Population Growth

• Geometric Growth – used when generations do not overlap, are frequently used for insects and annual plants
  - Phlox

\[ \lambda = \frac{N_{t+1}}{N_t} ; \frac{2408}{996} = 2.4177 \]

Since the average number of seeds = 2.4183 and there were 996 individuals at the start the total population produces 2408 seeds

\[ N_1 = 2408 \]
\[ N_2 = 5822 \]
\[ N_3 = 14,076 \]
Population Growth

This can be modeled as:

$$N_t = N_0 \lambda^t$$

Number at some initial time $0$ times $\lambda$ raised to the power $t$

Number of time intervals, in hours, days, years, etc.

Average number of offspring left by an individual during one time interval.

$$N_8 = (966)(2.4183)^8 = 1,129,948$$
Growing geometrically, the number of phlox at any point in time can be determined using $N_t = N_0 \lambda^t$ or by multiplying the previous population size by $\lambda = 2.4177$.

At $t = 10$, the number of phlox is $N = 1,162,730$.

$2.4177 \times 480,924 = 1,162,730$

At $t = 8$, the number of phlox is $N = 480,924$.

$2.4177 \times 198,918 = 480,924$

At $t = 6$, the number of phlox is $N = 198,918$.
Population Growth

• Exponential Growth – continuous growth with unlimited resources
Population Growth

- Exponential Growth Curve in Nature
  - Exponential Growth by Tree Populations

**Exponential growth of a colonizing population of Scotch pine, *Pinus sylvestris***.

- Pollen accumulation rate in lake sediments can be used as an index of population size.
- Pollen in lake sediments indicates that Scotch pine colonized the Norfolk region of Great Britain about 9,500 years ago.
- Following colonization, the Scotch pine population grew exponentially for 500 years.
Population Growth

- Exponential Growth In a Whooping Crane Population

Since their protection in 1940, the whooping crane population has grown exponentially from 15 adults to over 180.
Population Growth

- Slowing of Exponential Growth – Collared Doves – indicates a slowing in rate of growth from 1965 - 1970

After colonizing, the collared dove population of Great Britain grew exponentially.

However, in less than 20 years population size was less than that predicted by the exponential model, suggesting that population growth had slowed.
Population Growth

- Slowing of Exponential Growth – In real life populations do not continue to increase (Why?)
  - What does occur is what is known as **LOGISTIC POPULATION GROWTH** – Initially it appears as exponential growth which then levels off, producing what is known as a **SIGMOIDAL CURVE**.

  ![Diagram of Logistic Population Growth](image)

  - **Carrying capacity**: theoretical maximum population
  - **Population**: grows rapidly.
  - **Growth slows**.
  - **Growth stops**: population size stabilizes at carrying capacity, \( K \).
Population Growth

- Sigmoidal Growth – *Saccharomyces cerevisiae*

At low densities the yeast population grows at a high rate.

At higher densities, growth slows and then levels off.
Population Growth

- Sigmoidal Growth – *Paramecium caudatum*

![Graph showing population growth over days with notes indicating growth phases. The graph includes labels for population growth phases and days.]
Population Growth

- Settlement of a Barnacle - *Balanus balanoides*

Settlement rapidly increased barnacle density.

Then at about 2 weeks the population leveled off.
Population Growth

- Sigmoidal Growth – African buffalo, Syncerus caffer

When rinder pest, a disease of cattle and their relatives, was eliminated from the Serengeti, the buffalo population began to grow. Buffalo population levels off within a decade.

Rinder pest eliminated.

Years
0 5 10 15
Number of buffalo
20,000 30,000 40,000 50,000 60,000 70,000
Population Growth

- Logistic Equation

The logistic equation gives the rate of population change as a function of $r_{max}$, $N$, and $K$.

As the ratio $\frac{N}{K}$ increases, population growth slows.

\[
\frac{dN}{dt} = r_{max}N \left(1 - \frac{N}{K}\right)
\]

- Change in numbers
- Population size
- Change in time
- Intrinsic rate of increase
- Carrying capacity
Population Growth

In the logistic model, $r$, the realized per capita rate of increase, decreases as $N$ increases.

The maximum rate of increase, $r_{max}$, occurs at very low population size.

If $N < K$, $r$ is positive and the population grows.

If $N = K$, $r = 0$ and population growth stops.

If $N > K$, $r$ is negative and the population declines.
Population Growth

- Frank, Boll and Kelly (1957) – *Daphnia* populations

Each point is a separate population.

As experimenters increased the density of *D. pulex* populations, per capita rate of increase decreased.

At densities of 24 and 32 *D. pulex* per cm$^3$, $r$ was less than zero, indicating a declining population.
Population Growth

- Limits to Population Growth – the environment limits population growth by changing birth and death rates

  - Biotic factors, disease, predation, etc., are referred to as *density-dependent factors*

  - Abiotic factors, floods, droughts, etc., are referred to as *density-independent factors*

*Be careful not to assume all of these are detrimental to a population*
Population Growth

- Galagos Finches – Boag and Grant (1976)

• Looked at effects of rainfall on vegetation abundance and how that related to finch populations
Population Growth

- Dominant finch at beginning of study, medium ground finch (1,200 individuals)

- 1977, severe drought, population dropped to 180

- Drought effected seed production by plants and most of the finches died of starvation

- From 1977 – 1982 population hovered around 300

- 1983 large amount of rainfall, population grew to 1,100
  
  » Increased seed production for adults

  » Abundance of caterpillars for young
Population Growth

Drought led to high mortality of finches between 1976 and 1977.

Abundant rains in 1983 led to high rates of finch population growth.

As the number of caterpillars available for feeding nestlings increased from 1981 to 1983...

...the number of young birds produced by the population increased.
Population Growth

- Rainfall, Cactus Finches and Cactus Reproduction
  - Two species of finches utilize prickly pear cactus for food, they
    - Open flower buds in dry seasons to eat pollen, clip the style which prevents fertilization (seed production)
    - Eat pollen and nectar from mature flowers
    - Eat the seed coating (aril)
    - Eat seeds
    - Eat insects that feed on rotting cactus pads and underneath the bark
    - During the act of feed they pollinate the cacti and disperse seeds
  - 1983 El Niño had devastating effects on the cactus population
    - Absorbed too much water and tipped over
    - Salt spray from storm generated osmotic stress
    - Increased rainfall supported increased growth of a competitive vine
  - Both cactus and finch populations were influenced by both biotic and abiotic factors
Population Growth

When cactus flowers are abundant, damage by finches is low.

Damage increases when flower abundance is low.
Population Growth

- Small and Fast Versus Large and Slow – the Intrinsic Rate of Increase - typically
  - Small organisms have high $r_{\text{max}}$, with less stable populations
  - Large organisms have low $r_{\text{max}}$, with more stable populations
From viruses to large animals, intrinsic rate of increase declines predictably with increasing size.
Population Growth

With a daily per capita rate of increase of 0.91, tunicate densities can increase over 1,000 times in just 8 days.

The number of gray whales in the eastern Pacific Ocean increased an average of about 2.5% per year for 30 years...

...then dropped after 1998, when the population may have exceeded carrying capacity.