POPULATION ECOLOGY

Population Ecology Lecture

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Population Ecology Lecture Objectives

1. Define population ecology and identify population distributions seen in nature.
2. Recognize the role that population size and density play in population dynamics.
3. Identify population growth models and factors that affect population growth.
4. Compare species life history strategies and discuss population management approaches.

Objective 1: Define population ecology and identify population distributions seen in nature.

What is a population?

A population includes all the organisms that belong to the same species that are living within a designated area and can interact, breed and have offspring.

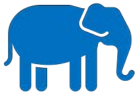
Population ecology is the study of these populations.

Population ecologists study different species around the world for many important reasons including:

- Determining which species need protection, such as endangered species
- Managing economically valuable species, such as commercial fisheries
- Controlling pest species and invasive species

Hierarchy of Life on Earth

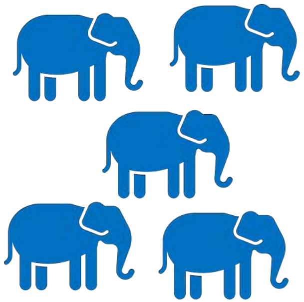
biotic



Organism

A living individual organism

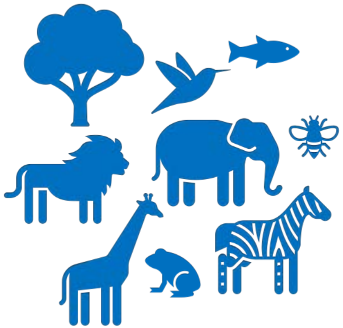
biotic



Population

Many individuals of the same species that can breed and produce offspring

biotic



Community

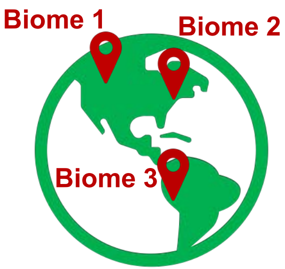
Many individuals from different species interacting with one another

abiotic + biotic

Ecosystem

A community and all its abiotic components

abiotic + biotic



Biome

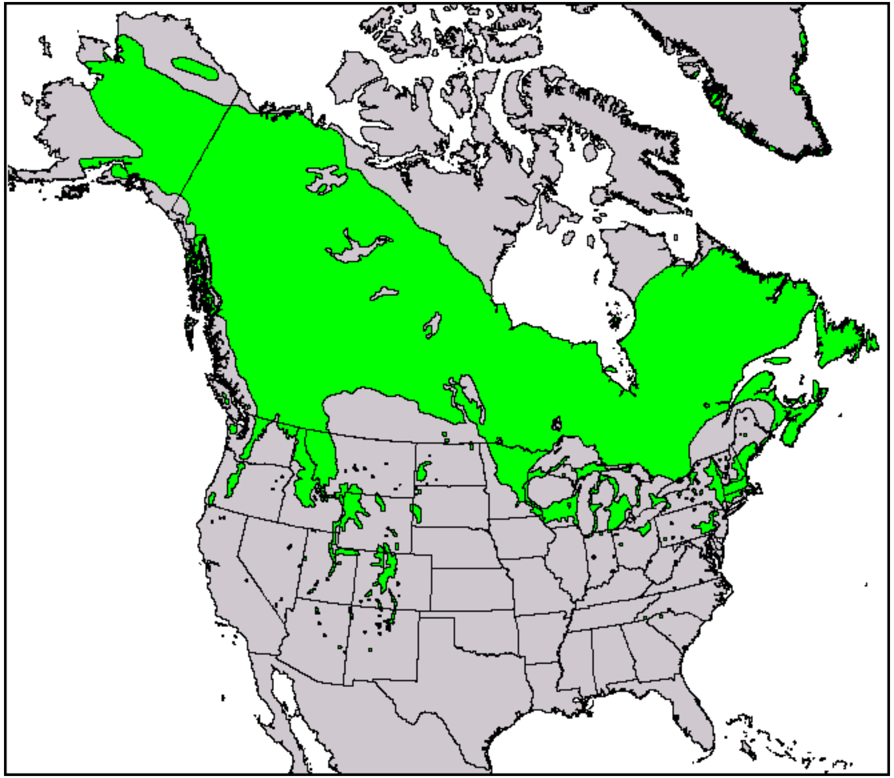
Ecosystems that occupy a large geographic area

Range = the geographic area where a species can be found

Factors such as the time of year, breeding activity, where a species historically originated can all determine its range.

A range map shows the distribution and boundary lines of a population.

Image from Elbert Little, U.S. Forest Service.



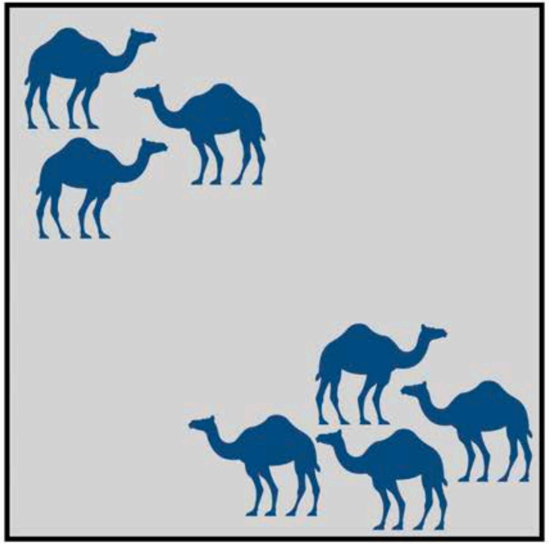
Range map for *Juniperus communis*, the common juniper.

Population Distribution = spacing and location of individuals within their range

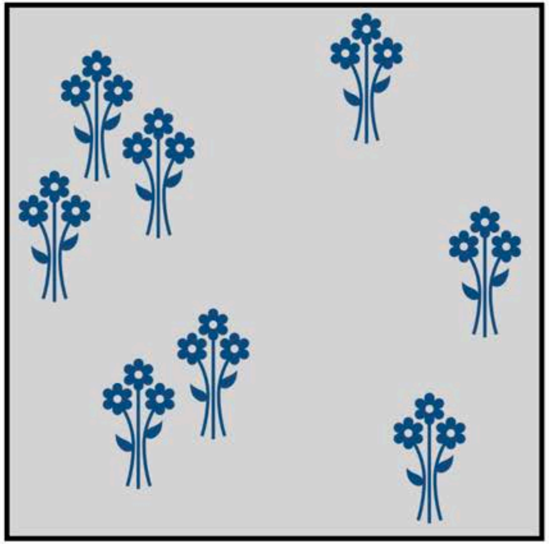
Both behavioral and ecological factors can influence a population distribution.

Understanding a population's distribution is essential for healthy population management.

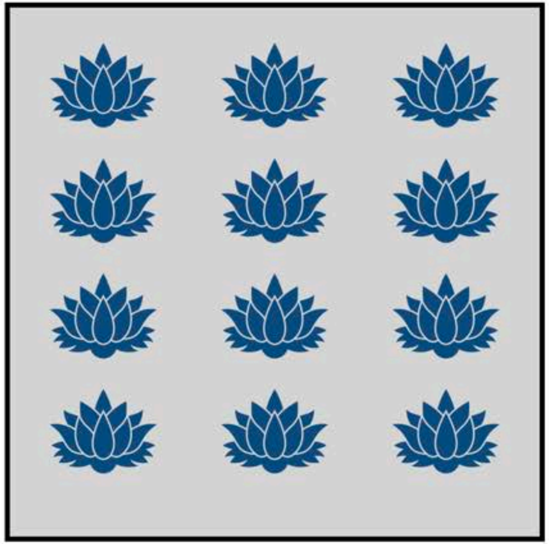
Population Distribution Patterns



Clumped



Random

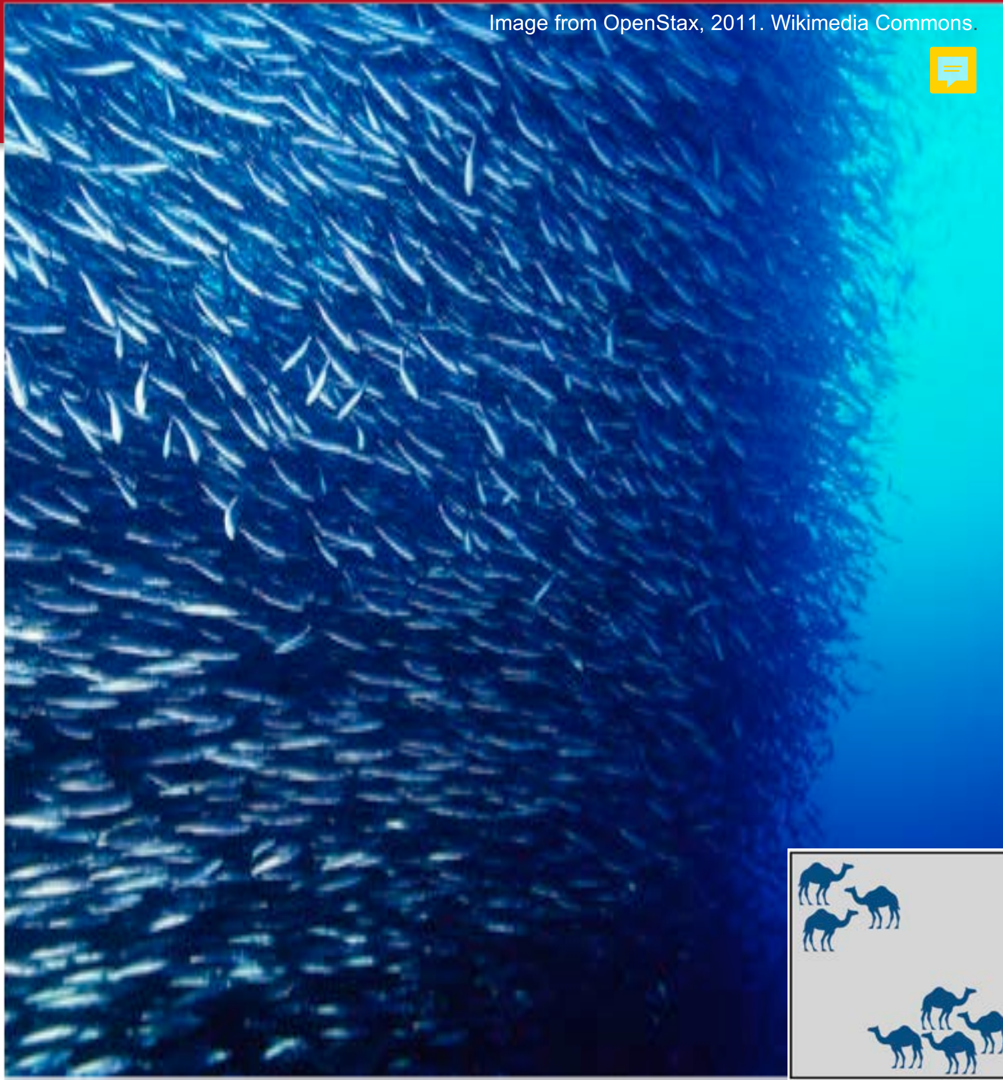


Uniform

Clumped Distribution

Organisms are **grouped together in clusters.**

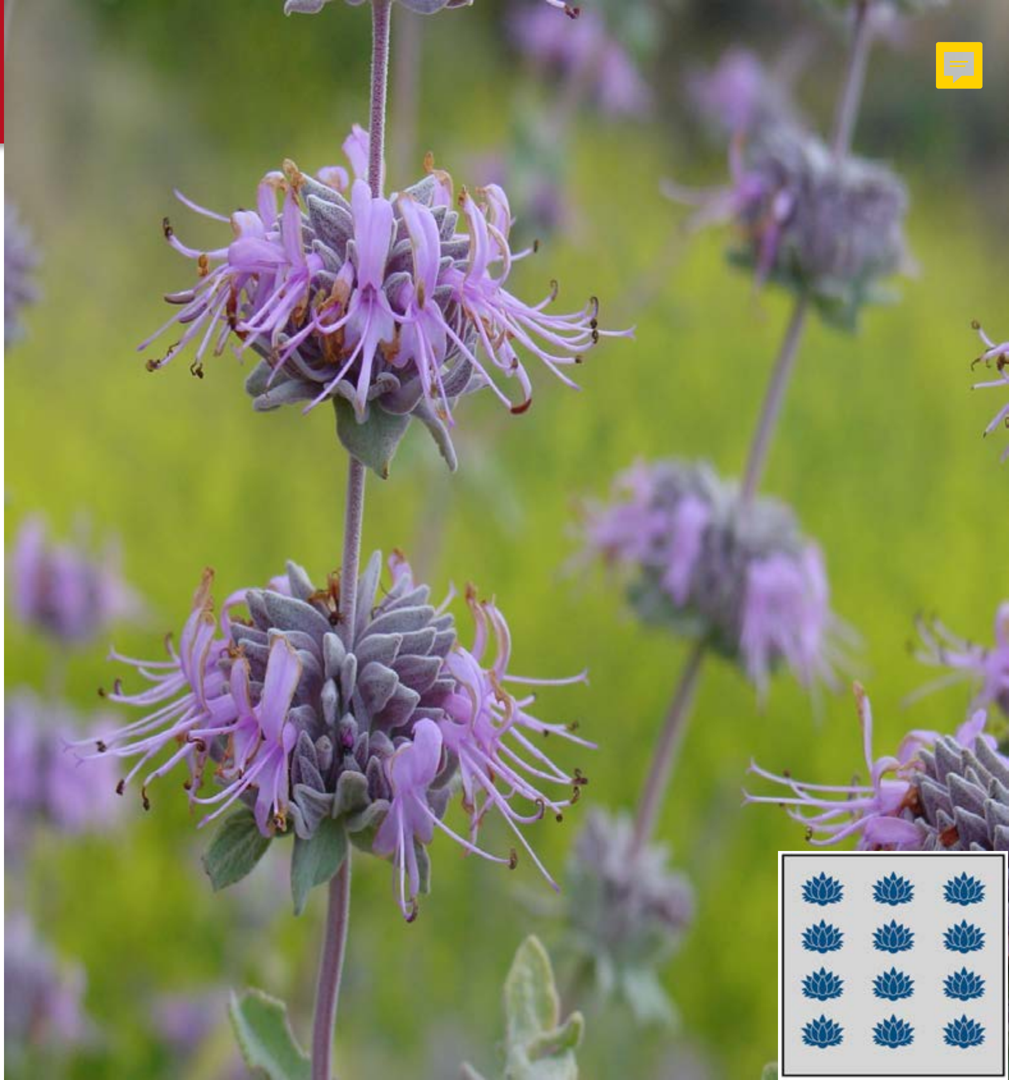
- Found in environments with unevenly distributed resources
- Organisms may be clustered together due to social factors, such as family groups
- Organisms may also group together to hunt more effectively or to protect themselves from predators



Uniform Distribution

Organisms are **evenly spaced** from one another.

- Found in populations where the distance between organisms is maximized
- Spacing is often a result of competition
- Farming and agricultural practices showcase man made uniform distribution



Random Distribution

Organisms are **randomly spaced.**

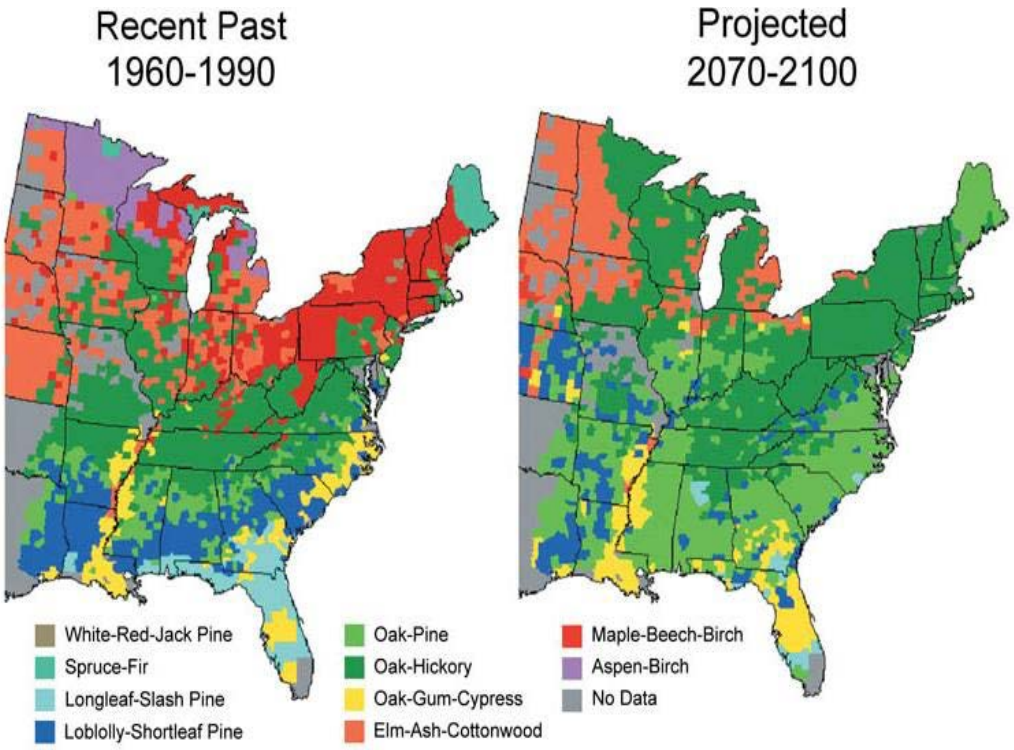
- Occurs when organisms of a species are in environments where the position of each individual is independent of all other individuals
- Often a lack of social interaction within the species
- More likely to occur where environmental conditions are consistent

Image from USGCRP, 2009.

Factors Affecting Species Distribution

<u>Abiotic factors</u>

- Climatic factors (precipitation, sunlight, humidity, sunlight, temperature, pH)
- Local geography (soil, terrain, elevation)
- Resource availability (nutrients, water)
- Land use (rural, city, natural setting)

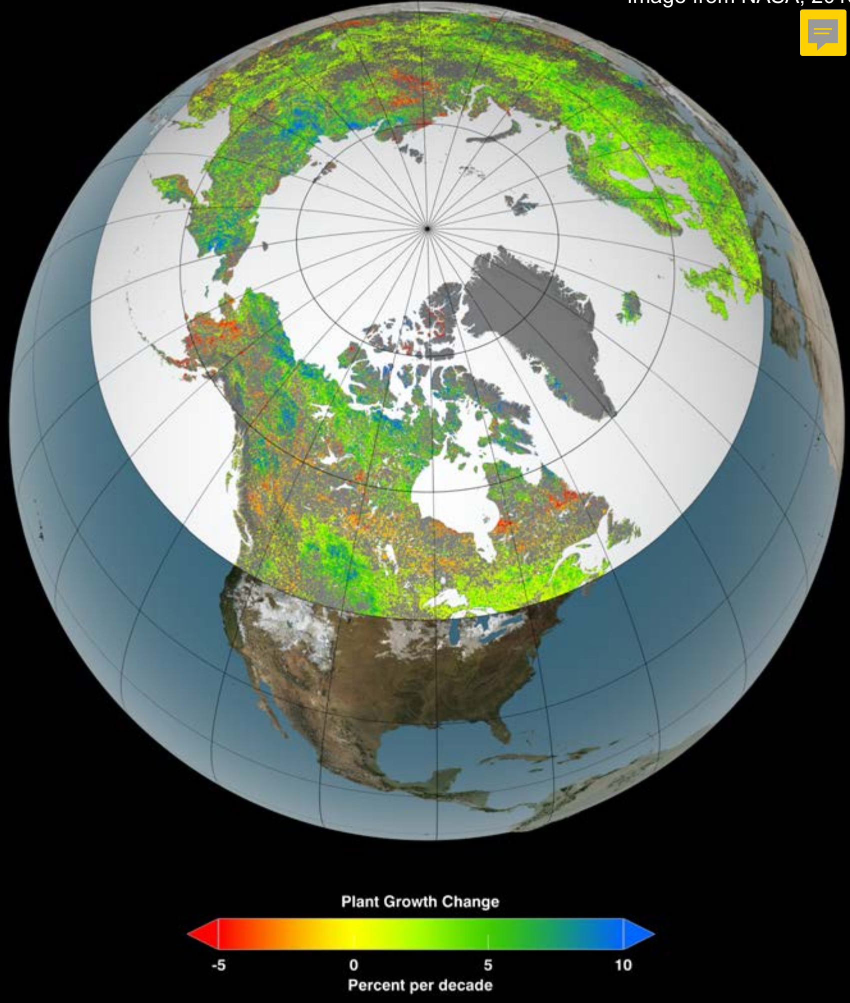


Factors Affecting Species Distribution

Climate

- Geographic ranges of plant and animal species are limited by climatic factors like temperature and precipitation
- The magnitude and variability of climatic changes limits an organism's ability to survive and produce offspring
- Species can respond to changing climate by migrating to new areas, for example, move to cooler locations at higher latitudes
- Climate changes are difficult to predict, and scientists use computer models to predict climate change and thus better prepare for shifts in organisms' range and distribution

Image from NASA, 2013.



Factors Affecting Species Distribution

Biotic factors

- Biotic factors are living organisms or material (for example, organic compounds) that originated from living organisms
- Predator and prey species
- Disease caused by viruses and microorganisms
- Competition for resources (e.g., water and food)
- Human influences and interactions

Objective 2: Recognize the role that population size and density play in population dynamics.

Population size = number of individual organisms in a population

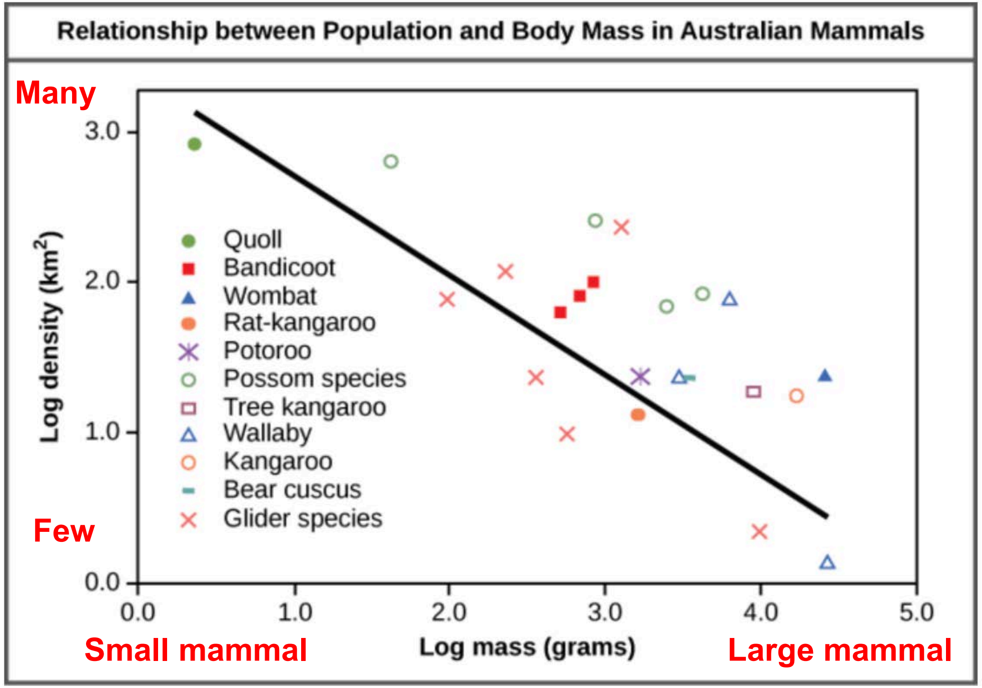
It's valuable to know a population's size as it can tell us about the stability and sustainability of a population. Larger populations are generally regarded as more stable because they have higher genetic diversity compared to a small population. High genetic diversity allows a population as a whole to better adapt to environmental changes.

Image from Antarctica Bound, 2010. Flickr.

Population density = number of individual organisms per area or volume in a habitat

Density can determine how easy or difficult it is for populations to acquire resources.

- Low density populations may have difficulty locating mates
- High density populations will experience an increase in competition for food or water



Generally, organisms with small body size live together in high population density.

Challenges with Population Density

Too Low (below minimum population size)	**Too High** (above carrying capacity)
• Natural social behaviors are deficient	• Social behaviors break down
• Unable to find mates	• Increase in disease
• Normal mating and courtship behaviors do not occur	• Food supplies are low
• Genetic diversity decreases and inbreeding can occur	• Increased chances of conflicts with humans
• Important community connections may be lost that can affect other species	• Environments are damaged from overuse of resources

Definitions from Environmental Science for a Changing World

Population Research Methods

The most accurate way to study a population is to count all individuals within the population. However, this often requires tremendous time, money and resources and is rarely possible. For example, its impossible to count all the Black Swallowtail Butterflies that live in Yellowstone National Park (USA).

Instead of counting an entire population, scientists typically study a portion of a population by **sampling**, which involves counting individuals within a certain area (or volume for aquatic organisms) that is part of their natural habitat.

Sampling can be done a variety of ways and depends on the type of organism, the habitat, and the research objectives.

Quadrat Method = a square area, market with boundaries to study the population size and density of slow-moving animals or plants

The quadrat method is typically used for sampling of areas to measure populations of plant species or slow-moving animal species. A quadrat is a square that encases an area within a habitat. A wooden stake or string is typically used to mark off each quadrat and then a square made from various materials (e.g., plastic, wood) on the ground.

Image from Yohan euano4, 2008. Wikimedia Commons.

Mark and Recapture Method = a sampling technique that estimates population size from a number of marked individuals in samples of mobile organisms

Researchers capture organisms and typically mark them with tags, bands, paint, or some other body marking. These marked species are released back into the wild and then recaptured and sampled sometime later (e.g., days to weeks).

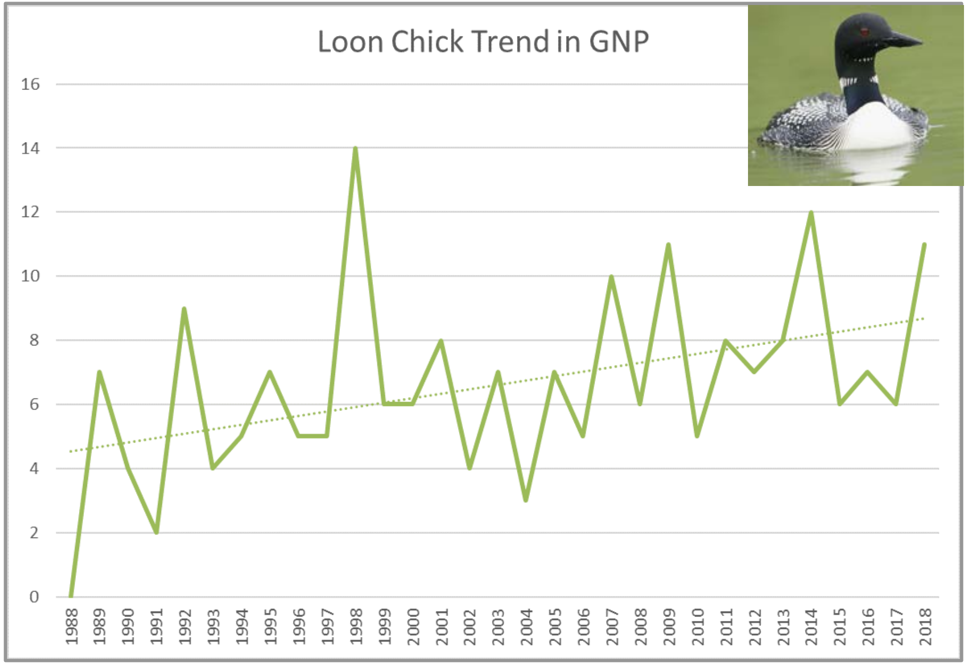
Image from Derek Ramsey, 2008. Wikimedia Commons.

$$\frac{\textbf{number marked in first catch X total number of second catch}}{\textbf{number of marked recaptures in second catch}}$$

Population Dynamics = changes over time in population size and composition

Population dynamics tell us how populations interact with other species and with the physical environment. By tracking populations, we can see how they have changed and predict their changes in the future. This influences management decisions and conservation efforts.

Graph from National Parks Service.



This graph shows data from the Common Loon Citizen Science project in Glacier National Park (GNP). Data was collected over time in order to gain a better understanding of the park’s loon population and to gauge factors that affect the nesting success.

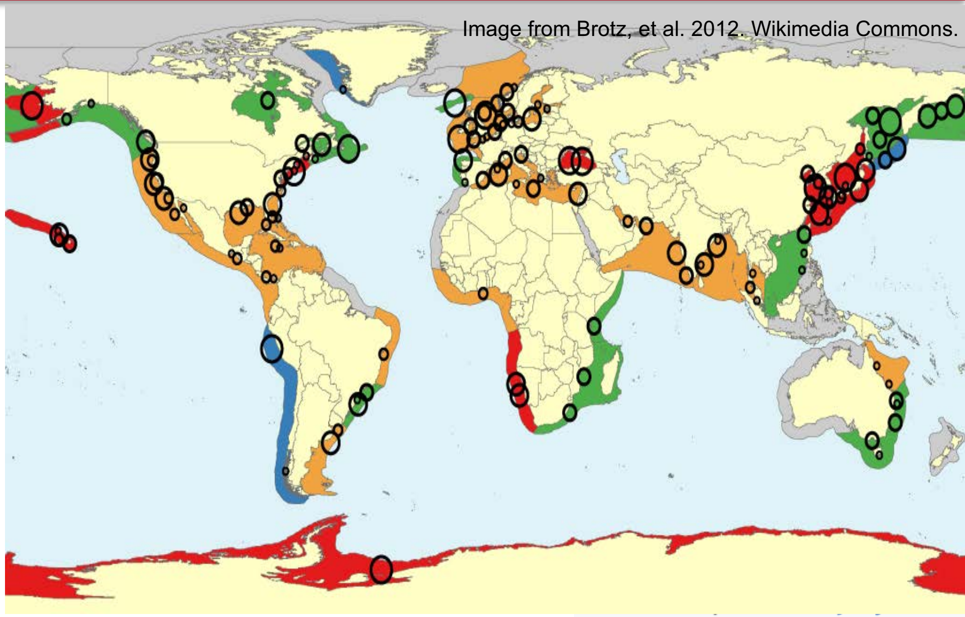
https://www.nps.gov/articles/common-loon-brief.htm

Population Dynamics

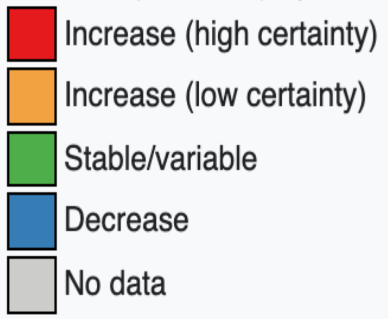
Population distribution, size and density describe a population at a fixed point in time.

To study how populations change over time, scientists use tools of **demography**, the statistical study of population changes over time.

Scientists use statistics such as birth rates, death rates, life expectancies, incidence of disease, immigration rates and emigration rates.



Map of population trends for native and invasive species of jellyfish.



Objective 3: Identify population growth models and factors that affect population growth.

Population Growth

Population growth is controlled by **growth factors**, which are resources (e.g., water, space, food) that individuals need to survive and reproduce so that a population can growth in number. A population that is able to grow without any environmental limitations, will eventually reach its full **biotic potential.**

Biotic potential is the unrestricted growth of a population as each member of the population survives and produces offspring resulting in maximum growth.

Resistance factors (also called **limiting factors**) are things that keep a population’s biotic potential in check. These are things that directly (e.g., predators, disease, fire) or indirectly (e.g., competition) reduce a population’s size.

Density-Dependent Factors

Density-dependent limiting factors are those that alter a population's growth and depend on the population's density. Typically, as a population's density increases (e.g., 100 deer living in Yellowstone National Park increases to 100,000 deer) its growth will start to decrease due to the factors listed below. These factors are usually biotic.

Examples of Density-Dependent Factors:

- Competition for Limited Resources
- Predation
- Waste Accumulation
- Disease
- Invasive Species

Interspecific versus Intraspecific Competition

Intraspecific competition occurs between members of the **same** species (e.g., gray wolves).

Grey Wolf

Red Fox

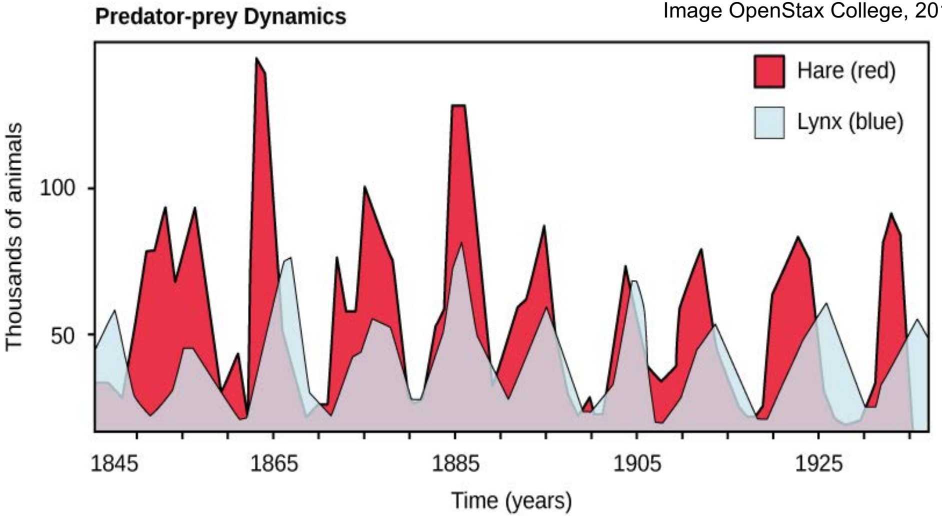
Interspecific competition occurs between members of **different** species (e.g., gray wolves and red fox).

Predation-prey Dynamics

Population sizes of both predators and prey species do not remain constant over time, rather they fluctuate in cycles that reflect their interactions.

A common example is the lynx and the snowshoe hare. We can see that the populations fluctuate on an approximately 10-year cycle with the predator populations slightly delayed behind the prey.

Image OpenStax College, 2016.



Snowshoe hare

Canada Lynx

Density-Independent Factors

Density-independent limiting factors affect population growth rate independent of the population's density. These factors are not capable of regulating populations at constant levels. They can often lead to inconsistent, sudden shifts in the population. These factors are most often abiotic factors.

Examples:

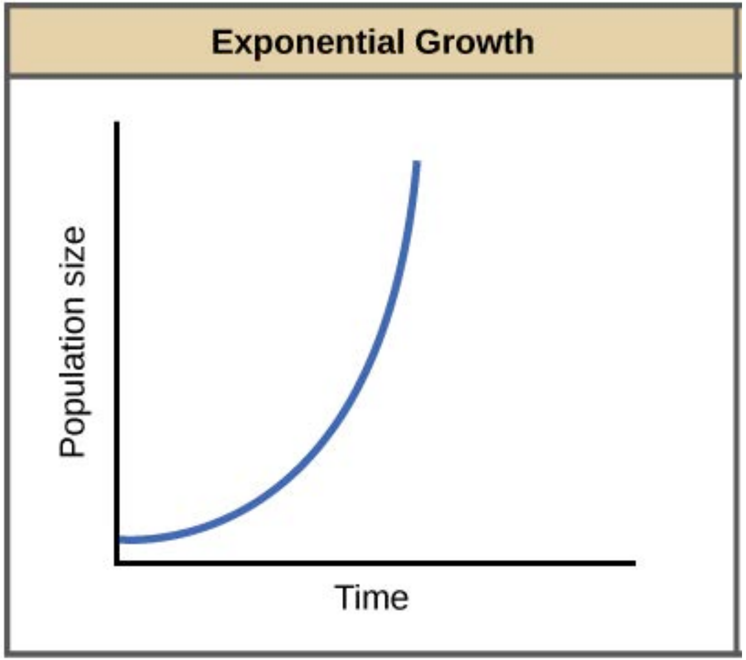
- Natural disasters
- Storms
- Fires
- Floods
- Pollution
- Human activities

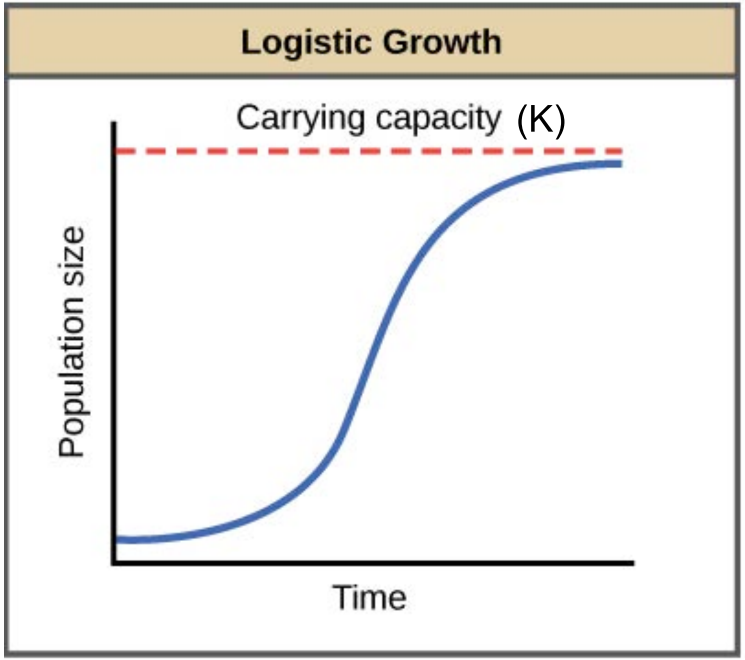
Density-Dependent and Density-Independent Factors

In nature, population growth is very complex and density-dependent and density independent factors are quite likely to interact.

Populations that are more dense reacting to environmental density-independent factors will recover differently than a population that is more spread out.

Population Growth Models





Images OpenStax College, 2016.

Exponential Growth

Growth rate increases over time as the number of individuals in the population increases.

Occurs when a population has unlimited resources and little to no environmental limitations. Isn't sustainable in nature.

When graphed, this population growth shows a **J-shaped curve**.

Bacteria growth are the prime example of exponential growth.

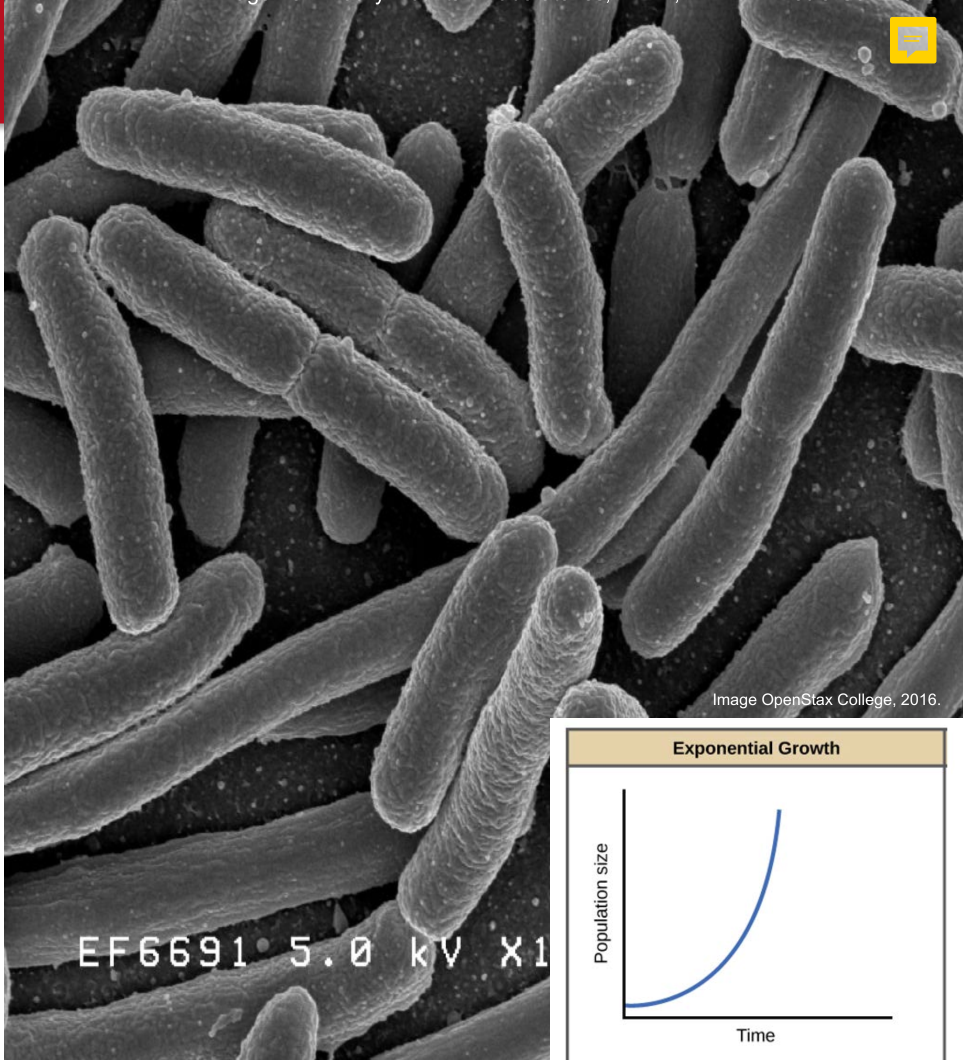


Image from Rocky Mountain Laboratories, NIAID, NIH. Wikimedia Commons.

Image OpenStax College, 2016.

Logistic Growth

In logistic growth, resources are limited, and this acts to controls a population's size because the environment can only support so many individuals.

Individuals must compete for resources and those that are successful will survive, reproduce and pass on their genetic traits to their offspring, thus producing the most fit individuals (natural selection).

When graphed, logistic population growth displays an **S-shaped curve.**

Carrying Capacity (K) is the maximum population size that a particular environment can support indefinitely

K is observed in logistic growth

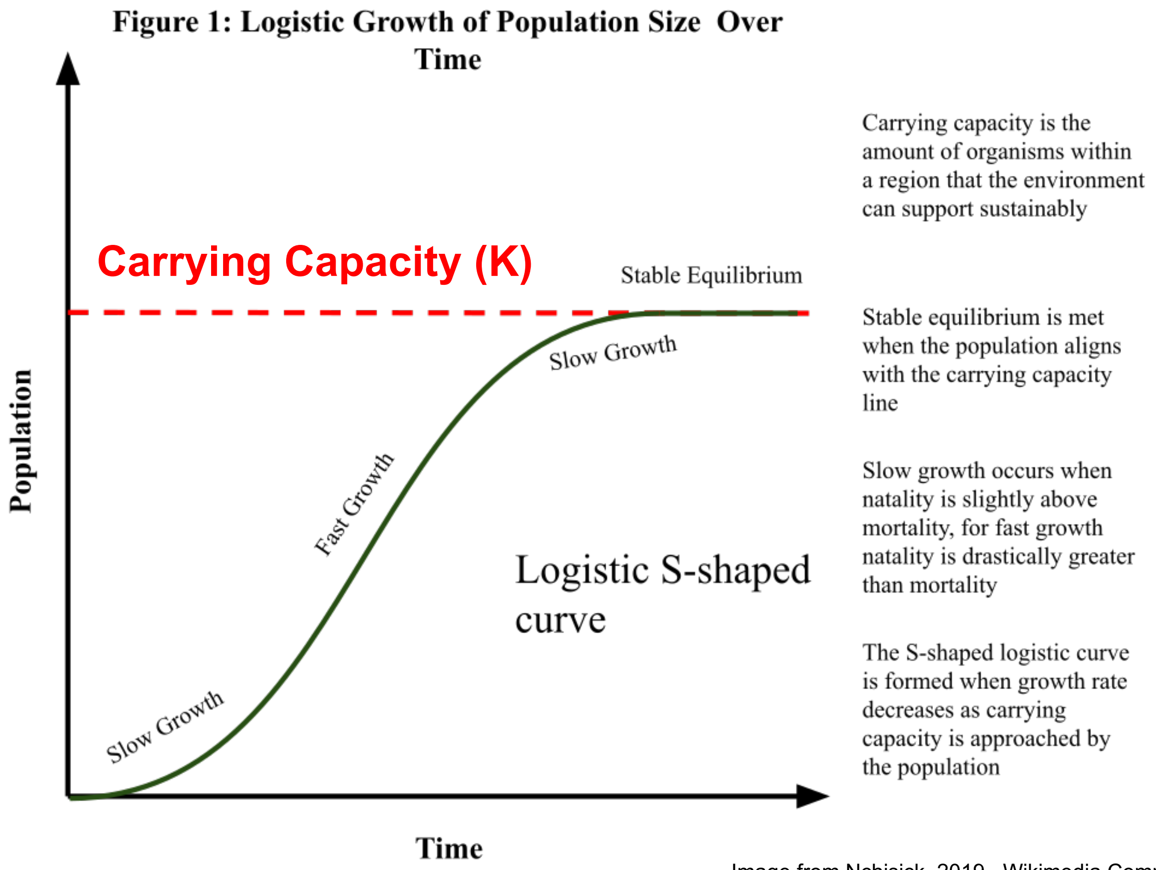


Image from Nchisick, 2019.. Wikimedia Commons

Minimum Viable Population (MVP) is the smallest population size at which a population can exist without facing extinction due to inbreeding, disasters or limiting factors.

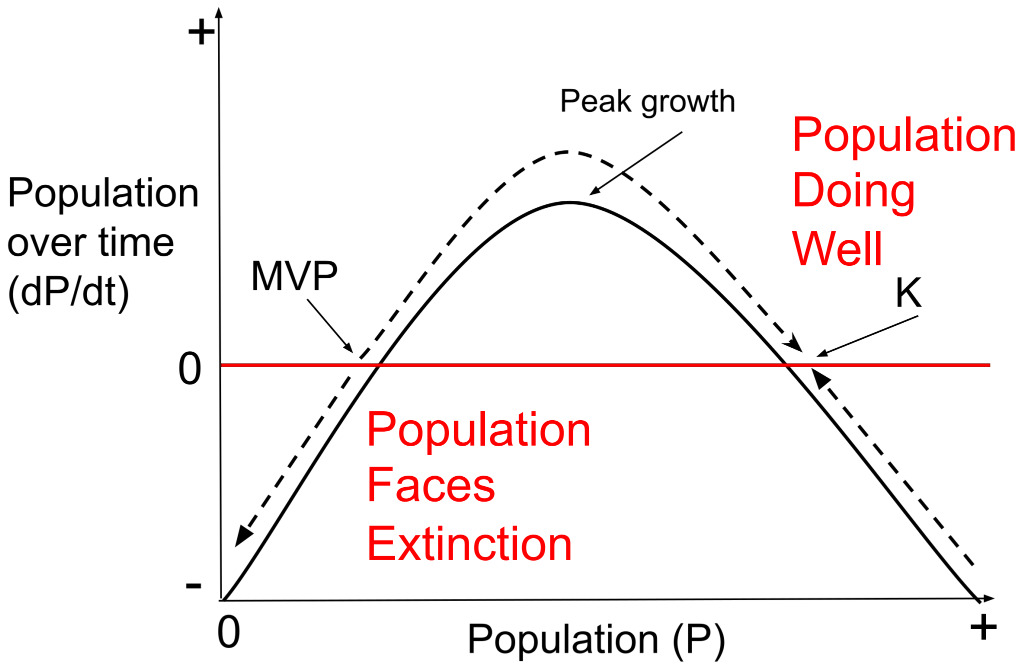


Image from Mathboy321,2019. Wikimedia Commons.

Population Growth Patterns

Limiting factors interact in complicated ways and produce patterns when it comes to population growth. In nature, populations grow, decline, and fluctuate in different ways.

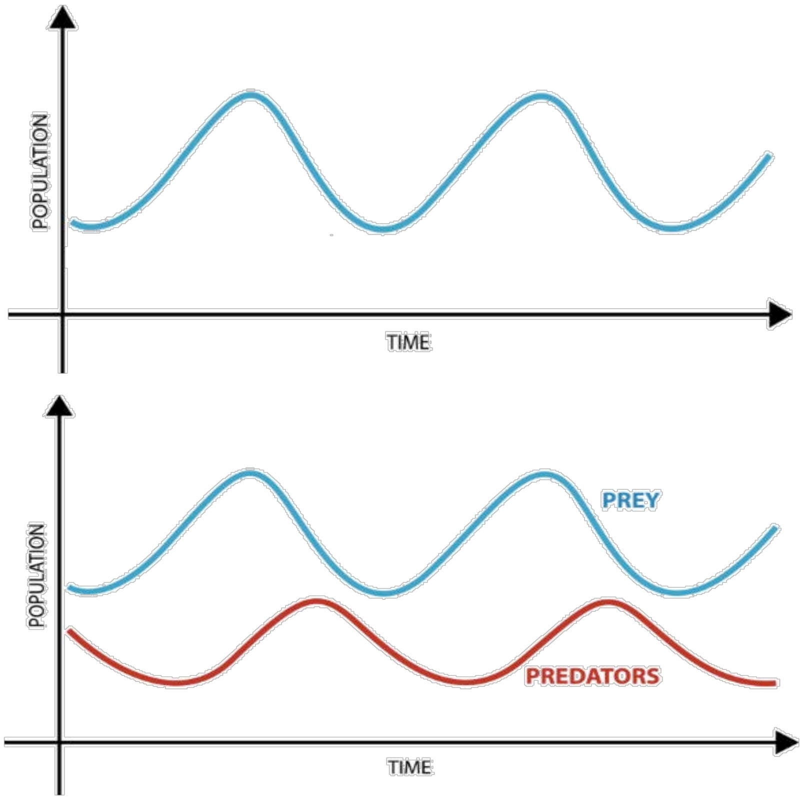
Populations do NOT permanently remain at their carrying capacity. Population ecology is a dynamic study in which these factors are constantly changing to influence populations and their growth. Even when populations appear to be stable, they often fluctuate around the carrying capacity, opposed to staying at the same value for long periods of time.

Population density influences how well a population thrives. When a population falls below the minimum viable population or rises above the carrying capacity the species will be challenged.

Population Growth Patterns

Some populations experience uneven rise and fall in their numbers; others have more regular cycles of boom (increase) and bust (decrease) referred to as **cyclical oscillations.**

Cyclical oscillations typically occur because of interactions between populations of multiple species or because of density-dependent limiting factors that drive a repeating cycle.

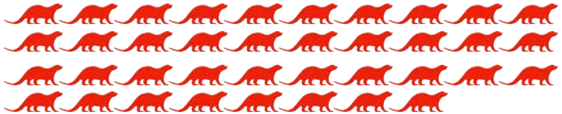


Images from CK-12 Foundation, 2016.

Calculating Annual Growth Rates and Doubling Times

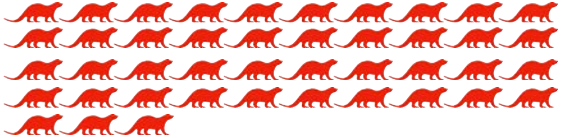
In 2018 Kennewick Island had 38 red otters living on it.

2018



In 2019 Kennewick Island had 43 red otters living on it.

2019



In 2019 the island had 43 otters. In 2018, the population consisted of 38 otters. We can use simple math to calculate the % increase, which is called annual growth rate.

43 - 38 = 5

In 1 year, the population grew by 5 otters.

1. What is the annual growth rate of red otters on Kennewick Island?

Answer: $\frac{5}{38} \times 100 = 13\%$ ← **The population grew by <u>13; this is the annual growth rate</u>**

2. Using the growth rate that you calculated in Question #1, approximately how long will it take the population of red otters to double from 38 individuals to 76 individuals living on Kennewick Island?

We will use the "Rule of 70" to answer Question 2. → $\frac{70}{13} = 5.4$ **years**

Answer: In 5.4 years (in the year 2023) we will see 76 otters; <u>5.4 years is the doubling time</u>.

Objective 4: Compare species life history strategies and discuss population management approaches.

Life History Strategies

Life history strategies are a species' biological characteristics that influence how quickly its population can potentially increase in number. Includes life span, fecundity (number of offspring an organism can produce) or maturity rate.

Life history is shaped by natural selection and produces specific traits for a species such as number of offspring an adult can produce, amount of parental care for offspring, and timing of reproduction. Life history strategies are different for each species and are dependent on its characteristics, its habitat, the environment and other outside pressures.

An organism's life history strategies and energy budgets will determine the type of reproductive capacity that a population will maintain over time.

Life Tables

Life tables provide data regarding the life history of an organism, divides the population into different age groups, and shows predicted life expectancy.

Life tables typically include:

- Mortality rate
- Percentage of organisms within specific age intervals
- Life expectancies

Life Table of Dall Mountain Sheep[1]				
Age interval (years)	Number dying in age interval out of 1000 born	Number surviving at beginning of age interval out of 1000 born	Mortality rate per 1000 alive at beginning of age interval	Life expectancy or mean lifetime remaining to those attaining age interval
0-0.5	54	1000	54.0	7.06
0.5-1	145	946	153.3	--
1-2	12	801	15.0	7.7
2-3	13	789	16.5	6.8
3-4	12	776	15.5	5.9
4-5	30	764	39.3	5.0
5-6	46	734	62.7	4.2
6-7	48	688	69.8	3.4
7-8	69	640	107.8	2.6
8-9	132	571	231.2	1.9
9-10	187	439	426.0	1.3
10-11	156	252	619.0	0.9
11-12	90	96	937.5	0.6
12-13	3	6	500.0	1.2
13-14	3	3	1000	0.7

Table 1: This life table of *Ovis dalli* shows the number of deaths, number of survivors, mortality rate, and life expectancy at each age interval for the Dall mountain sheep.

Image from OpenStax, 2020. Data adapted from Deevey, 1947.

Survivorship Curves

Life tables can also be plotted graphically as survivorship curves. These graphs show the number of individuals surviving at each age interval versus time. Population ecologists can use these graphs to compare the life histories of different populations.

There are three types of curves (shown here as Type I, II, III) that populations can display.

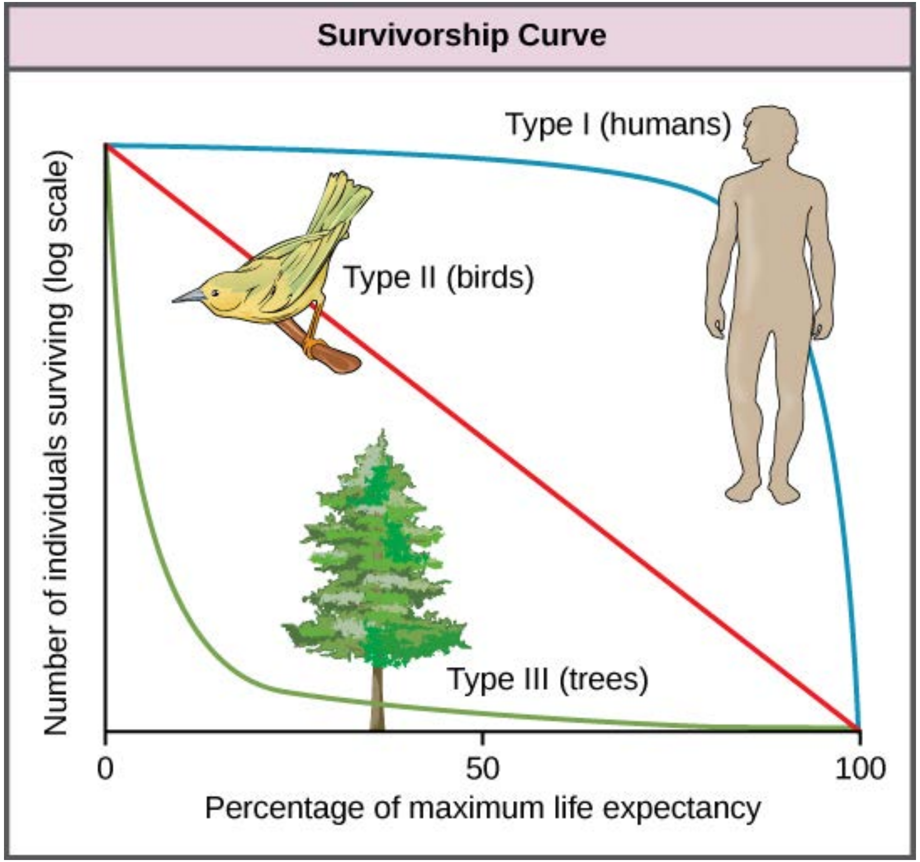
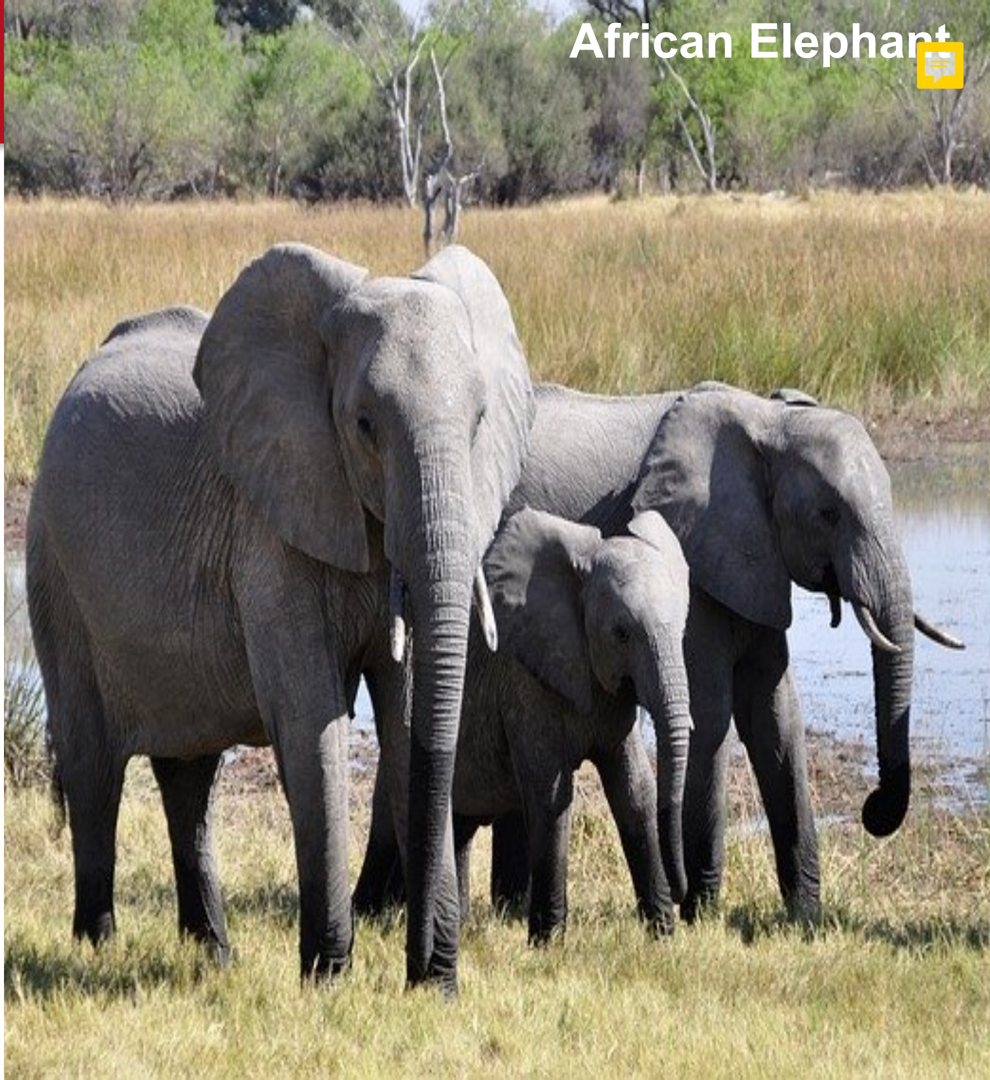


Image from OpenStax, 2012. Obtained from Wikimedia Commons.

K-selected Species

1. K = carrying capacity
2. Mature later and live longer
3. Experience a slower growth
4. Produce fewer, larger offspring
5. Experience a longer gestation period
6. High-level of parental care
7. Adapted to a stable environment
8. Often predators or higher-level consumers
9. Niche specialists

Examples: Elephants, Primates, Bears, Trees, Whales, Humans



r-selected Species

1. r = reproductive success
2. Mature quickly and have shorter life span, typically small in size
3. Experience rapid growth
4. Produce many offspring
5. Experience a short gestational period
6. Little parental care of offspring
7. Adapted to changing environments
8. Are often prey species
9. Niche generalists

Examples: Mice, rabbits, insects, many types of plants.

Boom-and-Bust Cycles

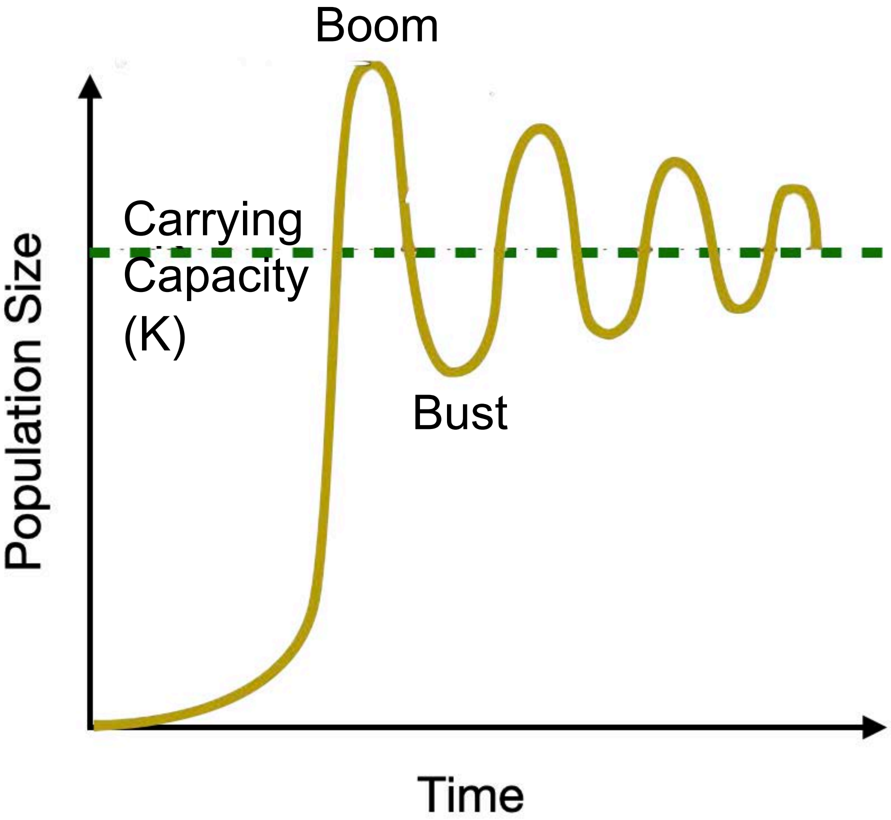
- K-selected species tend to have stable population size in undisturbed areas. There numbers increase and decrease in response to the environment. Their population size fluctuates at or near carrying capacity (K).

- r-selected species have rapid reproductive potential. These populations can experience sudden population growth with high peaks, which may exceed an ecosystem's carrying capacity. This will be followed by a sudden population crash as individuals die or migrate out of the area. Some populations may level off at or near the carrying capacity (K), while other populations continue to overshoot K and then crash. These cycles in population size are referred to as a **boom-and-bust cycles.**

Boom-and-Bust Cycles

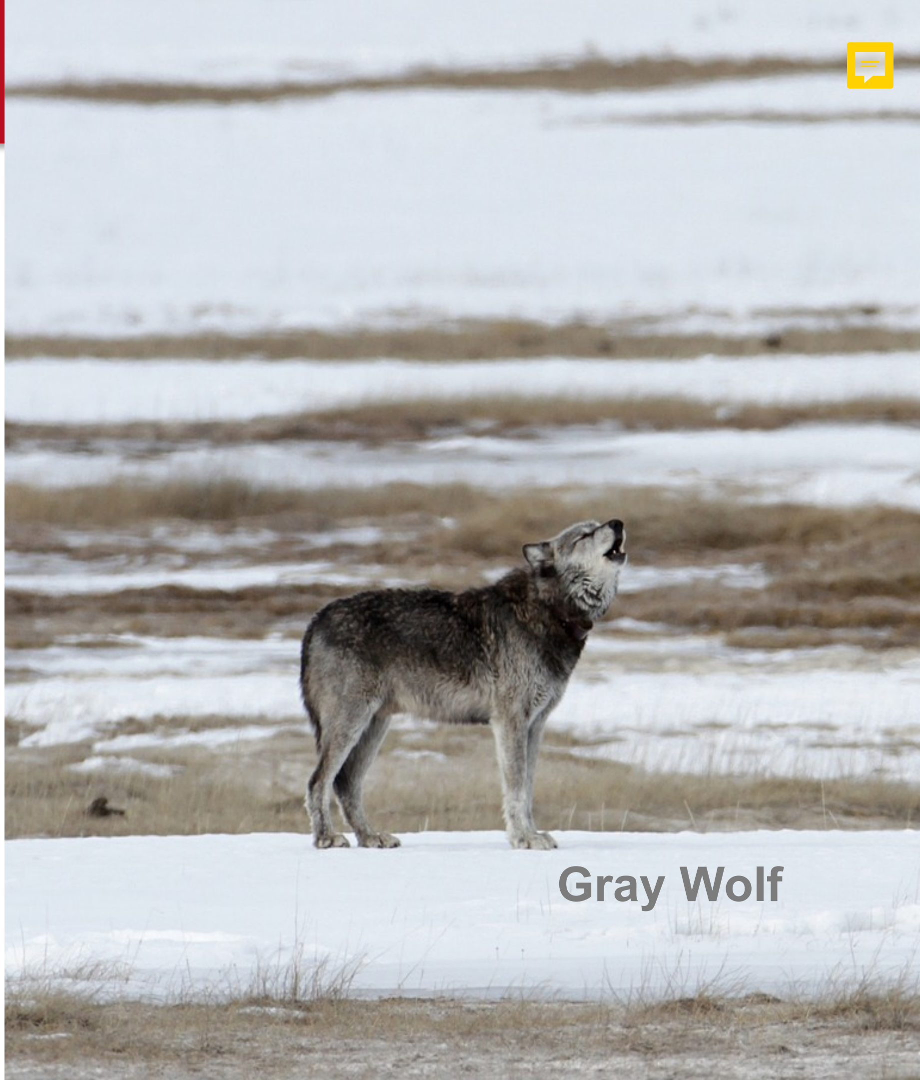
- Boom = the population grows rapidly to a maximum level
- Bust = the population declines rapidly to a minimal level

Image Argus fin, 2006. Wikimedia Commons.



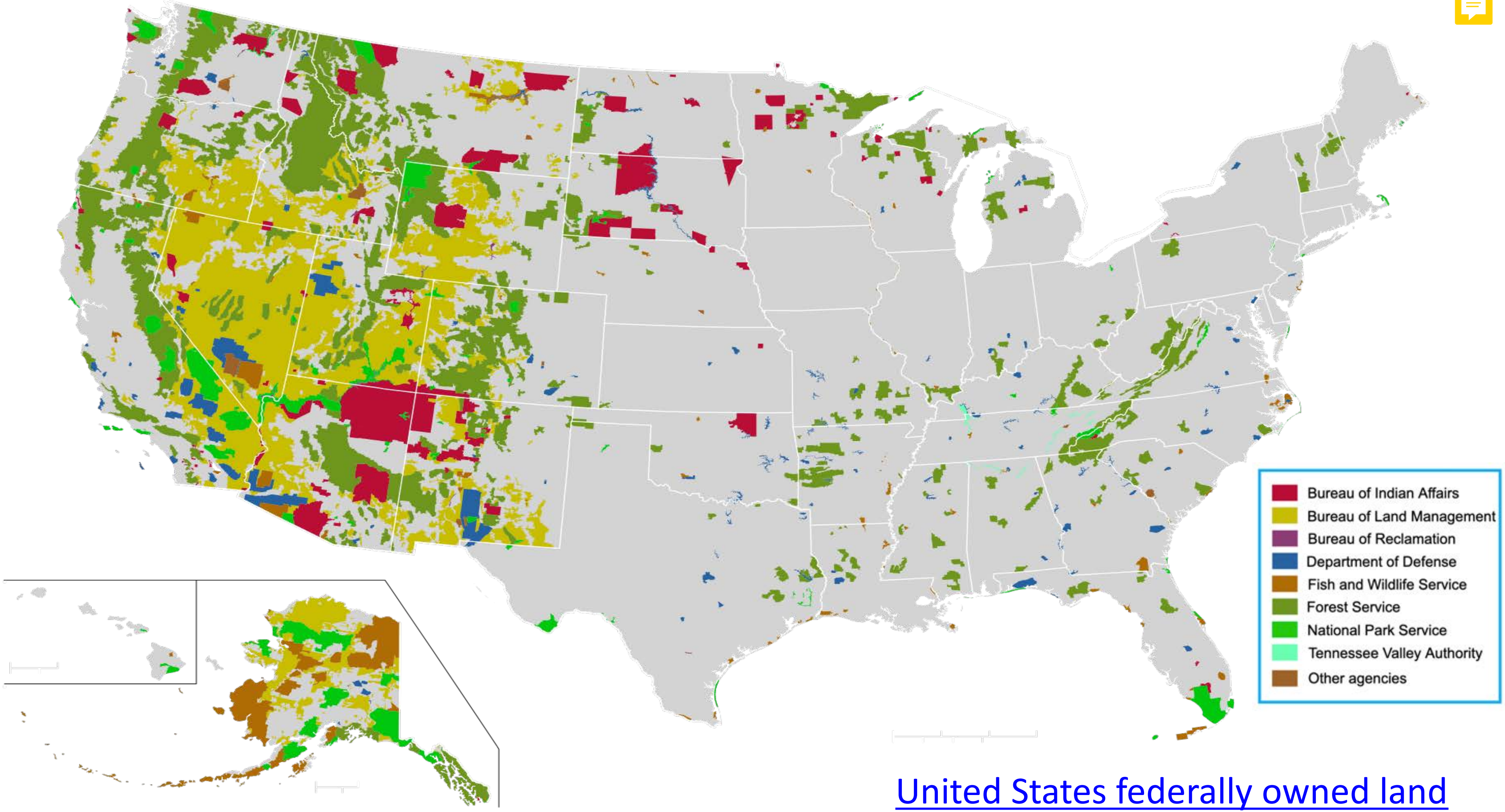
Top-Down Regulation is the control of a population's size due to pressures from the top tropic level that causes death. These include the resistance factors like predation, natural disasters, and disease.

Top-down models predict changes in population density at one tropic level caused by an inverse change in a higher trophic level. For example, elk population density declines in Yellowstone National Park due to an increase in the number of wolves in the park.



Bottom-Up Regulation is the control of a population's size due to factors at the bottom of a tropic pyramid that control growth and survival.   These include growth factors such as nutrients, water, sunlight, space and habitat.

This model focuses on how factors at lower trophic levels affect organisms living at higher trophic levels.

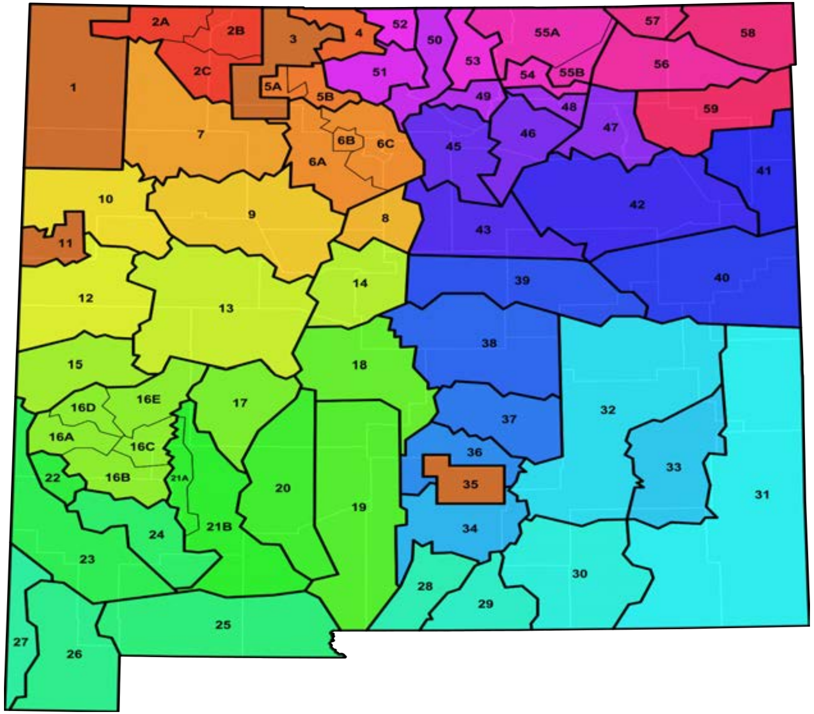


[United States federally owned land]

Image National Atlas of the US, 2014. Wikimedia Commons.

Wildlife Management works to balance the needs of people with the needs of wildlife (plants and animals). It uses both monitoring programs and research-based programs to maintain healthy populations. Wildlife management can include, reintroduction of native species, hunting, wildlife conservation and pest control.

Image by Ninjatacoshell, 2011. Wikimedia Commons.



This map shows New Mexico’s 58 Wildlife Management Units. These units are managed by the U.S. Bureau of Land Management and the New Mexico Department of Fish and Game.

Wildlife Management

Wildlife managers keep wildlife populations healthy, well-maintained and ensure that humans and wildlife can coexist in nature. Wildlife managers work in a variety of ecosystems and with a wide range of plant and animal species. They must be knowledgeable of the species living within their management ecosystem. Wildlife managers manage population numbers by:

1. Monitoring wildlife populations (health, age, sex, birth rate, death rate, migration)
2. Investing in and conducting research (biology, chemistry, ecology)
3. Adjusting harvest levels or objectives (catch quota for fish, hunting limits)
4. Preserving and restoring wildlife habitat (reintroduction of native species)
5. Providing access and information to the public (park rangers, news, classes)

Wildlife Management Plans

Wildlife management plans are created by management agencies to protect resources, plants, animals and to provide long-term strategies for their management.

These plans likely include;

1. Population management strategies
2. Habitat management strategies
3. Costs and expenditures
4. Outreach and education efforts
5. Evaluation of different techniques

No two management plans are the same, plans vary depending to the goals, size, available resources, type of habitat, number of different species needing protection, time, viable schedule, workload, cost, etc.