Chapter 52: Population Ecology

- **Population**: a group of individuals of the same species living in the same general area
- **Population ecology:** the study of populations in relation to the environment
    - Includes environmental influences on
        - Population density
        - Distribution
        - Age structure
        - Variations in population
- **Density:** the number of individuals per unit area or volume

Measuring Density

- Counting individuals
- Estimates by counting a subset of the total number
- Estimates by counting indirect indicators
    - Numbers of nests, etc.
- Mark and recapture method

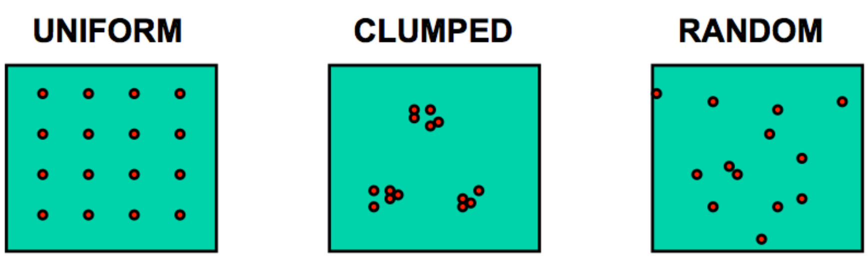
$$N = \frac{\text{(Number Marked) X (Catch Second Time)}}{\text{Number Of Marked Recaptures}}$$

Population Density Factors

- Population density results from interplay of processes that
    - Add individuals
        - Birth
        - Immigration
    - Remove individuals
        - Death
        - Emigration

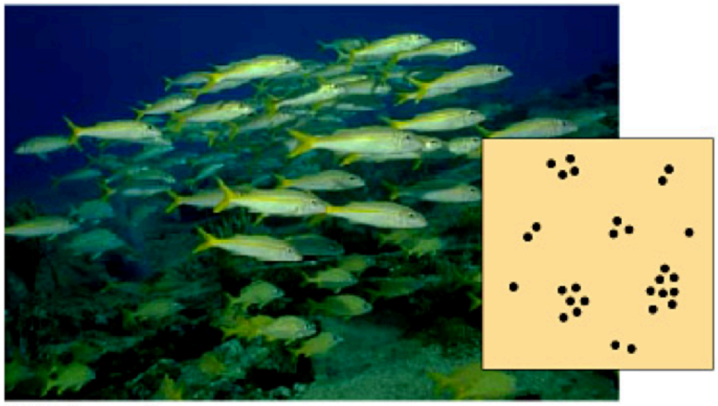
Patterns of Dispersion

- **Dispersion:** the pattern of spacing among individuals within the boundaries of the population
- Controlled by
    - Environmental factors
    - Social factors



Clumped

- Individuals aggregate in patches
- Grouping may be result of
    - Multiple individuals can cooperate effectively (e.g. wolf pack to attack prey or antelope to avoid predators, school of fish)
    - Resource dispersion (e.g. mushrooms clumped on a rotting log)

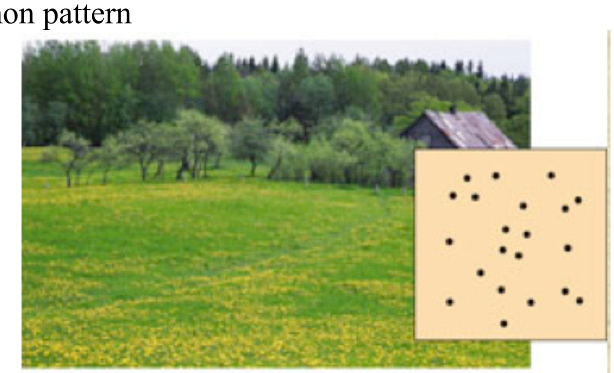


Uniform

- Individuals are evenly distributed
- Usually influenced by social interactions such as territoriality (e.g. penguins)

Random

- Position of each individual is independent of other individuals (e.g. plants established by windblown seeds, such as dandelions).
    - Uncommon pattern



(c) Random. Dandelions grow from windblown seeds that land at random and later germinate.

Demography

- **Demography:** the study of the vital statistics of a population and how they change over time
- Death rates and birth rates are of particular interest to demographers

Life Tables

- **Life table** is an age-specific summary of the survival pattern of a population (first developed by the insurance industry)
- Constructed by following the fate of a cohort (age-class of organisms) from birth to death.
- Life table built by determining number of individuals that die in each age group and calculating the proportion of the cohort surviving from one age to the next.
- Data for life tables is hard to collect for wild populations

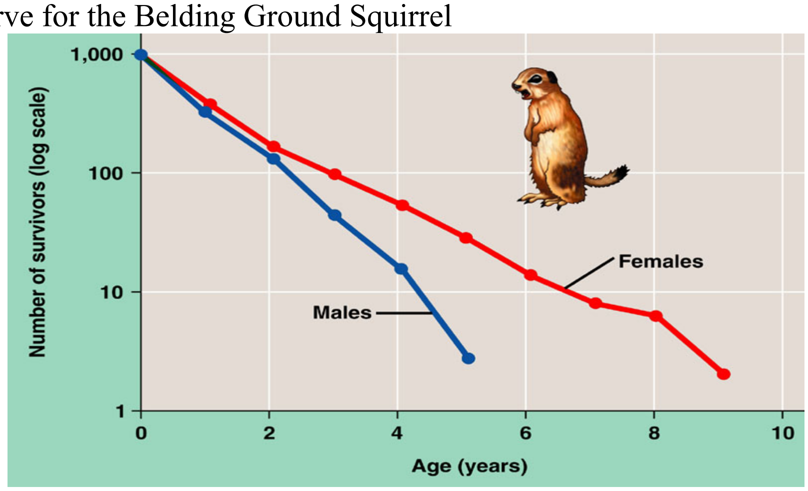
Table 52.1 Life Table for Belding's Ground Squirrels *(Spermophilus beldingi)* at Tioga Pass, in the Sierra Nevada Mountains of California*

	FEMALES					MALES				
Age (years)	Number Alive at Start of Year	Proportion Alive at Start of Year	Number of Deaths During Year	Death Rate†	Average Additional Life Expectancy (years)	Number Alive at Start of Year	Proportion Alive at Start of Year	Number of Deaths During Year	Death Rate†	Average Additional Life Expectancy (years)
0–1	337	1.000	207	0.61	1.33	349	1.000	227	0.65	1.07
1–2	252††	0.386	125	0.50	1.56	248††	0.350	140	0.56	1.12
2–3	127	0.197	60	0.47	1.60	108	0.152	74	0.69	0.93
3–4	67	0.106	32	0.48	1.59	34	0.048	23	0.68	0.89
4–5	35	0.054	16	0.46	1.59	11	0.015	9	0.82	0.68
5–6	19	0.029	10	0.53	1.50	2	0.003	0	1.00	0.50
6–7	9	0.014	4	0.44	1.61	0				
7–8	5	0.008	1	0.20	1.50					
8–9	4	0.006	3	0.75	0.75					
9–10	1	0.002	1	1.00	0.50					

*Males and females have different mortality schedules, so they are tallied separately.
†The death rate is the proportion of individuals dying in the specific time interval.
††Includes 122 females and 126 males first captured as one-year-olds and therefore not included in the count of squirrels age 0–1.
Source: Data from P. W. Sherman and M. L. Morton, "Demography of Belding's Ground Squirrel," *Ecology* 65(1984): 1617–1628.

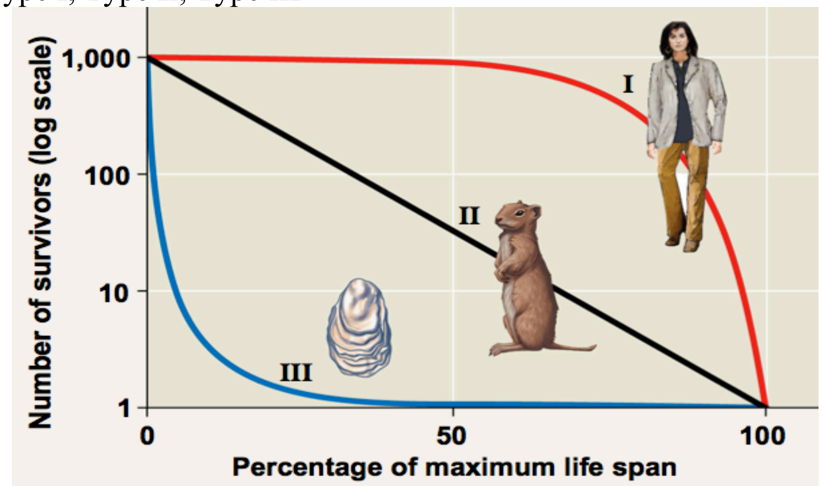
- Life table for ground squirrels shows death rate for males is higher than that for females.
- Also, notice that mortality rate is quite consistent from one year to the next.
- Data in a life table can be represented graphically by a survival curve.
- Curve usually based on a standardized population of 1000 individuals and the X-axis scale is logarithmic.

Survivorship Curve for the Belding Ground Squirrel



Idealized Survivorship Curves

- Survivorship curves can be classified into three general types
    - Type I, Type II, Type III



Type I Curve

- Typical of animals that produce few young but care for them well.
- Death rate low until late in life where rate increases sharply as a result of old age (wear and tear, accumulation of cellular damage, cancer).
- Examples: Humans and elephants

Type II Curve

- Has fairly steady death rate throughout life
    - Death is usually a result of chance processes over which the organism has little control
        - Predation
- Examples: rodents, birds

Type III Curve

- Typical of species that produce large numbers of young which receive little or no care
- Survival of young is dependent on luck.
    - Larvae released into sea have only a small chance of settling on a suitable substrate. Once settled however, prospects of survival are much better and a long life is possible.
- Examples: Oyster, insects

Reproductive Rates

- A **reproductive table**, or **fertility schedule**, is an age-specific summary of the reproductive rates in a population.
- Measured over life span of a cohort. The fertility schedule ignores males.
- The table tallies the number of females produced by each age group.
- Product of proportion of females of a given age that are breeding and the number of female offspring of those breeding females.
- Belding's Ground Squirrel reproduction peaks at age 4 years and falls off in older age classes.
- Reproductive tables differ greatly from species to species. Humans, squirrels, and oysters all produce very different numbers of young on very different schedules.

Table 52.2 Reproductive Table for Belding's Ground Squirrels at Tioga Pass

Age (years)	Proportion of Females Weaning a Litter	Mean Size of Litters (Males + Females)	Mean Number of Females in a Litter	Average Number of Female Offspring*
0–1	0.00	0.00	0.00	0.00
1–2	0.65	3.30	1.65	1.07
2–3	0.92	4.05	2.03	1.87
3–4	0.90	4.90	2.45	2.21
4–5	0.95	5.45	2.73	2.59
5–6	1.00	4.15	2.08	2.08
6–7	1.00	3.40	1.70	1.70
7–8	1.00	3.85	1.93	1.93
8–9	1.00	3.85	1.93	1.93
9–10	1.00	3.15	1.58	1.58

Population Growth

- Population growth occurs when birth rate exceeds death rate
- Organisms have enormous potential to increase their populations if not constrained by mortality.
- Any organism could swamp the planet in a short time if it reproduced without restraint.
- If immigration and emigration are ignored, a population's growth rate, "r" (per capita increase) equals the per capita birth rate, "b," minus the per capita death rate, "d."
- r indicates whether a population is growing (r>0), declining (r<0), or not growing (r=0).

The difference between the birth rate and the death rate is the per capita growth rate

$$r = b - d$$

The growth equation can be rewritten as

$$\frac{\Delta N}{\Delta t} = rN \quad \text{or} \quad \frac{dN}{dt} = rN$$

The change in population size (N) in an interval of time is

number of births – number of deaths, or

$$\frac{\Delta N}{\Delta t} = B - D$$

(ignoring immigration and emigration)

If b (birth rate) is the number of offspring produced over a period of time by an average individual, and d (death rate) is the average number of deaths per individual, then

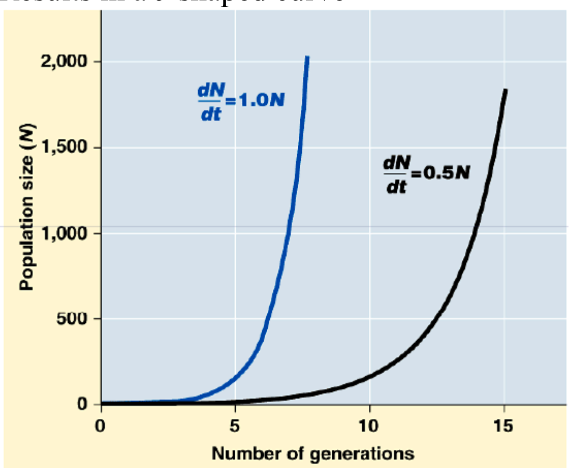
$$\frac{\Delta N}{\Delta t} = bN - dN \quad \text{or} \quad \frac{\Delta N}{\Delta t} = (b - d)N$$

Exponential Growth

- **Exponential population growth:** population increase under idealized conditions
- Under these conditions, the rate of increase is at its maximum, denoted as r_{max}
- The equation of exponential population growth is

$$\frac{dN}{dt} = r_{max}N$$

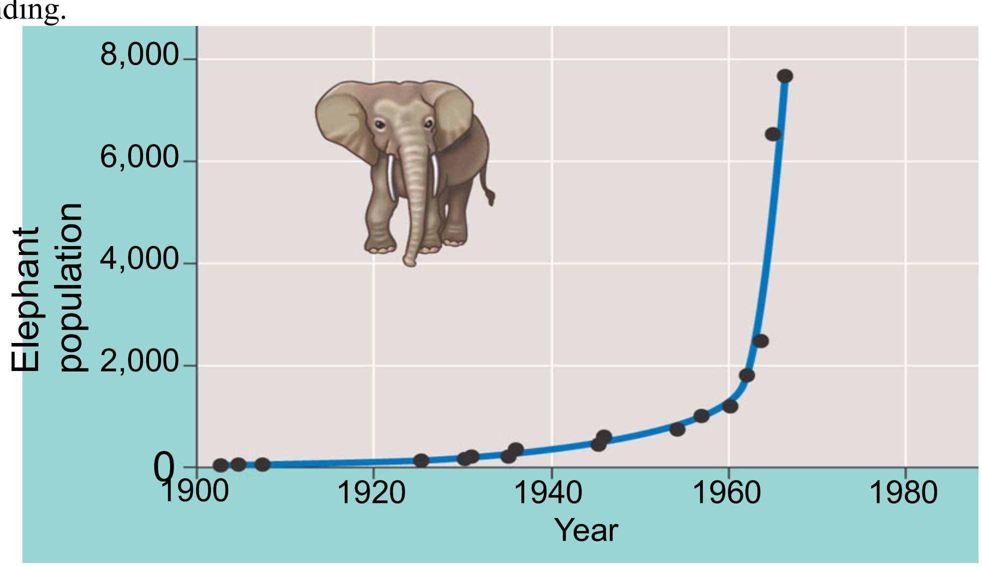
- Results in a J-shaped curve



Note that:
1. r is constant, but N grows faster as time goes on.
2. What happens with different r's in terms of total numbers and time to reach those numbers?

Exponential Growth in Nature

- The J-shaped curve of exponential growth is characteristic of some populations that are rebounding.



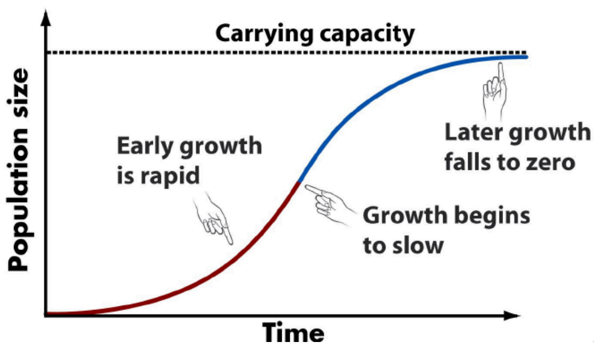
Logistic Population Growth

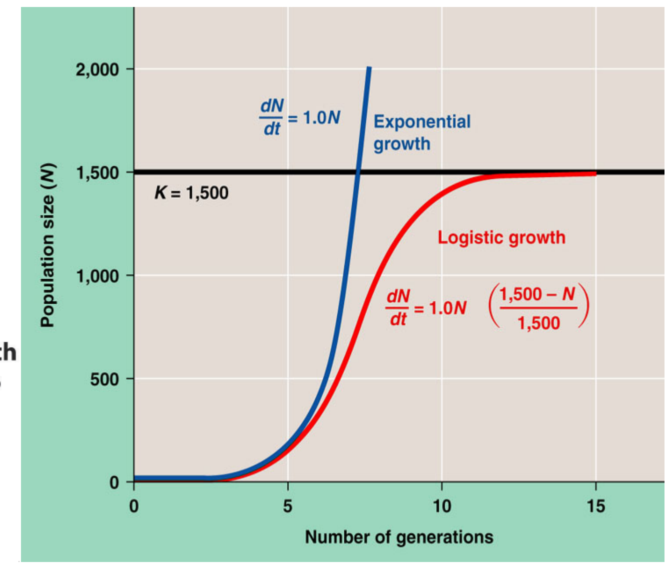
- Exponential growth cannot be sustained for long in any population.
- A more realistic population model limits growth by incorporating carrying capacity.
- **Carrying capacity (K)** is the maximum population size the environment can support.

- In the logistic population growth model the per capita rate of increase declines “r” as carrying capacity is approached.
- We construct the logistic model by starting with the exponential model and adding an expression that reduces the per capita rate of increase as N increases
- The logistic growth equation includes K, the carrying capacity (# of organisms environment can support)

$$\frac{dN}{} \quad dK \qquad r_{max} \frac{=}{(K - N)}$$

- As population size (N) increases, the equation ((K-N)/K) becomes smaller which slows the population’s growth
- Sigmoid (S-shaped) curve





The Logistic Model

Logistic growth model

- Population growth rates decreases as population approaches its carrying capacity

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

Adjustment for limited resources

Population size

Per capita growth rate

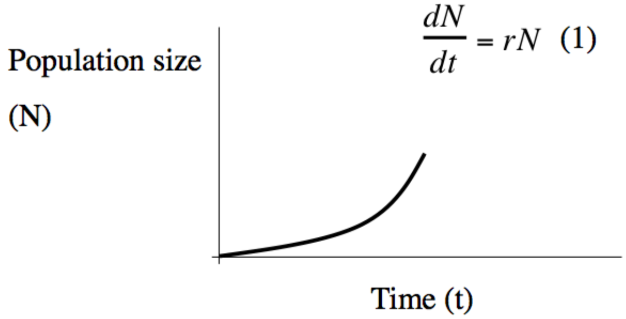
Population growth rate

- Exponential growth phase

  - **Population growth** $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$
    - – How does logistic growth model work?
      - When N is very small (imagine N is 1 and K is 1000)...

        $\left(\frac{K-N}{K}\right)$ is close to 1, so population grows exponentially

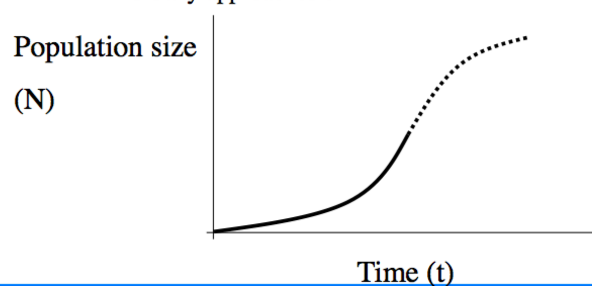
$$\frac{dN}{dt} = rN \quad (1)$$



- Population nears carrying capacity (K) → growth slows

  - **Population growth** $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$
    - – How does logistic growth model work?
      - When N approaches K (imagine N is 500, 600, ...900 and K is 1000)...

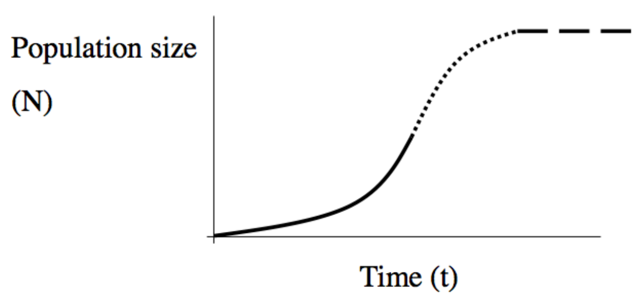
        $\left(\frac{K-N}{K}\right)$ Gets closer and closer to 0, so population growth slowly approaches 0

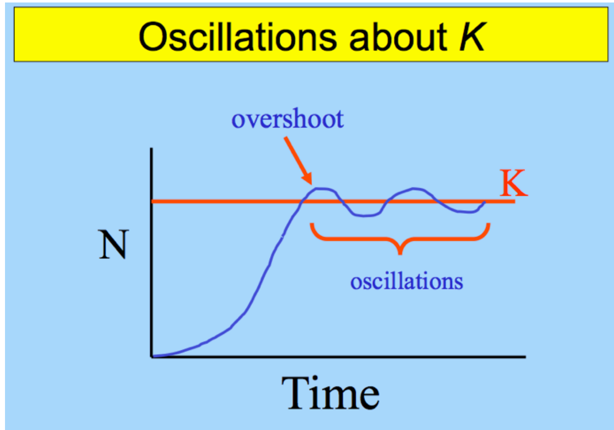


- N = K (population growth = 0)

  - **Population growth** $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$
    - – How does logistic growth model work?
      - When N equals K (imagine N is 1000 and K is 1000)...

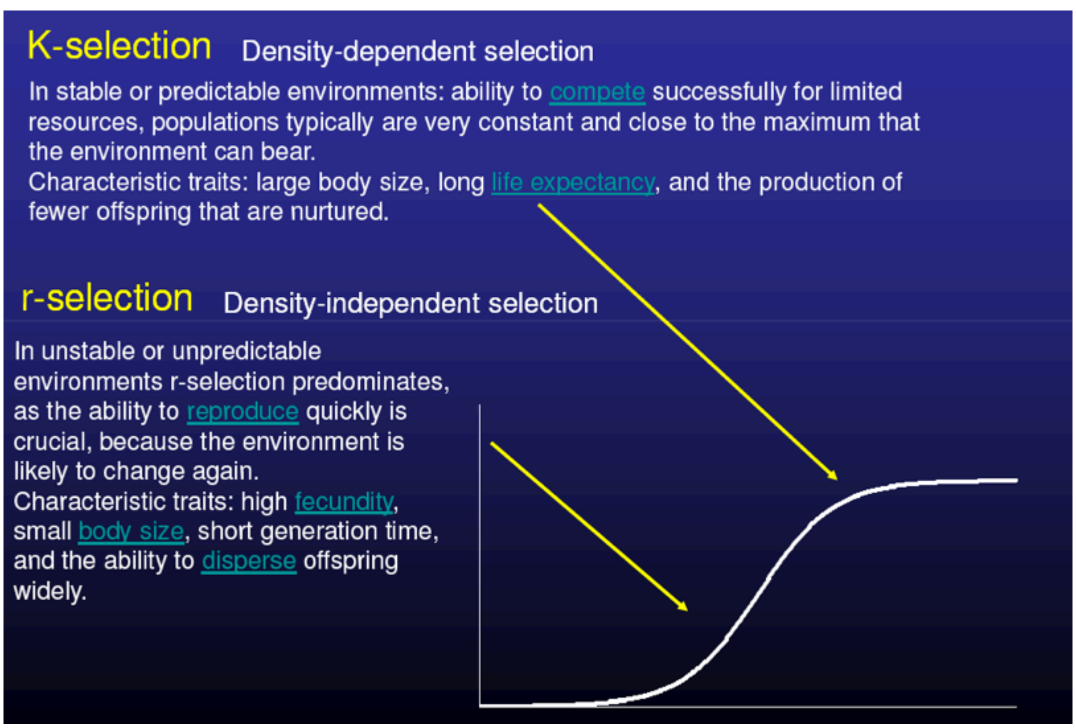
        $\left(\frac{K-N}{K}\right)$ is 0, so population growth is 0



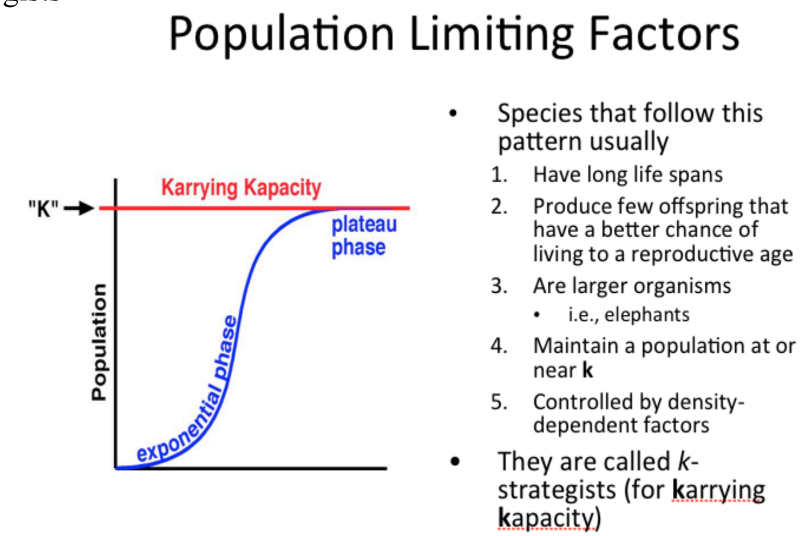


The Logistic Model and Life History Strategies

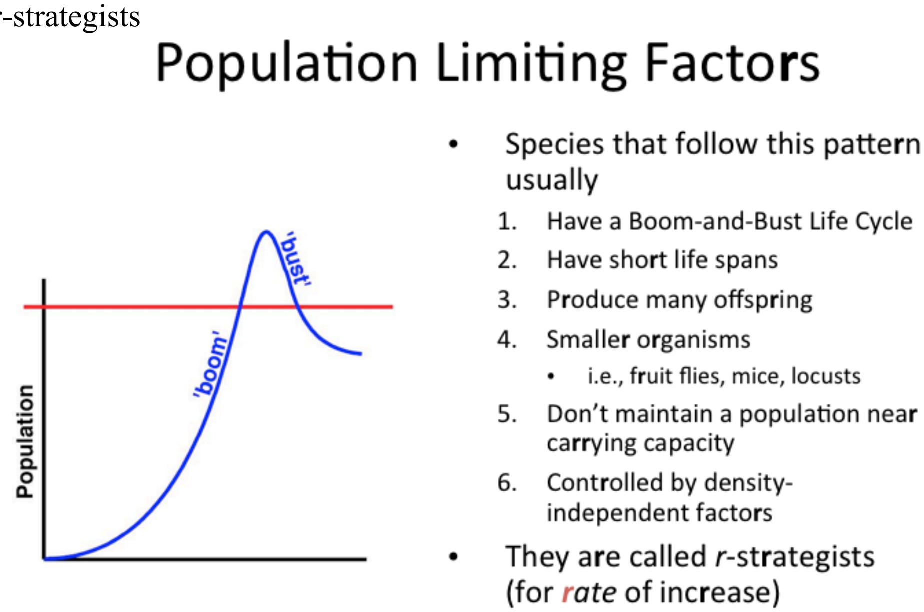
- Life history traits favored by natural selection may vary with population density and environmental conditions.
- At low density, per capita food supply is relatively high. Selection for reproducing quickly (e.g. by producing many small young) should be favored.
- At high density, selection will favor adaptations that allow organisms to survive and reproduce with few resources. Expect lower birth rates.
- **K-selection**, or **density-dependent selection**, selects for life history traits that are sensitive to population density
- **r-selection**, or **density-independent selection**, selects for life history traits that maximize reproduction



- K-strategists



- r-strategists



Life History Traits

- Study of life histories focuses on explaining why organisms differ in their reproductive patterns.
- Life history traits are products of natural selection.
- Life history traits are evolutionary outcomes reflected in the development, physiology, and behavior of an organism.
- The current life history reflects the fact that organisms in the past that adopted this strategy left behind on average more surviving offspring than individuals who adopted other strategies.

Life History Diversity

- Some species exhibit **semelparity**, or “big-bang” reproduction. These species reproduce once and die (bamboo, salmon, century plant).

- Word derivation
  - Semel: once
  - Pario: to begat
  - Semelparity: to reproduce once
- Semelparous reproduction is often an adaptation to erratic climatic conditions.
- Suitable breeding conditions occur rarely and organisms devote all their resources to reproduction when conditions are good (e.g. century plant).
- Also occurs when an organism's chances of reproducing again are so low that it is better to commit all resources to a single bout of reproduction (e.g. Salmon).

Century plant

- Some species exhibit **iteroparity**, or repeated reproduction and produce offspring repeatedly over time.
  - Word derivation
    - Itero: repeat
    - Pario: to begat
    - Iteroparity: species that reproduce multiple times over their lives
  - E.g. Humans, cats, birds.
- Iteroparous reproduction occurs when organisms have good prospects of reproducing in the future (i.e., they are long-lived).
- Characteristic of larger organisms and those that experience more stable environmental conditions.

- r- and K-selected life history traits (ends of continuum)

trait	r-selected	K-selected
– age at 1st reproduction	early	late
– lifespan	short	long
– Survivorship	low (type III)	high (type I)
– Fecundity	high	low
– Parity	semelparity	iteroparity
– Offspring size	small	large
– Parental care*	none	lots

* not a life-history trait

Limiting of Population

- A population can be limited in two ways:
    - Density-Independent Factors
    - Density-Dependent Factors

Density-Independent Factors

- Factors that limit population size, regardless of population density.
- These are usually abiotic factors
- They include natural phenomena, such as weather events
    - Fires
    - Drought
    - Flooding
    - Extreme heat or cold
    - Tornadoes
    - Hurricanes

Density-Dependent Factors

- Any factor in the environment that depends on the number of members in a population per unity area
- Usually biotic factors
- These include
    - Predation
    - Disease
    - Parasites
    - Competition

Population Pyramids

- Help us determine the future growth of the population