Population Growth

Population Growth

- Rate of Increase
  - Remember, individual organisms grow in length, mass, and allocate some energy to offspring (fitness)
  - Populations grow as well → dynamic
    - Density (births, immigration)
    - Total Biomass
  - Life tables allow for growth projections based on:
    - Survivorship schedule
    - Fecundity schedule
    - Proportion of animals surviving each age class
  - LT's → useful for making predictions about population dynamics (increasing vs. decreasing)

Population Growth

- Rate of Increase
  - Recall:
    - R_0 → net reproductive rate (growth)
    - $R_0 = \Sigma\, l_x * m_x$
    - Sum (survivorship x fecundity)
    - Sensitive to age at reproduction
      - If $R_0 = 1$; birth rate = death rate (individuals replacing themselves – population remains stable)
      - If $R_0 > 1$; population increasing
      - If $R_0 < 1$; population decreasing

Population Growth

- Rate of Increase
  - Discrete vs. overlapping generations
  - R_0 measures rate of increase in terms of discrete generation time
    - One cohort (age class) completes its entire life cycle before the next is produced (i.e., some insects and annual plants)
    - Thus unit of time (t) and generation time (T) are the same
  - What about populations with overlapping generation times?
    - T has to be adjusted for time elapsing between the birth of the parents and the birth of the offspring
    - Mean cohort generation time (T_c)

Population Growth

- Rate of Increase
  - Discrete vs. overlapping generations
  - Mean cohort generation time (T_c)
    - $T_c = (\Sigma\, l_x * m_x * x) \div (\Sigma\, l_x * m_x)$
    - This parameter allows us to calculate the per capita rate of increase (*r*) per unit time
    - A measure of the instantaneous rate of change of population size per individual
    - Thus how much is each individual contributing to population size

Population Growth

- Rate of Increase
  - Discrete vs. overlapping generations
  - Per capita rate of increase (r)
    - The difference between instantaneous birth rates (*b*) and instantaneous death rate (*d*)
    - Thus, $r = b - d$
    - In closed populations (no individual enters or leaves), *r* is known as the intrinsic rate of increase

Population Growth

- What does it all mean?

Note: These are approximations…need to account for the average generation time of discrete population

Discrete generation growth rate:

R_0 from life table

$N_t = N_0 (R_0)^t$

$0 < R_0 < 1 \rightarrow$ decreasing

$R_0 = 1 \rightarrow$ stable (unchanging)

$R_0 > 1 \rightarrow$ increasing

Overlapping generation:

Per capita growth rate

$r = \ln (R_0)$

$N_t = N_0 e^{rt}$

$r < 0 \rightarrow$ decreasing

$r = 0 \rightarrow$ stable (unchanging)

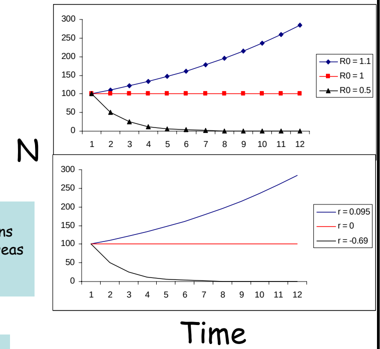
$r > 0 \rightarrow$ increasing

Population Growth

RATE

R_0	$r = \ln (R_0)$
1.1	0.09531
1	0
0.5	- 0.69315

Note: Rate is the same, except discrete generations have discrete points, whereas overlapping generations exhibit continuous growth



Note: Exponential growth!

Population Growth

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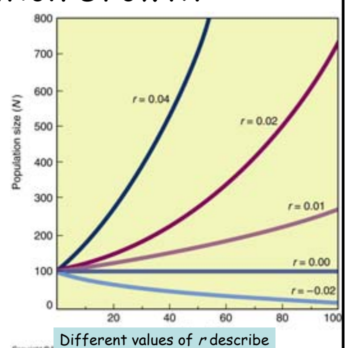


Different values of r describe different exponential curves

Note: Exponential growth!

Population Growth

- Exponential Growth
  - Assumes an unlimited environment (resources)
  - Assumes no movement (in or out), thus the excess number of births would account for changes in population numbers
  - Can be expressed as:

    $dN/dt = (b - d)N$

    or

    $dN/dt = rN$

Population Growth

- Exponential Growth

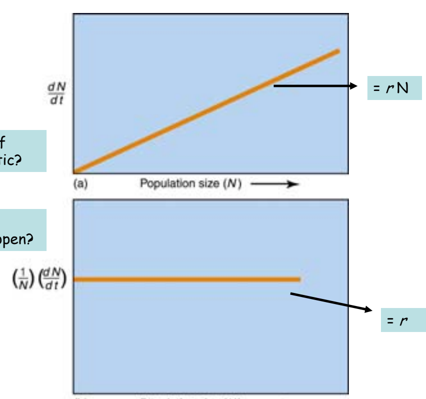
  $dN/dt = rN$

  - States that the change in population (dN/dt) is directly proportional to the size of the population (N)
  - Thus with instantaneous change in population growth, the time interval increments (or the change in per capita growth rate) approach zero

  $(1/N) * (dN/dt) = r$

Is this type of growth realistic?

What will eventually happen?



Population Growth

- Logistic Growth
- Populations limit their own growth… this depends on density (Density Dependent)
  - Limited environment (resources)
  - As density increases → competition, mortality (starvation, predation, disease), and eventually other detrimental effects (decreased fecundity, emigration, etc.) also increase
  - Eventually population growth slows down until it ceases

Population Growth

- Logistic Growth
- How does it work?
- Simply adds a new variable to the exponential growth equation that describes the effects of density

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

- K = carrying capacity

Population Growth

- Logistic Growth $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$

dN/dt → instantaneous rate of change

N → number of individuals

NOTE: Logistic growth suggests that the environment can only support a density of K individuals

K → carrying capacity

(K – N) ÷ K or 1 – N/K → the unutilized opportunity for pop growth

Population Growth

- Logistic Growth $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$

The equation tells us that the rate of increase of a population over time is equal to the potential increase of the population times the unutilized portion of the resources.

What does this mean, exactly?

If:

N is low, (K – N)/N ≈ 1 → most of the resources are unutilized

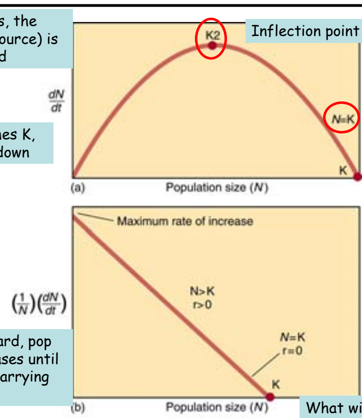
N ≈ K, (K – N)/K ≈ 0 → most of the resources are utilized (pop grows)

N > K, then dN/dt is negative and N declines towards K

As N increases, the environm. (resource) is being exploited

Inflection point → max growth

As N approaches K, growth slows down

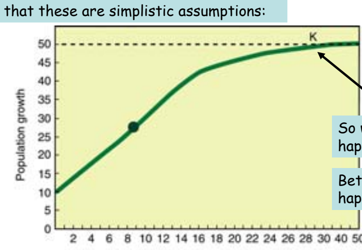


From K2 forward, pop growth decreases until reaching the carrying capacity

What will the growth curve look like then?

The population will grow "exponetially" until reaching its carrying capacity

Keep in mind that these are simplistic assumptions:



So what is happening here?

Better yet, what is happening after?

Do natural populations truly behave this way?

- assumes age distribution is stable
- assumes no immigration or emigration

Population Growth

- The logistic equation suggests that populations function as systems
  - Regulated by positive (+) and negative (-) feedbacks
  - Growth → positive feedback
  - Resource exploitation or competition → negative
  - As N approaches K → density dependent reactions

Population Growth

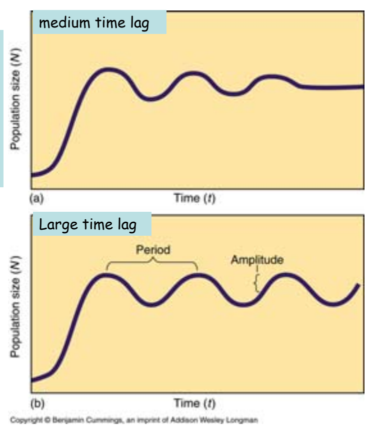
- Rarely happens “smoothly” in natural populations
- Often adjustments lag, and available resources allow populations to overshoot equilibrium
- To make the equation more realistic we need to factor in time lags (a lag between environmental change and corresponding change in rate of population growth):

$$\frac{dN}{dt} = rN\left(\frac{K - N_{t-w}}{K}\right)$$

Populations may fluctuate without reference to equilibrium size

May be influenced by some outside force

(i.e., weather)



Time lags create oscillations that may or may not eventually converge on K

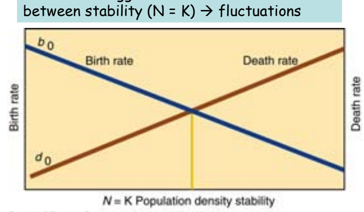
What does it tell us about equilibrium?

Population Growth

- A constant equilibrium rarely ever exists. Why?
  - Because the environment is variable
  - Thus the carrying capacity (K) should also be variable
  - Examples:
  - Resources may vary from season to season
  - Thus carrying capacity will also vary
  - K will be influenced by the most limiting resource (remind you of something?)
  - What main factors are influencing population growth?

birth rate vs. death rate

Constant struggle from one side to the other between stability (N = K) → fluctuations



Mortality and reproduction tend to bring the population back to the equilibrium set by limiting factors

As population increases, competition among its members and scarcity of resources result in increased mortality

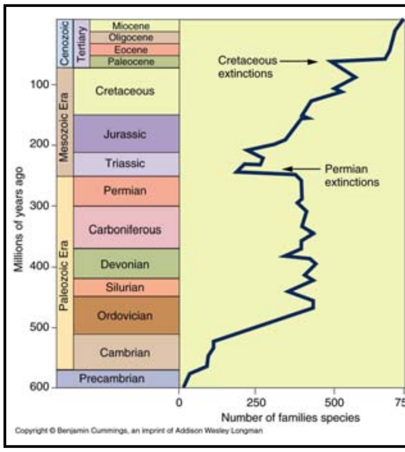
If population drops, resources may become abundant and again allow for population growth

Population Growth

- The nature of the fluctuation reflects a population’s resilience (the rate at which a population returns to equilibrium after a disturbance)
- In other words, how fast it declines from above and how quickly it increases from below equilibrium (influenced by reproductive rate)
- In general → small bodied animals fluctuate more widely than larger bodied animals. Why?
  - Small animals – shorter lives, die quickly, reproduce fast (high resilience)
  - Large animals – live longer, reproduce slowly (low resilience)

Extinction

- When deaths exceed births and emigration exceeds immigration, populations decline
- Unless populations can rebound (resilience), they will face extinction or the increased probability of becoming extinct
- Vulnerability to extinction varies widely among species
  - Some species are common – widely distributed
  - Some are rare and restricted to certain habitats



Extinction is a natural process

Massive extinctions:

Late Ordovician

Late Devonian

Late Permian

(96% of species lost)

Cretaceous-Tertiary

(end of dinosaurs)

Mass extinction happening today at accelerated pace

(100x faster)

Extinction

- Mass extinction today
- Causes:
  - Habitat loss (alteration & destruction)
  - Introduced predators and parasites
  - Predator and pest control
  - Competition for resources
  - Hunting of various types
  - Often interacting with each other

Extinction

- Two types of extinction:
- Deterministic extinction → caused by some force or change to which there is no escape
  - Cretaceous-Tertiary extinctions are an example
  - Habitat destruction on regional or local scale
  - Endemic species most vulnerable
- Stochastic extinction → caused by normal random changes within the population or environment
  - Such changes do not destroy a population, but merely thin it out
  - The smaller the population, the more vulnerable it becomes
  - Stochastic events may be demographic or environmental