DP IB Environmental Systems & Societies (ESS): SL

Your notes

Investigating Ecosystems

Contents


Your notes

Studying Ecosystems

Identifying an ecosystem

- The study of an ecosystem first requires that it be named and located to provide a specific and clear reference point for the ecosystem being studied
- Naming an ecosystem can include the identification of its physical characteristics, such as vegetation type, climate, and location
  - Location is important because it provides a specific geographic area for the ecosystem being studied, allowing for more accurate comparisons with other similar ecosystems
- Examples of named ecosystems and their geographical locations include:
  - **Amazon Rainforest, South America**:
    - The Amazon rainforest is located in South America, covering approximately 2.7 million square miles
    - It is the largest rainforest in the world and is home to a diverse range of plant and animal species
    - Characteristic vegetation: dense evergreen trees, such as mahogany, Brazil nut, and rubber trees, and understory vegetation, such as ferns, palms, and lianas

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Photo by Kai Pütter on Unsplash
The Serengeti is well known for its herds of wildebeest

- **Serengeti, Tanzania**:
  - The Serengeti National Park is located in Tanzania, covering an area of over 5,700 square miles
  - It is known for its large herds of wildebeest, zebras, and gazelles, as well as predators such as lions and cheetahs
  - Characteristic vegetation: grasslands dominated by perennial grasses, with scattered trees, such as acacia and baobab
- Naming and locating ecosystems not only provides a clear reference point for research, but it also helps to raise awareness about the unique characteristics and value of each ecosystem, encouraging conservation efforts

Identifying organisms in an ecosystem

- Organisms in an ecosystem can be identified using various tools and techniques
- These tools are important for understanding the biodiversity and ecological interactions within the ecosystem
- By accurately identifying organisms, scientists can better understand the roles they play in the ecosystem and how they contribute to its functioning

- Examples of these tools and techniques include:

1. Comparison to herbarium or specimen collections

- Herbariums and specimen collections are archives of pressed and preserved plants, animals, and other organisms
  These collections can be used to compare the characteristics of the organisms in question with the archived specimens to identify them

2. Technologies such as DNA profiling

- DNA profiling involves the extraction of DNA from an organism, which is then amplified and sequenced
- The resulting sequence can be compared to known sequences in databases to identify the organism

3. Scientific expertise

- Scientists with specialised knowledge of a particular group of organisms can identify them based on their morphology, anatomy, and behaviour

4. Dichotomous keys

- Dichotomous keys are tools used to identify organisms based on their characteristics
- The keys consist of a series of questions with two possible answers, leading to the identification of the organism


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Dichotomous Keys

A dichotomous key for animals in the Serengeti

- Below is an example of a dichotomous identification key for eight named species in the Serengeti ecosystem:

1	**a**	Animal covered in black and white stripes	Zebra (Equus quagga)
	b	Animal not covered in black and white stripes	go to 2
2	**a**	Animal is a large cat	go to 3
	b	Animal is not a large cat	go to 4
3	**a**	Animal covered in spots	Cheetah (Acinonyx jubatus)
	b	Animal not covered in spots	Lion (Panthera leo)

4	**a**	Animal has horns	go to 5
	b	Animal does not have horns	go to 7
5	**a**	Horns meet in middle of head	Cape buffalo (Syncerus caffer)
	b	Horns do not meet in middle of head	go to 6
6	**a**	Horns are long and curved	Grant's gazelle (Nanger granti)
	b	Horns are not long and curved	Oribi (Ourebia ourebi)
7	**a**	Animal has a long neck	Giraffe (Giraffa camelopardalis)
	b	Animal does not have a long neck	African elephant (Loxodonta africana)


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- There are several limitations of using a dichotomous identification key for identifying organisms:

1. Limited scope

- Dichotomous keys are typically designed to identify a limited number of species and may not be comprehensive enough to identify all organisms in a given ecosystem

2. Inaccuracies

- Dichotomous keys are only as accurate as the information provided
  If the key is not designed properly or lacks important distinguishing characteristics, the identification may be inaccurate

3. Variability

- Organisms can exhibit variability in their physical characteristics, which can make it difficult to accurately identify them using a dichotomous key

4. Time-consuming

- Using a dichotomous key can be a time-consuming process, especially for beginners who are not familiar with the organisms in question

5. Expertise required

- Dichotomous keys require a certain level of expertise and familiarity with the organisms in question
- Beginners may find it difficult to use the key without assistance from an expert

6. Limited to physical characteristics

- Dichotomous keys are limited to the physical characteristics of organisms and may not take into account other important factors, such as behaviour or habitat, which can be important in identifying certain species


Your notes

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Measuring Abiotic Components of Ecosystems

Abiotic Component	Measurement method	Strengths	Limitations
Light Intensity	Light-meter	Quick and easy to use, non-invasive, accurate and precise measurement if direction and angle of use is consistent over repeats	Can only measure at a single point, doesn't measure spectral quality or light direction, affected by shading, cloud cover and atmospheric conditions
Temperature	Thermometer	Simple and easy to use, highly accurate if using an electronic thermometer (temperature probe), which can measure temperature of air, water and varying soil depths	Can only measure at a single point, doesn't measure temperature fluctuations over time (unless used alongside a datalogger)
Wind Speed	Anemometer	Quick and easy to use, non-invasive, accurate and precise measurement if direction and angle of use is consistent over repeats	Gusty conditions can lead to large variations in data
Dissolved Oxygen	Oxygen-meter	Can measure changes over time if used alongside a datalogger	Can be expensive and require calibration, can be affected by temperature and salinity, or contaminated by oxygen in air if correct procedure not followed
Flow Velocity	Flow-meter	Provides accurate measurements and can be attached to a datalogger	Water flow can fluctuate greatly due to rainfall or ice melt, can be affected by turbulence or eddies

Turbidity	Secchi disc	More accurate if used in shady areas of water	Sun glare and reflections reduce visibility of disc, measurements are subjective, alternative more sophisticated optical equipment (e.g. nephelometer or turbidimeter
pH	pH meter or pH probe	Soil pH can also be measured (using a soil test kit)	Requires calibration, affected by surrounding environment
Soil Moisture	Evaporate water or soil moisture probe	Fairly inexpensive (although requires use of an oven)	Time consuming, organic soil content may be burned off during heating, reducing soil weight and giving inaccurate readings

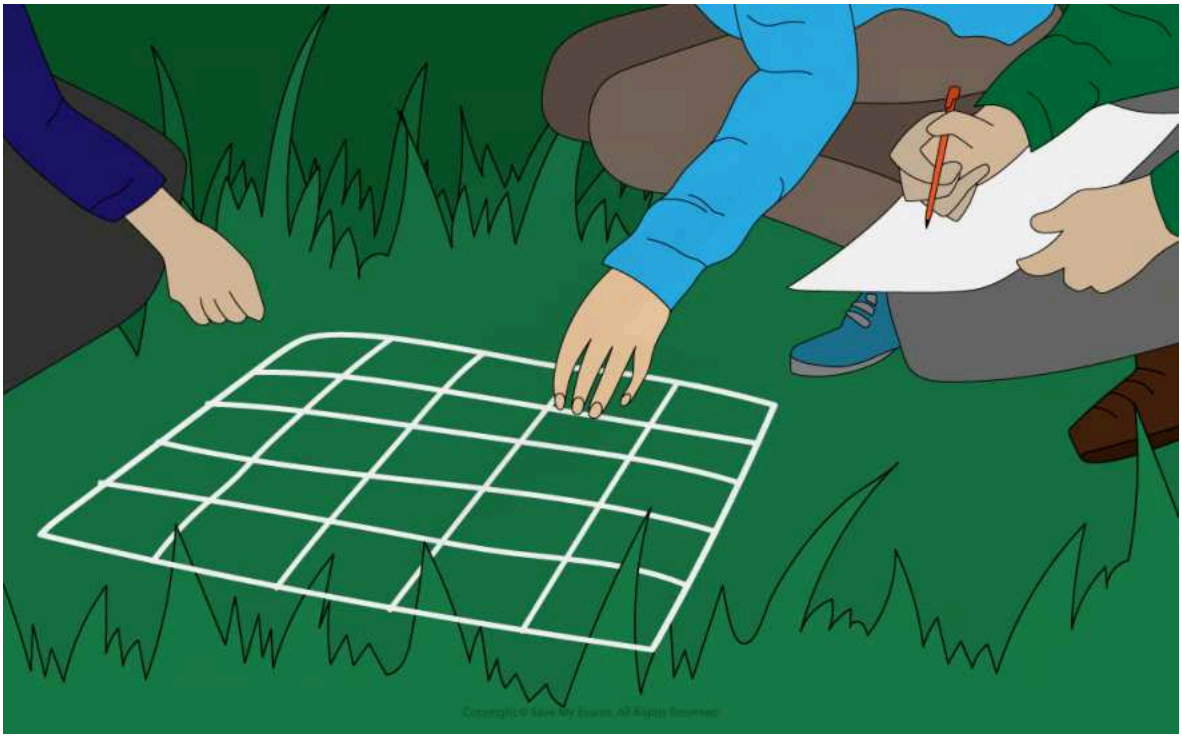

Your notes

Measuring Biotic Components of Ecosystems

- Measuring all the different levels of biodiversity within an ecosystem could be very time-consuming
- Finding out which species live in an ecosystem and the size of the populations requires the identification and cataloguing of all organisms present to build a species list
- This is possible for areas that are very small or where the species are very large like trees
- However, for larger and more complex ecosystems like rainforests, it is simply impossible to find, identify and count every organism that exists there
- When this is the case different samples of the area can be taken and used to make an estimate for the total species numbers in the area

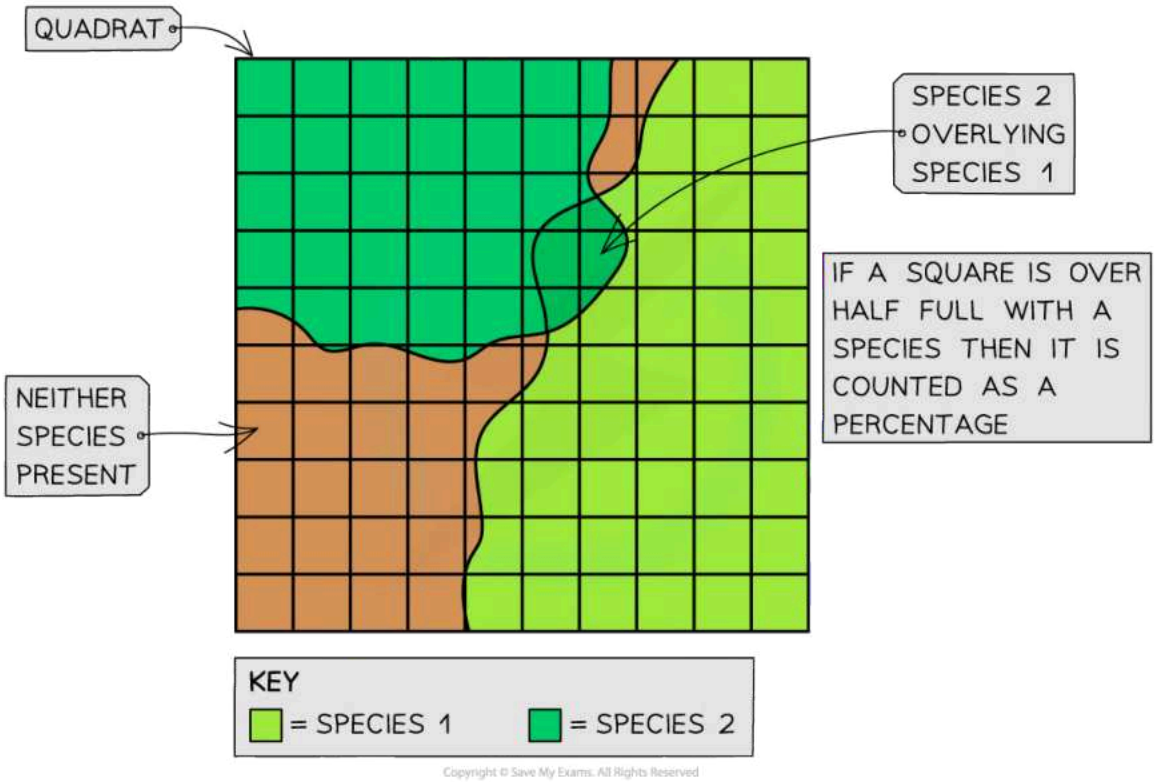
Quadrats

- Quadrats are square frames made of wood or wire
- They can be a variety of sizes eg. $0.25m^2$ or $1m^2$
- They are placed on the ground and the organisms within them are recorded
- Non-motile organisms such as plants species are commonly studied using quadrats to estimate their abundance
- Quadrats can be used to measure abundance by recording:
  - The number of an individual species: the total number of individuals of a single species (eg. daisies) is recorded
  - Species richness: the total number of different species (but not the number of individuals of each species) is recorded
  - Percentage cover: the approximate percentage of the quadrat area in which an individual species is found is recorded (this method is often used when it is difficult to count individuals of the plant species being recorded eg. grass or moss)



Using a quadrat to investigate population size or distribution

Your notes



Using a quadrat to investigate percentage cover of two species of grass. There may be some squares lacking any species and other squares with multiple species – this means the total percentage cover of a single quadrat can sometimes be over or under 100%

Estimating Population Size

- Quadrats must be laid randomly in the area to avoid sampling bias
  - This random sampling can be done by converting the sampling area into a grid format and labelling each square on the grid with a number
  - Then a random number generator is used to pick the sample points
- Once the quadrat has been laid on the chosen sample point the abundance of all the different species present can be recorded

How to estimate the population size of a plant species in a survey area

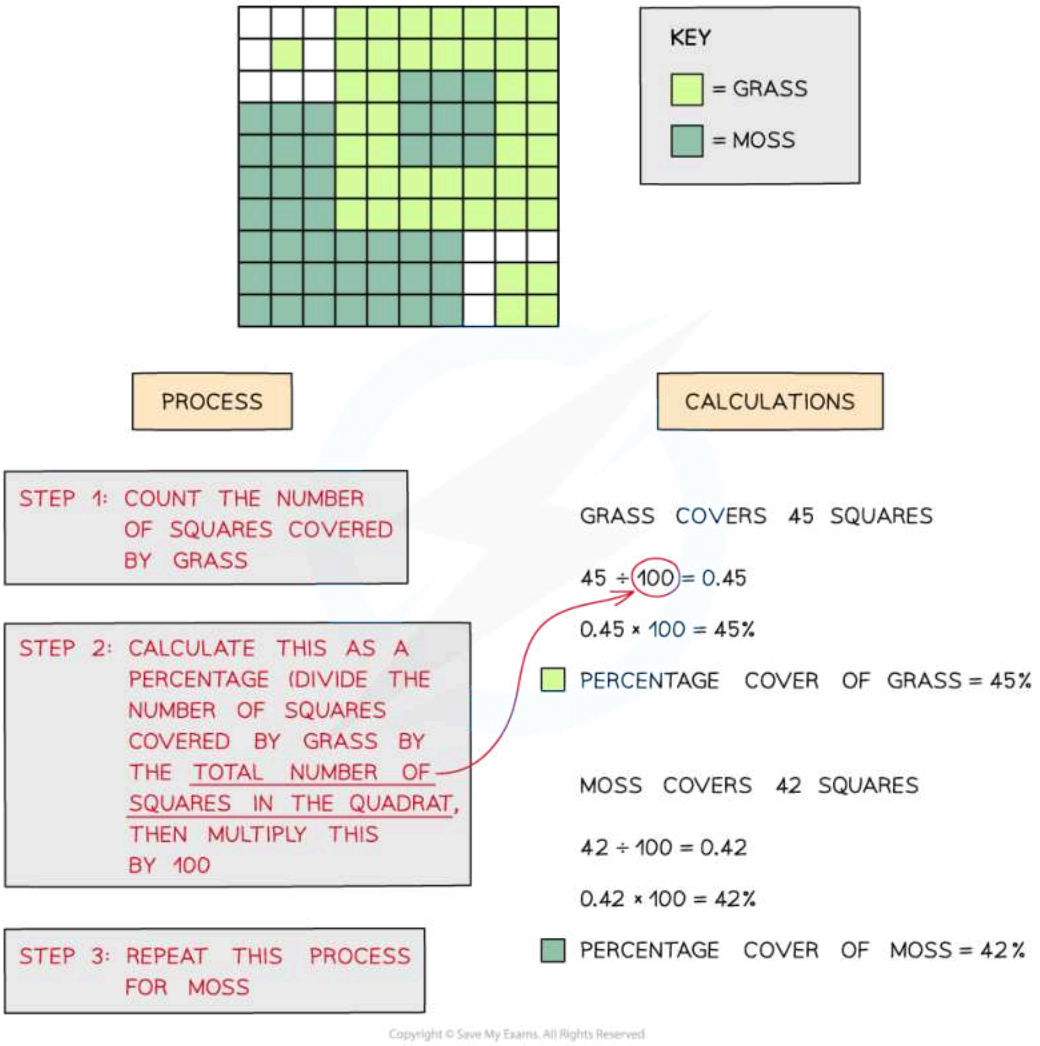
Your notes

Estimating percentage frequency and percentage cover


Your notes

- The results from the quadrats can be used to calculate the predicted frequency and density of a species within an area
- Species frequency is the probability that the species will be found within any quadrat in the sample area
  - The number of quadrats that the species was present in is divided by the total number of quadrats and then multiplied by 100
  - For example, if bluebells were found in 18 out of 50 quadrats the species frequency would be (18/50) x 100 = 36%
- Species density indicates how many individuals of that species there are per unit area
  - The number of individuals counted across all quadrats is divided by the total area of all the quadrats
  - For example, if 107 bluebells, a common woodland plant, were found across 50 quadrats that are $1m^2$ each the species density would be 107/50 = 2.14 individuals per m^2
- It can sometimes be difficult to count individual plants or organisms. When this is the case percentage cover of the species within the quadrat can be estimated instead
  - The quadrat is divided into 100 smaller squares. The number of squares the species is found in is equivalent to its percentage cover in that quadrat
  - For example, if grass is found in 89 out of 100 squares in the quadrat then it has a percentage cover of 89%

Your notes



How to estimate the percentage cover of one or more species using a quadrat

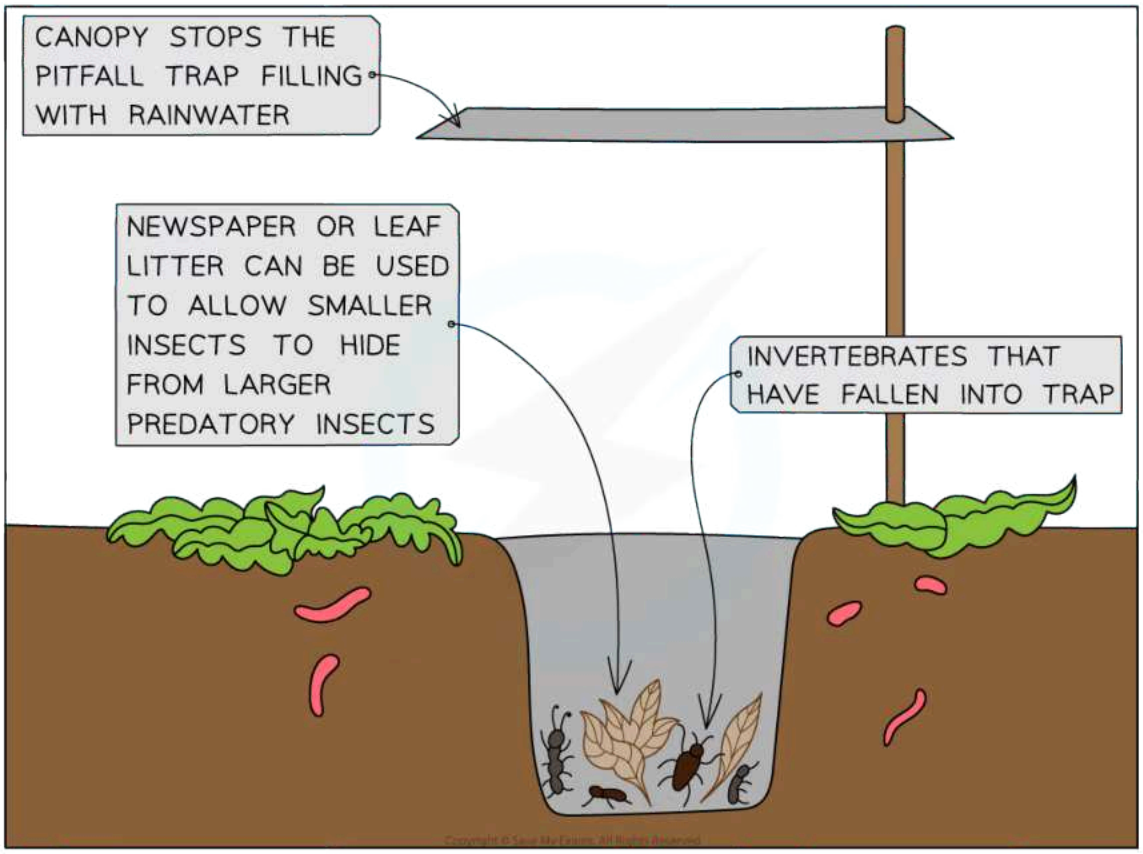
Limitations of Using Quadrats

- It can be easy to miss individual organisms when counting in a quadrat, especially if they are covered by a different species
  - Solution: Use a pencil or stick to carefully move leaves out of the way to check if there is anything else underneath
- Identifying species may be tricky
  - Solution: Use a species key to identify the species

Direct methods for estimating the abundance of motile organisms


Your notes

- Quadrats are suitable for sampling plants or slow-moving animals
- For many animal species, however, it is not possible to use quadrats to measure their distribution and abundance
- In these cases, other techniques involving other items of equipment are necessary, including:
  - **Sweeping nets**: these are large, strong nets with a fine material (very small holes) that are used to catch flying insects and insects that live in long grass by sweeping the net back and forth through the grass
  - **Pitfall traps**: these are cans or jars that are buried in the ground that are used to catch ground-dwelling (often nocturnal) insects and other invertebrates as they fall into the trap
  - **Pooters**: these are small plastic or glass containers with two tubes sticking out that are used to suck up small insects and other small invertebrates. The first tube is placed over the insect and the second tube is used by the scientist to create suction
  - **Tullgren funnel**: these are funnels with a light bulb above and a container below that are used to collect invertebrates that live in leaf litter or soil. The leaf litter or soil is placed in the funnel and the light and heat forces the invertebrates to move down until they drop into the container
  - **Kick-sampling**: this technique is used to catch freshwater invertebrates living in streams or rivers. A net in placed on the stream-bed so that the water is flowing into it and the stream-bed just above the net is churned up by the scientist (using their foot) for a set period of time. The invertebrates are carried by the stream into the net



An example of how a pitfall trap can be used

Your notes

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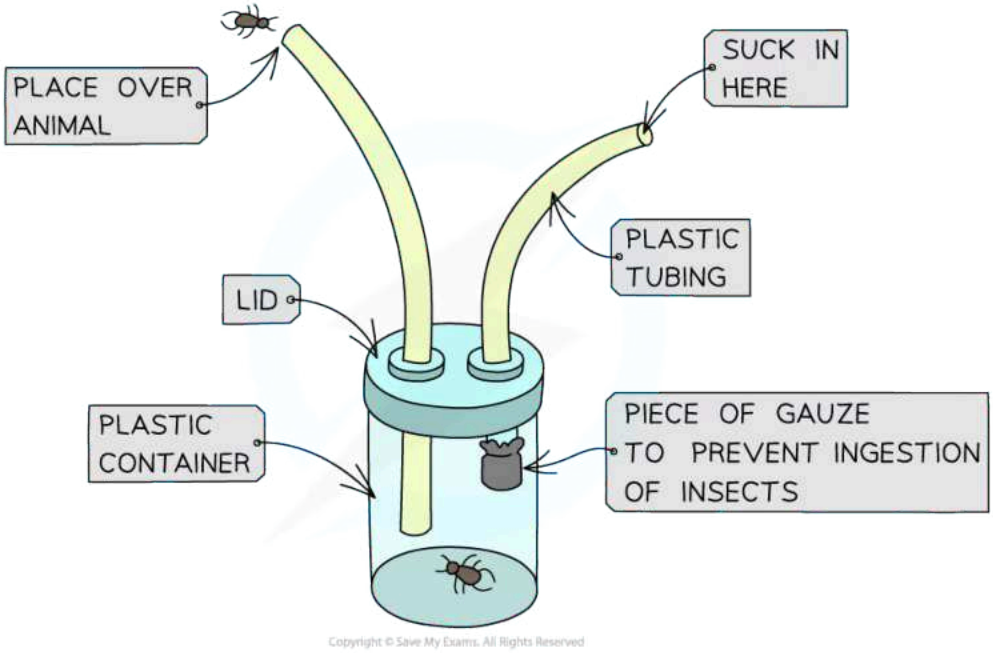

An example of how a pooter can be used

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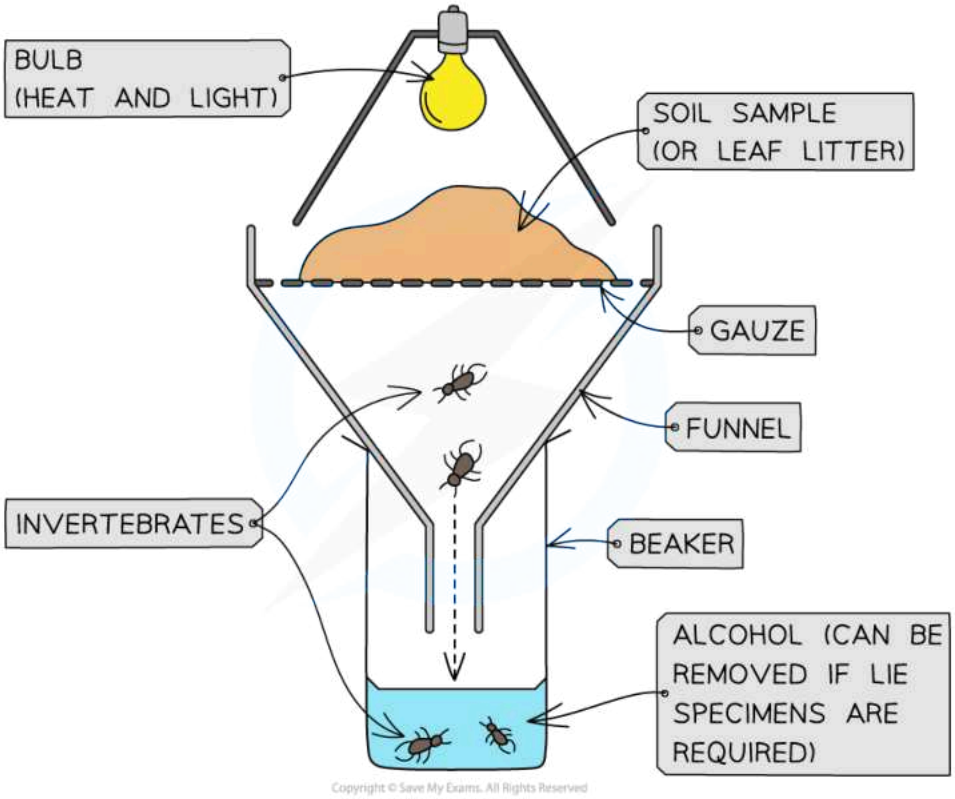

An example of how a Tullgren funnel can be used

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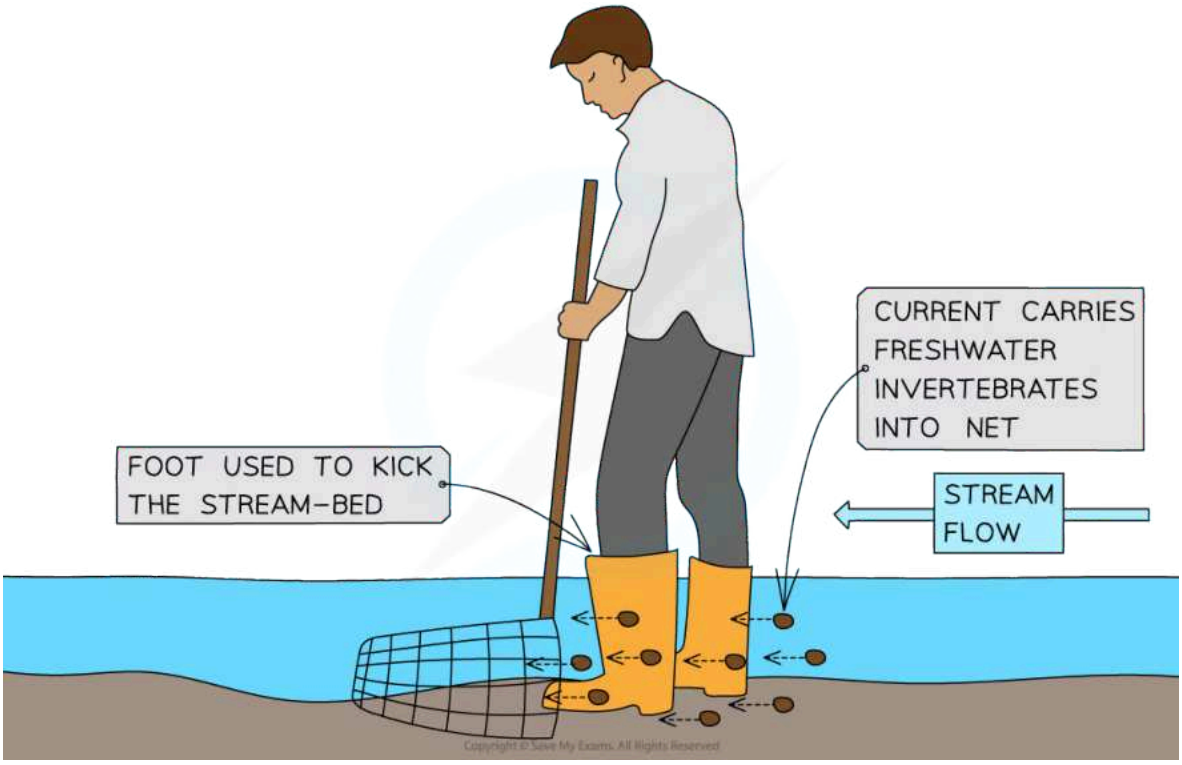


Example of how kick-sampling is done

Indirect method for estimating abundance of motile organisms: mark-release-recapture

- The sampling methods described above are only useful for non-motile (sessile) organisms
  - Different methods are required for estimating the number of individuals in a population of motile animals (i.e. animals that are mobile)
  - The mark-release-recapture method is commonly used alongside the Lincoln Index (a statistical measure used to estimate population size)
- For a single species in the area:
  - The first large sample is taken - as many individuals as possible are caught, counted and marked in a way that won't affect their survival e.g. if studying a species of beetle, a small amount of brightly coloured non-toxic paint can be applied to their carapace (shell)
  - The marked individuals are returned to their habitat and allowed to randomly mix with the rest of the population
  - When a sufficient amount of time has passed another large sample is captured
  - The number of marked and unmarked individuals within the sample are counted

Your notes

- The proportion of marked to unmarked individuals is used to calculate an estimate of the population size (the Lincoln Index, N)
- The formula for calculating the Lincoln Index is:

$$\text{Lincoln index} = \frac{n_1 \times n_2}{n_m}$$

- Where:
  n_1 = the number caught in the first sample (i.e. the number of marked individuals released)
  n_2 = number of individuals caught in the second sample (marked and unmarked)
  n_m = number of marked individuals in the second sample

Worked Example

Scientists wanted to investigate the abundance of leafhoppers in a small grassy meadow. They used sweep nets to catch a large sample of leafhoppers from the meadow. Each insect was marked on its underside with non-toxic waterproof paint and then released back into the meadow. The following day another large sample was caught using sweep nets. Use the figures below to estimate the size of the leafhopper population in this meadow.

- No. caught and marked in first sample (n_1) = 236
- No. caught in second sample (n_2) = 244
- No. of marked individuals in the second sample (n_m) = 71

Answer

Step One: Write out the equation and substitute in the known values

$N = (n_1 \times n_2) \div n_m$

$N = (236 \times 244) \div 71$

Step Two: Calculate the population size estimate (N)

$N = 57{,}584 \div 71$

$N = 811$

N (estimated population size) = 811

Limitation of Using Mark-release-recapture

- When using the mark-release-capture method, there are a few assumptions that have to be made:
  - The marked individuals must be given sufficient time to disperse and mix back in fully with the main population - this can be time-consuming

- The marking doesn't affect the survival rates of the marked individuals (e.g. doesn't make them more visible and therefore more likely to be predated)
- The marking remains visible throughout the sampling and doesn't rub off - this is often difficult to ensure and so the accuracy of population size estimates may be negatively affected
- The population stays the same size during the study period (i.e. there are no significant changes in population size due to births and deaths and there are no migrations into or out of the main population) - again, this is almost impossible to ensure, further affecting the accuracy of population size estimates

Examiner Tips and Tricks

You will be provided with the formula for Lincoln's index in the exam. You need to be able to carry out the calculation to estimate population size from mark-capture-release data, as you could be asked to do this in the exam.

Your notes


Your notes

Species Richness & Diversity

What is species richness?

- Species richness is the **number of species** in a community or defined area and can be a useful comparative measure in some cases
- However, in other cases, species richness can be a misleading indicator of diversity as it does not take into account the **number of individuals of each species**
- Once the abundance of each species in an area has been recorded, the results can be used to calculate the **species diversity** for that area
  - Species diversity looks at the number of different species in an area but also the **evenness of abundance** across the different species (i.e. their **relative abundances**)

Species Richness vs Diversity

- An index of diversity is a measurement that describes the relationship between the number of species present and how each species contributes to the total number of organisms that are present in that community
  - It is a **much more informative** measurement than species richness and conservationists often favour the use of an index of diversity as it takes into account both species richness and evenness
  - A commonly used index of diversity is known as **Simpson's Diversity Index**

Example

- Area 1 and Area 2 both contain 4 tree species
- However, Area 2 is actually dominated by one species and in fact, one of the species is very rare (only one individual)
- Although the two areas have exactly the same species richness, Area 1 has a higher species evenness (and therefore a higher overall species diversity) than Area 2
- This example illustrates the limitations of using just species richness on its own

Area 1 and Area 2 have the same species richness but different species evenness. As it has a higher species evenness, the overall species diversity of Area 1 is higher than that of Area 2, as species diversity takes both richness and evenness into account

Calculating Simpson's Diversity Index


Your notes

- A group of students used the kick sampling technique to collect, identify and count the invertebrates inhabiting a river
- Samples were obtained from different sites along the course of the river
- The data was used to calculate the Simpson's Diversity Index at two different river sites
- This index of diversity is useful when comparing two similar habitats, or the same habitat over time
- The formula for calculating Simpson's Diversity Index, D, is:

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

Species	Mean number of organisms per m^2 of river bed	
	Site A	Site B
Mite	14	0
Snail	9	0
Leech	3	26
Worm	0	6
Flat worm	132	9
Mayfly nymph	43	0
Olive mayfly nymph	154	0
Midge Larva	0	10
Blackfly larva	77	0
Caddis larva	15	1

Fish	1	0
Freshwater shrimp	211	6
Water hog louse	0	40

Site A

Species	**Number (n)**	**n (n-1)**
Mite	14	182
Snail	9	72
Leech	3	6
Worm	0	0
Flat worm	132	17 292
Mayfly nymph	43	1 806
Olive mayfly nymph	154	23 562
Midge Larva	0	0
Blackfly larva	77	5 852
Caddis larva	15	210
Fish	1	0
Freshwater shrimp	211	44 310
Water hog louse	0	0


Your notes

Total	N= ∑n= 659	∑n(n-1)= 93 292


Your notes

$$D = \frac{N(N-1)}{\Sigma n(n-1)} = \frac{659(658)}{93292} = 4.65$$

Site B

Species	**Number (n)**	**n (n-1)**
Mite	0	0
Snail	0	0
Leech	6	30
Worm	26	650
Flat worm	9	72
Mayfly nymph	0	0
Olive mayfly nymph	0	0
Midge Larva	10	90
Blackfly larva	0	0
Caddis larva	1	0
Fish	0	0
Freshwater shrimp	6	30
Water hog louse	40	1560
Total	N= ∑n= 98	∑n(n-1)= 2 432

Your notes

$$D = \frac{N(N-1)}{\Sigma n(n-1)} = \frac{98(97)}{2432} = 3.91$$

- Site A was located just 5 km downstream from the river's source
- Site B was located 50 m downstream from a sewage inlet pipe
- The lower diversity index for site B reflects the stress placed upon the river as a consequence of the **pollution load** from the sewage inlet point; although the river is recovering from the pollution, sensitive species are unable to tolerate the unfavourable abiotic conditions and **species diversity is reduced**

Examiner Tips and Tricks

Remember, this index of diversity is only useful when comparing two similar habitats, or the same habitat over time.

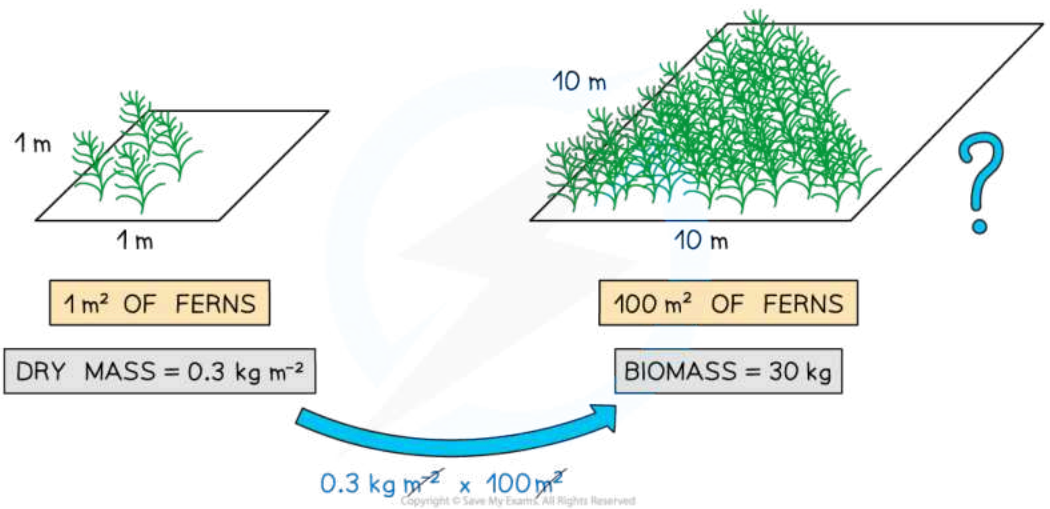
You will be provided with the formula for Simpson's Index in the exam but you need to know how to use it to calculate Simpson's Diversity Index for example sets of data.

Estimating Biomass & Energy of Trophic Levels

- Estimating the biomass and energy of trophic levels in a community is an important step in understanding the structure and function of an ecosystem
- There are several methods for measuring biomass and energy, including:
  - Measurement of dry mass
  - Controlled combustion
  - Extrapolation from samples

Measurement of Dry Mass

- One common method for estimating biomass is to measure the dry mass of organisms
- This involves collecting samples of organisms and drying them in an oven to remove all water within the tissues
- The dry weight of the sample is then measured, and this can be used to estimate the biomass of the population
- For example:
  - If the dry mass of one daffodil plant is found to be 0.1 kg, then the dry mass (i.e. the biomass) of 200 daffodils would be 20 kg (0.1 x 200 = 20)
  - If the dry mass of the grass from 1 m^2 of a field is found to be 0.2 kg, we can say that the grass has a dry mass (i.e. biomass) of 0.2 kg m^{-2} (this means 0.2 kg per square metre). If the grass field is 200 m^2 in size, then the biomass of the whole field must be 40 kg (0.2 x 200 = 40)



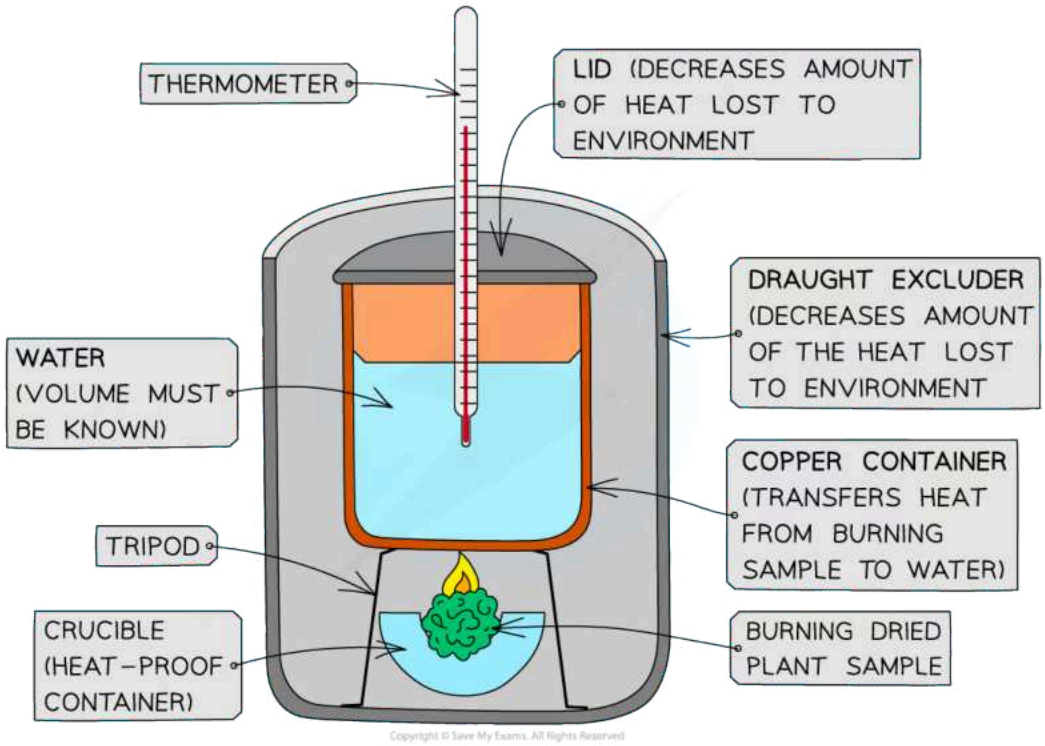
It is possible to estimate the biomass of organisms in a larger area if you know the dry mass of the organisms in a given (smaller) area

Controlled Combustion

- Another method for estimating biomass is controlled combustion
- This involves burning a known quantity of biomass and measuring the heat produced
- By knowing the heat value of the biomass, it is possible to estimate the total biomass of a population based on the amount of heat produced
- A piece of equipment known as a calorimeter is required for this process
  - The burning sample heats a known volume of water
  - The change in temperature of the water provides an estimate of the chemical energy the sample contains

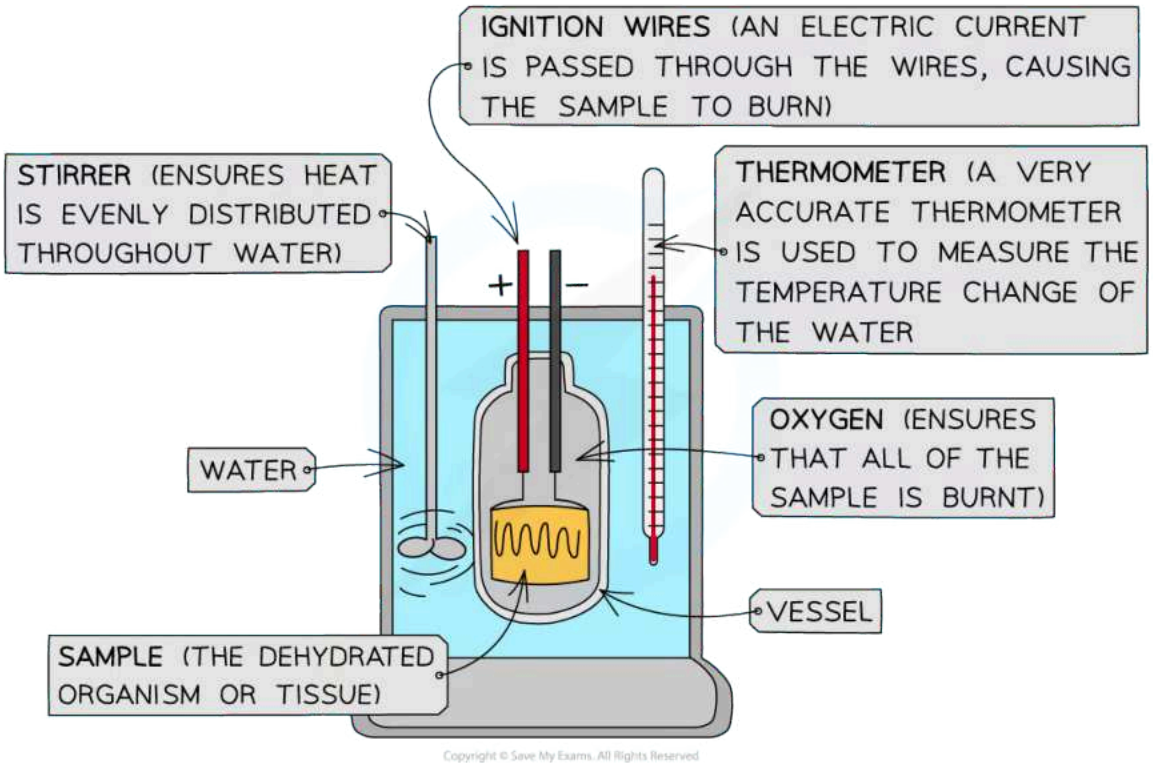
Your notes

Your notes



A simple, inexpensive version of a calorimeter that can be set up using classroom equipment

Your notes



An example of a more precise (and much more expensive) version of a calorimeter known as a bomb calorimeter – this type is used in professional scientific laboratories

Extrapolation from Samples

- A third method for estimating biomass is to take small samples of organisms and extrapolate to estimate the total biomass of a population
- This method can be particularly useful when dealing with large or difficult-to-sample populations

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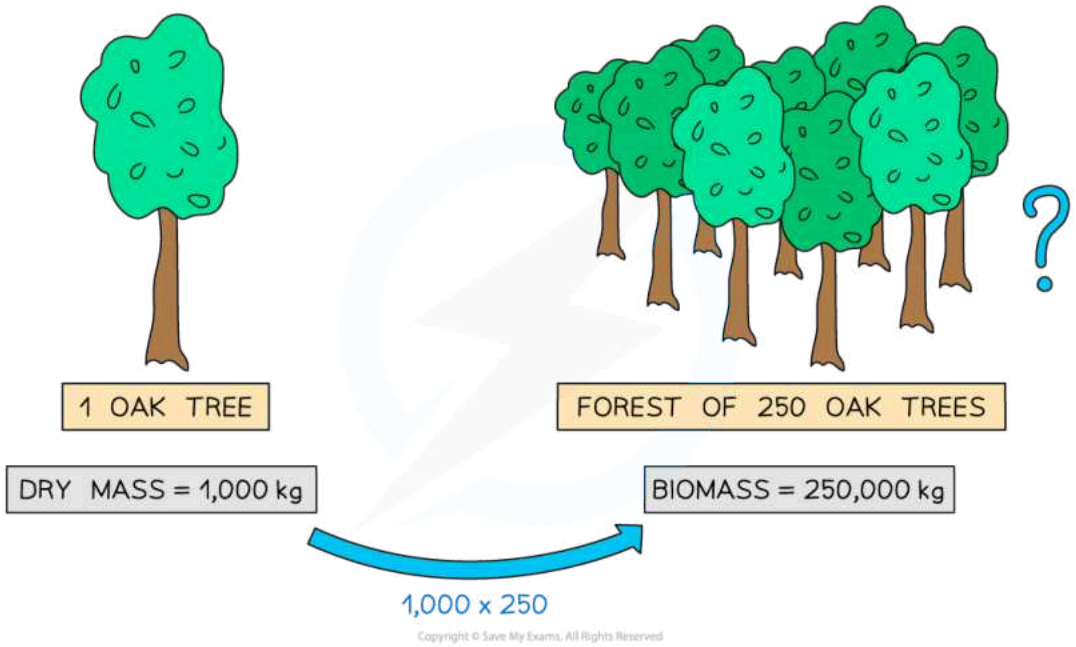


It is possible to estimate the biomass of a group of organisms if you know the dry mass of a single organism

- Data obtained from these methods can be used to construct ecological pyramids
  - Ecological pyramids (such as pyramids of biomass) are very useful in visually illustrating the relationships between different trophic levels in an ecosystem and how energy and biomass are transferred through the system

Limitations of Calorimetry

- It can take a long time to fully dehydrate (dry out) a plant sample to find its dry mass
  - This is partly because the sample has to be heated at a relatively low temperature to ensure it doesn't burn
  - Depending on the size of the sample, the drying process could take several days
- Precise equipment is needed, which may not be available
  - A very precise digital balance should be used to measure the mass of the plant sample as it is drying (to detect even extremely small changes in mass)
  - It is preferable to use a very precise digital thermometer when measuring the temperature change of the water in the calorimeter (again, to detect even very small temperature changes)
- The more simple and basic the calorimeter, the less accurate the estimate will be for the chemical energy contained within the plant sample

- This is due to heat energy from the burning sample being lost and not being transferred efficiently to the water
- A bomb calorimeter ensures that almost all the heat energy from the burning sample is transferred to the water, giving a highly accurate estimate

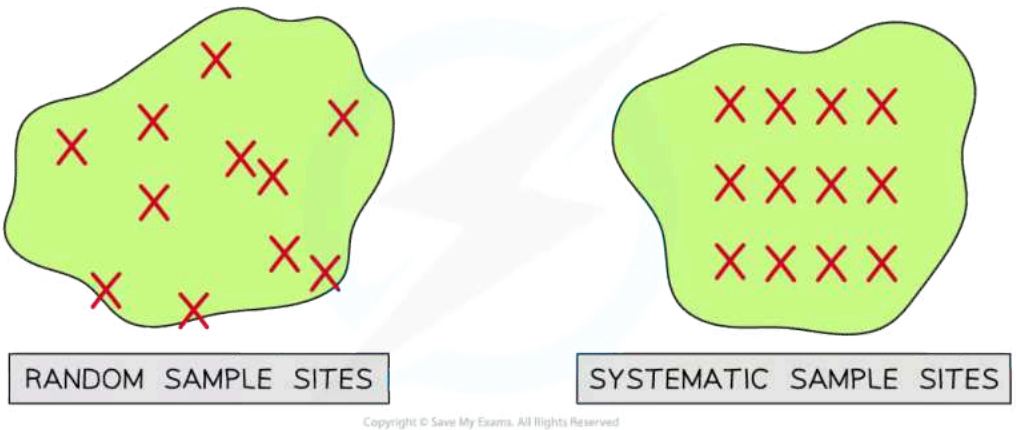

Your notes

Your notes

Measuring Changes in Ecosystems

Sampling

- Sampling is a method of investigating the abundance and distribution of species and populations
- There are two different types of sampling
  - **Random**
  - **Systematic**
- In random sampling, the positions of the sampling points are selected at random
  - This method **avoids bias** by the person that is carrying out the sampling
  - Bias can affect the results - for example, a student might choose to carry out samples in a particular location because it looks interesting, and this might give the impression that the habitat contains more species than it really does
- In systematic sampling, the positions of the sampling points are located at fixed intervals throughout the sampling site
  - This avoids accidentally missing out sections of habitat due to chance
  - Systematic sampling allows researchers to investigate the effect of the presence of certain environmental features on species distribution e.g. by taking samples along a line that extends away from an environmental feature such as a river
  - A line of this type is known as a transect

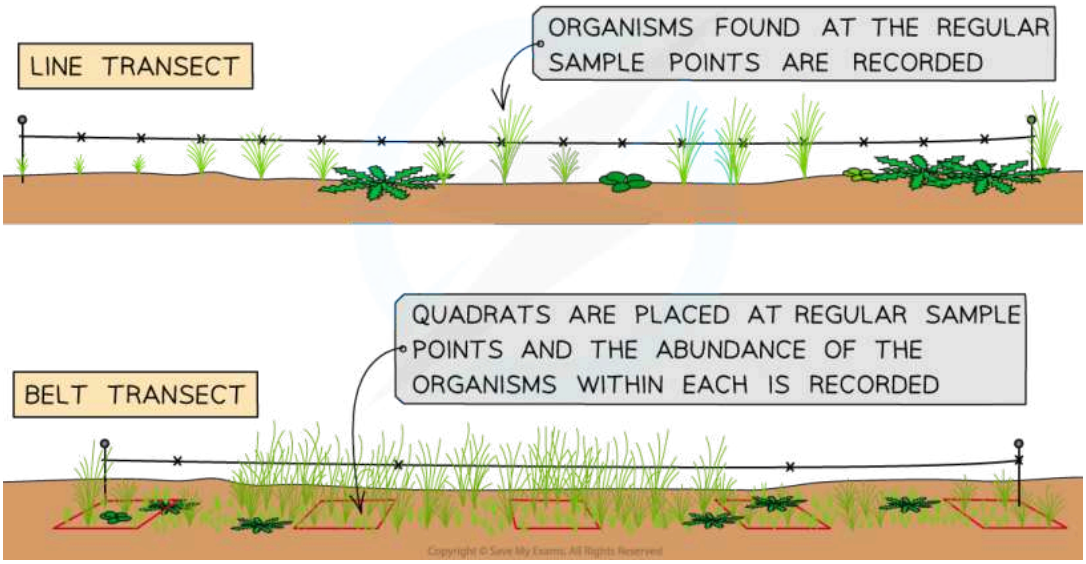


Random sampling involves selecting sample sites at random while systematic sampling involves placing sample sites at regular intervals.

Your notes

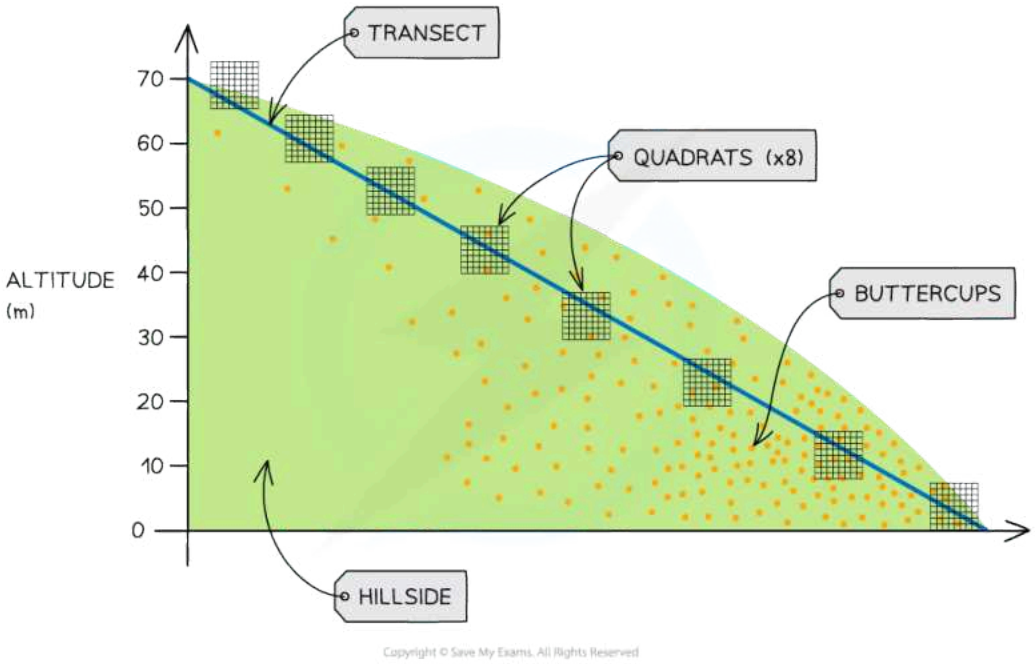
Transects

- Systematic sampling is used when there is a clear change in the physical conditions across the area being studied
  - For example, there may be changes in altitude, soil pH or light intensity
  - Methods using transects can help show how species distribution changes with the different physical conditions in the area
  - A transect is a line represented by a measuring tape, along which sample are taken
- For a **line transect**:
  - Lay out a measuring tape in a straight line across the sample area
  - At equal distances along the tape, record the identity of the organisms that touch the line (e.g. every 2 m)
- For a **belt transect**:
  - Place quadrats at regular intervals along the tape and record the abundance or percentage cover of each species within each quadrat



A line transect and belt transect is carried out in a habitat

Your notes



An example of a belt transect on a hillside. A quadrat is placed at regular intervals (every 10m of altitude gained) and the number of individuals (of the species being investigated e.g. buttercups) in each quadrat is recorded

Worked Example

Investigate changes in the distribution of a species along an environmental gradient.

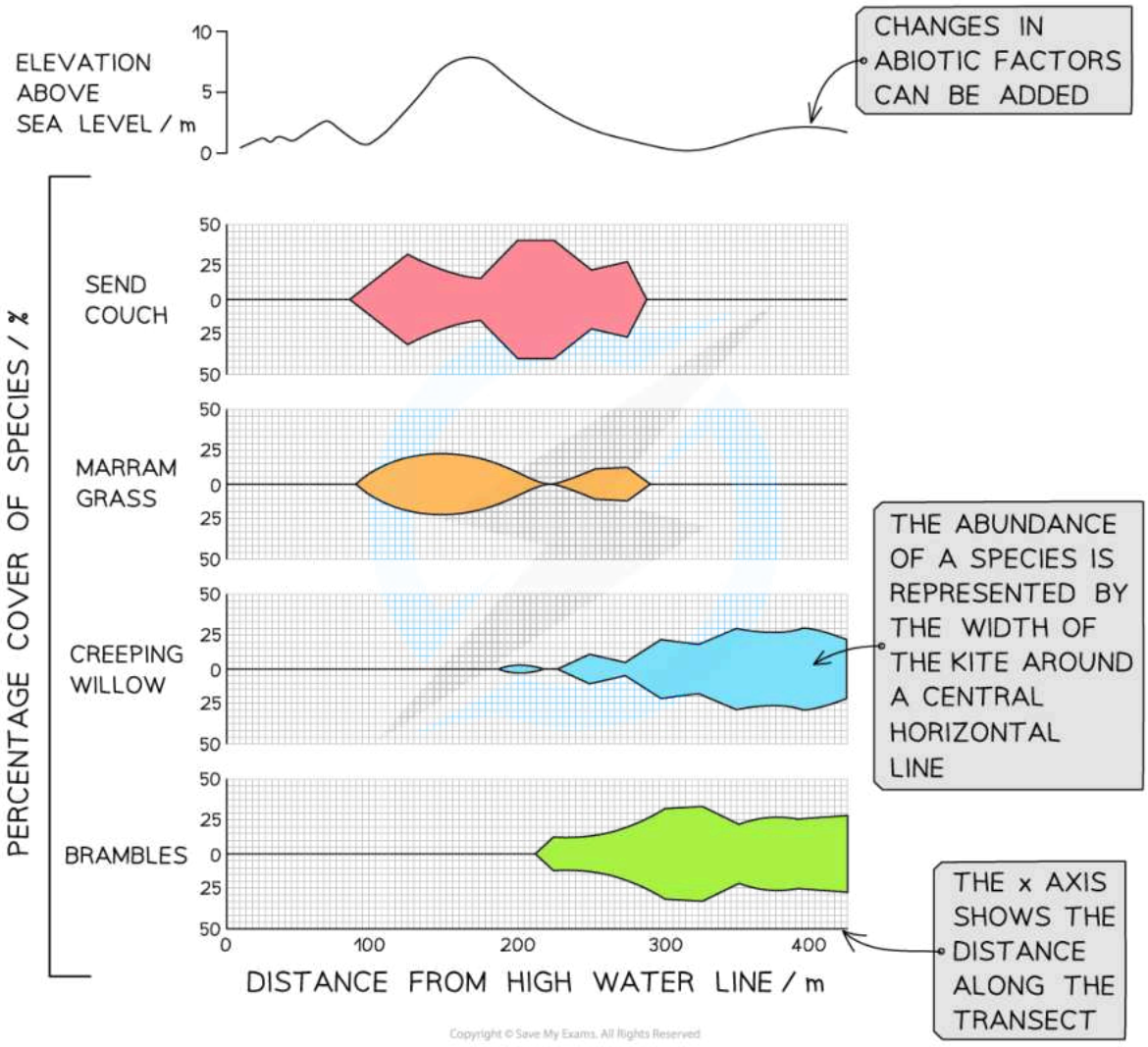
How to investigate the effect of an ecological factor on the number of plants across a survey area

Representing Results

- The results of an investigation into the distribution and abundance of organisms can be represented visually using a type of graph known as a kite diagram
- Kite diagrams can show both distribution and abundance
  - The distribution of a species along a transect can be shown by its position along a central horizontal line in each section of a kite diagram
  - Each section represents a different species

- The distance along the transect is given on the x-axis, to which the horizontal line is parallel
- The abundance of a species can be shown by the width of the 'kite' around the central horizontal line
- The shape is referred to as a kite because it extends an equal distance on each side of the central horizontal line

- Additional sections can be added to a kite diagram to show the changes in abiotic factors at different points along a transect e.g. the height above sea level or the pH of soil



Kite diagrams can be used to provide a visual representation of both abundance and distribution of species, as well as changes to abiotic factors such as elevation

Your notes

Examiner Tips and Tricks

You could be asked to describe or design an investigation that could be used to measure the effect of a specific abiotic factor on species abundance or distribution, so make sure that you know the circumstances in which each sampling technique would be used, and how to use it.

Remember that when describing a practical you should always consider:

- How you will change the independent variable
  - In this context you might be measuring a change in the independent variable, or abiotic factor, rather than causing the change yourself
  - Note that this might not be relevant if you have just been asked to measure the abundance of a species in one habitat
- How you will measure the dependent variable
- How you will ensure that your results are valid

Your notes