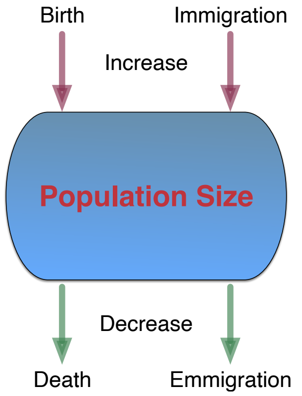
Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

Population dynamics - changes

No population remains constant forever. Even the human population is not stable; while it is growing rapidly, the growth is not the same in every country and is even actually falling in some. The same thing occurs in natural populations of all organisms. Numbers of individuals can increase or decrease over time

Many factors can affect population size, but their total combined impact can be determined by 4 measures that directly alter the population size of any species:



Birth rate

Death rate

Immigration

Emigration

Every organism needs certain resources from its environment. This could include food, shelter, light, salinity and pH etc, the list could be even longer. But only a limited quantity or fixed value of any of these exists in a habitat. Therefore a habitat will only support a maximum number of any individual species at any one time. This is **carrying capacity** of the environment.

SO HOW DO POPULATIONS GROW?

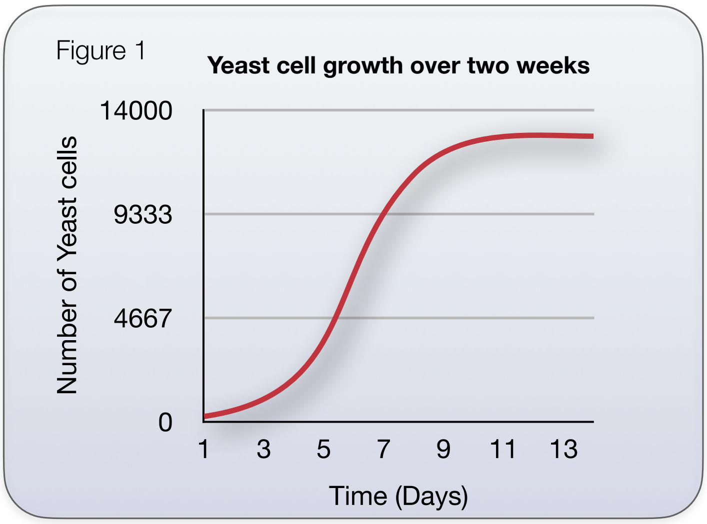
A population released in a favourable environment will begin to increase in numbers.

Lokta (1929) worked out that in ideal conditions, with limitless resources, populations show exponential growth. The population doubles each generation: 2 .. 4 .. 8 . .16 .. 32 .. 64 .. 128 .. 256 .. etc

You don't get a straight line. (fig.1)

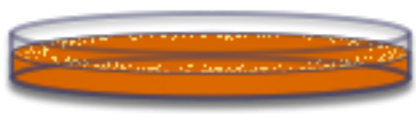
You don't get a straight line.

But in natural habitats the resources available are not infinite, so as the population grows it starts to experience environmental resistance. Lack of resources become limiting factors that have an effect on continued population growth. The result is that population growth slows down.



Eventually the population reaches a maximum number that the limited resources in the habitat can support (carrying capacity). When carrying capacity is reached the number of gains in population size (birth and immigration) equals the number of losses (death and emigration) and the population size stabilises.

This gives us the S or Sigmoid shape curve that can be seen in Figure 1.



Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

Population dynamics - changes

A sigmoid growth curve can be divided into four distinct regions where different population factors occur.

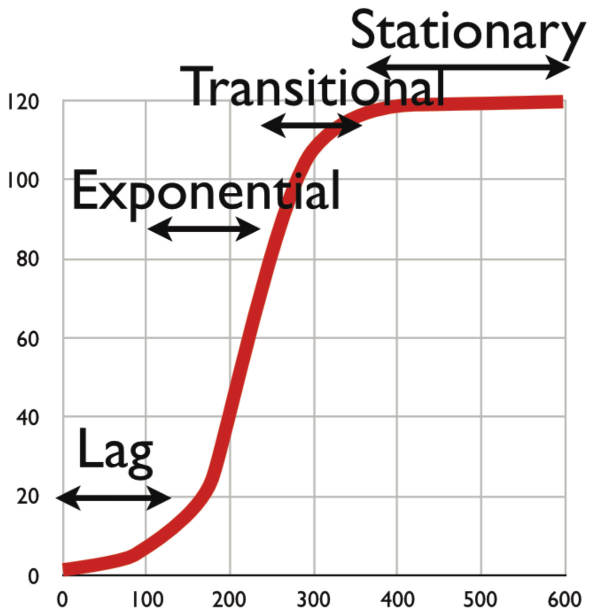


Figure 2: Phases of logistic growth

Lag phase: This is where the population growth is very slow. The population is small and adapting to the environment.

Exponential phase: Growth increases rapidly as there are more available resources than numbers in the population to fully exploit them. The population feels no effects of environmental resistance.

Transitional Phase: The rate of increase begins to slow as resources start to become limiting. Less food is available for instance.

Stationary Phase: The carrying capacity of the environment has been reached. There are no unused resources to be exploited by the population so the habitat can not support any more individuals.

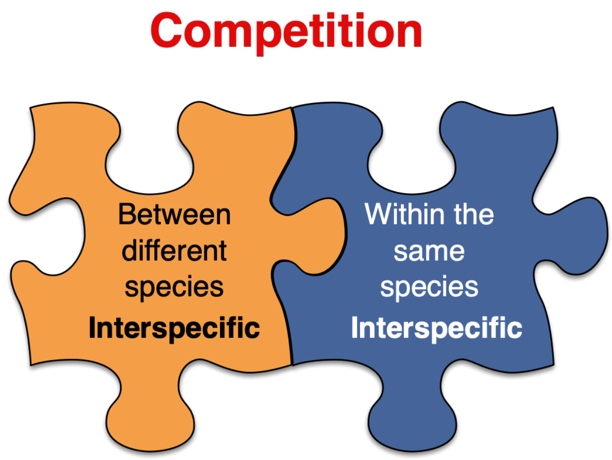
Factors that limit population growth

The factors that limit population growth affect the birth or death rates.

These can be either biotic or abiotic, and involves competition.

Competition between organisms within the same species for mates, shelter, food, water, light, nutrients form one set of limits - this is called **intraspecific competition**

While competition with other species, sometimes directly for space or food or indirectly in herbivore and predator - prey interactions and parasitism, forms another - **this is called interspecific competition**



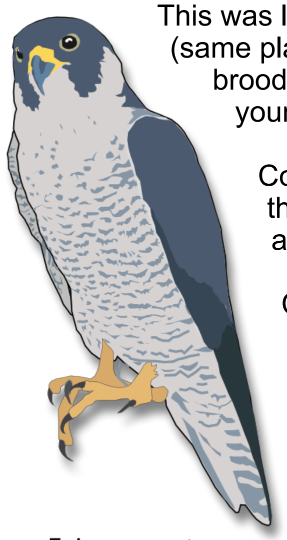
Population regulation

Until the 1940's the British population of Peregrine falcons had remained fairly constant - about 820 breeding pairs

This was limited by available nest sites (same places each year). The average brood size was about 2.5 fledged young each summer

Come the next breeding season the population was back to about 820 pairs.

Competition for suitable nesting sites regulated the population of Peregrine falcons . **Intraspecific competition.**



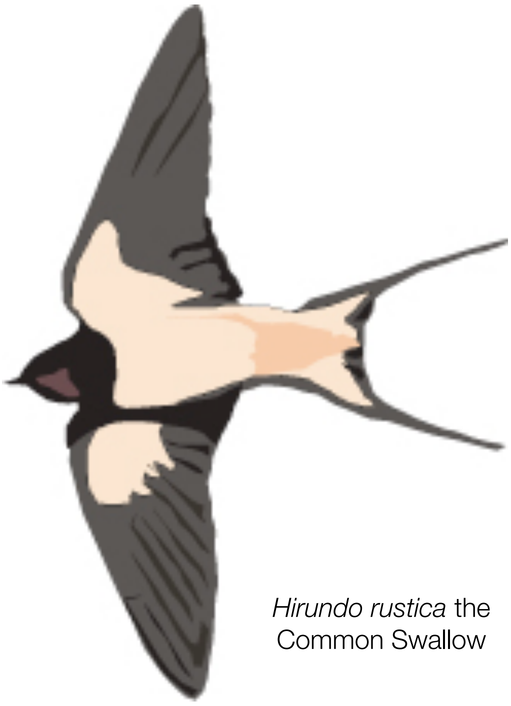
Falco pereginus

Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

Population dynamics - changes

As populations grow then competition between individuals within the population tends to come into play and resources start to become limited, as more and more individuals compete for a smaller and smaller share of the resource. This can continue until a theoretical point is reached where the amount resources available can not support any additions above current population. As mentioned earlier this is the carrying capacity of the environment.



Hirundo rustica the Common Swallow

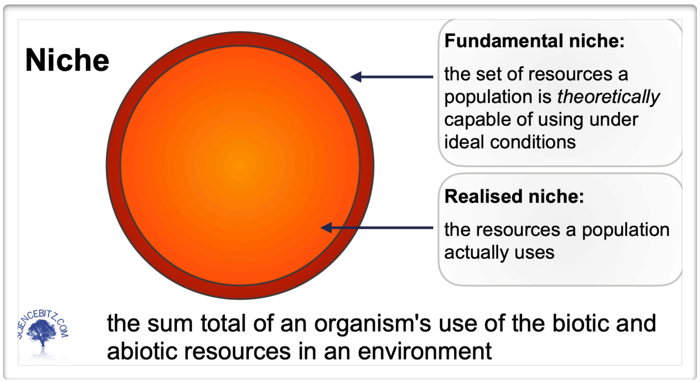
This can be illustrated by examining the declining Swallow population in Europe. Since the 1970's concern has been raised about an apparent decline in the breeding populations of these birds across Europe. Two possible explanations are linked to changes in farming practices. Extensive use of pesticides on crop plants has reduced the number of insects that swallows can feed on. However another factor is the loss of old brick and stone farm buildings that Swallows require for nest sites: this is an effect on their reproductive success, fewer breeding sites means fewer young and so eventually fewer adults.

This is known as **density dependent** competition.

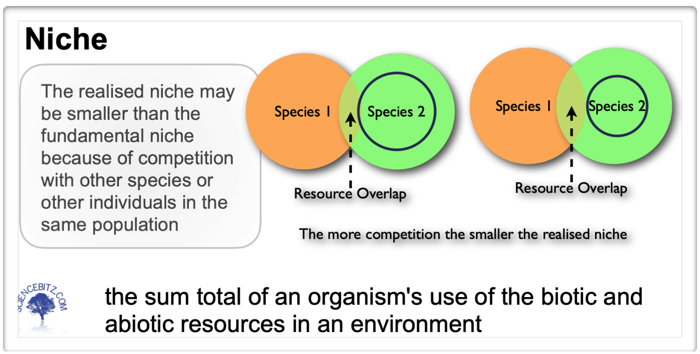
Density dependent competition increases as the population grows. The population of mussels in the image below is limited by the availability of suitable sites to anchor onto. AS the population grows so the area of uncolonised rock decreases. The population is limited by available space.

Edible mussels at Worms Head in South Wales, UK.

Density dependent competition can also occur between organisms of different species. This is especially true if organisms occupy a similar **niché.**



When two species compete for similar resources competition occurs. If one species is competitively fitter than the other, the competition may result in the population of the second species disappearing from that habitat.



Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

Population dynamics - changes

A classic study of niché and competition between two species

Joseph Connell's Barnacle experiment.

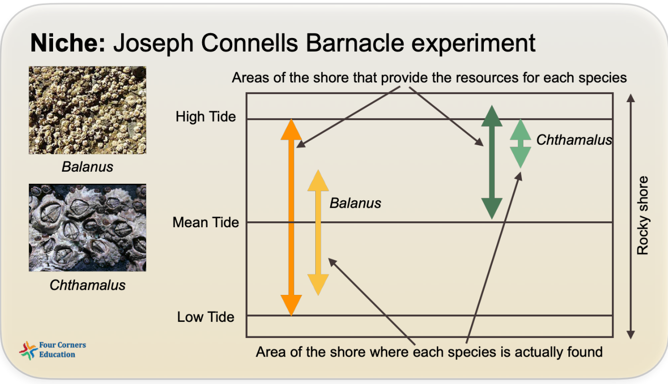
From observations of of two barnacle species on a rocky shore and their distribution up and down the shore, Connell noted:

That one species *Balanus* mainly found on the lower shore between high and low tides

That the other species *Chthamalus* was mainly on the upper area

However the larvae of each species can swim anywhere on the the rocky shoreline so should be able to survive anywhere.

These observation led Connell to pose a Research Question (RQ): **Why are they not found together?**



Connell conducted a series of experiments:

EXPERIMENT ONE

He removed *Chthamalus* for the top of the shore but *Balanus* did not replace it. His conclusion was that *Balanus* need to be in the tidal area and could not survive the often dry periods between the highest tides

Balanus realised niche was the same as its fundamental niche.

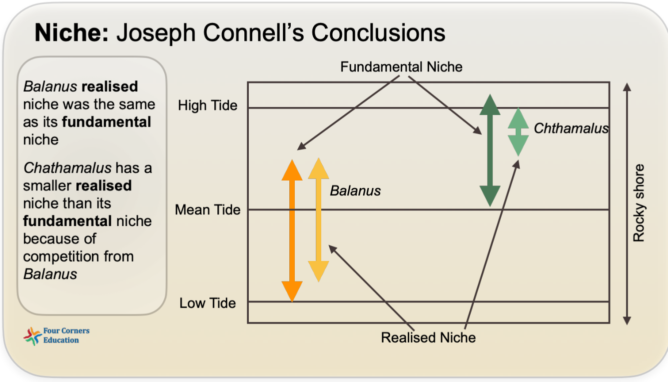
EXPERIMENT TWO

He removed *Balanus* for the bottom of the shore and *Chthamalus* replaced it:

His conclusion was that *Balanus* outcompeted *Chthamalus* in the lower tidal area

Chathamalus has a smaller realised niche than its fundamental niche because of competition from *Balanus.*

What Connell had shown was that biotic interactions between individuals of different species can explain the actual conditions and resources (abiotic) in which a species exists as its realised niche.



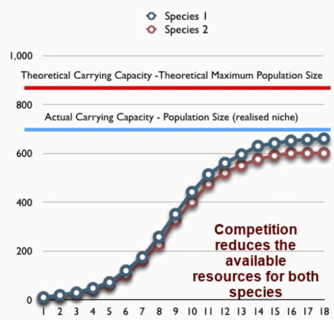
So from this we can see that competition between two species can either reduce the size of both populations:

Or one species may totally out competes the other species.

Competition

Competition may result in a balance, in which both species share the resource.

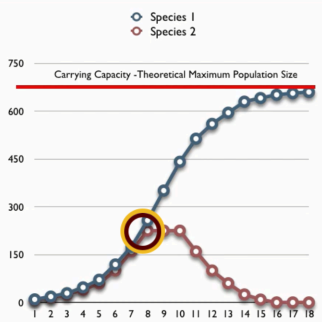
But with the population size of each species reduced compared to without competition *(Balanus and Chthamalus)*



The other outcome is that one species may totally out compete the other.

This is the principal of competitive exclusion

Species 1 starts to outcompete Species 2 at this population size



Four Corners Education

Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

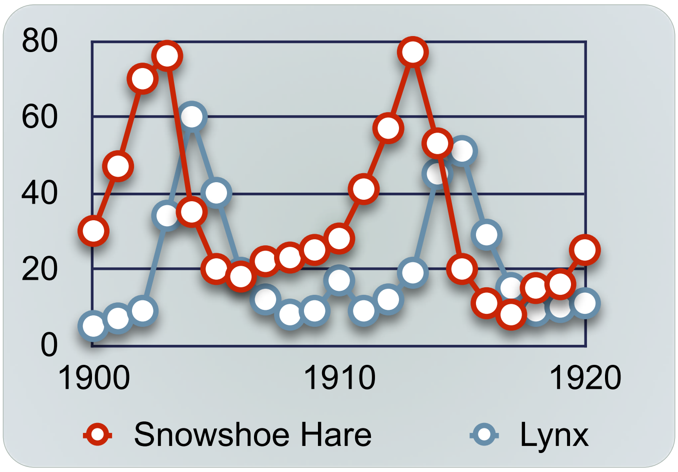
Population dynamics - changes

Predator and prey relationships

Populations of predators and prey are linked. That might seem obvious.

In any area there are only so many prey. The number of prey available is the maximum amount of energy available to the predator population. Think back to energy flow through an ecosystem and how the amount of energy available at one trophic level affects the next trophic level. If there are only a small number of prey there can only be a small number of predators - this is one reason why most predators in most ecosystems do not feed exclusively on one prey species.

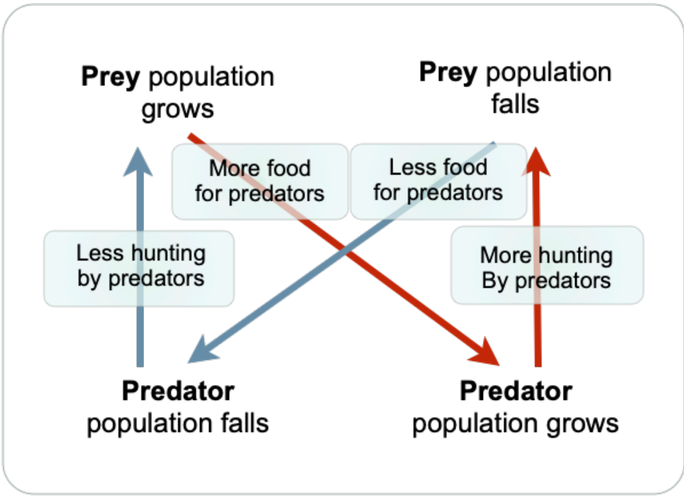
If prey is plentiful the predator population can grow. But as it grows it starts to reduce the numbers of the prey population. This relationship can be seen in the classic snowshoe hare, lynx population fluctuations.



In 1942 Elton and Nicholson published a famous time series of snowshoe hare and lynx population figures from hunting records of the Hudson's Bay Company in Canada.

These figures captured a 10 year cycle in the populations driven by predation. Each population dependent on the population size of the other but remaining in an equilibrium.

The snowshoe hare lynx cycle is an example of Negative feedback. This tends to damp down, neutralise or counteract any deviation from an equilibrium, and promotes stability.



Predation by the lynx population controls the number of snowshoe hares which in turn controls the maximum size of the lynx population.

The effect of one population on the other can be seen in the time lag between each.

Herbivore, plant interactions can be thought of in exactly the same way.

Studies of Reindeer populations on on St Mathew island Alaska show:

That the amount of winter food available sets the carry capacity for that ecosystem

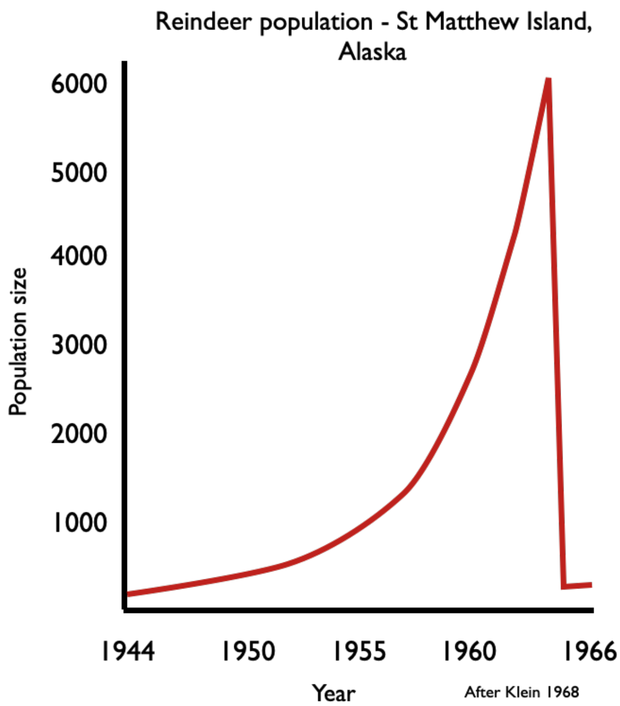
The carrying capacity of the herbivore population controls the size of any predator population - (part of the predators niche)

The studies also show that without predation to control the population, reindeer numbers often outstrip their food supply (Biotic control)

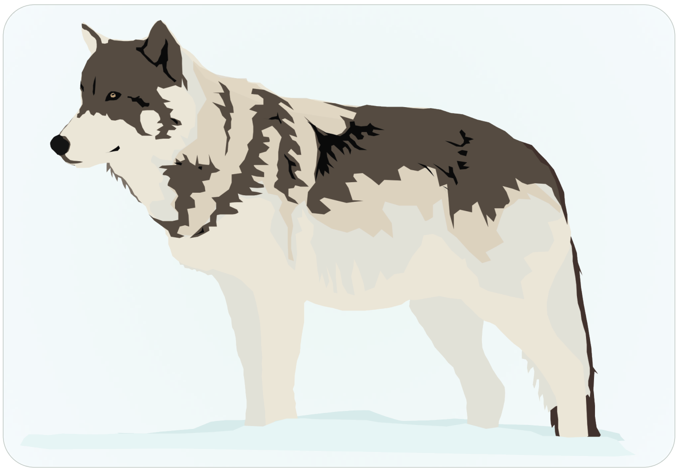
Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

Population dynamics - changes



The boom or bust conditions above are also driven by density dependent factors. While there is plenty of food, the reindeer population grows. However eventually it overgrazes the food and then starves. Without predators on St Matthew Island, the reindeer outcompete themselves.



In parts of Finland Grey Wolf populations changes appear to follow behind Reindeer population changes

Is this evidence of a Negative feedback - predator / prey relationship?

While the actual answer is more complex - the population numbers of all predator and prey systems do have an effect on each other.

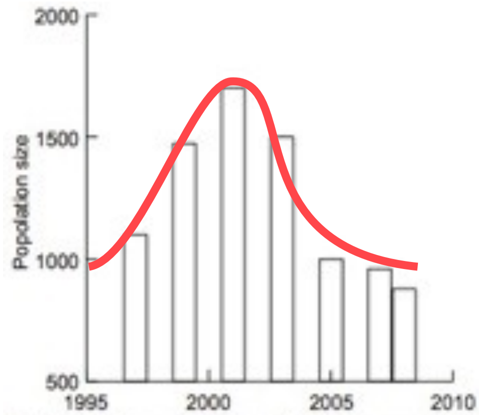


Fig. 1. Development of the wild reindeer population during 1997–2008, eastern Finland.

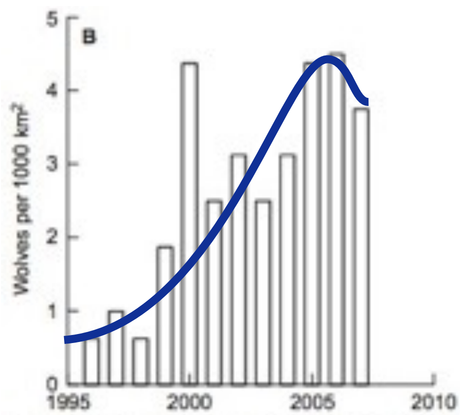


Fig. 4. (A) The number of wolf territories occupied by packs or pairs, and (B) the estimated density of wolves in early winter, 1996–2007, eastern Finland.

Figures from: Kojola, I., Tuomivaara, J., Heikkinen, S., Heikura, K., Kilpeläinen, K., Keränen, J., Paasivaara, A. & Ruusila, V. 2009: European wild forest reindeer and wolves: endangered prey and predators. — Ann. Zool. Fennici 46: 416–422

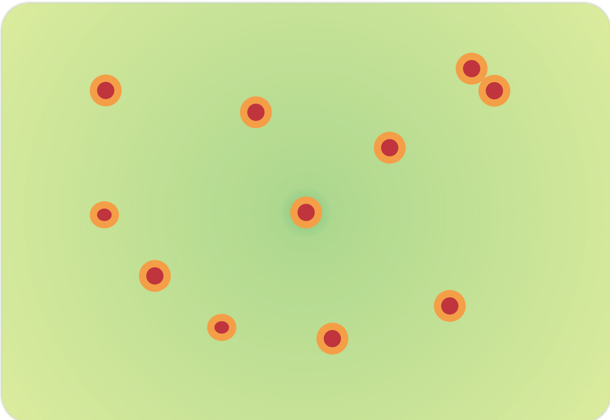
Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

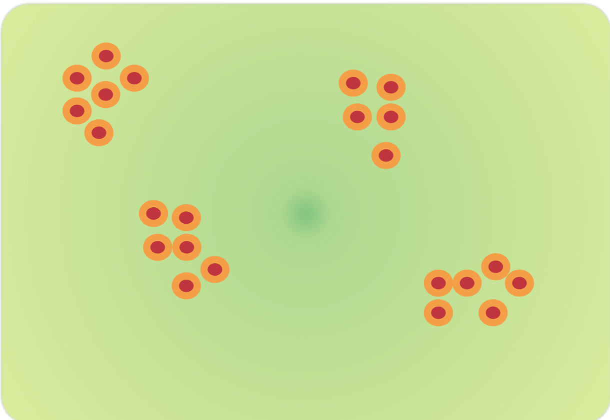
Population dynamics - changes

Distribution of individuals in population

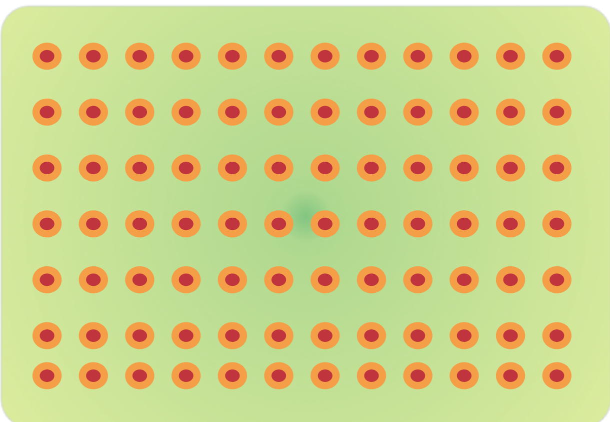
Random distribution



Clumped distribution



Uniform distribution



Populations exist in three basic distribution patterns: Random, Clumped or Uniform.

Random distribution is an irregular pattern of distribution. The presence or absence of any member of the population does not have an effect on where the next member of the population is found. Random distribution is common in many plant species.

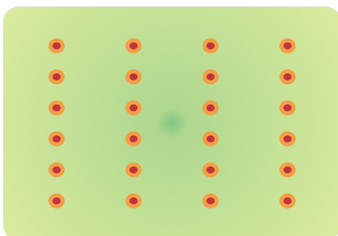
Clumped distribution is a pattern where individuals are grouped together in small groupings. Presence elf one individual increases the chances of another individual being near bye, though space exists between each group. This is a pattern often found in herding or among certain predators such as lions.

Uniform distribution is a regular pattern where individual are evenly spaced. Penguins are the classic example of uniform distribution.

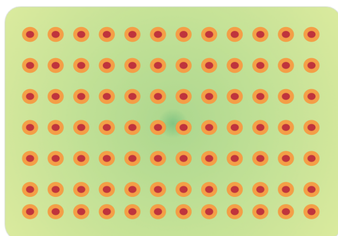
Density

Regardless of the distribution pattern as any population grows the density of the population increases - the space between individual or the space in which individuals can live reduces.

Low density



High density



Density can be number of organisms per unit area or unit volume (aquatic systems)

Higher the density the greater the infraspecific density depended competition.

If two different species are at high density then this could lead to interspecific density dependent competition, increasing.

Topic 2: Ecosystems and Ecology

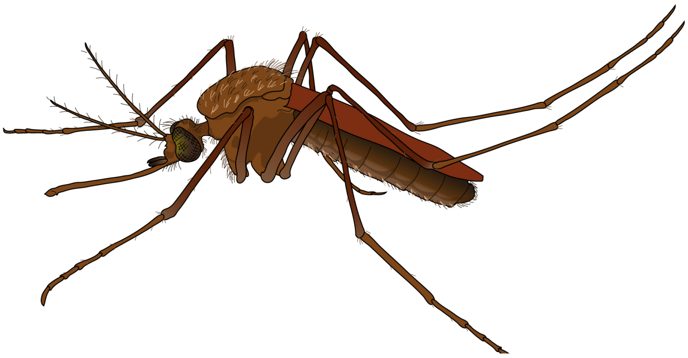
Topic 2.1: Species and Population

Population dynamics - changes

Types of interaction

We have already looked at predation and herbivory, and competition, but they are not the only forms of biotic interactions between species.

Parasitism: *is a relationship between two species in which one species lives in or on another gaining its food from it.*



Mosquitos are not only parasites of human populations but also of many other animals.

Parasitism can be thought of as a special form of predation.

Mutualism: a relationship between two or more species in which both or all benefit and none suffer.

Lizard orchid - Himantoglossum hercinium

Many orchids have bacteria associated with root nodules that fix nitrogen that the orchid then uses, the bacteria gains a source of glucose from the orchid.

Density in dependent factors

As well as density dependent factor, population are also subjected to density independent factor. These are abiotic factor that can affect the entire population or just part of it.

Density independent factors	
Physical factors	**Catastrophic events**
Precipitation	Fire
Temperature	Flood
Humidity	Dought
Acidity	Earthquakes
Salinity	Tsunami
Pollution	Volcanic activity

Feral goat herds in the Pyrenees in France, do not have any natural predators, so their population is controlled by available food. In the last 30 years populations have risen dramatically and are now causing a problem in some areas. The only control on population is severity of winter and early spring, when in very cold years, many older goats die and few young are born. Winter temperature is a density independent factor.

Topic 2: Ecosystems and Ecology

Topic 2.1: Species and Population

Population dynamics - changes

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Kojola, I., Tuomivaara, J., Heikkinen, S., Heikura, K., Kilpeläinen, K., Keränen, J., Paasivaara, A. & Ruusila, V. 2009: European wild forest reindeer and wolves: endangered prey and predators. — Ann. Zool. Fennici 46: 416–422

Further reading:

Joseph Connell's classic paper on interspecific competition in barnacles: http://www.life.illinois.edu/ib/453/connell.pdf

What limits the Serengeti zebra population? A study of population dunbamics and limiting factors for zebra and wildebeest https://cbs.umn.edu/sites/cbs.umn.edu/files/public/downloads/What_limits_the_Serengeti_zebra_population_Grange_et_al_2004.pdf

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