Week 12.
Survivorship: resource cycling

- Lecture summary:
  - Resource cycles:
    - Water.
    - Carbon.
  - Fertilizers & pollution.
  - Harvesting resources.
  - Sustainability.

http://attra.ncat.org/attra-pub/nutcycle.html
2. Biogeochemical cycles:

- Terrestrial and aquatic ecosystems are linked much as in Fig. 19.2.
- Within these links, the primary resources of water, phosphorus, nitrogen, sulfur and carbon circulate as in Figs 19.12, 19.13 & 19.14.
3. Water cycle (values as $10^{17}$ kg water):

- **Atmosphere**: 0.15
- **Run-off**: 0.37
- **Precipitation**: (1.08) from Atmosphere, (4.49) from Ocean
- **Evaporation**: (0.71) from Atmosphere, (4.12) from Ocean

Ecological cycle:
- **Lithosphere**: 250,000
  - Sedimentary rocks: 2,100
- **Ice**: 255
- **Ground water**: 76.5
- **Surface water**: 2.04

Ocean water: 13,800

95%
4. Carbon cycle:
5. Monthly variations in atmospheric CO$_2$ concentrations at Mauna Loa Observatory, Hawaii:
7. Predicted environmental change from doubled CO$_2$:

<table>
<thead>
<tr>
<th>Degree of Confidence$^a$</th>
<th>Predicted Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>The lower atmosphere and Earth’s surface warm</td>
</tr>
<tr>
<td>****</td>
<td>The stratosphere cools</td>
</tr>
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<td>***</td>
<td>Near the Earth’s surface, the global average warming lies between +1.5°C and +4.5°C, with a “best guess” of 2.5°C</td>
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<tr>
<td>***</td>
<td>The surface warming at high latitudes is greater than the global average in winter, but smaller than in summer (in time-dependent simulations with a deep ocean, there is little warming over the high-latitude ocean)</td>
</tr>
<tr>
<td>***</td>
<td>The surface warming and its seasonal variation are least in the tropics</td>
</tr>
<tr>
<td>Precipitation</td>
<td>The global average increases (as does that of evaporation); the larger the warming, the larger the increase</td>
</tr>
<tr>
<td>****</td>
<td>Increases at high latitudes throughout the year</td>
</tr>
<tr>
<td>***</td>
<td>Increases globally by 3 to 15 percent (as does evaporation)</td>
</tr>
<tr>
<td>**</td>
<td>Increases at midlatitudes in winter</td>
</tr>
<tr>
<td>**</td>
<td>The zonal mean value increases in the tropics, although there are areas of decrease; shifts in the main tropical rain bands differ from model to model, so there is little consistency between models in simulated regional changes</td>
</tr>
<tr>
<td>**</td>
<td>Changes little in subtropical arid areas</td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>Increases in high latitudes in winter</td>
</tr>
<tr>
<td>**</td>
<td>Decreases over northern midlatitude continents in summer</td>
</tr>
<tr>
<td>Snow and Sea Ice</td>
<td>The area of sea ice and seasonal snow cover diminish</td>
</tr>
</tbody>
</table>

$^a$ The number of stars indicates the degree of confidence, five stars indicating virtual certainty and one star low confidence in the prediction.

8. Pollution and pesticides:

- Product of anthropogenic impact on biogeochemical cycles plus waste generation, fossil fuel use, pesticides and fertilizer application:

  - "Environmental pollution is the unfavorable alteration of our surroundings, wholly or largely as a by-product of man’s actions, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution, and abundances of organisms. These changes may affect man directly, or through his supplies of water and of agricultural and other biological products, his physical objects or possessions, or his opportunities for recreation and appreciation of nature."

9. Harvesting, fishing, shooting & culling:

- Harvesting can reduce intraspecific competition and so increase yield through increased survivorship and fecundity of remaining individuals.

- **Maximum sustainable yield (MSY):**
  - Represents the maximum ideal.

- **“Fixed-quota” harvesting:**
  - Based on a typical n-shaped recruitment curve.
10. Harvesting, fishing, shooting & culling:

• **“Fixed-quota” harvesting:**
  – High quotas drive the population to extinction
  – Medium quotas have a single equilibrium
    • The MSY (the maximum rate of recruitment) = fragile equilibrium that can shift easily
  – Low quotas have two equilibria:
    • One low & unstable
    • The other high & stable
  – Risky because MSY ignores age structure, habitat variability, or reliability of MSY and fixed quota harvesting commonly leads to extinction *(Fig. 16.13).*
11. Harvesting, fishing, shooting & culling:

• “Fixed-effort” harvesting:
  – Can reduce risk associated with fixed quotas because equilibria are stable.
  – As long as effort is not increased to harvest faster than the MSY can be attained.
  – But multiple equilibria can lead to extinction. (Figs 16.15 & 16.16).
  – Density-independent abiotic events like El Niños can also influence population crashes (Figs. 16.13 & 16.17).
12. Sustainability:

• “Sustainability has rightly become one of the core concepts - perhaps the core concept - in an ever-broadening concern for the fate of the earth and the ecological communities that occupy it.” .... “...achieving sustainability will require the advances made by ecologists in years to come.”

 – Begon et al. (2006), page 439.
Figure 19.2: Components of nutrient budgets of terrestrial and aquatic systems.
Figure 19.12: Hydrological cycle.
Figure 19.13: Major global pathways of nutrients between abiotic and biotic reservoirs.
Figure 19.14:

Four main pathways of nutrient flux (black arrows) and human perturbations (orange arrows).
### Table 16.6

Effects produced in populations of the blowfly *Lucilia cuprina* by the destruction of different constant percentages of emerging adults. (After Nicholson, 1954b.)

<table>
<thead>
<tr>
<th>Exploitation rate of emerging adults (%)</th>
<th>Pupae produced per day ((a))</th>
<th>Adults emerged per day ((b))</th>
<th>Mean adult population ((c))</th>
<th>Mean birth rate (per individual per day) ((a/c))</th>
<th>Natural adult deaths per day ((d))</th>
<th>Adults destroyed per day ((e = b - d))</th>
<th>Accessions of adults per day ((c/e))</th>
<th>Mean adult life span (days) ((c/e))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>624</td>
<td>573</td>
<td>2520</td>
<td>0.25</td>
<td>573</td>
<td>0</td>
<td>573</td>
<td>4.4</td>
</tr>
<tr>
<td>50</td>
<td>782</td>
<td>712</td>
<td>2335</td>
<td>0.33</td>
<td>356</td>
<td>356</td>
<td>356</td>
<td>6.6</td>
</tr>
<tr>
<td>75</td>
<td>948</td>
<td>878</td>
<td>1588</td>
<td>0.60</td>
<td>220</td>
<td>658</td>
<td>229</td>
<td>7.2</td>
</tr>
<tr>
<td>90</td>
<td>1361</td>
<td>1260</td>
<td>878</td>
<td>1.55</td>
<td>125</td>
<td>1134</td>
<td>126</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Figure 16.11: Fixed-quota harvesting based on n-shaped recruitment curve.
Figure 16.13: Harvested declines in (a) Antarctic baleen whales and (b) Peruvian anchoveta.
Figure 16.14: Fixed-effort harvesting.
Figure 16.15: Multiple harvesting equilibria for (a) low recruitment at low density (like the Allee effect), (b) density dependent decrease in harvesting efficiency.
Figure 16.16: Decline in North Sea herring.
Figure 16.17: Fluctuations in north Atlantic herring populations.
24. References: