Ecology

(Freeman Chs 50, 52-53)

11 March 2010
ECOL 182R UofA
K. E. Bonine

Video: browser
Lecture Schedule (middle third)

18 Feb KB - Fungi, Ch31

23 Feb KB - Prokaryotes & Protists, Ch28&29
25 Feb KB - Plant Diversity, Form, Function, Ch30&40

2 Mar KB - Plant Form and Function, Ch36&37
4 Mar KB - Plant Function, Ch38&39

9 Mar KB - Plant Ecology, Ch50,52,53
11 Mar KB - Ecology, Ch50,52,53

13-21 Mar Spring Break

23 Mar KB - Biology of the Galapagos
            Wikelski 2000 and http://livinggalapagos.org/
25 Mar KB - Part 2. Discussion and Review.

30 Mar KB - EXAM 2
Ecology

\[ \frac{dN}{dt} = rN \]

\[ \frac{dN}{dt} = rN \left( \frac{K-N}{K} \right) \]

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What would an ecologist say about this picture?
What is Ecology?

• Study of the distribution and abundance of organisms.

• Study of the myriad interactions among organisms and their environment.

• Includes both biotic and abiotic interactions/components.
Distribution and Abundance

• Primary Driver is ________
  - Temperature
  - Precipitation
  - weather is short-scale climate

• Secondary Drivers:
  - Resources
  - Competition
  - Predation (interspecific interactions)
One tree in _____ with same ant diversity as Britain
FIGURE 3.5 In North America, as in all the continents, the numbers of bird, tree, and mammal species increase toward the Tropics. The numbers of species indicated in the bar graphs correspond to latitude in the map at left. Tree species diversity is not available for some lower latitudes. (From Briggs 1995.)
[Phylogeny and Biogeography]

- Also important drivers of distribution and abundance

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ROLES
What else explains some of the observed patterns of species' distribution and abundance?

• **Populations**
  - Life-history strategies
  - *Intraspecific* interactions

• **Communities**
  - *Interspecific* interactions
Population: individuals of the same species & actually

Population sizes change over time!
**Community**: all species living in the place at the same time.

Also Dynamic
Dynamics differ enormously across populations and species.
Age Structure Diagram

Humans in Australia
Life History Variation
Life History Variation
Unlimited Growth

Bacteria:
• Binary fission (1 cell → 2 cells)
• Pop. can ___ every 1/2 hour
• > 1 million after 10 hours!

<table>
<thead>
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<th>#</th>
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<tbody>
<tr>
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<td>0.5</td>
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</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1.5</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>65,536</td>
</tr>
<tr>
<td>10</td>
<td>1,048,576</td>
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</table>
Unlimited Growth

<table>
<thead>
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<tr>
<td>0 minutes</td>
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<tr>
<td>20</td>
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<tr>
<td>40</td>
<td>4 = $2^2$</td>
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<td>16 = $2^4$</td>
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<td>100</td>
<td>32 = $2^5$</td>
</tr>
<tr>
<td>120 (= 2 hours)</td>
<td>64 = $2^6$</td>
</tr>
<tr>
<td>3 hours</td>
<td>512 = $2^9$</td>
</tr>
<tr>
<td>4 hours</td>
<td>4096 = $2^{12}$</td>
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<td>8 hours</td>
<td>16,777,216 = $2^{24}$</td>
</tr>
<tr>
<td>12 hours</td>
<td>68,719,476,736 = $2^{36}$</td>
</tr>
</tbody>
</table>

Exponential growth; the exponential curve.
Unlimited Growth

Exponential growth:
- constant doubling time
- growth rate.
Exponential Vs. Arithmetic

FIGURE 6.2  Arithmetic and geometric growth curves. Note that the geometric or exponential curve grows more slowly at first, but then accelerates past the arithmetic curve, which grows at a steady incremental pace throughout.
Exponential growth

\[ \frac{dN}{dt} = N (b - d) \]

(if you prefer, \( \frac{\Delta N}{\Delta t} \))

Maximum \((b - d)\) for a pop. is its intrinsic rate, \(r\).

\[ \frac{dN}{dt} = r N \]
Biotic Potential...

### TABLE 6.2

**Biotic Potential of Houseflies**

*(Musca domestica)* **in One Year**

Assume that a female lays 120 eggs per generation, half of the offspring are females, and all offspring live long enough to reproduce.

<table>
<thead>
<tr>
<th>DAYS</th>
<th>TOTAL POPULATION</th>
</tr>
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<tbody>
<tr>
<td>56</td>
<td>120</td>
</tr>
<tr>
<td>112</td>
<td>7,200</td>
</tr>
<tr>
<td>168</td>
<td>432,000</td>
</tr>
<tr>
<td>224</td>
<td>25,920,000</td>
</tr>
<tr>
<td>280</td>
<td>1,555,200,000</td>
</tr>
<tr>
<td>336</td>
<td>93,312,000,000</td>
</tr>
<tr>
<td>392</td>
<td>5,598,720,000,000</td>
</tr>
</tbody>
</table>


Exponential!
Why isn’t the universe full of flies?
Resources NOT unlimited

J vs. S

Exponential vs. Logistic

FIGURE 6.5  Idealized J and S population curves. The J curve represents theoretical unlimited growth. The S curve represents population growth and stabilization in response to environmental resistance.
FIGURE 6.4  Population oscillations. Some species demonstrate a pattern of cyclic overshoot and dieback.

K = carrying capacity
Exponential Vs. Logistic GROWTH

Pop. growth rate = exponential growth rate
× a factor that slows growth as pop. approaches carrying capacity.

\[
\frac{dN}{dt} = (b - d)N \times \frac{(K - N)}{K}
\]

\[
= r, \quad K = \text{carrying capacity}
\]
To determine K we’d need to know:

(  = carrying  )

• What resources are required, in what amount
• Rates of resource renewal
• How much habitat is required
• Etc......
"r vs. K selected"

**TABLE 6.3 Characteristics of Contrasting Reproductive Strategies**

<table>
<thead>
<tr>
<th>EXTERNALLY CONTROLLED GROWTH</th>
<th>INTRINSICALLY CONTROLLED GROWTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Short life</td>
<td>1. Long life</td>
</tr>
<tr>
<td>2. Rapid growth</td>
<td>2. Slower growth</td>
</tr>
<tr>
<td>3. Early maturity</td>
<td>3. Late maturity</td>
</tr>
<tr>
<td>4. Many small offspring</td>
<td>4. Fewer large offspring</td>
</tr>
<tr>
<td>5. Little parental care or protection</td>
<td>5. High parental care and protection</td>
</tr>
<tr>
<td>6. Little investment in individual offspring</td>
<td>6. High investment in individual offspring</td>
</tr>
<tr>
<td>7. Adapted to unstable environment</td>
<td>7. Adapted to stable environment</td>
</tr>
<tr>
<td>8. Pioneers, colonizers</td>
<td>8. Later stages of succession</td>
</tr>
<tr>
<td>11. Regulated mainly by extrinsic factors</td>
<td>11. Regulated mainly by intrinsic factors</td>
</tr>
<tr>
<td>12. Low trophic level</td>
<td>12. High trophic level</td>
</tr>
</tbody>
</table>
Human Population

Miller 2003

Figure 1-1 The J-shaped curve of past exponential world population growth, with projections beyond 2100. Notice that exponential growth starts off slowly, but as time passes the curve becomes increasingly steep. The current world population of 6.1 billion people is projected to reach 7-14 billion sometime during this century. (This figure is not to scale.) (Data from World Bank and United Nations; photo courtesy of NASA)
Figure 14.3 Exponential growth results in a continuously accelerating curve of increase. The curve of exponential growth is shown for a population growing at rate $r$ between time $0$ and time $t$. During this period, the number of individuals increases from $N(0)$ to $N(t)$. Notice that the slope becomes steeper as the population increases. Ricklefs 2001

Figure 14.4 Logistic growth follows an S-shaped curve. The curve is symmetrical about the inflection point $K/2$; that is, accelerating and decelerating phases of population growth have the same shape.


VanDyke 2003

Figure 12.6 Thomas Malthus, an English cleric and economist, whose work. An Essay on the Principle of Population proposed that human populations were limited by environmental constraints and increased mortality.

The size of the human population passed the 6 billion mark on October 12, 1999. This reflects a doubling of the population that has taken only 40 years.
Exponential Growth \[ N = N_0 e^{kt} \]

- \( N \) = future population size at next time interval
- \( N_0 \) = population size at beginning of time interval
- \( e \) = 2.71828 (base of natural logarithms)
- \( k \) = rate at which population increases over time interval
- \( t \) = number of time intervals (usually years)

If \( k = 0.0136 \) (1.36% annual increase), and \( N_0 = 6.2 \) billion

what will population be in 20 years?

\[ N = (6.2 \times 10^9) \times e^{(0.0136 \times 20)} \]

\[ N = 8.14 \times 10^9 \text{ (8.14 billion)} \]
Exponential Growth

Doubling Time

\[ N = N_0 e^{kt} \]

\[ T_d = \frac{\ln 2}{k} \]

\[ T_d = \frac{0.693}{R/100} \]

\[ T_d = \frac{69.3}{R} \sim \frac{70}{R} \]

\[ R = \text{growth rate} \]

Therefore, \( k = \frac{R}{100} \)

(e.g., \( R = 1.36\% \))

**RULE OF 70...**

If \( R = 10\% \) then
\[ T_d = \frac{70}{10} = 7 \text{ years} \]

If \( R = 1.36\% \) then
\[ T_d = \frac{70}{1.36} = 51.5 \text{ years} \]
Metapopulation...

“Spatially disjunct groups of individuals with some demographic or genetic connection”

“largely independent yet interconnected by migration”

1. All local populations must be prone to extinction
2. Persistence of entire population requires recolonization of individual sites.

(p.193 in VanDyke text)

...a population of populations
Figure 5.16
Types of metapopulation models. In a classical metapopulation, (a) some colonies may not exhibit high rates of movement for long periods of time. Also, colonization may unite several patches within a larger patch as a single entity that contributes to other sinks. Colonies farthest from the source are most prone to extinction. The mainland-island metapopulation (b) depicts local extinctions occurring mainly among a subset of populations. The mainland/source, resistant to extinction, functions as the major provider of colonists. The island and sink metapopulations have little effect upon regional persistence. In patchy populations (c), because of the high levels of emigration and immigration, the patches function as a single unit. It is rare that discrete local populations become extinct. The absence or insufficiency of recolonization to balance extinction distinguishes nonequilibrium populations (d). Extinction of metapopulations occurs as part of an overall regional decline (i.e., a product of the reduction, fragmentation, or deterioration of a habitat).


Figure 5.17
A visual representation of the source-sink model of habitat distribution. In source habitats, reproduction produces a population surplus (i.e., mortality does not decrease the number of individuals because of overcompensation through reproduction). Surplus individuals move to sink habitats where mortality exceeds survivorship. Sink habitats cannot be maintained by reproduction, but depend on immigration to maintain a population.
Metapopulation Examples:

- Hydrothermal Vents
- Lowland Leopard Frogs (thanks to Don Swann)
Metapopulation Dynamics
Aspen Fire Continues To Burn In Arizona

CORONADO NATIONAL FOREST, AZ - JUNE 24: Plumes of smoke from the Aspen fire that burned 270 homes in Summerhaven on Mount Lemmon in the Santa Catalina Mountains are seen June 24, 2003 in the Coronado National Forest, in Arizona. The 20,000 acre wildfire is still spreading north and east, but is 15
Chytrid Fungus
Habitat-

Human Pinworm (Nematode)

Giraffe

MRSA

Thermus aquaticus

Methicillin-resistant Staphylococcus aureus

Taq polymerase

Canyon treefrog
The Niche

“Resources limit population growth ...”

Each species requires many specific resources:
- Food
- Water
- Shelter
- Range of OK abiotic conditions ...

...and plays specific roles in the ecosystem
The Niche

“Resources limit population growth …”

**Niche**: total range of abiotic & biotic conditions tolerated, used, and played.
The Niche

"Resources limit population growth ..."

**Niche**: total range of abiotic & biotic conditions tolerated, resources used, and roles played.
**Fundamental niche:**
niche that can be occupied.

**Realized niche:**
part of the fundamental niche that's occupied, in the presence of other species.

Axes shown are for saguaro. In reality, there are >>3 axes!!
Habitat vs. Niche

Which one is best described as an organism’s ______? Why?

Which one is best described as an organism’s ___? Why?
What could keep a species out of part of its fundamental niche?

- **Predators** in some OK sites.
- **Competitors** monopolizing some necessary resources.
PREDATION
Bio control example: Prickly pear, Australia

- Introduced 1839
- 1 potted plant
- No native enemies

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SQ KM</th>
<th>INFESTED</th>
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<td>1839</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1900</td>
<td>40,000</td>
<td>0</td>
</tr>
<tr>
<td>1920</td>
<td>90,600</td>
<td>0</td>
</tr>
<tr>
<td>1925</td>
<td>93,700</td>
<td>0</td>
</tr>
</tbody>
</table>
• Herbivore *Cactoblastis* moth introduced 1925.
• Plant nearly gone by 1940.
What’s so interesting about predation?

Predator & prey pop. growth aren’t independent.
Data from Canadian trapping records.

Why do they cycle?
Interactions between pairs of species are amazingly diverse.
Interspecific Interactions

Interactions between 2 species can

• benefit (+)
• harm (-)
• have no effect (0)

on each of them.
Interspecific Interactions

**Competition:**

Both do worse when together.
Competition

In nature, resources are limited in availability.

**Competition**: resource use by 1 individual that reduces its availability for others.
Competition

WHO competes?

A. **Intraspecific** comp: individuals of the **same** species.

- Comp. for mates
- Comp. for space
WHO competes?

B. **Interspecific** comp: individuals of **different** species.

Comp. for space & water
Competition

HOW does comp occur?

1. **Interference** comp: individuals have **direct** confrontations.
Competition

HOW does comp occur?

1. **Interference** comp: individuals have direct confrontations.

Dragonflies:
- 1st sperm in fertilizes female.
- 2nd male to mate w/ female scoops out 1st male’s sperm!
Competition

HOW does comp occur?

2. **Exploitation** comp: Indirect depletion of shared resources.
Interspecific interference

Interspecific exploitation

Intraspecific interference

Intraspecific exploitation
**Example:** How do 2 barnacle sp. coexist in the rocky intertidal zone?

Both do best in low wet zone.
**Example**: How do 2 barnacle sp. coexist in the rocky intertidal zone?

Both do best in low wet zone.

**Hypothesis**: the worse competitor gets pushed to high dry zone, but is able to hang on.
Example: How do 2 barnacle sp. coexist in the rocky intertidal zone?

Both do best in low wet zone.

Hypothesis: the worse competitor gets pushed to high dry zone, but is able to hang on.

Test: if better competitor is removed, does the poorer move into that area?
Yes. Removing the lower sp. causes the upper sp. to shift to the wet habitat (but not vice versa).
Attempted Predation & Interspecific Competition

http://www.youtube.com/watch?v=LU8DDYz68kM
## The Interaction Grid

<table>
<thead>
<tr>
<th>Effect on Species 2</th>
<th>Effect on Species 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>
Commensalism:

One does **better** when together; one is **unaffected**.
Amensalism:

One does **worse** when together; one is **unaffected**.
Interspecific Interactions

Antagonism:

There are many kinds of antagonistic interactions.

One does worse, one does better when together.
Forms of antagonism (±):

1. Predation

Killing + eating of prey by predator.
Forms of antagonism (-+):

1. Predation
2. **Herbivory**

Partial consumption of plants by animals.
Forms of antagonism (-+):

1. Predation
2. Herbivory
3. Parasitism

Partial consumption of animals by animals.

**Endoparasite:**
lives inside host

**Ectoparasite:**
feeds from the outside
Forms of antagonism (-+):

1. Predation
2. Herbivory
3. Parasitism
4. Pathogens

Microorganisms living & reproducing inside hosts & causing disease.
Interspecific Interactions

**Mutualism:**

Both do better when together.
Many Kinds of Mutualism

Mutualism:

Each species uses its mutualist to get things it requires to survive & reproduce.

Pollination mutualism
Animal: gets food.
Plant: gets pollen moved between flowers.
Many Kinds of Mutualism

Mutualism:

Each species uses its mutualist to get things it requires to survive & reproduce.

Seed dispersal mutualism
Animal: gets food.
Plant: gets seeds moved to good spot to germinate.
Many Kinds of Mutualism

Mutualism:
Each species uses its mutualist to get things it requires to survive & reproduce.

Protection mutualism
Ant: gets food.
Aphid: gains protection from antagonists.
Many Kinds of Mutualism

Mutualism:

Each species uses its mutualist to get things it requires to survive & reproduce.

Protection mutualism
Ant: gets food.
Cactus: gains protection from herbivores.
Mutualism: Each species uses its mutualist to get things it requires to survive & reproduce.

**Protection mutualism**
- **Cleaner:** gets food.
- **Host:** gets its ectoparasites removed.
Many Kinds of Mutualism

Mutualism: Each species uses its mutualist to get things it requires to survive & reproduce.

**Nutrition mutualism**
Plant: gets nutrients.
Bacteria: gains habitat.
Mutualism: Each species uses its mutualist to get things it requires to survive & reproduce.

Here, *Rhizobium* bacteria make N available to plant in usable form.
Many Kinds of Mutualism

This is a mutualism: partners are physiologically integrated.

Here, *Rhizobium* bacteria make N available to plant in usable form.
Many Kinds of Mutualism

Other mutualistic symbioses

lichens
coral
Most between-species interactions have parallels to **within**-species interactions.

**Altruism** (++)

**Intraspecific competition** (--)
Lots of species seem similar...
Coexistence

There must be mechanisms that permit similar species to coexist.

1. **Resource partitioning**
Splitting up of shared, limiting resources.

**Example:** varying root depths
Example: 5 warbler sp. on same insect food by feeding in different parts of the same tree.
Example: 5 warbler sp. coexist on same insect food by feeding in different parts of the same tree.

**Fund. niche** of each sp. = entire tree.

**Realized niche** of each sp = part of tree it actually feeds in.
Predator/Prey Dynamics
Influences Coexistence

What’s so interesting about predation?

Hypothesis:
Predators reduce prey #. So, more prey species can coexist on a limiting resource.

Test: remove predators.
• Space is the limiting resource.
• Space is the limiting resource.
• What happens if starfish removed?
Mussels

• What happens if starfish removed?
• Mussels outcompete, eventually exclude limpets.
Starfish = **keystone predators**. Their presence *increases* species diversity.
Keystone predator.

species plays larger in ecosystem than you would from numbers or biomass alone.