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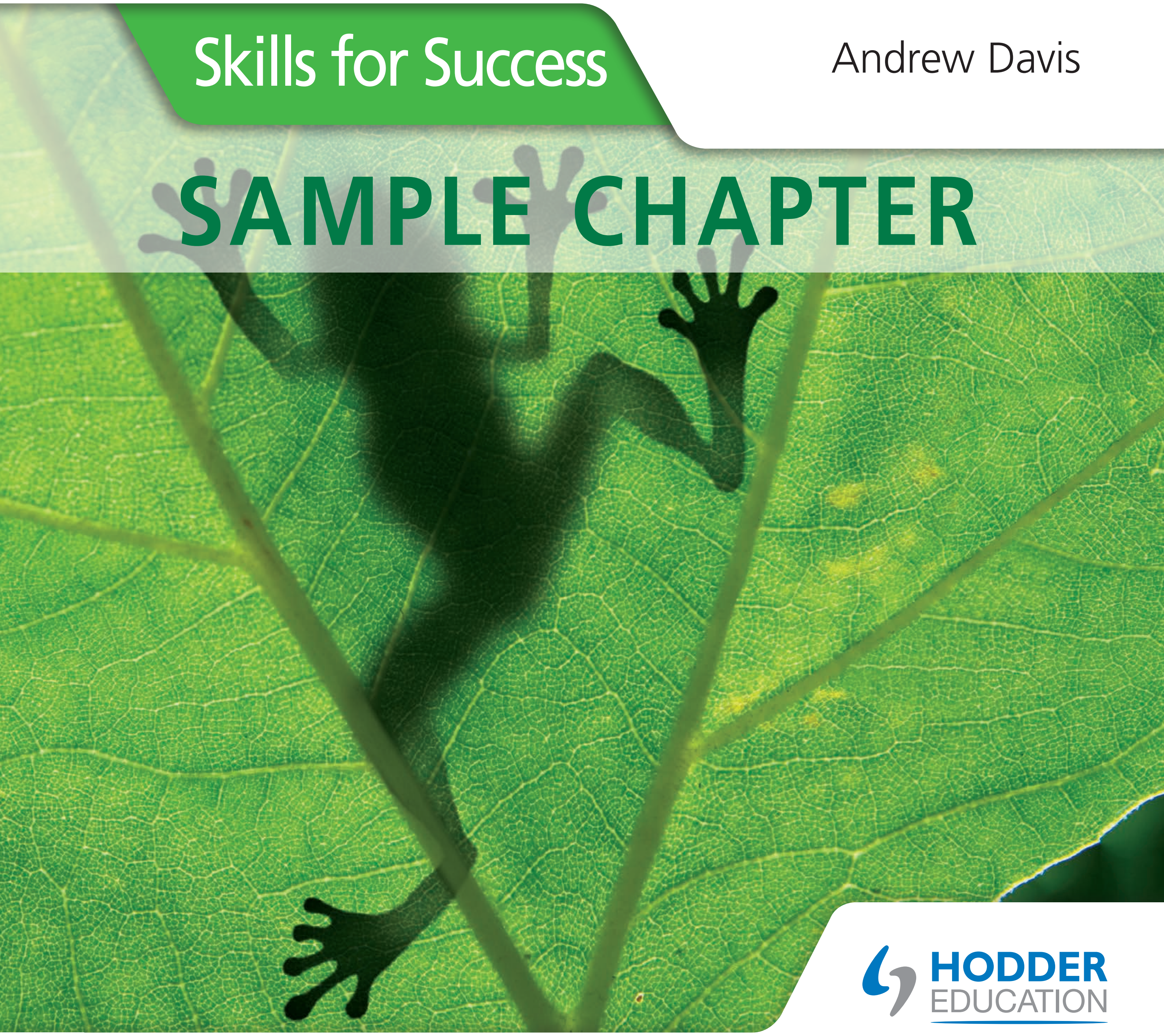

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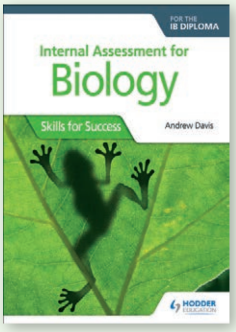

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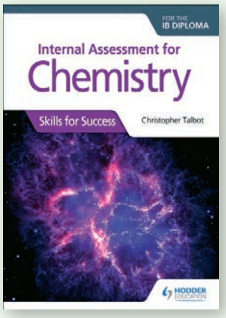

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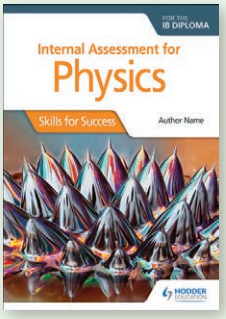

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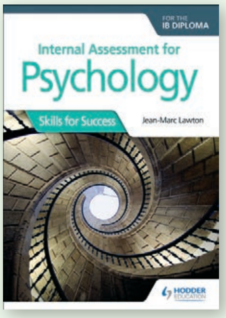

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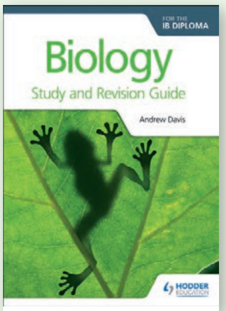

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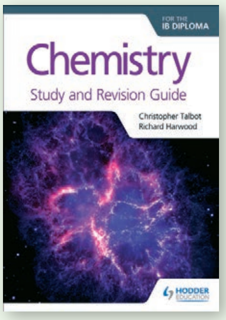

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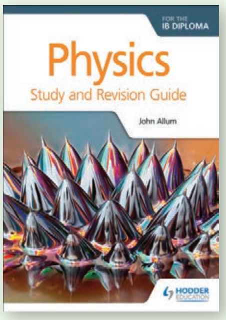

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Contents

5 Ecology practical skills

Measuring abiotic components of the system

Abiotic factors include:

- **marine** – turbidity, salinity, pH, temperature, dissolved oxygen, wave action
- **freshwater** – turbidity, flow velocity, pH, temperature, dissolved oxygen
- **terrestrial** – temperature, light intensity, wind speed, particle size of soil, air content of soil, slope, soil moisture, drainage, mineral content.

Standardized methods are needed to compare ecosystems.

Abiotic factor	How is it measured?	Ecosystem	Evaluation
Wind speed	Anemometer	Terrestrial	Gusty conditions can lead to large variations in data
Temperature	Thermometer	Terrestrial, freshwater, marine	Problems in data reproducibility and accuracy if temperature is not taken from consistent depth
Light	Light meter	Terrestrial, freshwater, marine	Cloud cover changes light intensity, as does shading from plants or light-meter operator
Soil compaction	Penetrometer	Terrestrial	Readings must be taken in the same way, with the metal bolt (Figure 5.2) dropped from the same height
Flow velocity	Flow meter	Freshwater	Readings must be taken from same depth; water flow can vary due to rainfall/ice melt
Wave action	Dynamometer	Marine	Changes in wave strength during a day and over a monthly period affect results
Turbidity	Secchi disc	Marine	Reflections off water reduce visibility; measurements are subjective
Dissolved oxygen concentration (in ppm)	Dissolved oxygen meter	Freshwater	Possible contamination from air/oxygen bubbles in the **samples** when using dissolved oxygen meter
Soil moisture	Evaporate water; soil moisture probes	Terrestrial	If soil is too hot when evaporating water, organic content can also burn off

Table 5.1 The measurement of abiotic factors in ecosystems

Key definition

Abiotic factor – A non-living, physical factor that can influence an organism or ecosystem – for example, temperature, sunlight, pH, salinity or precipitation.

Expert tip

You need to be able to evaluate methods to measure abiotic factors in an ecosystem.

Common mistake

'Climate' and 'temperature' are sometimes used interchangeably. These terms are not the same: climate includes rainfall, humidity, altitude, air pressure and wind speed as well as temperature.

Key definition

Sample – A sub-set of a whole population or habitat used to estimate the values that might have been obtained if every individual or response was measured.

Expert tip

Oxygen, and other solutes present in very low concentrations in solution, are measured in 'parts per million concentration (ppm)'. This is another non-SI unit of measurement (Chapter 1, page 5), concerning weight per volume (w/v) concentration.

Figure 5.1 Using an anemometer to measure wind speed in a shingle ridge succession

Figure 5.2 Using a simple penetrometer to measure soil compaction. A metal bolt with a pointed end is dropped within a guide sleeve – depth of penetration of soil indicates compaction.

Figure 5.3 Using a flow meter to measure water speed in a forest river

Abiotic factors can vary from day to day and season to season. Electronic data loggers overcome many of the limitations shown by abiotic measuring devices (page 73):

- They provide continuous data over a long period of time.
- They make data more representative of the area being sampled.
- More data can be collected, making results more reliable.

Soil moisture

Soils contain water and organic matter. Weighing samples before and after heating in an oven gives the mass of water evaporated and therefore moisture levels. Repeated readings should be taken until no further mass loss is recorded – the final reading should be used. Loss of mass can be calculated as a percentage of the starting mass.

Expert tip

If the oven is too hot when evaporating the water, organic content can also burn off further reducing soil weight and giving inaccurate readings.

ACTIVITIES

1. **Identify** an abiotic factor found in a freshwater ecosystem. **Outline** how you would measure this factor.
2. **Identify** an abiotic factor found in a marine ecosystem. **Outline** how this factor would vary with depth.
3. **Identify** an abiotic factor found in a terrestrial ecosystem. **Evaluate** the technique used to measure this factor.

Expert tip

You need to be able to evaluate sampling strategies.

Measuring biotic components of the system

Standardized methods are needed to compare **biotic factors** of ecosystems with one another. Such studies also allow ecosystems to be monitored and evaluated over time, and for the effects of human disturbance to be understood.

Key definition

Biotic factor – A living part of an ecosystem, such as a species, population or community that influences an ecosystem.

Keys

Your investigation might require you to identify and name different terrestrial or marine animals or plants. One approach is to use a book that has photographs of groups of related animals and plants and use that to identify them. Another approach is to use a biological key. Any keys or books that you plan to use in the identification of animals or plants should be outlined in your plan and later referenced in your bibliography (see page 141).

Expert tip

When carrying out fieldwork you must follow the IB ethical practice guidelines and IB animal experimentation policy: that is, animals and the environment should not be harmed during your work.

Naming of organisms

Binomial names should be used to describe organisms. Binomial means two names: the first name gives the genus and the second gives the species. For example, *Cardamine pratensis* is the binomial name for an English flower known as the 'cuckoo flower' or 'lady's smock'. The first name in the binomial name is the genus (group of closely related species) and the second name is the species name. The binomial name is written in Latin and italicized.

Methods for estimating the abundance of organisms

The way in which the abundance of an organism is measured depends on whether it is **motile** or **non-motile**.

Key definitions

Motile organism – An organism that can actively move from place to place.

Non-motile organism – An organism that cannot move or, for the purposes of sampling, can only move very slowly (such as limpets on the rocky shore).

Lincoln index

This technique uses the capture–mark–release–recapture method. It is used for estimating the population size of motile animals.

- Organisms are captured, marked, released and then recaptured.
- Marking varies according to the type of organism. For example, wing cases of insects can be marked with pen, snails with paint, and fur clippings can be used for mammals.
- Markings must be difficult to see – high visibility increases predation risk.
- The number of individuals of a species is recorded at each stage.
- The total population size is estimated using the following equation:

$$N = \frac{n_1 \times n_2}{m}$$

Where:

N = total population of animals in the study site

n_1 = number of animals captured (marked and released) on first day

n_2 = number of animals recaptured on second day

m = number of marked animals recaptured on second day

In 'mark, release, recapture' the size of the animal population is estimated by the formula:

$$N = \frac{n_1 \times n_2}{m}$$

where
N = the population being estimated
n_1 = number captured, marked and released
n_2 = total number captured on the second occasion
m = number of marked individuals recaptured

here: $N = \frac{5 \times 8}{1} = 40$

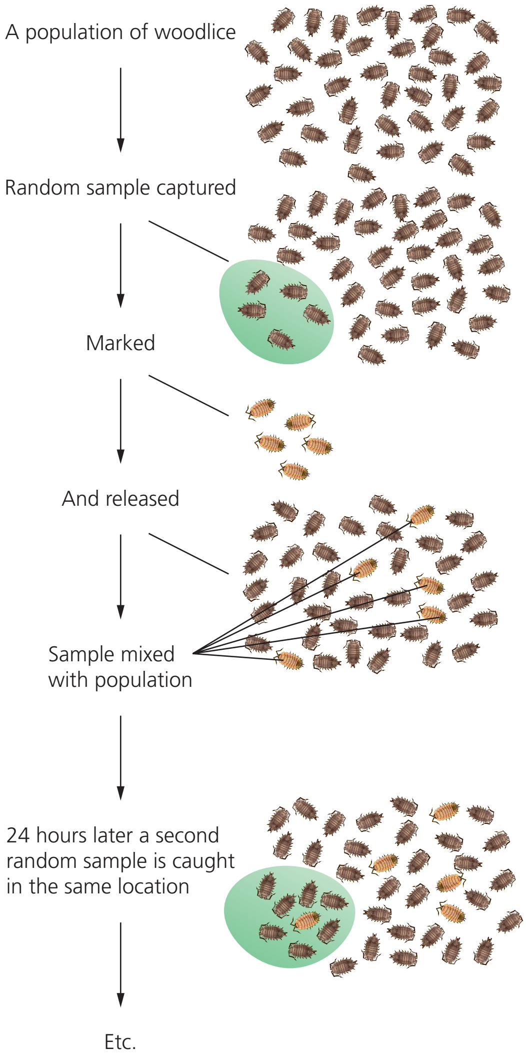

Figure 5.4 Estimating animal populations using mark, release and recapture

ACTIVITY

4 **Describe** the way the capture–mark–release–recapture method is used to estimate population size using a named animal species.

Quadrat methods

Quadrats are used for estimating the abundance of plants and non-motile animals.

- A quadrat is a square frame that outlines a known area for the purpose of sampling (Figure 5.5).
- Quadrats are placed according to random numbers, after the area has been divided into a grid of numbered sampling squares. The presence or absence in each quadrat of the species under investigation is then recorded.
- **Percentage frequency** is the percentage of quadrats in an area in which at least one individual of the species is found. It is calculated by taking the number of occurrences and dividing by the number of possible occurrences; for example, if a plant occurs in 3 out of 100 squares in a grid quadrat, then the percentage frequency is 3%.
- **Percentage cover** is the proportion of a quadrat covered by a species, measured as a percentage. It is worked out for each species present. Estimates can be made by dividing the quadrat into a 10 × 10 grid (100 squares), where each square is 1% of the total area covered.
- **Population density** is the number of individuals of each species per unit area. It is calculated by dividing the number of organisms by the total area of the quadrats.

Expert tip

There are several limitations to the Lincoln index method of estimating population size. The method assumes that the population is closed, both geographically and in terms of population numbers: animals may move in and out of the sample area, however, and new individuals might be born and others die. The method also assumes that all animals are equally likely to be captured in each sample, which might not necessarily be the case. The density of the population in different habitats might vary: there might be many in one area but few in another.

Figure 5.5 A quadrat being used to estimate the species richness of plants in a water meadow at Slapton Ley, Devon

Key definition

Quadrat – a square frame which outlines a known area for the purpose of sampling.

Expert tip

Formulas do not need to be memorized for exams but should be applied to given data.

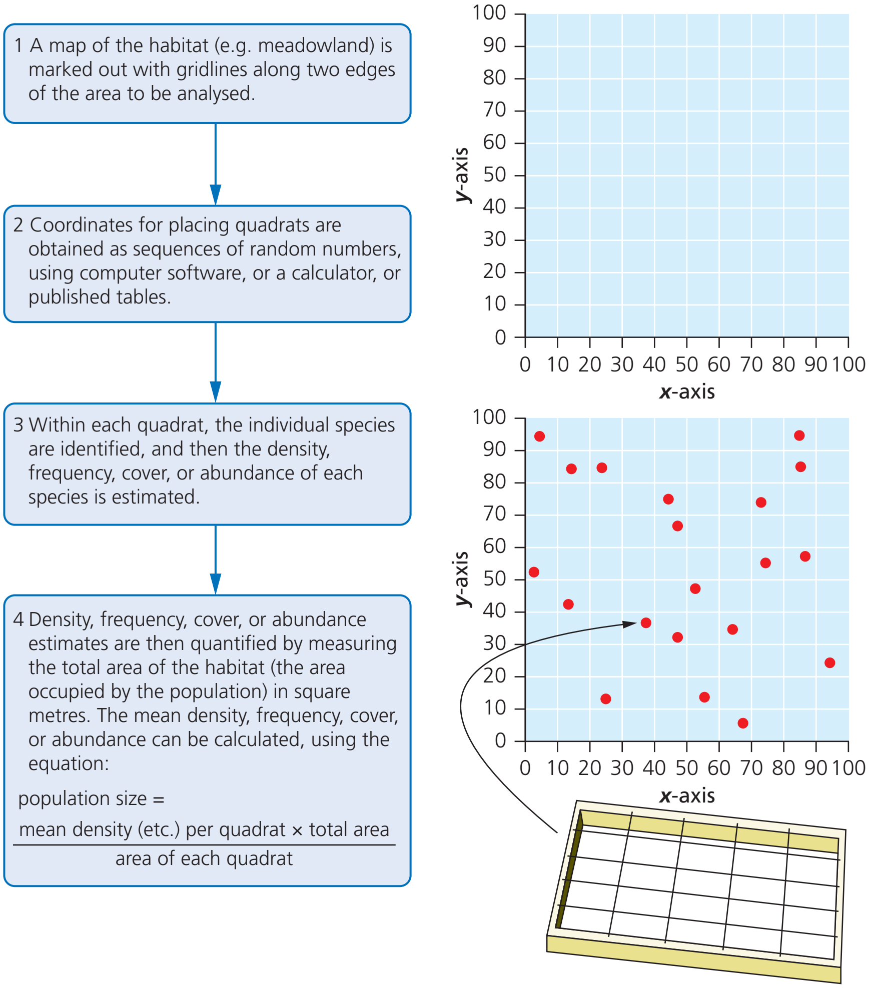

Figure 5.6 Random locating of quadrats

It is not possible to measure all organisms in an ecosystem, and so a sample must be taken. The **sample size** is the number of samples taken from a population.

The sampling system used depends on the areas being sampled:

- **Random sampling** is used if the same habitat is found throughout the area.
- **Stratified random sampling** is used in areas which contain two or more different habitat types. For example, if an area of woodland is being studied, there are likely be different types of habitat within it: random sampling may miss one or more of these and so stratified sampling is used. This technique takes into account the proportional area of each habitat type within the woodland and samples each one accordingly. The technique can also be used to compare undisturbed and disturbed areas.
- **Systematic sampling** is used along a **transect** where there is an environmental gradient, such as the change from the edge of a woodland, adjoining open land, into interior forest where, for example, warmer and lighter conditions predominate at the edge of the forest and cooler, darker ones in the interior.

Key definitions

Random sampling – A method of choosing a sample from a population without any bias.

Sample size – The number of samples taken from a population.

Transect – arbitrary line through a habitat, selected to sample the community.

Expert tip

If you have an i-Phone, you can convert it into a scientific calculator by turning it sideways (ie 'landscape') when in calculator mode. The scientific calculator has a random number generator function.

Expert tip

Random sampling ensures that every individual in the community has an equal chance of being selected and so a representative sample is assured.

Expert tip

Quadrats must be placed randomly to avoid sampling bias. Subjective choice of location for quadrats would lead to samples that are not representative of the area they are sampling. For example, areas that have a large number of species might be chosen at the expense of those with less species richness. Random allocation of sampling sites should always be used when a uniform habitat is being sampled.

Investigations

Sampling strategies may be used to measure biotic and abiotic factors and their change in space, along an environmental gradient (pages 80–82), or before and after a human impact for example.

Method for estimating the biomass of trophic levels

Biomass is calculated to indicate the total energy within a trophic level.

- Biomass is a measure of the organic content of organisms.
- Water is not an organic molecule, and its amount varies from organism to organism, so water is removed before biomass is measured. This is called **dry weight biomass**.
- One criticism of the method is that it involves the killing of living organisms (although not all the organisms in an area need to be sampled – see below).
- Problems exist with measuring the biomass of very large plants such as trees, and with roots and underground biomass.

Key definition

Biomass – The mass of organic material in organisms or ecosystems, usually stated per unit area.

Calculating dry weight biomass

To obtain quantitative samples, biological material is dried to constant mass:

- The sample is weighed in a container of known mass.
- The sample is put in a hot oven (80°C).
- After a specific length of time the sample is reweighed.
- The sample is put back in the oven.
- This is repeated until the same mass is recorded from two successive readings.
- No further loss in mass indicates that water is no longer present.

Biomass is recorded per unit area (eg per metre squared) so that trophic levels can be compared. Not all organisms in an area need to be sampled:

- The mass of one organism, or the average mass of several organisms, is taken.
- This mass is multiplied by the total number of organisms to estimate total biomass.
- This is called an **extrapolation** technique.

Expert tip

To estimate the biomass of a primary producer, all the vegetation, including roots, stems and leaves, is collected within a series of 1 m × 1 m quadrats. The dry weight method is carried out and average biomass calculated.

Expert tip

Data from methods for estimating biomass can be used to construct ecological pyramids.

ACTIVITIES

5 **Describe** and **evaluate** methods for measuring **three** abiotic factors in a forest ecosystem.

6 **Explain** the difference between percentage frequency and percentage cover.

7 Which data are needed to estimate the size of an animal population? Write the equation needed to calculate population size.

8 **Explain** how biomass is calculated.

Diversity and the Simpson's diversity index

Species **diversity** refers to the number of species and their relative abundance. It can be calculated using a **diversity index** (plural indices).

Species diversity can be calculated using the **Simpson's diversity index**, using the equation:

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

where:

- D = Simpson's diversity index
- N = total number of organisms of all species found
- n = number of individuals of a particular species
- Comparisons can be made between areas containing the same type of organism in the same ecosystem.
- A high value of D suggests a stable and ancient site, where all species have similar abundance (or 'evenness').
- A low value of D could suggest disturbance through, say, logging, pollution, recent colonization or agricultural management, where one species may dominate.

Key definitions

Diversity – A generic term for heterogeneity (ie variation or variety). The scientific meaning of diversity becomes clear from the context in which it is used; it can refer to heterogeneity of species or habitat, or to genetic heterogeneity.

Diversity index – A numerical measure of species diversity calculated by using both the number of species (species richness) and their relative abundance.

ACTIVITY

9 One habitat has a Simpson's diversity index of 1.83 and another has an index of 3.65. What do these values indicate about each habitat?

Expert tip

Index values are relative to each other and not absolute, unlike measures of, say, temperature, which are on a fixed scale.

Expert tip

The size of a D value depends on the site being sampled and can only be used in comparison with another site.

Expert tip

You need to be able to calculate and interpret data for species richness and diversity.

Worked example

The table below contains data from two different habitats. Total number of species (= 'species richness') and total number of individuals is the same in each case. Calculate the diversity of both habitats and comment on the differences between the habitats.

Species found	Number found in habitat X	Number found in habitat Y
A	10	3
B	10	5
C	10	2
D	10	36
E	10	4
Number of species =	**5**	**5**
Number of individuals =	**50**	**50**

The Simpson's index must be calculated for each habitat. This can be done using a table to calculate components of the index:

Species	Numbers (n) found in habitat X	$n(n-1)$	Numbers (n) found in habitat Y	$n(n-1)$
A	10	10(9) = **90**	3	3(2) = **6**
B	10	10(9) = **90**	5	5(4) = **20**
C	10	10(9) = **90**	2	2(1) = **2**
D	10	10(9) = **90**	36	36(35) = **1 260**
E	10	10(9) = **90**	4	4(3) = **12**
	$\Sigma n(n-1)$	**450**	$\Sigma n(n-1)$	**1 300**

Species diversity for each habitat:

Habitat X:

$$D = \frac{50(49)}{450} = \frac{2450}{450} = 5.44$$

Habitat Y:

$$D = \frac{50(49)}{1300} = \frac{2450}{1300} = 1.88$$

What do these values say about each habitat?

- Greater 'evenness' between species in habitat X.
- Less competition due to non-overlapping niches in habitat X.
- One species does not dominate in X, reflecting greater habitat complexity/more niches.
- Habitat Y is less complex with fewer/overlapping niches, where one species can dominate, leading to lower diversity.

ACTIVITY

10 Consider a man-made park in your city or town. **Suggest** what variables might be important in determining the relative species richness of trees and other plants.

Measuring changes along an environmental gradient

Ecological gradients are found where two ecosystems meet or where an ecosystem ends. Abiotic and biotic factors change along the same ecological gradient.

Transects are used to measure changes along the gradient, which ensures that all parts of the gradient are measured (Figure 5.7):

- The whole transect can be sampled – a **continuous** transect – *or* samples can be taken at points of equal distance along the transect – an **interrupted** transect.
- A **line transect** is the simplest transect, where a tape measure is laid out in the direction of the gradient. All organisms touching the tape are recorded.
- A **belt transect** allows more samples to be taken – a band usually between 0.5 m and 1.0 m is sampled along the gradient.

Figure 5.7 Sampling along an environmental gradient. A tape measure is laid out at 90° to the sea and abiotic and biotic factors measured at regular intervals along it. The photo shows a site near the end of the succession which starts on a shingle ridge and ends in shrub communities.

Figure 5.8 A point quadrat being used to measure plant species richness along a transect

Quadrats can be used to sample at regular intervals along a transect (see page 80):

- **Frame quadrats** are empty frames of known area (eg 1 m^2).
- **Grid quadrats** are frames divided into 100 small squares.
- **Point quadrats** are made from a frame with 10 holes, inserted into the ground by a leg (see Figure 5.8). They are used for sampling vegetation that grows in layers. A pin is dropped through each hole in turn and the species touched are recorded. The total number of pins touching each species is converted to percentage frequency data (ie if a species is touched by 7 out of the 10 pins it has 70% frequency).

ACTIVITIES

11 Distinguish between using a transect and a quadrat in collecting ecological field data.

12 An investigation was carried out on the effect of pesticide treatment on earthworm populations. The results are shown in the table.

Quadrats on soil treated with pesticide		Quadrats on untreated soil	
Worms per quadrat	Frequency	Worms per quadrat	Frequency
0	0	7	0
1	1	8	2
2	3	9	3
3	4	10	6
4	6	11	12
5	10	12	9
6	9	13	6
7	5	14	4
8	4	15	2
9	3	16	1
10	0	17	0

(a) Plot a histogram of frequency against numbers of earthworms per quadrat.

(b) Describe the effect of pesticides on earthworm populations and **suggest** a reason for the observed results.

Zonation can be measured by recording biotic and abiotic factors at fixed heights along a transect:

- A cross staff is used to move a set distance (eg 0.6 m) vertically up the transect (Figure 5.9).
- The staff is set vertically and a point measured horizontally from an eye-sight 0.6 m from the base of the staff.
- Biotic and abiotic factors are measured at each height interval.

Figure 5.9 A cross staff being used to relocate quadrats at regular height intervals along a rocky shore. This allows zonation on the shore to be studied.

Expert tip

Studying both biotic and abiotic factors allows research questions such as *how do abiotic factors affect the distribution of organisms in ecosystems?* Different species can be expected to be found at different locations along the gradient as they will be adapted to different conditions.

ACTIVITIES

13 What is meant by the term *ecological gradient*?

14 **Outline** how you would measure changes in abiotic factors along an environmental gradient.

15 **Describe three** different methods for recording biotic factors along a belt transect.

16 **Describe** how you would collect data to show zonation in an ecosystem.

Common mistake

Do not confuse the terms biotic and abiotic – biotic refers to the living parts of the ecosystem and abiotic to the non-living parts.

Practical 5: Setting up sealed mesocosms to try to establish sustainability

A **mesocosm** can be set up to investigate eutrophication, so avoiding the destruction of a natural ecosystem, and allowing one variable to be altered and the rest controlled.

Mesocosms are enclosed experimental areas that are set up to explore ecological relationships. Because they are contained experimental areas they can be closely controlled and variables monitored. Studying natural ecosystems can be difficult because there are so many variables that cannot be controlled – mesocosms enable all variables other than the independent and dependent variables to be kept constant, so as to ensure a fair test.

Key definition

Mesocosm – Enclosed experimental area that is set up to explore ecological relationships. Because it is a contained experimental area it can be closely controlled and variables monitored.

Mesocosms can be set up in open tanks, but sealed glass vessels are preferable because entry and exit of matter can be prevented but light can enter and heat can leave. Aquatic systems are likely to be more successful than terrestrial ones.

The sustainability of an ecosystem can change when an external 'disturbing' factor that disrupts the natural balance is applied. An investigation of this can be attempted in natural habitats or in experimental, enclosed systems. A mesocosm can be used as an enclosed system to investigate the effect of altering one variable on the stability of an ecosystem, and to establish whether the changes are sustainable or not. Both approaches have advantages and drawbacks, as detailed in Table 5.2.

	A natural ecosystem, eg an entire pond or lake	A small-scale laboratory model aquatic system (a mesocosm)
Advantages	Realistic – actual environmental conditions experienced	Able to control variables; opportunity to measure degree of stability/change in a community, and to investigate the precise impact of a disturbing factor
Disadvantages	Variable conditions – minimum or non-existent control over 'controlled variables'	Unrealistic – possibly of disputed relevance/applicability to natural ecosystem

Table 5.2 Comparison between ecosystem and mesocosm studies

Setting up a mesocosm

You can set up a mesocosm to investigate the effect of changing one variable on the sustainability of the system. For example, in an aquatic system you could set up one mesocosm with fish and the other without fish to investigate the effect of fish on the aquatic ecosystem.

When setting up the mesocosm you need to consider:

- What variables will you be controlling (keeping the same) and why? What effect might these variables have on the system if they are changed (ie why do you need to control them)?
- For terrestrial mesocosms, large glass jars can be used, although plastic containers can be just as effective. Which will you use, and why? Should the sides of the container be transparent or opaque?
- Which groups of organism will you need to include in the mini-ecosystem? Think of the organisms that would be present in a natural ecosystem (eg autotrophs, consumers and decomposers).
- Because the mesocosm will be sealed, you need to consider how the organisms will obtain fresh sources of oxygen. Photosynthetic organisms will ensure a supply of oxygen – how will you ensure these are kept alive?
- Because the mesocosm is a closed system, there is a danger that the organisms in it will suffer from lack of food, competition, excess heat and so on. How will you ensure the well-being of the organisms in your mesocosm?

Case study: An investigation of eutrophication

Lakes and ponds where there is an excess of nutrients can undergo a process called eutrophication. Excess nutrients might come from, for example, fertilizer run-off from surrounding land. The excess nitrates and phosphates provide high levels of nutrition for algae, which undergo rapid population growth (an algal bloom occurs). The algae block light to underwater plants which die, providing detritus for bacteria to absorb and use for respiration – these bacteria undergo rapid growth and remove oxygen from the water, causing fish and other aquatic animals to die. A few organisms can survive in these conditions and prosper, but the death of many aquatic organisms results.

Expert tip

In water enriched with inorganic ions, the increase in concentration of ammonium, nitrate and phosphate ions increases algal and plant growth.

A mesocosm can be set up to investigate eutrophication, thereby avoiding the destruction of a natural ecosystem, and allowing one variable to be altered and the rest controlled (Figure 5.10).

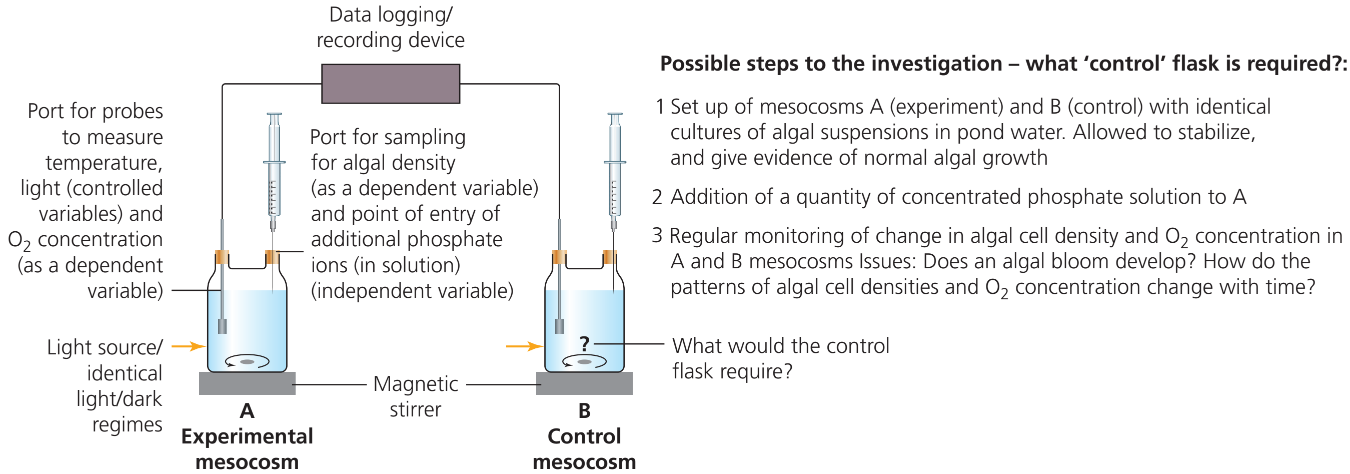

Figure 5.10 An experimental mesocosm investigating the effect of nutrient enrichment

In this experiment:

- The independent variable = volume of phosphate ions of fixed concentration added.
- The dependent variable = either dissolved oxygen concentration, or algal density.
- Controlled variables = temperature, light intensity, degree of stirring of solution.

Further reading and ideas

- Mini-ecosystem ideas: http://www.biologycorner.com/worksheets/ecosystem.html#.U0rw2VVdXww
- Create an ecosystem in a bottle: http://www.bottlebiology.org/
- Aquatic mesocosms: http://plankt.oxfordjournals.org/content/23/10/1081.full
- Aquatic (ocean acidification): http://www.egu.eu/medialibrary/image/549/researchers-working-on-a-mesocosm-deployed-for-the-ocean-acidification-study/
- Freshwater, and why use mesocosms: http://www.whoi.edu/cms/files/spivak_et_al_2011_fw_biol_80204.pdf
- Biosphere 2: http://archive.bio.ed.ac.uk/jdeacon/biosphere/mesocos.htm

Planning ecological investigations

Ecology is the study of the interaction between organisms and their environment. In any given ecosystem, there are numerous complex, interrelated relationships. It is important in an ecological investigation to have a clear idea about the organisms that will be the focus of the investigation, and the relationship that is to be studied. You have to be careful that your investigation does not get too wide in scope, and has clearly defined parameters. Initial ideas about possible investigations can be gained from visiting a local nature reserve, woodland or other ecosystem. You might notice, for example, that certain species are only found in particular areas. You could test various abiotic factors, such as pH, light intensity, soil moisture and so on, to explore the reason for such patchy distribution, as well as sampling other species to see if there are any biotic interactions. Based on initial studies, you then need to decide on one specific independent variable to investigate, and one dependent variable, such as the effect of soil moisture on the distribution of one species. Other confounding variables, which might have an effect on the dependent variable, but which cannot be controlled, must be monitored.

Ecological investigations can draw on the range of techniques and skills you have learned in this chapter, such as the use of:

- quadrats
- transects
- keys to identify organisms
- abiotic sampling techniques
- biotic sampling techniques
- laboratory skills, eg measuring and calculating soil moisture
- diversity indices.

The sampling methodology will be central to your investigation. Will you carry out random sampling (appropriate if your study area is homogeneous) or sample along a line transect (suitable where there is an environmental gradient and a change in species composition)?

Statistical tests are usually used in ecology to investigate whether observed results are significant or not (ie whether they are due to chance, or show that there is a real link between independent and dependent variables). It is important to select the appropriate test for your investigation. The use of statistical tests in ecological investigations is covered in the next chapter (Chapter 6, pages 91–102).

Investigations

Possible ecological investigations are almost limitless, but here are a few suggestions:

- Determine whether there is a correlation between the distribution of a plant species and an abiotic factor, such as light intensity.
- Explore whether there is an association between plant species, or between a plant species and an animal. For example, thyme (*Thymus serpyllum*) is often observed growing on anthills.
- Rocky shores provide many opportunities for investigations:
  - Whether there is a correlation between height and width of molluscs, eg limpets (*Patella vulgata*), and exposure to wave action. Sheltered and exposed shoreline could be studied.
  - Whether location of different species of seaweeds on the shore is determined by their resistance to desiccation, eg seaweeds higher on the shore, which spend a greater proportion of their time not submerged by the sea, might be more tolerant to desiccation than ones lower on the shore. Seaweeds could be dried out for specific periods of time and percentage loss of water recorded for each species.
  - Crabs make good subjects for ecological investigations, for example, fiddler crabs (*Uca* spp.), ghost crabs (*Ocypode* spp.) and soldier crabs (*Mictyris* spp.). They play an important role in the nutrient cycling and energy flow of coastal ecosystems, and can be used as indicators of ecosystem disturbances. See: http://ecolabnie.wixsite.com/shirley/research.
- Acid rain has an adverse effect on aquatic plants. The effect of acidity on plant growth could be studied.
- Lichens (a symbiotic association between fungal and algal species) are sensitive to air pollution, specifically sulfur dioxide. The abundance and distribution of lichens in industrial and rural areas could be studied and compared.
- Plant leaves often accumulate unpleasant tasting chemicals called tannins. These chemicals are used by plants to discourage insects from eating them. In general, older leaves have more tannins in them. The concentration of tannins can be measured by boiling leaves in water and adding a solution of iron(III) chloride to the boiled sample. The intensity of the resulting black colour is an indication of the concentration of tannin in the sample. The colorimetry methods described on pages x–x (Chapter 2) could be used to quantitatively compare samples.

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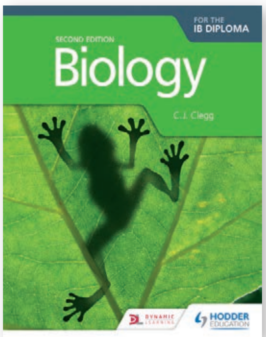

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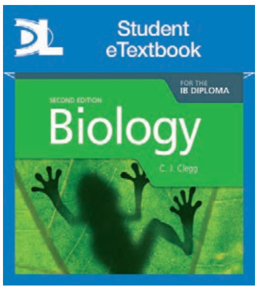

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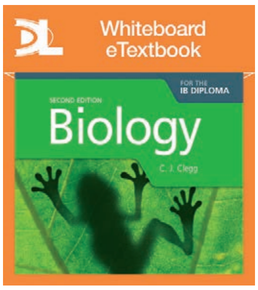

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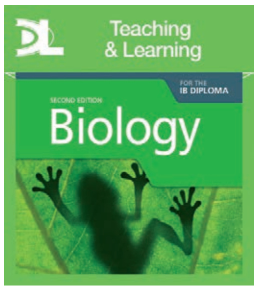

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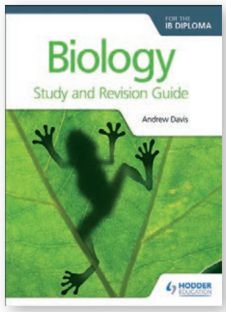

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