6</td>
<td>734</td>
<td>etc. 46</td>
</tr>
<tr>
<td>6-7</td>
<td>688</td>
<td>48</td>
</tr>
<tr>
<td>7-8</td>
<td>640</td>
<td>69</td>
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<td>8-9</td>
<td>571</td>
<td>132</td>
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<tr>
<td>9-10</td>
<td>439</td>
<td>187</td>
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<td>10-11</td>
<td>262</td>
<td>156</td>
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<td>11-12</td>
<td>96</td>
<td>90</td>
</tr>
<tr>
<td>12-13</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>13-14</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>14-15</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Dall sheep: lifetable.

Plotting age on the x-axis and number of survivors on the y-axis creates a survivorship curve.

Dall sheep surviving their first year of life have a high probability of surviving to about age 9.

Sheep 10 years old and older are easier prey for wolves and die at a high rate.

Dall sheep: survivorship curve.
Population Dynamics

Despite going through a more diverse set of life stages, the annual plant *Phlox drummondii* shows a pattern of survival similar to Dall sheep.

High rates of survival among the young in plant and rotifer populations.

A similar pattern of survival by the rotifer, *Floscularia conifera*, is complete within 11 days.

Survival by *P. drummondii* is played out in less than a year.
Population Dynamics

- Constant Survival Rates – seen in many birds and turtles

**Constant rates of survival.**

- White-crowned sparrow
- American robin

Like many other bird species, white-crowned sparrows and American robins show approximately, constant rates of mortality.

Common mud turtle populations are also subject to approximately constant rates of mortality.
Population Dynamics

- High Mortality Rate Among the Young

**A high rate of mortality among the young of a perennial plant population.**

- The vertical scale has been extended so that survivors appear on the graph.
- In a population of *Cleome droserifolia* only 39 plants survive to 1 year of age out of each 1 million seeds.
Population Dynamics

- Three Types of Survivorship Curves

**Three types of survivorship curves.**

- **Type I survivorship:** Juvenile survival is high and most mortality occurs among older individuals.

- **Type II survivorship:** Individuals in a population with type II survivorship die at equal rates, regardless of age.

- **Type III survivorship:** Individuals showing type III survivorship die at a high rate as juveniles and then at much lower rates later in life.
Population Dynamics

- Stable and Declining Tree Populations

The age distribution of a white oak, *Quercus alba*, population in Illinois.

![Age distribution of white oak population](chart)

- The age structure of this population of white oaks shows that older trees are being replaced by young trees.
- This population of white oaks is dominated by young individuals.

The age distribution of a population of Rio Grande cottonwoods.

![Age distribution of cottonwood population](chart)

- The age structure of this population shows that older trees are not being replaced by young trees.
- 40- to 50-year-old trees dominate this population.

The absence of young trees suggests that this population will not persist.
Population Dynamics

A Dynamic Population in a Variable Climate

- A fairly even distribution of individuals among several age classes suggests several years of successful reproduction.
- Six-year-old finches are absent because the birds did not nest during the 1977 drought.
- Droughts in 1984 and 1985 prevented nesting.
- The population is dominated by birds hatched during the abundant rains of 1983.
- The 1977 reproductive failure is still evident.
- Droughts of 1984 and 1985 reduced numbers of older birds.
Population Dynamics

To fully understand population dynamics we need to look at not only survival rates but also reproductive rates.

Reproductive Rate = the number of young produced per unit time

For a population we need to know the

average number of young produced / female

And

the number of females in each age class
Population Dynamics

We can combine birth rate and survivorship data to predict whether a population is increasing or decreasing.

Net Reproductive Rate = the average number of offspring produced by and individual

Geometric Rate of Increase - seen in non-overlapping generations, it is an estimate of the rate of population growth (the ratio of population growth at two points in time)
## Population Dynamics

### Estimating Rates for an Annual Plant

Table 10.1

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Number surviving to day x</th>
<th>Proportion surviving to day x</th>
<th>Average number of seeds per individual during time interval</th>
<th>Multiplication of $l_x$ and $m_x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>$n_x$</td>
<td>$l_x$</td>
<td>$m_x$</td>
<td>$l_xm_x$</td>
</tr>
<tr>
<td>0–299</td>
<td>996</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>299–306</td>
<td>158</td>
<td>0.1586</td>
<td>0.3394</td>
<td>0.0532</td>
</tr>
<tr>
<td>306–13</td>
<td>154</td>
<td>0.1546</td>
<td>0.7963</td>
<td>0.1231</td>
</tr>
<tr>
<td>313–20</td>
<td>151</td>
<td>0.1516</td>
<td>2.3995</td>
<td>0.3638</td>
</tr>
<tr>
<td>320–27</td>
<td>147</td>
<td>0.1476</td>
<td>3.1904</td>
<td>0.4589</td>
</tr>
<tr>
<td>327–34</td>
<td>136</td>
<td>0.1365</td>
<td>2.5411</td>
<td>0.3470</td>
</tr>
<tr>
<td>334–41</td>
<td>105</td>
<td>0.1054</td>
<td>3.1589</td>
<td>0.3330</td>
</tr>
<tr>
<td>341–48</td>
<td>74</td>
<td>0.0743</td>
<td>8.6625</td>
<td>0.6436</td>
</tr>
<tr>
<td>348–55</td>
<td>22</td>
<td>0.0221</td>
<td>4.3072</td>
<td>0.0951</td>
</tr>
<tr>
<td>355–62</td>
<td>0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Data from Leverich and Levin 1979.

The value of $R_0$, which is greater than 1.0, indicates that this population of *P. drummondii* is growing.

$R_0 = \sum l_xm_x = 2.4177$

Each individual leaves an average of 2.4177 offspring.

Summing the final column yields $R_0$, the net reproductive rate per individual.
Population Dynamics

The geometric rate of increase, $\lambda$, is the ratio of numbers at a later time, $N_{t+1}$, to numbers at an earlier time, $N_t$.

\[ \lambda = \frac{N_{t+1}}{N_t} \]

Previous Example
(P. drummondii)

\[ \lambda = \frac{N_{t+1}}{N_t} \]

\[ N_{t+1} = 2.4177 \times 996 \]

2,408

2,408 / 996

2.4177
Estimating Rates When Generations Overlap

- **Example: Mud Turtle**
  - about ½ nest each year (.507)
  - nest on average 1/yr some 2 or 3 times (ave. 1.2)
  - average clutch size = 3.17
  - average # eggs/yr = (3.17)(1.2) = 3.8
  - since only .507 nest/yr
    - (3.8)(.507) = 1.927 eggs/yr/female
  - ratio of eggs is typically 50/50
    - therefore (1.927)(.5) = 0.96 female eggs

- **Generation Time**
Population Dynamics

The common mud turtle's generation time is close to that of other organisms of similar size.
Population Dynamics

- Per Capita Rate of Increase = \( r = b - d \)

\[
r = \frac{\ln R_0}{T}
\]

\[
\ln(.601)/10.6 = -.05
\]

Being negative, this indicates that the population is decreasing
Dispersal

• African Bees
  
  – Honeybees (Apis melifera) evolved in Africa and Europe and have since differentiated into many locally adapted subspecies.

  • Africanized honeybees disperse much faster than European honeybees.
    
    – Within 30 years occupied most of South America, Mexico, and all of Central America.
Cold winter temperatures will likely halt the northern spread of Africanized bees.

Africanized bees have not permanently colonized South America south of 34° S latitude.
Collared Doves

- *Streptopelia decaocto* spread from Turkey into Europe after 1900.
  - Dispersal began suddenly.
    - Not influenced by humans.
    - Took place in small jumps.
      - 45 km / yr
In less than 60 years collared doves expanded their range to the farthest corners of Europe.

Most collared dove fledglings disperse a few kilometers.

Collared doves began to spread out of Turkey into Europe early in the twentieth century.

But some disperse hundreds of kilometers.
Africanized bees spread across the Americas 10 times faster than...

...the rate of expansion by collared doves across Europe, which was 100 times faster than...

...the rate of expansion of elk across New Zealand.
Rapid Changes in Response to Climate Change

- Organisms began to spread northward about 16,000 years ago following retreat of glaciers and warming climate.
  
  - Evidence found in preserved pollen in lake sediments.

  - Movement rate 100 – 400 m/yr.
Maple reached the northeastern part of its present range about 6,000 years ago.

In contrast, hemlock did not reach its present range limits until just 2,000 years ago.

Maple spread north and east from the southwestern part of its range.

Hemlock spread north and west from the southeast.
Dispersal in Response to Changing Food Supply

- *Holling*, studied the relationship between cocoon abundance and the effect on mice and shrew populations, observed numerical responses to increased prey availability.
  - Increased prey density led to increased density of predators.
    - Increase in reproductive rate
    - Individuals move into new areas in response to higher prey densities.
Korpimäki and Nordahl (1991)

Kestrel and owl densities closely follow variation in vole densities in western Finland.
Dispersal in Rivers and Streams

- Stream dwellers have mechanisms to allow them to maintain their stream position.
  - Streamlined bodies
  - Bottom-dwelling
  - Adhesion to surfaces

- Tend to get washed downstream in spates.

- Muller hypothesized pops. are maintained via dynamic interplay between downstream and upstream dispersal.
In the colonization cycle, upstream and downstream dispersal and reproduction have major influences on stream populations.

Many organisms engage in upstream movements that appear to compensate for downstream drift.

Drift moves organisms downstream, sometimes actively as behavioral drift, sometimes passively with floods.