Previous Lecture

Populations Rarely Grow Exponentially Due to Limited Resources

Lecture 6

- Problem solving: Selecting the right equation
- Density dependence in nature
- 'r' and 'K' selection
- Density-dependence in species that vary greatly in size (e.g., plants, fish)
- Modifying the logistic to incorporate competition from other species.

Problem-solving Practice

Exponential Growth

Population Growth Rate: $\frac{dN}{dt} = rN$

Projecting N: $N_t = N_0 e^{rt}$

Note: you will NOT be given these equations for the test

Logistic Growth

Population Growth Rate: $\frac{dN}{dt} = r(\frac{K-N}{K})N$

Projecting N: $N_t = \frac{K}{1+\left(\frac{K}{N_0}-1\right)e^{-rt}}$

Note: you WILL be given these equations for the test

Sample Problem from 2010 midterm

- A population of coyotes has taken up residency at Coopers Rock State Forest. Predation, hunting, and car accidents have minimal effect on the coyote population dynamics. In addition, since wolves and mountain lions are no longer found at Coopers Rock, they are the top dog (apex) carnivore. But coyotes do respond to their own densities with territoriality in order to defend resources, so there is a limit to the maximum sustainable population size. Which equation, if solved appropriately, would allow you to determine amount of time it would take to go from 10 to 100 individuals, given the scenario described above?

A.	B.	C.	D.
$\frac{dN}{dt} = rN$	$N_t = N_0 e^{rt}$	$\frac{dN}{dt} = r(\frac{K-N}{K})N$	$N_t = \frac{K}{1+\left(\frac{K}{N_0}-1\right)e^{-rt}}$

Sample problem from 2011 midterm

- Dr. Peter C. Tail is studying population growth of rabbits that have been let loose on a small Caribbean island. Assuming density-dependent population growth, which of the following equations would best describe the population growth rate when a specific population size had been reached?

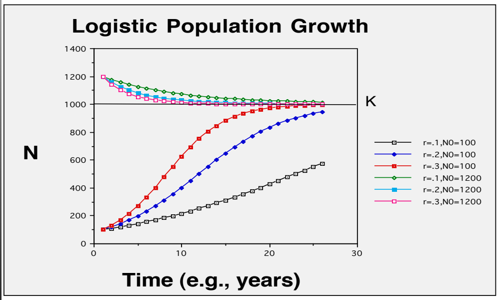
A.	B.	C.	D.
$\frac{dN}{dt} = rN$	$N_t = N_0 e^{rt}$	$\frac{dN}{dt} = r(\frac{K-N}{K})N$	$N_t = \frac{K}{1+\left(\frac{K}{N_0}-1\right)e^{-rt}}$

Sample Problem 2012 Midterm

- If the early phases of population growth in one defined stretch of the river showed no density-dependence and unconstrained population growth of the mud snail, which equation would best predict the instantaneous rate of change of the population size?

A.	B.	C.	D.
$\frac{dN}{dt} = rN$	$N_t = N_0 e^{rt}$	$\frac{dN}{dt} = r(\frac{K-N}{K})N$	$N_t = \frac{K}{1+\left(\frac{K}{N_0}-1\right)e^{-rt}}$

Logistic Population Growth



Limits on Population Growth in Nature

- **Density-dependent effects:**
- A. Direct effects of resource depletion:
  - decrease in birth rate,
  - increased starvation (increased death rate)

Limits on Population Growth (cont'd)

- B. Indirect effects
  - 1. Increased foraging effort required at high N
    - higher predation hazard for adults
    - higher death rate of young in the 'nest'

(even deer predate bird nests!)

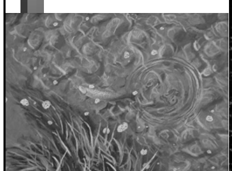
Indirect Effects (cont' d)

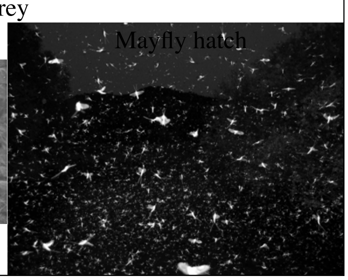
- 2. Increased time devoted to social interaction; territorial defense requires increased effort, at the expense of other activities

Elephant Seal Male

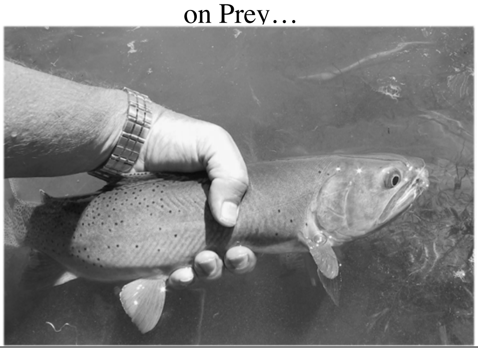
Indirect Effects (cont' d)

- 3. Predation rate (i.e., death rate) *per individual* may increase as predators 'key in' on abundant prey


Trout rising

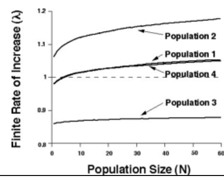

Mayfly hatch

Professors As Predators…Taking Advantage of Fish Predators Keying In on Prey…



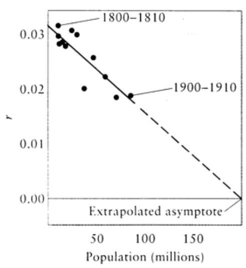
Limits on Population Growth (cont' d)

- Indirect effects:
  - 4. Inverse density-dependence*; at low N some organisms do worse - Allee Effect.
    - nurse plants in the deserts, tundra
    - reproductive limitation at low N- mates are found in insufficient numbers at low N



Logistic Growth in the 'Real World'

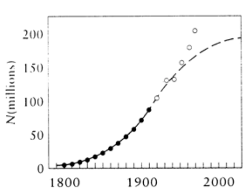
- Human population growth (U.S.):



Note: this extrapolation was incorrect; we have exceeded 320 million now!

Logistic Growth in Nature (cont' d)

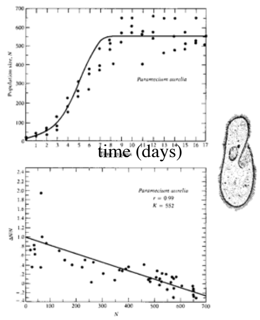
- Observed growth of N in U.S.



Logistic Growth in Paramecium

N

r

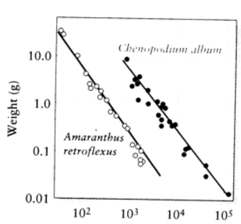


time (days)

Density-dependence in plants

- There is a law that describes density-dependence in plants: it is NOT logistic.
- -3/2 thinning rule:

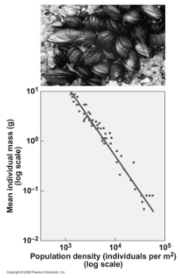
Sample Data (Density-dependence in Plants)

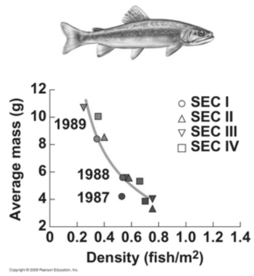


N

-3/2 thinning patterns for pigweed and lamb's quarters

Similar thinning rules occur with other ‘plastic’ species





However there is a controversy about the exponent in these relationships

Review

- Exponential growth - considers potential population growth rate
- Logistic growth - considers effects of intraspecific competition
- More advanced models - consider effects of two-species or higher-order interactions

Effect on Species 2 \ Effect on Species 1	-	0	+
-	Competition	Amensalism	Predation Parasitism
0		Neutral	Commensalism
+			Mutualism

Another View

Competition	Species 1	→ -	← -	Species 2
Amensalism	Species 1	→ -	← 0	Species 2
Predation/Parasitism	Species 1	→ -	← +	Species 2
Neutralism?	Species 1	→ 0	← 0	Species 2
Commensalism	Species 1	→ 0	← +	Species 2
Mutualism	Species 1	→ +	← +	Species 2

Testing Understanding

A. Competition	Species 1	→ -	← -	Species 2
B. Amensalism	Species 1	→ -	← 0	Species 2
C. Predation/Parasitism	Species 1	→ -	← +	Species 2
D. Commensalism	Species 1	→ 0	← +	Species 2
E. Mutualism	Species 1	→ +	← +	Species 2

Question: Removal of species 2 results in an increase in species 1, but removal of species 1 results no effect on species 2. What type of relationship do the two species have?

Testing Understanding

A. Competition	Species 1	→ -	← -	Species 2
B. Amensalism	Species 1	→ -	← 0	Species 2
C. Predation/Parasitism	Species 1	→ -	← +	Species 2
D. Commensalism	Species 1	→ 0	← +	Species 2
E. Mutualism	Species 1	→ +	← +	Species 2

Question: Removal of species 2 results in an increase in species 1, and removal of species 1 also results in an increase in species 2. What type of relationship do the two species have?

Testing Understanding

A. Competition — Species 1 ⇄ Species 2 (− / −)

B. Amensalism — Species 1 ⇄ Species 2 (− / 0)

C. Predation/Parasitism — Species 1 ⇄ Species 2 (− / +)

D. Commensalism — Species 1 ⇄ Species 2 (0 / +)

E. Mutualism — Species 1 ⇄ Species 2 (+ / +)

Question: Removal of species 2 results in a decrease in species 1, and removal of species 1 also results in a decrease in species 2. What type of relationship do the two species have?

Lotka-Volterra Competition

$$\frac{dN}{dt} = r(\frac{K-N}{K})N$$

How did we incorporate intra-specific competition?

$$\frac{dN_1}{dt} = r_1(\frac{K_1 - N_1 - \alpha N_2}{K_1})N_1$$

$$\frac{dN_2}{dt} = r_2(\frac{K2_1 - N_2 - \beta N_1}{K_2})N_2$$

Summary

- The two logistic growth equations are used to describe population growth and project future N when there is intra-specific competition
- Density-dependence in nature is manifested in many ways
- 'r' and 'K' selection are outdated concepts that contributed to life history theory for a short time*
- Density-dependence in size-plastic species tends to follow a 'thinning rule'
- Competition between species will be modeled in a manner similar to density-dependence.

*but should now be relegated to the dustbin of history.

Next Lecture

- Interspecific competition
- Read Chapter 13, Smith & Smith