Lecture 5 - Density Dependence

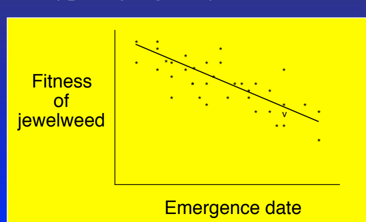
- Reading/Watching: Smith & Smith Chap. 11, VideoIntro5 (Bio. 221 web site)
- Fitness
- Assumptions of the logistic
- Problem solving with the logistic
- Implications of the theory
- Density-dependence in plants
- General importance of density-dependence

What is fitness?

An individual has a high fitness if: A) it has the most mates B) it leaves the most offspring, C) it survives the best, D) it can lift the most weights, E) none of the above

Need for a fitness measure

- In studies of selection, the 'value' of the phenotype is judged by fitness, for example:



Propensity fitness

- Fitness is a property of the individual
- Fitness should measure the rate at which that individual's genes are propagated
- The **propensity fitness** is the expected 'population growth rate of the individual', where λ is measured for a matrix constructed for each individual in the population

Propensity fitness

- We determine an **individual's** propensity to produce a certain number of offspring at each age and to survive at each age, then fill in the traditional matrix:

- $\lambda^{(i)}$ for this matrix gives the individual's 'propensity fitness' (McGraw and Caswell 1996)

Fitness

- Because $\lambda^{(i)}$ is determined by the eigenvalue of the matrix $A^{(i)}$, we see that:
  - Fitness depends on the probability of survival
  - Fitness depends on the amount of reproduction
  - Fitness depends on the timing of that reproduction

What is fitness (revisited)?

An individual has a high fitness if: A) it has the most mates B) it leaves the most offspring, C) it survives the best, D) it can lift the most weights, E) it has a high $\lambda^{(i)}$

Limits on Population Growth

- There must be limits to exponential growth
  - (projections of exponential growth are eventually, inevitably, wrong)
- Two classes of ‘checks’ on population growth
  - Density-independent factors
  - Density-dependent factors* (b, d are functions of N)

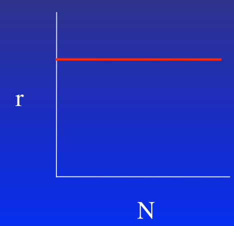
Density-dependent theory

- Logistic population growth - a parsimonious approach

‘Parsimony’ - characterized by frugality; sparing; using extreme economy

r as a function of N*

- With exponential growth, r is a constant as N increases:



*note: your book has a different derivation using b, d; it gives the same end result

r as a function of N (cont' d)

- With logistic growth, r declines with increasing N in a linear fashion
- Let the maximum r = r_{max}
- Let the N where r=0 be called K (carrying capacity)

Why does r decline as N increases?

- b declines as N increases.
- d goes up as N increases.
- r=b-d!

How does r=f(N) affect population growth?

- Now ‘r’ changes with N according to a *function*. What is this function?

Show how population growth changes as N increases

dN/dt

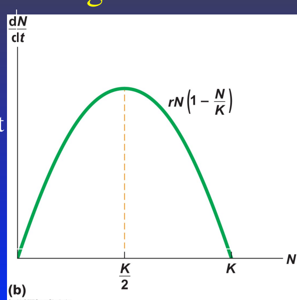
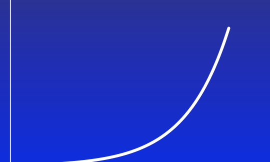


Fig. 11.2(b) from your book

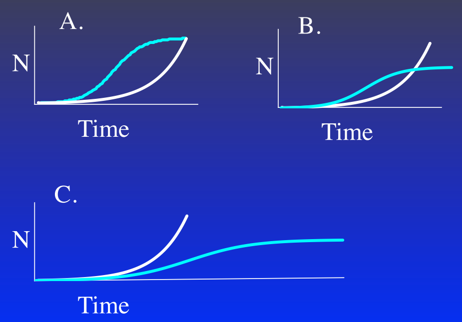
Thought problem: Given how ‘r’ now changes with N, draw density-dependent population growth in the correct position on the graph relative to the exponential growth curve shown

N



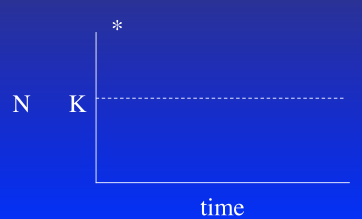
Time

Which green curve shows the correct logistic growth curve? (white curve is exponential)



Thought problem

- If a population follows logistic density-dependent growth, how will N change with time with a starting point at the '*'?



Logistic Population Growth

- Logistic population growth is sigmoidal (if initial N<K)
- Population size approaches K asymptotically
- Population size increases to K if N<K
- Population size decreases to K if N>K

Problem-solving with the logistic

Integrated form of the logistic equation:

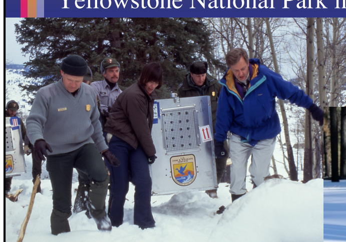
Assumptions* of the Logistic

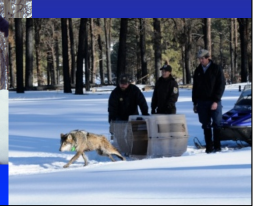
- All individuals reduce growth rate equally
- r_{max} and K are constants
- No time lag in response of dN/dt to changing N

- *Note: All assumptions questionable for some (most?) organisms in some (most?) environments

Sample Problem

- Ten wolves were introduced into Yellowstone National Park in 1996.



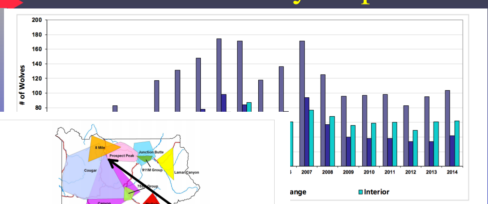


Sample Problem (cont'd)

- Assuming r is 0.30 and the carrying capacity is 50, in what year will the wolf population reach 80% of its carrying capacity?

See Practice Problem Video to Learn how To Solve the Integrated Form of the Logistic

Wolves and Density-Dependence



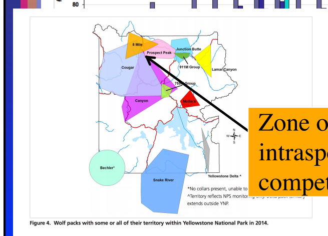


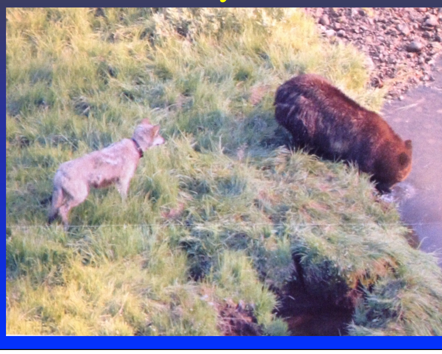
Figure 4. Wolf packs with some or all of their territory within Yellowstone National Park in 2014.

Zone of intense intraspecific competition

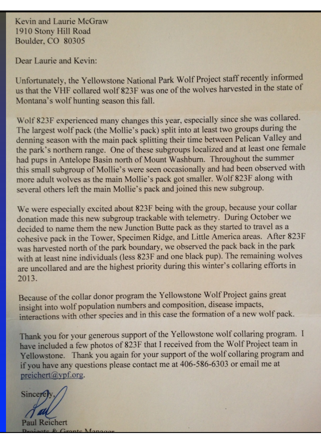
Intraspecific strife, food stress, and mange were likely causes of the population decline.

How do researchers determine wolf pack territories?

The Story of 823F



823F



Kevin and Laurie McGraw
1910 Stony Hill Road
Boulder, CO 80305

Dear Laurie and Kevin:

Unfortunately, the Yellowstone National Park Wolf Project staff recently informed us that the VHF collared wolf 823F was one of the wolves harvested in the state of Montana's wolf hunting season this fall.

Wolf 823F experienced many changes this year, especially since she was collared. The largest wolf pack (the Mollie's pack) split into at least two groups during the denning season with the main pack splitting their time between Pelican Valley and the park's northern range. One of these subgroups localized and at least one female had pups in Antelope Basin north of Mount Washburn. Throughout the summer this small subgroup of Mollie's were seen occasionally and had been observed with more adult wolves as the main Mollie's pack got smaller. Wolf 823F along with several others left the main Mollie's pack and joined this new subgroup.

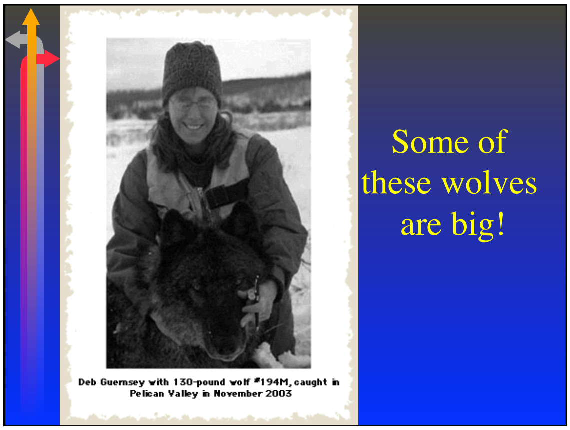
We were especially excited about 823F being with the group, because your collar donation made this new subgroup trackable with telemetry. During October we decided to name them the new Junction Butte pack as they started to travel as a cohesive pack in the Tower, Specimen Ridge, and Little America areas. After 823F was harvested north of the park boundary, we observed the pack back in the park with at least nine individuals (less 823F and one black pup). The remaining wolves are uncollared and are the highest priority during this winter's collaring efforts in 2013.

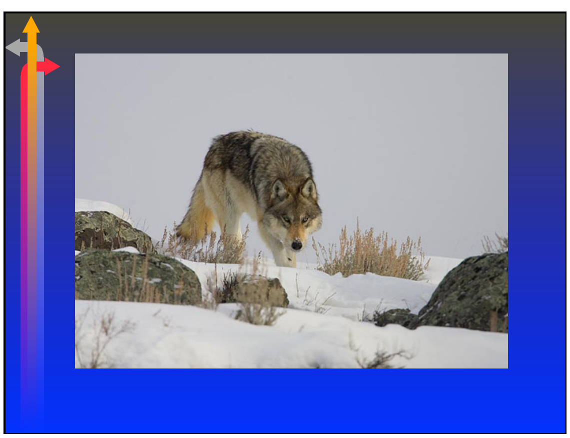
Because of the collar donor program the Yellowstone Wolf Project gains great insight into wolf population numbers and composition, disease impacts, interactions with other species and in this case the formation of a new wolf pack.

Thank you for your generous support of the Yellowstone wolf collaring program. I have included a few photos of 823F that I received from the Wolf Project team in Yellowstone. Thank you again for your support of the wolf collaring program and if you have any questions please contact me at 406-586-6303 or email me at preichert@ypf.org.

Sincerely,

Paul Reichert

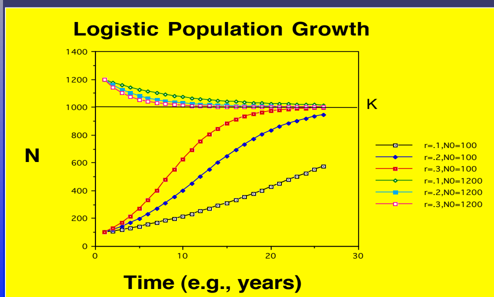

Deb Guernsey with 130-pound wolf #194M, caught in Pelican Valley in November 2003
Some of these wolves are big!



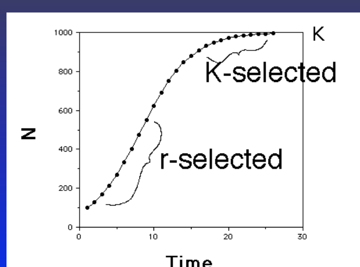
Theory vs. Real World

- r may not decline linearly with increasing N
  - **Allee effect** at low densities
  - no competition until a threshold
- K certainly varies with the environment
- Time lags in population response to density occur

Logistic Population Growth



Life History 'Strategies'



"r-selected" organisms

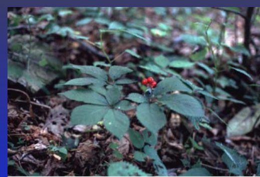
<--Garlic Mustard

Characterized by:
-early reproduction
-high offspring numbers
-rapid maturation

Hemipterans (bugs)

“K-selected” organisms

Siberian Tiger



American Ginseng

Characterized by:
-late reproduction
-low offspring numbers
-slow maturation

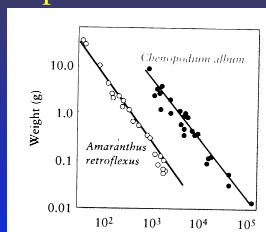
Caution

- Most species (even ‘r-selected’ species) will experience some density dependence at some N
- ‘K-selected’ species go through periods where their dN/dt is not limited by density.
- r and K are theoretical constructs
- Numerous factors other than density affect selection on life history traits

Density-dependence in plants

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

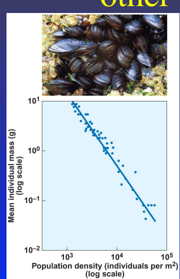
Sample Data (Density-dependence in Plants)

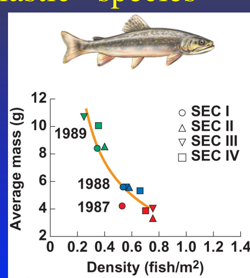


N

-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

Summary

- Logistic theory predicts that populations have some maximum sustainable N (=K) due to resource limitation
- Logistic theory can make predictions about the real world, such as the prey population size that would be optimal for a prudent predator

Sample Problem 4 u off recent 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 long gone from 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.
- 1. Which equation would govern the rate of change of population size, given the scenario described above?
- 2. If the maximum sustainable N for coyotes at Coopers Rock is 100, the current population size is 10, and r_{max} is 0.5, how fast is the population growing?
- (A) 2.5, (B) 4.5, (C) 6.3, (D) 12.5, (E) 50.0
- 3. *Theoretically*, how long would it take the coyote population to reach its carrying capacity? (A) 22 y, (B) 47 y, (C) 79 y, (D) 1,028 y, (E) an infinite number of years; the population size approaches K asymptotically.

Next Lecture

- IV. Population Dynamics
  - D. Interspecific competition
    S&S Chapter 13