POPULATIONS

Content Statements:

C4.1.1	Populations as interacting groups of organisms of the same species living in the same area
C4.1.2	Estimation of population size by random sampling
C4.1.3	Random quadrat sampling to estimate population size for sessile organisms
C4.1.4	Capture-mark-release-recapture and Lincoln index to estimate population for motile species
C4.1.5	Carrying capacity and competition for limited resources
C4.1.6	Negative feedback control of population size by density-dependent factors
C4.1.7	Population growth curves
C4.1.8	Modelling of the sigmoid population growth curve
C4.1.9	Competition versus cooperation in intraspecific relationships
C4.1.16	Predator-prey relationships as an example of density-dependent control of animal populations

POPULATIONS

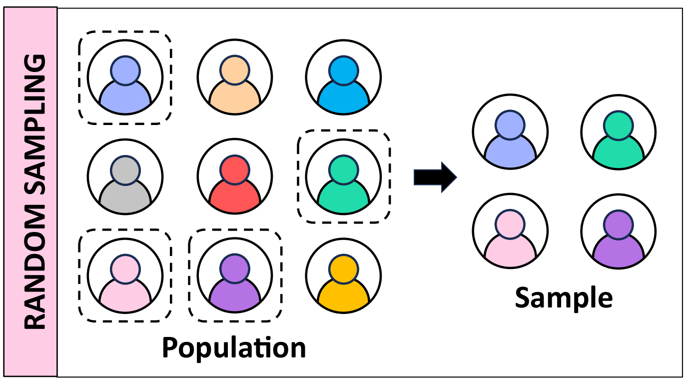
A population is a group of organisms of the same species, living in the same area (or habitat) at the same time. The size of a population can be increased by natality (births) or immigration, while it is decreased by mortality (deaths) and emigration. Members of the same population will typically breed together, meaning **reproductive isolation** can be used as a measure to distinguish one population of a species from another.

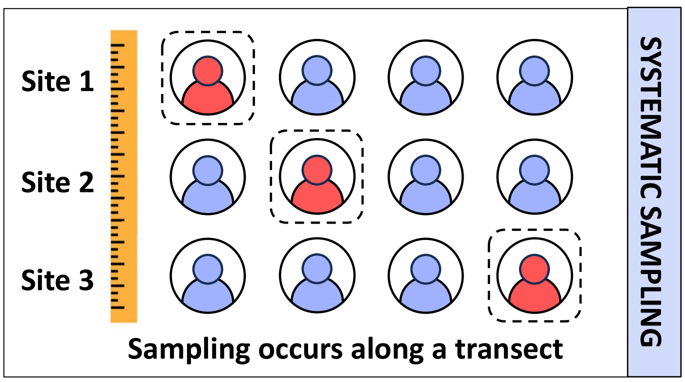
POPULATION SAMPLING

Population sampling involves identifying the number of individuals in small areas and then extrapolating to estimate population totals. The difference between the estimate of population size and the true size of the whole population is known as the **sampling error**. The more samples that are undertaken and the larger the sampling area, the more accurate the estimates are likely to be. Sampling can be random or systematic:

- **Random sampling:** The positions of the sampling points are selected at random to avoid potential bias
- **Systematic sampling:** Positions of sampling points are assigned at fixed intervals throughout the area

Random sampling can be undertaken by establishing a grid of the target area and arbitrarily assigning grid coordinates (e.g. via a computer program). Systematic sampling could occur by establishing a straight line through a habitat (transect) and sampling at regular intervals. Systematic sampling allows the distribution of a species to be measured against a changing environmental condition (e.g. elevation, soil salinity, etc.)





QUADRATS

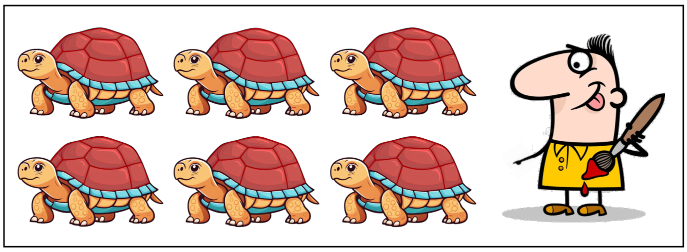
The population size or distribution of a **non-motile** (or *sessile*) species can be determined using quadrat sampling. A quadrat is a rectangular frame of known dimensions that can be used to establish population densities. Quadrats are placed inside a defined area in a random arrangement or according to a transect. The number of individuals of a species is either counted or estimated via percentage coverage. When the process is repeated many times, a mean and standard deviation can be calculated. The standard deviation shows the degree of data spread and could be used to indicate how evenly distributed the population is.

LINCOLN INDEX

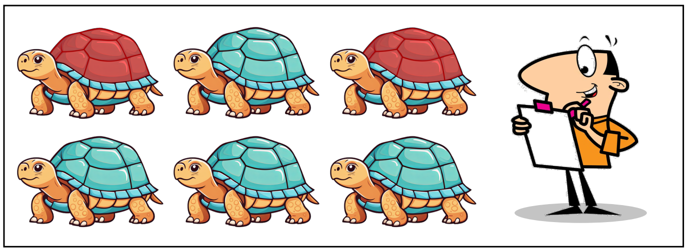
The population size of **motile** species can be determined using a *capture-mark-release-recapture* method. This method involves the collection of three pieces of data which are used to derive a population estimate:

- **M:** The number of individuals that are captured in a defined area, before being marked and released
- **N:** The number of individuals recaptured after a sufficient period of time has passed for reintegration
- **R:** The number of marked individuals that are present within the second recaptured sample group

The **Lincoln index** is a formula that can then be used to provide a population size estimate based on the three collected values. The Lincoln index formula is written as follows: **Population Estimate = M × (N ÷ R)**



Capture and Mark



Release and Recapture

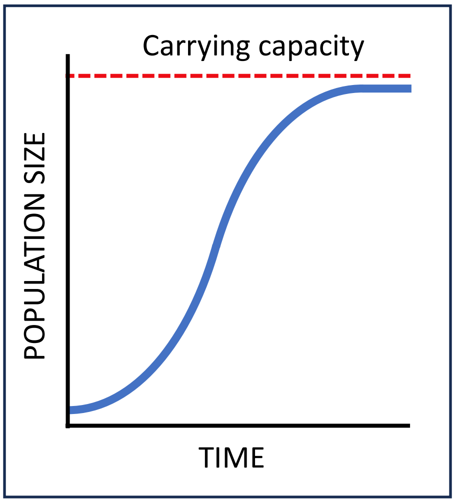
For the Lincoln index formula to be considered valid and reliable, certain assumptions must be held true:

- That all individuals in a given area have an equal chance of being captured (sampling must be random)
- That marked individuals will be randomly distributed after release (reintegration allows for even spread)
- That the action of marking individual organisms won't affect the mortality or natality of the population
- That the marking will remain visible for the duration of the sampling (not removed before recapture)
- That the population size does not change significantly between the periods of first and second capture

POPULATION GROWTH

Stable populations occupying a fixed geographic space demonstrate a sigmoidal (S-shaped) growth curve that involves three main stages:

SIGMOIDAL GROWTH CURVE



1. Exponential Growth Phase

Initially, growth is slow as there are few individuals. As the numbers accumulate, there is rapid growth as natality rates exceed mortality.

2. Transitional Phase

As the population grows, resources eventually become limited, which leads to competition. Mortality rates start to rise, slowing the growth.

3. Plateau Phase

When mortality rates equal the natality rate, the growth will become static. The population size will oscillate around a **carrying capacity**.

MODELLING POPULATION GROWTH

Population growth curves can be modelled using simple organisms that grow under laboratory conditions – such as **yeast** or **duckweed**. These organisms are small and so can easily populate small containers that are easy to store. Also, their nutritional requirements are low, making experiments inexpensive to conduct. The organisms will reproduce very rapidly, allowing results to be generated in a relatively short period of time. The growth rate of yeast can be measured by growing the microorganism in a broth culture and measuring turbidity, while duckweed reproduces to form clusters of fronds that can be counted via a visual inspection.

INTRASPECIFIC RELATIONSHIPS

Intraspecific interactions occur between members of the **same species** and may include cooperation and competition. When cooperation occurs, both members of the relationship will benefit from the interaction, whereas competition involves one member deriving a greater benefit from the interaction between them. Examples of cooperation include pack animals demonstrating coordinated hunting practices or insects that work together to build nests and search for food. Competition can involve trees (such as oak) competing for access to light and minerals in the soil, while animals (like gorillas) compete for territory or access to mates.

CARRYING CAPACITY

The **maximum number** of individuals of a species that the environment can support is called the carrying capacity. In a population growth curve, the carrying capacity (K) represents the point at which the plateau phase is achieved. Populations will oscillate around the carrying capacity, as exceeding environmental limits results in mortality. The carrying capacity is not a static value and is influenced by abiotic and biotic factors.

DENSITY-DEPENDENT FACTORS

Density-dependent factors push population size back towards the carrying capacity, as higher population densities result in more competition and increased mortality. This is an example of **negative feedback**, as increases in density result in reductions in a population's size. Specific examples of density-dependent factors may include:

- **P**redation (big populations experience more predation than small populations)
- **A**ccess to habitat (in large populations there is more competition for territory)
- **N**utrient supply (less food per organism will be available in larger populations)
- **D**iseases (infectious contagions are more easily spread in dense populations)
- **A**ccumulation of wastes (metabolic by-products can be toxic in large amounts)

Mnemonic: PANDA

PREDATOR-PREY RELATIONSHIPS

A predator-prey dynamic is a biological interaction whereby one organism (**predator**) hunts and feeds on another organism (**prey**). Because the predator relies on the prey as a food source, the two population levels are inextricably intertwined. The predator-prey dynamic is an example of density-dependent population control. If the prey population drops, predator numbers will dwindle as intraspecific competition increases, but if prey population rises, predator numbers will increase as a result of the over-abundance of food. The arctic fox and snowshoe hare are a classic example.