Population Growth

I. Geometric growth
II. Exponential growth
III. Logistic growth

Bottom line:

When there are no limits, populations grow faster,

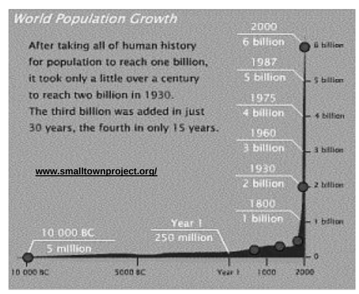
and FASTER

and ***FASTER***!

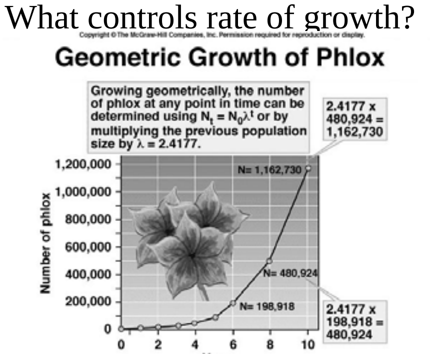
Invasive Cordgrass (*Spartina*) in Willapa Bay

http://two.ucdavis.edu/willapa1.jpg

Human Population Growth



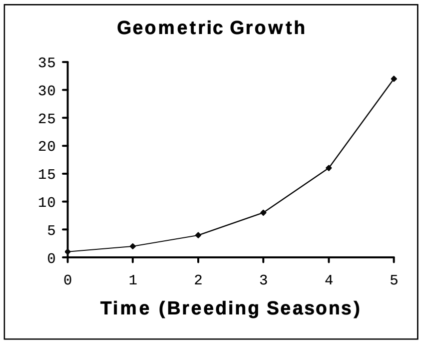
What controls rate of growth?



The Simple Case: Geometric Growth

- Constant reproduction rate
- Non-overlapping generations (like annual plants, insects)
- Also, discrete breeding seasons (like birds, trees, bears)

- Suppose the initial population size is 1 individual.
- The indiv. reproduces once & dies, leaving 2 offspring.
- How many if this continues?



Equations for Geometric Growth

- Growth from one season to the next: $N_{t+1} = N_t\lambda$, where:
  - N_t is the number of individuals at time t
  - N_{t+1} is the number of individuals at time t+1
  - λ is the rate of geometric growth

  - If $\lambda > 1$, the population will increase
  - If $\lambda < 1$, the population will decrease
  - If $\lambda = 1$, the population will stay unchanged

Equations for Geometric Growth

- From our previous example, $\lambda = 2$
  - If $N_t = 4$, how many the next breeding cycle?
    - $N_{t+1} = N_t \lambda = (4)(2) = 8$
  - How many the following breeding cycle?
    - $N_{t+1} = (4)(2)(2) = 16$
- In general, with knowledge of the initial N and λ, one can estimate N at any time in the future by:
  - $N_t = N_0 \lambda^t$

Using the Equations for Geometric Growth

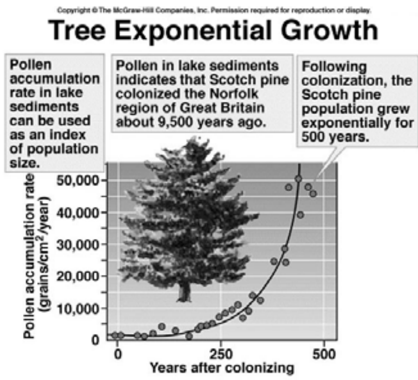
- If $N_0 = 2$, $\lambda = 2$, how many after 5 breeding cycles?
  - $N_t = N_0 \lambda^t = (2)(2)^5 = (2)(32) = 64$
- If $N_0 = 1000$, $\lambda = 2$, how many after 5 breeding cycles?
  - $N_t = N_0 \lambda^t = (1000)(2)^5 = (1000)(32) = 32{,}000$

What does "faster" mean?

Growth rate vs. number of new individuals

Using the Equations for Geometric Growth

- If in 2001, there were 500 black bears in the Pasayten Wilderness, and there were 600 in 2002, how many would there be in 2010?
- First, estimate λ:
  - If $N_{t+1} = N_t \lambda$, then $\lambda = N_{t+1}/N_t$, or 600/500 = 1.2
- If $N_0 = 500$, $\lambda = 1.2$, then in 2010 (9 breeding cycles later)
  - $N_9 = N_0 \lambda^9 = (500)(1.2)^9 = 2579$
  - In 2060 (59 breeding seasons), N = 23,478,130 bears!



Exponential Growth - Continuous Breeding

$dN/dt = rN$, where

dN/dt is the instantaneous rate of change

r is the <u>intrinsic rate of increase</u>

Exponential Growth - Continuous Breeding

r explained:

$r = b - d$, where b is the birth rate, and d is the death rate

Both are expressed in units of indivs/indiv/unit time

When $b>d$, $r>0$, and dN/dt ($=rN$) is positive
When $b<d$, $r<0$, and dN/dt is negative
When $b=d$, $r=0$, and $dN/dt = 0$

Equations for Exponential Growth

- If $N = 100$, and $r = 0.1$ indivs/indiv/day, how much growth in one day?
  - $dN/dt = rN = (0.1)(100) = 10$ individuals

- To predict N at any time in the future, one needs to solve the differential equation:
  - $N_t = N_0e^{rt}$

Exponential Growth in Rats

- In Norway rats that invade a new warehouse with ideal conditions, $r = 0.0147$ indivs/indiv/day
  - If $N_0 = 10$ rats, how many at the end of 100 days?
  - $N_t = N_0e^{rt}$, so $N_{100} = 10e^{(0.0147)(100)} = 43.5$ rats

Comparing Exponential and Geometric Equations:

- Geometric: $N_t = N_0\lambda^t$
- Exponential: $N_t = N_0e^{rt}$
- Thus, a reasonable way to compare growth parameters is: $e^r = \lambda$, or $r = \ln(\lambda)$

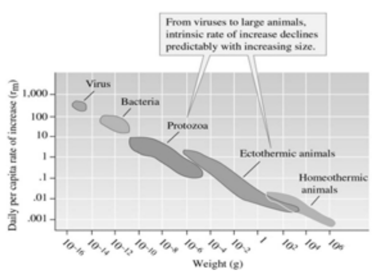
Assumptions of the Equations

- All individuals reproduce equally well.
- All individuals survive equally well.
- Conditions do not change through time.

I. Points about exponential growth

A. Body size and r

On average, small organisms have higher rates of per capita increase and more variable populations than large organisms.



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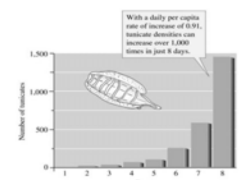
Small and fast vs. large and slow

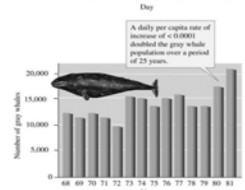
TUNICATES:
Fast response to resources

WHALES:
Reilly et.al. used annual migration counts from 1967-1980 to obtain 2.5% **annual** growth rate.

Thus from 1967-1980, pattern of growth in California Gray Whale pop fit exponential model:

$$N_t = N_o e^{0.025t}$$





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What happens if there ARE limits? (And eventually there ALWAYS are!)

LOGISTIC POPULATION GROWTH