Realising potential

AS AND A-LEVEL ENVIRONMENTAL SCIENCE

AS (7446)
A-level (7447)

Required practical handbook

Version 1.0

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The purpose of practical work

There are three interconnected, but separate, reasons for doing practical work in schools and colleges. They are:

1. To support and consolidate **scientific concepts** (knowledge and understanding).

   This is done by applying and developing what is known and understood of abstract ideas and models. Through practical work we are able to make sense of new information and observations, and provide insights into the development of scientific thinking.

2. To develop **investigative skills**. These transferable skills include:
   - devising and investigating testable questions
   - identifying and controlling variables
   - analysing, interpreting and evaluating data.

3. To build and master **practical skills** such as:
   - using specialist equipment to take measurements
   - handling and manipulating equipment with confidence and fluency
   - recognising hazards and planning how to minimise risk.

By focusing on the reasons for carrying out a particular practical, teachers will help their students understand the subject better, to develop the skills of a scientist and to master the manipulative skills required for further study or jobs in STEM subjects.

Why study A-level Environmental Science?

As a society we are at an interesting period in Earth's history, with increasing concentrations of greenhouse gases, a climate that is warming up at a rate that has never been seen before, more extreme weather, increasing pollution and a decrease in biodiversity. There is therefore the need for a better, holistic understanding of Earth's systems in order to learn from the past, understand the present and influence the future. Environmental Science is the study of how physical, chemical and biological processes maintain and interact with life, and includes the study of how humans affect nature.

Environmental problems are inherently cross-disciplinary and they cannot be solved solely by experts in a single discipline. Planetary health requires multidisciplinary thinking, but for students the multidisciplinary nature of their education is often lost once they complete their GCSEs. A-level Environmental Science remedies this. As an applied science, it engages students with learning through continual opportunities to observe the object of study and recognise its importance. Students who have developed the ability to synthesise knowledge from different subjects are well-equipped as problem solvers and communicators, making them attractive to employers. Furthermore, the Intended Learning Outcomes of the A-level Environmental Science Practical Handbook map directly onto the subject as taught at university where the practical skills are used and further developed.

The practical work case studies described in this handbook are well designed to support students' abilities to understand and use critical concepts in environmental science that they will use in employment or return to at university. Whilst designed to allow development of particular skills, each case study has a clear context as an investigation with aims and objectives. This ensures the students are fully engaged and most importantly sets an example for any subsequent independent investigations. This handbook therefore is an exciting programme that forms a solid foundation for anyone interested in a career in environmental science.

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Guidance for supporting students with practical work

Developed in collaboration with NFER and CLEAPSS

Clarify the importance of keeping a lab book or other records of practical work

Explain that students need a record of their achievements to guide their learning. Lab books also can be an opportunity to develop a skill used both by scientists and in business. They allow students to accurately and clearly record information, ideas and thoughts for future reference which is a very useful life skill.

Warn students against plagiarism and copying

Explain the meaning of the term plagiarism and that the use of acknowledged sources is an encouraged and acceptable practice, but trying to pass off other people's work as their own is not, and will not help them learn. Show students how sources should be cited.

Explain the learning criteria for each skill

This will help students learn and allow them to know when they have met the criteria. The student lab book contains the criteria, but they own the process and have the responsibility for collecting appropriate evidence of success.

Use clearly defined learning outcomes

For example, if you are running a practical session to teach students how to use a soil penetrometer or a Muffle furnace safely and efficiently, then make sure they know why they are learning this. This will also make it much easier for them to know when they have met the criteria.

Start with simple tasks initially

Students need to become confident with the apparatus and concepts of practical work before they can proceed to more complicated experiments. It may be more effective to start with simple manipulation skills and progress to the higher order skills.

Teach practical work in your preferred order

Teach the skills as you see fit and suit your circumstances – the assessment process is aimed to be flexible and help you teach practical work, not to dictate how it should be done.

Use feedback and peer assessment

Feedback is essential to help students develop skills effectively. Allowing self and peer review will allow time for quality feedback as well as provide powerful learning tools. However, this is a decision for teachers. The scheme is designed to be flexible while promoting best practice.

Research shows that feedback is the best tool for learning in practical skills. Students who normally only receive numerical marks as feedback for work will need to be trained in both giving and receiving comment-based feedback. Provided it is objective, focused on the task and meets learning outcomes, students will quickly value this feedback.

Feedback does not need to be lengthy, but it does need to be done while the task is fresh in the students' mind. Not everything needs written feedback but could be discussed with students, either individually or as a class. For example, if a teacher finds that many students cannot calculate percentage change, the start of the next lesson could be used for a group discussion about this.

The direct assessment of practical work is designed to allow teachers to integrate student-centred learning (including peer review), into day-to-day teaching and learning. This encourages critical skills. Research indicates these are powerful tools for learning. For example, teachers could ask students to evaluate each other's data objectively. The students could identify why some data may be useful and some not. This can be a very good way of getting students to understand why some conventions are used, and what improves the quality of results. This also frees up marking time to concentrate on teaching.

Use group work

This is a very useful skill, allowing students to build on each other's ideas. For example, planning an experiment can be done as a class discussion. Alternatively, techniques such as snowballing can be used, in which students produce their own plan then sit down in a small group to discuss which are the best collective ideas. From this, they revise their plan which is then discussed to produce a new 'best' plan.

Safety

At all times, the teacher is responsible for safety in the classroom. Teachers should intervene whenever they see unsafe working. Risk assessments should be carried out before working, and advice from CLEAPSS and other organisations should be followed.

It is appropriate to give students at A-level more independence when making decisions about safety. They should be taught how to assess risks and how to write risk assessments when appropriate. They should also understand the appropriate use of safety equipment and how to put measures in place to reduce risks.

To support teachers further, Mary Philpott, AQA Biology Practical Adviser, previously from CLEAPSS, outlines the difference between identification of major hazards, associated risk and control measures and a full risk assessment:

The risk assessment should always be complete, as it is this that prevents injury or ill-health.

The risk assessment is fundamentally the **thinking** that has taken place before and during an activity, so that any foreseeable risk is reduced to a minimum. A written record is necessary only to show that the thinking has taken place.

We tend to get caught up in the paperwork that provides evidence for the risk assessment, but the guidance from the Health and Safety Executive is that the written record should be on a **point-of-use document** and there is no particular form etc that needs to be filled in.

The tables/forms etc that many schools use are simply planning documents that the teachers use to provide the point of use risk assessment for each of their lessons. Incidentally, CLEAPSS members must refer to our current advice when preparing their point-of-use documents.

The student is not responsible for their risk assessment. In a large part, therefore, the student's risk assessment will be that they carry through the safety measures that the teacher has put in place. It is therefore fine if the student makes a note on their point-of use document that shows they have thought about how to behave safely, and carried it through. The teacher will also be able to record what they have seen in a practical that shows that the student's risk assessment is effective. For example, the student's written risk assessment could be as simple as making notes on a method sheet about where they will put on eye protection or how they will arrange any heating equipment so that there is a minimum risk of scalding or burning themselves or the person next to them.

It might help the students to think safely if the teacher gives them a little time at the start of each practical to highlight or make notes about the safety aspects, and a class discussion about safety could show up any safety aspects that perhaps the teacher had not considered.

The students may also note where they have reminded other students about any safety issues.

If the students are planning their own practical activities, they could use the safety advice given in the CLEAPSS Student Safety Sheets.

In this case, they could identify hazards, risks and control measures.

In this case, they would make their own point of use document, with the control measures clearly identified.

The teacher would need to check that the risk assessment is adequate before they let the students proceed with the activity.

Trialling

All practicals should be trialled before use with students.

Risk assessment and risk management

Risk assessment and risk management are the responsibility of the centre.

Safety is the responsibility of the teacher and the centre. It is important that students are taught to act safely in the laboratory or in the field at all times, including the wearing of goggles and the use of additional safety equipment where appropriate.

Notes from CLEAPSS

Technicians/teachers should follow CLEAPSS guidance, particularly that found on Hazcards and recipe sheets. The worldwide regulations covering the labelling of reagents by suppliers are currently being changed. Details about these changes can be found in leaflet GL101, which is available on the CLEAPSS website. You will need to have a CLEAPSS login.

Criteria for the assessment of practical work

A-level Environmental Science is a 100% terminally assessed qualification, as is also the case for A-level Biology, Chemistry and Physics. With the absence of both a practical skills endorsement and a list of required activities specified in the A-level Environmental Sciences specification, AQA require centres to sign a declaration statement to confirm that students have had the opportunity to carry out the practical skills and to do **a minimum of two (AS Level) or four (A-level) days of fieldwork**.

For further details of the practical skills endorsement required in A-level Biology, Chemistry and Physics please see our specifications and associated resources.

As A-level Environmental Science is an area that is changing all the time it wasn't sensible to specify a list of required activities. Instead, opportunities to deliver the theoretical aspects of the Research Methods (3.7, page 84 of the specification) are signposted throughout the specification, teaching guide and scheme of work. Whether a school or college is situated in a rural or urban area for example will make a big difference to the choice of practical skills experiences (6 Appendix A: Working Scientifically, page 97 of the specification) that students can have first-hand.

The teaching of key skills and methodologies in this specification are required but essentially the way that students experience them first-hand is down to professional judgement. Students however must understand the general principles of scientific methodology and be able to apply these to a wide range of environmental situations and techniques.

Overall, at least 15% of the marks for the A-level Environmental Science qualification require the assessment of practical skills. Students must undertake experimental and investigative activities, including appropriate risk management, in a range of environmental contexts. They must also know how to safely and correctly use a range of practical equipment and materials.

Practical skills for assessment in the written papers

Independent thinking

Practical skill number	Description of skill
PS 1.1	solve problems set in practical contexts
PS 1.2	analyse and evaluate existing scientific knowledge
PS 1.3	apply scientific knowledge to practical contexts
PS 1.4	plan scientific investigations and apply investigative approaches and methods to practical work.

Use and application of scientific methods and practices

Practical skill number	Description of skill
PS 2.1	comment on experimental design and evaluate scientific methods
PS 2.2	evaluate results and draw conclusions with reference to measurement uncertainties and errors
PS 2.3	identify variables including those that must be controlled
PS 2.4	collect and present information and data in a scientific way.

Numeracy and the application of mathematical concepts in a practical context

Practical skill number	Description of skill
PS 3.1	plot and interpret graphs
PS 3.2	process and analyse data using appropriate mathematical skills as exemplified in the mathematical requirements
PS 3.3	consider margins of error, accuracy and precision of data.

Instruments and equipment

Practical skill number	Description of skill
PS 4.1	Know and understand how to use experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification, including: • using appropriate apparatus/instruments to record quantitative measurements (for example temperature, length and pH) • using appropriate apparatus/instruments and methodologies to measure abiotic and biotic factors (for example, light intensity, humidity, population size) • sampling techniques (for example pitfall traps, Tüllgren funnel, soil texture analysis, water turbidity, light traps).

All the practical skills tabulated above could be developed after the initial theoretical teaching of scientific methodologies and sampling techniques (research methods). It is not expected that students will have first-hand experience of all of these although, where this is possible, it will enhance their learning experience.

Scientific methodologies

Content	Additional information
Sample location: random sampling	Importance of the avoidance of bias.
Sample location: systematic sampling	Regular sample intervals. Transects – applied to 'environmental gradients': • line transects • belt transects • continuous/interrupted transects.
Sample timing	To ensure data variability is detected. Selection of time intervals between samples.
Sample size	Dependent on sample homogeneity.
Number of samples	Dependent on data variability. To enable analysis of statistical significance.
Standardisation of techniques	To allow comparisons between different studies/ ensure consistent reliability.
Collection of statistically significant data	Experimental design should allow the assessment of statistical significance of the data collected.

Sampling techniques

Standard environmental techniques

Content	Additional information

Methods:
• quadrats
  • quadrat size selection
• types of quadrat
  • open frame quadrat
  • grid quadrat
  • point quadrat
• kick sampling
• surber samplers
• colonisation media
• pitfall traps
• sweep nets
	Students must understand the following features of each technique:
	• purpose/application of the method
	• how the method is carried out
	• limitations.

• beating trays
• light traps
• Tüllgren funnel
• extraction of earthworms from soil.
Quantitative/comparative/numerical measures:
• abundance scales, eg DAFOR scales
• species richness
• species diversity
• species frequency
• species density
• percentage cover
• Lincoln Index
• Simpson's Index of Biodiversity.
Measurement of abiotic factors:
• light intensity
• temperature
• wind velocity
• humidity
• water turbidity
• water pH
• water ion concentration, eg nitrates
• soil analysis:
    • texture: sedimentation, sieving
    • pH
    • water content
    • organic matter content
    • measurement of bulk density the use of a soil triangle.	

Fieldwork and laboratory activities

Content
Fieldwork and laboratory activities. These should include, but not be limited to, the following. Ecological studies in suitable available habitats: • population size/density

- species frequency
- species distribution
- biodiversity
- soil analysis.

The effects of climatic variability on the use of renewable energy resources: insolation intensity, wind velocity.

Factors affecting the rate of heat loss: insulation, volume.

The use of biotic indices in monitoring pollution: lichens, aquatic invertebrates.

The effect of pH on seed germination.

The effect of water turbidity on light penetration.

The effect of inorganic nutrients on the growth of aquatic plants/algae.

Factors affecting noise levels: distance from source, acoustic insulation.

The effect of slope and vegetation on rain splash soil erosion.

The effect of trees on microclimates.

Specialist techniques

Content
Knowledge/understanding/application of the following techniques is required, but first-hand experience is not.

Photography:

- motion sensitive cameras
- databases of physical features may be used to identify individuals, eg tiger stripe patterns, whale shark spots, whale and dolphin fin damage.

Marking: tags, rings, collars etc.

Auditory monitoring (sounds)/sonograms: birds, bats, cetaceans.

Radio/GPS/satellite tracking.

Data collected by satellite sensors, eg to monitor habitat change, water availability, rock density, ice cover, ice thickness.

Databases of blood/tissue samples/DNA/eDNA.

Indirect evidence – shows the presence of the species even if it is not actually seen:

- nests/burrows
- droppings – can give information on diet, gender, territories
- feeding marks, eg nuts, fruit
- owl pellets – also give information on diet
- tracks/footprints
- territorial marks, eg scratching posts.

What is important however is that students **do have first-hand experience of the methodologies Me1, Me2, Me3, Me4, Me5 and Me6 and all the practical sampling techniques included in ST1, ST2, ST3, ST4, ST5 and ST6 in detail** which, when carried out, will build on the knowledge and understanding gained from the teaching of scientific methodologies and sampling techniques (Research Methods). **These are tabulated below** and students should develop an understanding of how these methodologies enable the planning of better scientific research so they can evaluate their impact on the reliability of the data collected.

This will be important because at least 15% of the marks for the qualification require the assessment of practical skills.

To gain the greatest education benefit from these activities, the investigations should be planned with an environmental context where the results would inform environmental decision-making, eg the effect of field cultivation on river water or nutrient concentration or the effect of different farming techniques on soil organic matter content. The case studies that have been written in this practical handbook are not required activities but they have been designed to secure first-hand experience of the compulsory methodologies and practical sampling techniques.

Planning for representative data

Methodology skill number	Description of skill
Me 1	Sample location – random sampling, where there is no directional difference in sample results or there is no environmental gradient.
Me 2	Sample location – systematic sampling, where there is an environmental gradient or fixed sample intervals are appropriate.
Me 3	Number of samples – an assessment of the number of samples needed, as influenced by the variability between samples.
Me 4	Sample size – an assessment of how large each sample should be, as influenced by the homogeneity of the subject matter.
Me 5	Sample timing – when a temporal variable may affect the reliability of results, eg weather-related, seasonal or diurnal changes.
Me 6	Standard deviation – an analysis of the variability of results by calculating the Standard Deviations of mean values. An assessment of the statistical significance of results by selecting and carrying out an appropriate statistical test.

Sampling techniques

Sampling technique skill number	Description of skill
ST 1	**Measurement of abiotic factors:** • Light intensity • Temperature • Wind velocity • Humidity • Water turbidity • Water ion concentration, eg nitrates, phosphates • pH

ST 2	**The use of quadrats to measure biotic factors:**
	Population size, species richness, species distribution, biodiversity
	• Selection of suitable quadrat size
	• Types of quadrat:
	    • Open frame quadrat
	    • Grid quadrat
	    • Point quadrat

ST 3	**Measurement of edaphic factors** Soil texture: • Sedimentation • Soil sieves • Soil triangle Soil water content Soil organic matter content Soil pH Soil bulk density
ST 4	**The use of methods to measure biotic factors related to animal taxa on the soil surface and in soil:** Population size, species richness, species distribution, biodiversity • Pitfall traps • Tüllgren funnel • Extraction of earthworms from soil

ST 5	**The use of methods to measure biotic factors related to animal taxa on foliage and flying animals:** Population size, species richness, species distribution, biodiversity • Light traps • Sweep nets • Beating trays • Bat detector
ST 6	**The use of aquatic sampling methods to measure biotic factors:** Population size, species richness, species distribution, biodiversity • Pond net • Kick sampling • Surber samplers • Colonisation media

To summarise and reinforce the guidance provided above, there is no prescribed list of compulsory investigations that must be carried out. Centres and teachers must choose appropriate practical activities that allow students to gain first-hand experience of the required methodologies and sampling techniques (Me1, Me2, Me3, Me4, Me5 and Me6, ST1, ST2, ST3, ST4, ST5 and ST6). **It is anticipated that the time devoted to practical activities would take a minimum of two (AS Level) or four (A-level) days of fieldwork. One day of fieldwork equates to six sessions of laboratory-based activities.** Practical activities should also be carried out with the consideration of their environmental impacts and how these can be minimised. All activities should be planned and carried out to ensure the safety of students and other people.

How this resource can be used by Geography teachers

This handbook has a wide range of applications for teachers of A-level Geography, including the planning and delivery of geographical fieldwork, the teaching of geographical skills and supporting students in their NEA investigations. There is considerable overlap with the following modules: water and carbon cycles, ecosystems under stress and contemporary urban environments.

The majority of the 13 practical case studies can be adapted to suit a variety of geographical fieldwork, with detailed method steps, sample results tables, suggestions for data presentation and statistical analysis guidance. There are also examples of similar, alternative studies that could be undertaken. In addition, there is very little requirement for expensive technical equipment for any of the practical work, beyond what may be expected within an A-level Geography department. Geography teachers could therefore use the handbook for inspiration for planning their four days of compulsory fieldwork required by the current A-level Geography course.

The scientific methodologies outlined on p12 covering considerations such as sample size, sampling methods and standardisation of techniques are all highly relevant to Geography students undertaking primary data collection for their NEA, in planning for high quality and representative data. The Figure 1 route to enquiry model on p26 also follows precisely the format of a fieldwork investigation, documenting the key stages of planning, methodology, data presentation and analysis.

Geography teachers may also find the practical case studies useful when approving NEA proposal forms in related topics, to ensure the student has chosen appropriate data collection techniques and sampling strategies. Though Geography students must independently devise NEA investigation titles, it may be useful for them to see examples of the detailed methodologies accompanying each practical in this handbook, for greater clarity on how to write up methods effectively to be replicable – one of the key assessment criteria in their NEA. The quotes at the top of each case study also tend to highlight a link to the theoretical context of the practical, also useful for Geography students in understanding how geographical theory can be integrated and applied to their investigations.

The case study practicals most relevant to Geography teachers are outlined below.

Links to the water and carbon cycles

Case Study 3 – The impact of land management on flood risk: Exploring the impact of soil compaction on infiltration rates of soils in two contrasting areas. This could be adapted to support a variety of fieldwork opportunities and NEA investigations on the water cycle (Changes in the water cycle over time to include natural variation including storm events, seasonal changes and human impact including farming practices, land use change and water abstraction – 3.1.1.2). This practical includes an example of random sampling, a sample results table and an opportunity to apply the Mann Whitney U Test.

Case Study 6 – Investigating differences in carbon storage and sequestration between a coniferous and deciduous woodland could make an excellent field trip for a Geography class as it only requires access to trees and non-technical equipment-tape measure, clinometer, Tree ID guide and random number table. There is a recording sheet provided as a template and lots of opportunities to practise a variety of numeracy skills in the follow up tasks, including calculations of carbon storage, box and whisker plots and application of the Mann Whitney U Test. For NEA links, this case study may be useful for students wishing to design their investigation around the topic of climate change which is often difficult in terms of primary data collection.

Links to ecosystems under stress

Case Study 4 – Assessing biodiversity **–** Investigating differences in invertebrate communities between a deciduous and coniferous woodland could be adapted for geographical NEAs related to ecosystems and includes guidance on carrying out a pH test which may be used by Geographers in such studies.

Case Study 5 – Measuring edaphic characteristics, has practical guidance and methods to investigate a variety of soil properties **–** some of these methods may be supportive in collecting data for Geography NEAs linked to the water cycle (3.1.1.2) or a local ecosystem (3.1.6.6). These practicals would require some access to laboratory equipment.

Case Study 7 – Succession of plant communities **–** investigating how species' presence, abundance and diversity changes over time. This can be adapted for Geography fieldwork on the study of sand dune succession in coastal systems and landscapes **–** origin and development of landforms and landscapes of coastal deposition, sand dunes **–** factors and processes in their development (3.1.3.3) and Ecosystems under stress **–** concepts of succession: seral stages, climatic climax, sub-climax and plagioclimax (3.1.6.2). There are example recording sheets for vegetation and abiotic factors and opportunities to practice geographical skills such as transect sampling and Spearman's rank.

Links to contemporary urban environments

Case Study 1 – Microclimate regulation by trees could be adapted to support Geography students undertaking microclimate NEAs with links to Contemporary Urban Environments (3.2.3.4 Urban climate). This practical includes data presentation in the form of scatter graphs and the application of Spearman's Rank, alongside a sample results table for guidance on how to collect and record data.

Case study 10 – Assessing Air Pollution **–** Investigating air quality using a biotic index can be adapted for fieldwork or NEA investigations relating to Urban climate **–** air quality **–** particulate and photo-chemical pollution (3.2.3.4). The sticky tape method of measuring particulate pollution could be easily incorporated into a local fieldwork study on air quality.

Case Study 9 – Assessing noise pollution **–** Investigating how noise levels change with distance from the site of point source noise pollution**.** This lacks a clear geographical focus but the practical skills in measuring noise levels could be used and adapted for geographical fieldwork as a component of data collection for a variety of investigations.

Practical skills assessment in question papers

Practical skills that students have learned will be indirectly assessed on the exam papers at the end of the course. The examples provided below are from specimen assessment materials.

1. Assess students directly on the practical skills, apparatus and techniques they have used in fieldwork

A-level SAMs Paper 1 Q9.6

0 9 . 6 Give **two** limitations of using a Secchi disk to monitor the turbidity of water.

[2 marks]

A-level SAMS Paper 2 Q7.1

0 7 . 1 The effect of soil pH on the growth of oats and wheat was investigated.

Describe how soil pH may be measured.

[2 marks]

2. Assess students on the methodologies that they have studied (directly or indirectly where students are required to apply the methods scenario)

AS SAMs Paper 1 Q4.3

0 4 . 3 The suitability of mangrove forests as nursery areas for fish is affected by water turbidity.

Describe **one** method that may be used to collect representative data on water turbidity in mangroves.

[5 marks]

AS SAMs Paper 1 Q9.3

0 9 . 3 Describe the plan of a study of the impact of light levels on the ground vegetation in a broadleaf woodland.

[9 marks]

A-level SAMs Paper 1 Q6.2

0 6 . 2 Describe how the nitrate concentration of the water could have been measured.

[1 mark]

A-level SAMs Paper 1 Q8.2

0 8 . 2 Suggest **three** variables, other than the times of collection of samples, that should have been standardised in this study to ensure the results were representative.

[3 marks]

A-level SAMs Paper 2 Q2.2

0 2 . 2 Other than light intensity, state **four** factors that should be standardised when investigating the effect of nutrient concentration on aquatic algal growth in a laboratory.

[2 marks]

1

2

3

4

A-level SAMs Paper 2 Q10.4

1 0 . 4 Describe the plan of an investigation that would show whether there is a synergistic relationship between the neonicotinoid insecticide, thiacloprid, and an EBI fungicide.

[6 marks]

3. Assess the maths requirements.

A-level SAMs Paper 1 Q9.3/9.4

0 9 . 3 A t value of 3.01 was calculated.

Use **Table 10** to find the level of significance of this t value.

[1 mark]

Level of significance ____________________

0 9 . 4 What is the percentage probability that these data occurred by random chance?

[1 mark]

____________________ %

A-level SAMs Paper 2 Q3.1

0 3 . 1 Complete **Table 2** by calculating Simpson's Index of Diversity **(D)** for the insects at **Site 2** using the formula.

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

where
N = total number of organisms of all species
n = number of individuals of a particular species
Σ = sum of

Show your working.

[3 marks]

Subject specific vocabulary

Definitions of key terms used in our A-level Environmental Science specification (7447) can be found on our subject specific vocabulary page.

Students should be familiar with and gain an understanding of these terms.

Case studies

Foreword

With the challenging future that the world faces, never has it been more important to educate young people about the earth, the environment, ecosystems and both the challenges and opportunities ahead. A-level Environmental Science is a relevant, exciting specification with the potential to empower young people in a field which will be increasingly called upon to tackle the challenges of the future.

The Field Studies Council (FSC) was particularly excited by the opportunities presented by this A-level for practical, outdoor work. FSC believes that the more we understand about and take inspiration from the world around us, the more we can appreciate its needs and protect its diversity and beauty for future generations. High quality fieldwork provides opportunities for young people to be curious and creative learners, developing essential enquiry skills.

AQA's A-level Environmental Science specification is full of inspiring practical fieldwork opportunities, and FSC are delighted to have been invited by AQA to write some example case studies for the Environmental Science Practical Handbook.

The 13 case studies shared in this handbook are mapped against and provide multiple opportunities to cover:

- 6 methodologies – which students must have opportunities to study in detail
- 6 sampling techniques – of which students should gain first-hand experience.

Each of the 13 case studies have been mapped in the specification against the practical skills for assessment (6.1, page 97-98), scientific principles (6.5, page 101-106) and maths skills (Appendix B, page 107-112). The case studies have been written with specific environmental challenges in mind, and it is this context which teachers should be encouraged to discuss and engage students with to bring to life the necessary methodologies and sampling techniques.

In writing these case studies FSC is mindful of both the specification requirements and school budgets for technical equipment so the teacher notes section details information on low-cost alternatives.

The case studies will work as written, but opportunities are signposted within the Teacher Notes for alternatives and extensions and all case studies could be adapted to suit local sites and conditions. We recommend that schools collect and keep data from year to year, as the temporal variation will provide interesting discussion points for students.

With all the case studies featured, FSC advocates a route to enquiry approach, as shown in the diagram below. Students should be engaged with all stages of the enquiry process, and at the end of a practical, students should be encouraged to consider: So what? What next? How does this inform future ideas for investigations?

We both hope these are useful in your delivery of A-level Environmental Science and can help you to inspire the next generation of environmental scientists.

Janine Maddison
David Morgan
FSC Education Development Officers

Figure 1 – A route to enquiry approach

Figure 2 – Examples of practical work in action

Source: Field Studies Council

Case Study	Focus	Investigation Title
1	Ecosystem service provision – microclimate regulation by trees	Investigating the effect of trees on microclimate.
2	Estimating population size of a motile organism	Producing an estimate of the population size of woodlice in a defined habitat.
3	The impact of land management on flood risk	Exploring the impact of soil compaction on infiltration rate of soils in two contrasting areas.
4	Assessing biodiversity	Investigating differences in invertebrate communities between a deciduous and coniferous woodland
5	Measuring edaphic characteristics	Investigating differences in soil characteristics between two contrasting areas.
6	Carbon Sequestration	Investigating differences in carbon storage and sequestration between a coniferous and deciduous woodland
7	Succession of plant communities	Investigating how species presence, abundance and diversity changes over time.
8	Building energy conservation	Investigating building energy loss through different construction materials.
9	Assessing noise pollution	Investigating how noise levels change with distance from the site of point source noise pollution.
10	Assessing air pollution	Investigating air quality using a biotic index.
11	Assessing water quality	Investigating the use of a biotic index to assess water quality.
12	Constructing new habitats	Investigating how size and material type impacts the rate and abundance of colonisation in a freshwater environment.
13	Sampling flying organisms	Investigating how temporal change impacts the populations of flying organisms.

		Case Study												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Sampling technique	1	x			x			x		x	x	x		x
	2						x	x			x		x	
	3			x	x	x		x						
	4		x		x									
	5													x
	6											x	x	
Methodology	1		x	x	x	x	x				x			
	2	x						x		x		x		x
	3	x		x	x		x		x					
	4										x		x	
	5			x					x					x
	6				x	x		x		x	x	x		
Scientific principle	6.5.1	x	x	x		x	x	x			x	x	x	x
	6.5.2	x		x	x	x	x	x	x	x	x	x	x	x
	6.5.3									x				x
	6.5.4	x	x	x	x	x	x	x	x	x	x	x	x	x
	6.5.5	x	x	x	x	x	x	x	x	x	x	x	x	
	6.5.6	x		x	x	x	x	x	x	x	x	x	x	x
	6.5.7					x			x		x			
	6.5.8						x	x	x	x				
	6.5.9	x	x	x	x	x	x			x	x	x	x	x
	6.5.10		x		x							x	x	x
	6.5.11			x										
	6.5.12	x	x	x		x	x	x	x	x	x	x	x	
Practical skills	1.1		x	x	x		x		x	x	x		x	x
	1.2							x						
	1.3	x	x	x	x	x	x	x	x	x	x	x	x	x
	1.4	x	x	x	x	x	x	x	x	x	x	x	x	x
	2.1	x	x	x	x	x	x	x	x	x	x	x	x	x
	2.2	x	x	x		x	x	x	x	x	x		x	x
	2.3	x	x	x		x	x	x	x	x	x	x	x	x
	2.4	x	x	x	x	x	x	x	x	x	x	x	x	x
	3.1			x	x		x	x	x				x	x
	3.2	x	x	x		x	x	x				x		
	3.3	x	x				x		x	x				
	4.1	x	x	x	x	x	x	x	x	x	x	x	x	x

Case study 1

Ecosystem service provision – microclimate regulation by trees

> “Trees and other plants help cool the environment, making vegetation a simple and effective way to reduce urban heat islands.” (US EPA)

Investigation title: Investigating the effect of trees on microclimate.

Links to the specification

	Sampling techniques (ST)						Methodology (ME)					
	1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation
Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.1 The living environment 3.1.3 Life processes in the biosphere and conservation planning 3.1.3.1 How adaptation to the environment effects species habitat requirements and influences conservation decision makers
Maths skills	Handling data (1.1, 1.5, 1.7, 1.9) Algebra (2.3) Graphs (3.3)
Subject specific vocabulary	Abiotic factors Transect

Student sheet

Ecosystem service provision – microclimate regulation by trees

"Trees and other plants help cool the environment, making vegetation a simple and effective way to reduce urban heat islands." (US EPA)

Trees in urban areas deliver many valuable ecosystem service benefits, one positive effect is the regulation of microclimates. In this investigation you will use a transect to be explore how proximity of trees affects temperature, humidity, and windspeed.

Investigation title: Investigating the effect of trees on microclimate.

Method

You are provided with the following:

- whirling hygrometer (and conversion chart)
- anenometer
- metre ruler
- tape measure
- three marker poles.

You should read these instructions carefully before you start work

1. You will be shown to the area you are investigating − lay out your tape measure to create a 100m transect from the wooded area to the open area as shown in Figure 1.
2. Start at 0m along the transect, measure windspeed temperature (°C) and relative humidity (%). To standardise your measurements;
   a. spin the whirling hygrometer for 30 seconds at 1m above ground level before reading off the wet and dry bulb temperatures (°C).
   b. Use the dry bulb temperature to record air temperature (°C).
   c. Use the wet bulb and dry bulb temperatures (°C). to read the relative humidity (%) value from the conversion chart.
   d. Record the average windspeed (ms^{-1}), over 30 seconds at 1m above the ground.
3. Place the first pole at 0m on the transect and then place the second pole 5m away along the transect line.
4. Repeat step 2 at 5m from the start of the transect.
5. Leave the first two poles in place, have one person stand at 0m-sight through the second pole to ensure the third is placed in a straight line along the transect (Figure 2).
6. Repeat steps 2 − 5 until you reach the end of the transect, you should have 21 measurements.
7. Record the location of the woodland margin along the transect in your table.
8. Draw three scatter graphs to see how temperature (°C), relative humidity (%) and windspeed (ms^{-1}) change with distance along the transect.
9. Use Spearman's Rank Correlation Coefficient to assess the strength of correlation between distance along transect (m) and each of the microclimate variables.

$$r_s = 1 - \frac{6\Sigma D^2}{n(n^2 - 1)}$$

Figure 1-Transect running from wooded to open area.

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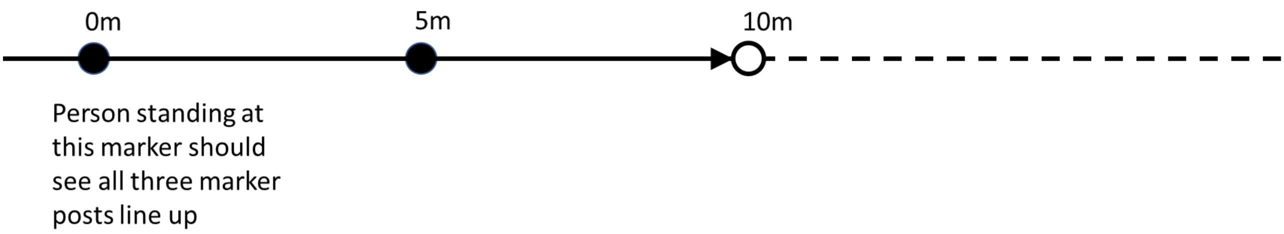
Figure 2-Using marker posts to keep transect in a straight line.



Teacher notes

Ecosystem service provision – microclimate regulation by trees

"Trees and other plants help cool the environment, making vegetation a simple and effective way to reduce urban heat islands." (US EPA)

Investigating the effect of trees on microclimate

Materials

Each student will need:

- whirling hygrometer (and conversion chart)
- wind speed meter
- metre ruler
- tape measure
- three marker poles.

Technical Information

The investigation requires access to an area of trees and neighbouring open space-an area of trees in a park would be ideal for this. Students should set up a transect running from within the wooded area, through the woodland margin and into open space. Whilst the student notes use a 100m transect, this can be adjusted to fit the location you are using.

The student notes assume that students are familiar with the use of equipment and include details on standardising measurements but not on the use of instruments as these may vary dependent on those used.

The use of marker poles is suggested to keep the transect in a straight line over long distances, these could be ranging poles, however broom handles with a brightly coloured painted end would be equally effective.

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Trialling

The practical should be trialled before use with students.

Additional notes

Students should work in pairs for the completion of this investigation.

Sample results

Distance along transect (m)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Air temperature (°C)	14	14	14.5	14	15	14.5	15	15	15.5	16	17	16.5	17	17.5	18	18	18.5	18.5	18	18.5	19
Relative humidity (%)	66	67	66	65	64	66	59	61	58	57	57	55	58	54	54	54	55	56	55	55	57
Wind speed (ms^{-1})	0.0	0.2	0.1	0.2	0.2	0.1	0.0	0.1	0.2	0.2	0.3	0.2	0.1	0.4	0.4	0.4	0.2	0.1	0.2	0.3	0.4
Woodland/Open	W	W	W	W	W	W	W	W	W	O	O	O	O	O	O	O	O	O	O	O	O

Woodland edge at 43m along transect

Case study 2

Estimating population size of a motile organism

"Humanity has wiped out 60% of animal populations since 1970." (WWF, 2018)

Investigation title: Producing an estimate of the population size of woodlice in a defined habitat.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12

Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.1 The living environment 3.1.2 Conservation of biodiversity 3.1.2.3 Methods of conserving biodiversity 3.1.2.3.5 The importance of ecological monitoring in conservation planning
Maths skills	Arithmetic and numerical computation (0.4) Algebra (2.3)
Subject specific vocabulary	Detritivores Habitat Lincoln index Population Species

Student sheet

Estimating population size of a motile organism

"Humanity has wiped out 60% of animal populations since 1970." (WWF, 2018)

Compared to sessile (non-moving) organisms, sampling motile (moving) organisms for a determination of population size can be challenging. This experiment utilises the Lincoln Index-a capture, mark, release and recapture process, to estimate population size of a motile organism.

Investigation title: Producing an estimate of the population size of woodlice in a defined habitat.

Method

You are provided with the following:

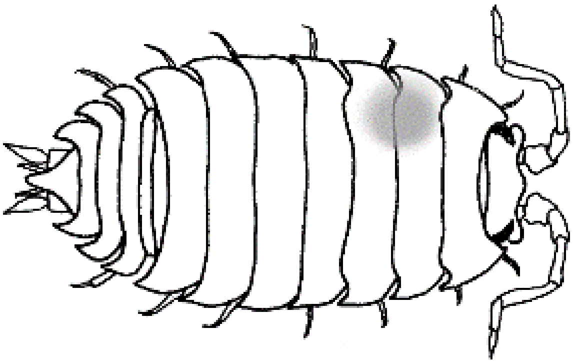
- 2 x tape measures
- teaspoon
- suitable container for holding woodlice
- non-toxic soluble paint
- cocktail stick.

You should read these instructions carefully before you start work

1. At the edge of the woodland, lay out tape measures at right angle to each other, to define an area (10m x 10m).
2. Make sure you can identify a woodlouse, see Figure 1.
3. Use a random number table, to generate a pair of coordinates in the format (XX,YY) this be the location of the sample site within the 100m² area.
4. At your sample site conduct a timed search for woodlice. Look under logs and leaf litter, use the teaspoon to collect as many woodlice as you can find in five minutes, place these woodlice in a suitable container. (Capture)
5. Once the five minutes is up, record the total number of woodlice collected by the whole class (n_1)
6. Using the cocktail stick and the non-toxic soluble paint, paint a small spot on the back of each woodlice collected as shown in Figure 1. (Mark)
7. Wait till the mark is completely dry.
8. Place woodlice back in the exact location where they were found. (Release)
9. Wait 2−3 hours.
10. Go back to the same sample location.
11. Repeat the timed search at your sample site. Look under logs and leaf litter, use the teaspoon to collect as many woodlice (marked or unmarked) as you can find in five minutes, place in a suitable container. (Recapture)
12. Record the total number of woodlice collected by the whole class (n_2).
13. Record the total number of marked woodlice collected by the whole class (m).
14. Calculate an estimate of total population size

$$estimate\ of\ total\ population\ (p) = \frac{Number\ of\ individuals\ in\ first\ sample\ (n_1) \times number\ of\ individuals\ in\ second\ sample (n_2)}{Number\ of\ marked\ in\ second\ sample\ (m)}$$

Figure 3-Location of mark on woodlouse



Source: Field Studies Council

Teacher notes

Estimating population size of a motile organism

"Humanity has wiped out 60% of animal populations since 1970." (WWF, 2018)

Investigation title: Producing an estimate of the population size of woodlice in a defined habitat.

Materials

- 2 x tape measures
- teaspoon
- suitable container for holding woodlice
- non-toxic soluble paint
- cocktail stick

Technical information

Non-toxic soluble paint should always be used, this will wash off the organisms after a few of hours.

Risk assessment

- Risk assessment and risk management are the responsibility of the centre.
- Students with shellfish allergies should not handle woodlice.
- All students should wash their hands thoroughly after this practical.

Trialling

This practical should be trialled before use with students.

Additional notes

The Lincoln Index is a method which is used to estimate the size of closed populations. Random samples of the population are captured, these individuals are marked and then released to redistribute with the general population. The population is then re-sampled after enough time has passed to allow complete remixing of the marked individuals. This will vary, and depends on the species, its mobility and the habitat in which it lives. For example, it is likely to take longer for a population of marked snails to remix compared to a population of mice.

The identifying mark on the organisms, must be placed on the exoskeleton of the organism, away from legs, antennae, feeding and reproductive parts of the organism. Students are given a line drawing of a woodlouse with placement of the mark on to assist them.

There are a number of assumptions to the use of the Lincoln Index in estimating population size.

1. There have been no births, deaths or migrations over the sampling period.
2. Marked individuals from the first sample, redistribute evenly amongst the population after release.
3. The mark does not wash or wear off during the investigation.
4. Marking of the organisms does not reduce the individuals' chance of survival-(due to increased visibility, decreased movement, toxicity etc.)
5. Individuals are all equally likely to be caught.

Students must be briefed on the ethical treatment of organisms before this practical.

Alternatives to this practical

This practical can easily be adapted to suit different habitats and population estimates of different species. Other species that work well for this practical:

- Marine gastropods (common topshells, purple topshells, dogwhelks, edible periwinkle). These species are all found on the rocky shore. Sample time between Catch 1 and Catch 2 must be ~24 hours, this is because of the diurnal regime of the tide, and the slow-moving nature of marine gastropods.
- Land snails. These can be found in hedgerows.
- Pond snails. These can be found in freshwater ponds.

Ensure that all organisms are dry before marking, and that the mark is placed on the exoskeleton/shell of the organisms.

Sample results

Freshwater pond snails, 30 students

Number of individuals in the first sample (n_1)	**56**
Number of individuals in the second sample (n_2)	**72**
Number of marked individuals in the second sample (m)	**31**
Population estimate (p)	**130**

Case study 3

The impact of land management on flood risk

"Flooding is blamed on sheep and cows." Daily Telegraph (02/04/03)

Investigation title: Exploring the impact of soil compaction on infiltration rate of soils in two contrasting areas.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12

Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.2 The physical environment 3.2.2 The hydrosphere 3.3.3.1 The impact of unsustainable exploitation
Maths skills	Arithmetic and numerical computation (0.1, 0.2, 0.3) Handling data (1.1, 1.2, 1.5, 1.6, 1.9) Graphs (3.1, 3.3, 3.7)
Subject specific vocabulary	Hydrology Hydrosphere Ploughing Edaphic factors

Student sheet

The impact of land management on flood risk

"Flooding is blamed on sheep and cows." Daily Telegraph (02/04/03)

Infiltration is the mechanism of transfer in the hydrological cycle whereby water on the surface passes into the soil. Infiltration rate can be used to compare how quickly water moves into the soil. A number of factors including soil texture, soil moisture content soil compaction, land cover and angle slope effect the process of infiltration.

On a catchment scale reduced infiltration rate can lead to shorter lag times and contribute to increased flood risk. In this investigation you will carry out fieldwork to compare the effect of soil compaction on infiltration rates between two areas.

Investigation title: Investigating the impact of soil compaction on infiltration rates.

Method

You are provided with the following:

- infiltration tube (a length of drainpipe approximately 30cm in length)
- timer
- rubber mallet
- block of wood
- 30cm ruler
- large bottle of water (and access to tap to refill as required)
- random number table
- two tape measures.

You should read these instructions carefully before you start work

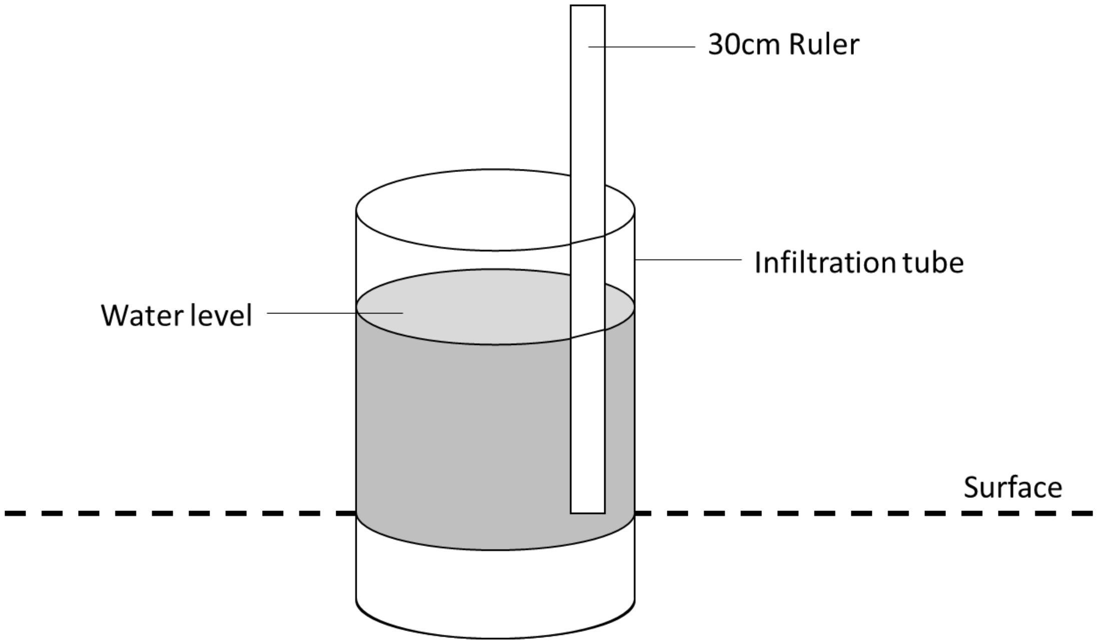
1. You will be advised on the two contrasting areas of study.
2. In the compacted soil area lay out tape measures at right angle to each other, to define an area (10m x 10m).
3. Use a random number table to generate a pair of coordinates in the format (XX,YY),these will be the location of the sampling site in the 100m^2 area.
4. Place the infiltration tube at the first set of random coordinates. Set up the equipment as shown in Figure 1, placing the wooden block on top of the tube and using the rubber mallet to sink the tube into the surface of the soil.
5. Add water to a depth of 150mm and start the timer. Use a Table like the one in Table 1 to record the depth (mm) of water at the start.
6. Record water depth (mm) at 30 second intervals until 6 minutes has elapsed. **If when a recording of depth is made the depth has fallen below 100mm, record this depth, then top up the water to 150mm and record the new water level.**
7. Calculate the difference in water level (mm) for each 30 second observation.
8. Calculate infiltration rate (mm hr^{-1} in each 30 second period using the equation;

   $$Infiltration\ Rate\ (mm\ hr^{-1}) = \frac{Difference\ in\ water\ depth\ (mm)}{Time\ (hours)}$$

9. Calculate the mean infiltration rate (mm hr^{-1}).
10. Repeat steps 2 – 9 as instructed by your teacher.
11. Repeat steps 2-10 in the non-compacted soil area.

12. Draw a scatter graph to show change in infiltration rate over time (mm hr^{-1})for each of the compacted and non-compacted areas.
13. Draw box and whisker plots to compare mean infiltration rates (mm hr^{-1}) in compacted and non-compacted areas.

Figure 4-Setting up the infiltration tube



Source: Field Studies Council

Table 1-Suggested recording table

Time (s)	Water level (mm)	Difference in water level (mm)	Infiltration rate (mm hr^{-1})
0			
30			
60			
90			
120			
150			
180			
210			
240			
270			
300			
330			
360			
		Mean infiltration rate (mm hr^{-1})	

Teacher notes

The impact of land management on flood risk

"Flooding is blamed on sheep and cows." Daily Telegraph (02/04/03)

Investigation title: Investigating the impact of soil compaction on infiltration rates.

Materials

Each student will need

- infiltration tube
- timer
- rubber mallet
- block of wood
- 30cm ruler
- large bottle of water
- random number table
- two tape measures.

Technical information

The investigation requires two areas where different degrees of trampling pressure result in contrasting levels of soil compaction. Goal mouth areas of playing fields compared with other areas of the pitch or neighbouring area would make good comparison.

It is important as far as possible for other characteristics such as soil type, gradient, vegetation to be kept as similar as possible-this is usually achieved by using two areas in close proximity which will also aid supervision of students working.

Sourcing equipment;

- Infiltration tube-a length of rigid plastic or metal tubing approximately 30cm in length, drainpipe or similar will work well, but any robust pipe between 5-15cm in diameter will work for this.
- Rubber mallet-these are used to embed the tube into the soil-place the block of wood on top of the tube and hammer the wood-the tube will need to be 2-8cm into the soil in order to prevent water escaping under the sides of the tube.
- Block of wood-large enough to be held on top of the infiltration tube to assist hammering the tube into the ground without damaging the tube or rubber mallet.
- Large bottle of water-minimum of 2l and access to tap to refill as required
- Two tape measures-these may have been set up for the whole class in advance-if doing so, two tape measures are required for each of the compacted and non-compacted areas. This has the benefit of demarking the two areas.

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Particular care should be taken when students are hammering in the tube − the same person holding the piece of wood should hammer.

Trialling

The practical should be trialled before use with students.

Alternatives to practical

Alternative areas for comparison of infiltration rates between woodland/grassland, grazed/not grazed, on/off a grassy footpath, at different locations on a slope.

Students could carry out fewer repeats and pool results into a class set.

Additional notes

Mann Whitney U Test could be used to compare infiltration rates between the two different areas.

Opportunity to discuss effects of antecedent conditions on infiltration rates, using the graphs showing change in infiltration rate over time. Students could do use secondary sources to record antecedent conditions over the previous week, repeating the practical at another time of year and comparing the results.

Sample results

	Not trampled		Trampled	
Time (s)	Difference in water level (mm)	Infiltration rate (mm hr^{-1})	Difference in water level (mm)	Infiltration rate (mm hr^{-1})
0	0	0	0	0
30	300	36000	0	0
60	35	4200	0	0
90	50	6000	0	0
120	50	6000	20	2400
150	50	6000	0	0
180	30	3600	20	2400
210	70	8400	0	0
240	50	6000	10	1200
270	50	6000	0	0
300	50	6000	0	0
330	50	6000	10	1200
360	50	6000	0	0
Mean infiltration rate (mm $hr^{-1)}$		7707.7		553.8

Case study 4

Assessing biodiversity

"Invertebrates are declining in response to widespread habitat loss and fragmentation, urbanisation, changing agricultural and land management practices, environmental pollution, non-native invasive species and many other factors." (buglife, 2019)

Investigation title: Investigating differences in invertebrate communities between a deciduous and coniferous woodland

Links to the specification

	Sampling techniques (ST)						Methodology (ME)					
	1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation
Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.1 The living environment 3.1.2 Conservation of biodiversity 3.1.2.1 The importance of conservation of biodiversity 3.1.2.1.3 Ecosystem services and their interaction with each other. 3.1.2.3.5 The importance of ecological monitoring in conservation planning
Maths skills	Handling data (1.1, 1.5) Algebra (2.3)

Subject specific vocabulary	Biodiversity Community of species Decomposers Detritivores Habitat Exoskeleton Ecological niche Ecosystem Pitfall Trap Population Species Tullgren funnel Simpsons index of biodiversity

Student sheet

Assessing biodiversity

"Invertebrates are declining in response to widespread habitat loss and fragmentation, urbanisation, changing agricultural and land management practices, environmental pollution, non-native invasive species and many other factors." (buglife, 2019)

Vegetation species and abundance has a direct impact on soil characteristics including the species and abundance of organisms, in this investigation you will use a range of methods to sample invertebrate communities on the soil surface and in the soil in two contrasting areas, comparing the differences in species present and their relative abundance.

Investigation title: Investigating differences in invertebrate communities between a deciduous and coniferous woodland.

Method

You are provided with the following:

- 2 x 10m tape measures
- 2 x 30cm ruler
- spade or trowel
- test tube and bung
- distilled water
- barium sulphate
- spatula
- PH indicator solution
- mustard powder
- 1l bottle of water
- teaspoon
- OPAL earthworm key
- white tray

You should read these instructions carefully before you start work:

For this investigation you will be collecting field data to use as part of a class investigation, the data you collect will form part of a larger class data set. You will be told how many repeats to carry out in each of the two woodland areas.

A. Soil measurements and earthworm sampling

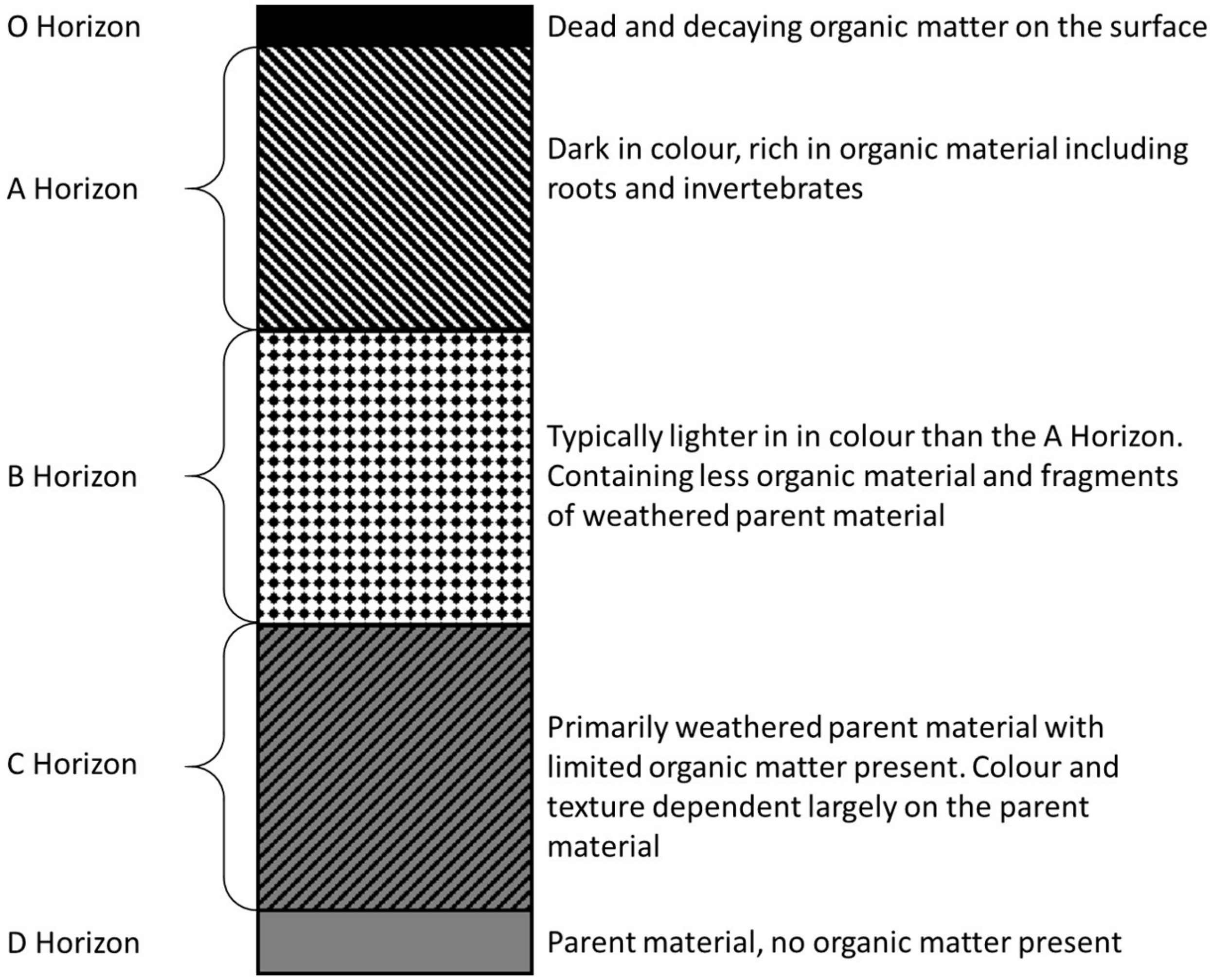
1. In woodland 1 lay out the tape measures at right angles to each other to define an area (10m x 10m).
2. Use a random number table to generate a pair of coordinates in the format (XX,YY), this will be the sample location.
3. Use the 30cm ruler to mark out an area (30cm x 30cm).
4. Record the depth of the litter layer in the centre of the area.
5. Remove all leaf litter within the 900cm^2 area-place this into a large plastic bag and seal the top-label the bag with the area that the sample came from (you need to take this bag back to the lab with you where you will use Tullgren funnels to separate the invertebrates from the leaf litter.)
6. Dig a soil pit 30cm x 30cm to a depth of 10cm.
7. Take a 1cm^3 sample of soil from the A-Horizon (Figure 1) and place into a test tube for testing pH.

8. When digging the soil pit, place the removed soil on a plastic bin bag and put any earthworms in a white tray.
9. Look at each earthworm and see if it has a well-developed saddle (Figure 2). Sort all earthworms found in the removed soil into two groups, those with saddles (adults) and those without saddles (immature), Record the numbers in each group.
10. Rinse all earthworms with water and return the immature worms to the soil (not the pit). Save adult worms in the white tray for identification. Add a little water to the tray and cover to avoid the worms drying out.
11. To extract deep burrowing earthworms, mix 6g of mustard powder (1½ teaspoon) into 1l of water and pour into the pit (this is not toxic to the earthworms but encourages them to come to the surface).
12. Collect any earthworms that emerge and separate into adult and immature as in step 10. Count and add to your tally before returning immature worms to the soil.
13. Use the Earthworm Identification Guide to identify and record the species of each adult earthworm found.
14. Repeat steps 1–13 in the second area.

Testing pH

15. Take a $1cm^3$ sample of soil from the A-Horizon (Figure 1) and place into a test tube for testing pH.
16. Add a spatula full of Barium Sulphate to the test tube.
17. Half fill the test tube with distilled water
18. Place a bung in the test tube and agitate the sample for 2 minutes
19. Place 3 drops of Universal Indicator solution into the sample
20. Rest the test tube in the test tube rack for 20 minutes
21. Using the colour key provided with the Universal Indicator solution, record the pH of the soil sample

Figure 5-Soil profile



Source: Field Studies Council

Figure 6-Identifying the saddle on an earthworm

Source: Field Studies Council

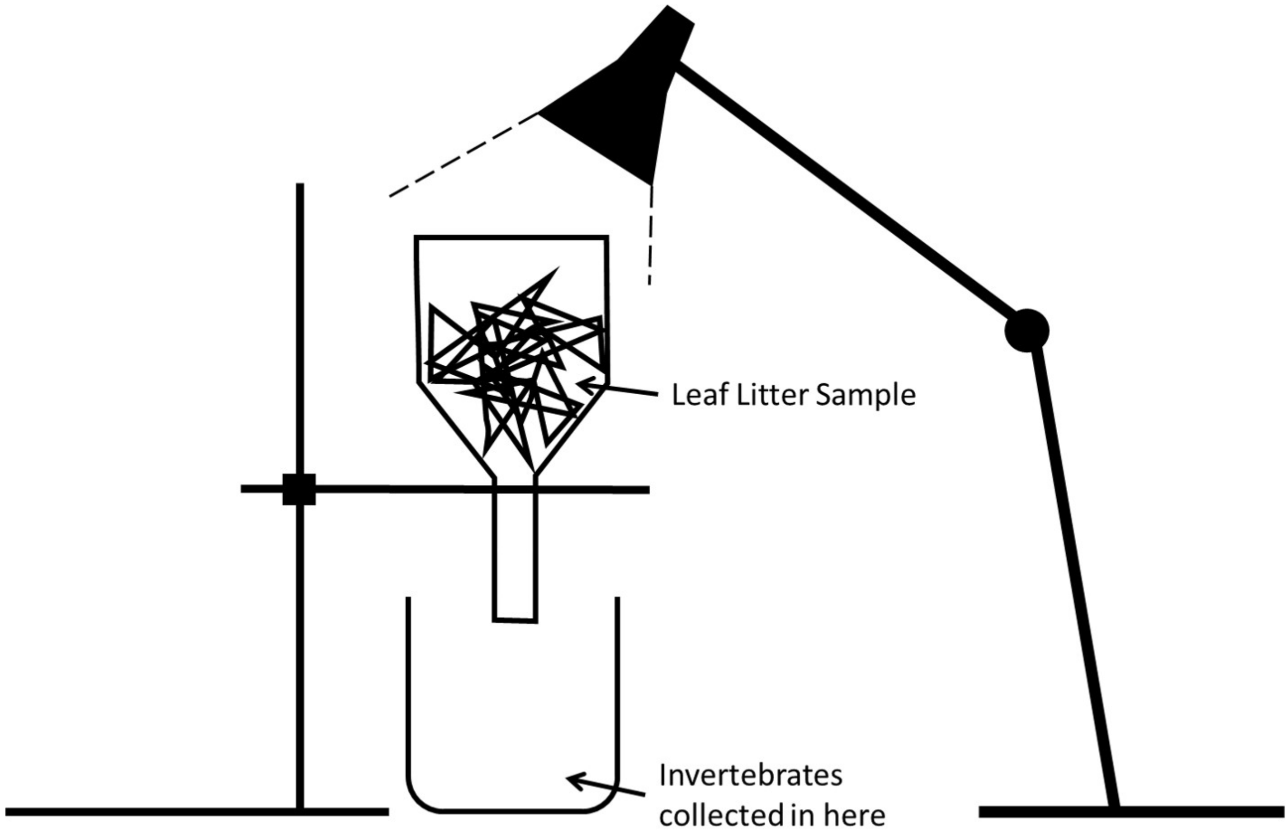
B. Tullgren funnel

You are provided with the following:

- 2 x desk lamps
- 2 x clamp, stand and boss
- 2 x large funnels
- 2 x beakers
- washing up liquid
- ID key

1. Set up the two sets of Tullgren funnels as shown in Figure 3. Add 2cm depth of water to the beakers and a small drop of washing up liquid.
2. Place the sample of leaf litter into each funnel, labelling which sample came from which area, and place the light close to the top of the soil.
3. Leave the Tullgren funnels (at least overnight) before collecting any invertebrates that have fallen into the beaker.
4. Use the key to identify and count any invertebrates using the key and add these to your results.

Figure 7-Setting up Tullgren funnel



Source: Field Studies Council

C. Setting pitfall traps

You are provided with the following:

- soil corer (garden bulb planter)
- pitfall trap: plastic cup and thin wooden cover

1. In each of the two woodland areas two tape measures will have been set up at right angles to each other, to define an area (10m x 10m). Use a random number table to generate a pair of coordinates in the format (XX,YY).
2. Use the random coordinates to identify a location in the 10m x 10m area to place the pitfall trap.
3. Use the garden bulb planter to create a hole deep enough for the plastic cup. The top of the cup should be just below the surface of the soil but below any leaf litter.
4. Place the cover over the top of the cup, using sticks or stones to ensure that the lid sits above the surface of the soil (Figure 4).
5. Repeat steps 2–4 as instructed.

Leave the pitfall traps overnight, returning the next day to collect any invertebrates which have fallen into the traps.

Figure 8-Setting up pitfall traps

Source: Field Studies Council

D. Emptying pitfall traps

You are provided with the following:

- white tray
- plastic spoon (for handling invertebrates)
- identification key.

1. Return to your pitfall traps and empty each into a large white tray.
2. Use the key to identify invertebrates found and record species and number of each.
3. Fill in the hole and return any invertebrates to the surrounding leaf litter.
4. Repeat for all traps and the second area.

E. Compare the two areas

1. Compile a species list for each area using records from each survey method.
2. Tally number of each species found in each area.
3. Calculate species richness for the two areas.
4. Draw pie charts to compare species richness in the two areas.
5. Calculate diversity in the two areas.

Teacher notes

Assessing biodiversity

"Invertebrates are declining in response to widespread habitat loss and fragmentation, urbanisation, changing agricultural and land management practices, environmental pollution, non-native invasive species and many other factors." (buglife, 2019)

Investigation title: Investigating differences in invertebrate communities between a deciduous and coniferous woodland.

This practical must be completed over at least 2 days.

Day 1–Soil measurements and earthworm sampling, set pitfall traps and set up Tullgren funnels.

Day 2–Empty pitfall traps and Tullgren funnels.

Materials

Each pair of students will need:

- pitfall traps
- soil corer
- 2 x tape measures
- 2 x 30 cm ruler
- spade or trowel
- beaker
- distilled water
- pH indicator solution
- mustard powder
- 1l bottle of water
- teaspoon
- opal earthworm identification guide
- white tray
- 2 x stand, clamp and boss
- 2 x desk lamps
- 2 x beakers
- 2 x large funnels.

Technical information

The investigation requires access to two contrasting areas of woodland, one deciduous and one coniferous.

Pitfall traps − these can be made using plastic cups with a small hole in the bottom to allow for drainage. The cups act as the pit and need to be covered with a small piece of thin plywood or hardboard. Pitfall traps should be set up as shown in Figure 1.

Figure 1-Setting pitfall traps

Source: Field Studies Council

Soil corer−Garden bulb planters (Figure 2) work well for creating holes for the placement of pitfall traps

Figure 2−Garden bulb planter

Tape measures–these could be set up for the whole class in advance-if doing so, two tape measures are required for each of the two areas. This has the benefit of demarking the two areas which students should work in.

OPAL earthworm identification guide

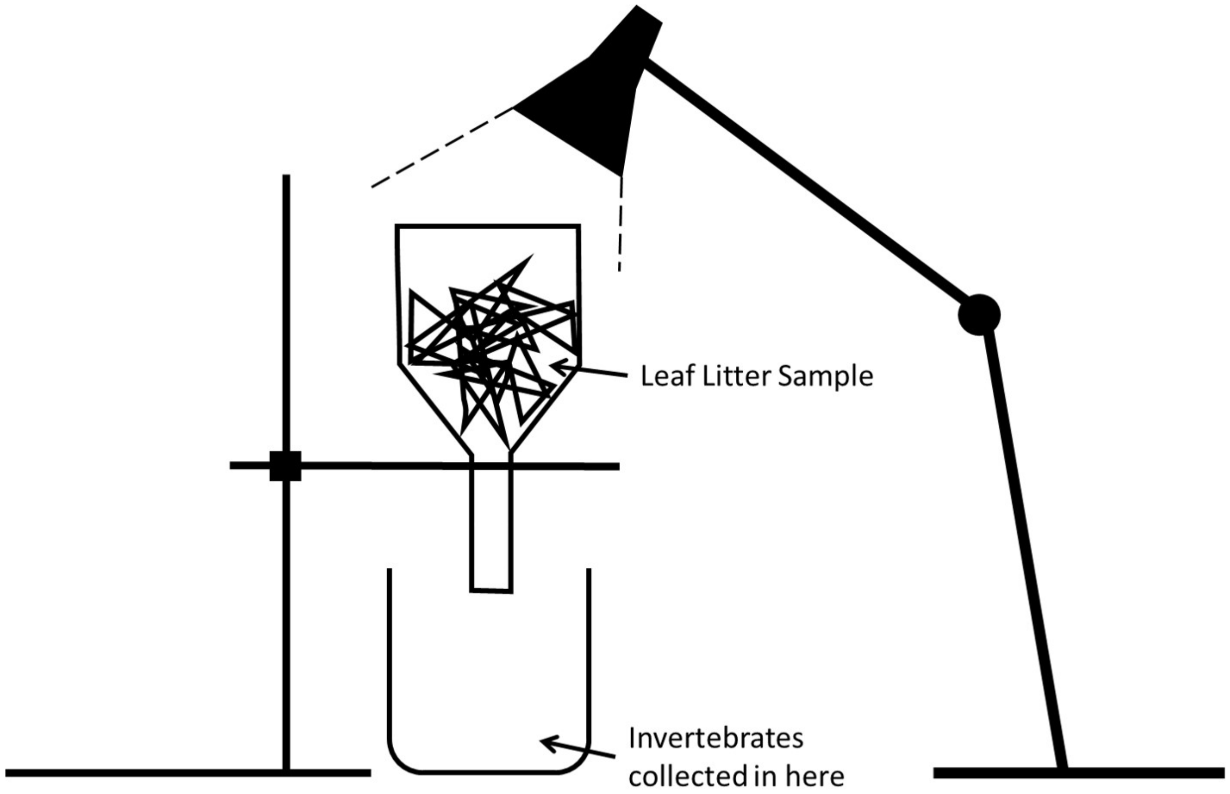
Setting up Tullgren funnels – fairly standard lab equipment, or easily obtainable items can be used to create a Tullgren funnels;

2 x desk lamps – these need to have heat producing bulbs such as halogen or incandescent bulbs 'cool running' lights such as LED or energy saving bulbs will not work for Tullgren funnels.

2 x large funnels cut down 2l fizzy drinks bottles also work well as a deep funnel can be created.

Tullgren funnels should be set up as shown in Figure 3 and should be left at least overnight.

Figure 3-Setting up Tullgren funnel



Source: Field Studies Council

Risk assessment

Risk assessment and risk management are the responsibility of the centre. If pitfall traps are set in a publicly accessible area, restrict access or use signage to avoid trip hazard. Refill holes dug for pitfall traps after emptying.

Trialling

The practical should be trialled before use with students.

Alternatives to this practical

This practical can easily be adapted to investigate differences in invertebrate communities in:

- managed and unmanaged woodland
- monoculture plantation and mixed woodland.

Additional notes

Students must be briefed on the ethical treatment of organisms before this practical

Case study 5

Measuring edaphic characteristics

“Healthy soils are the basis for healthy food production.” (FAO, 2015)

Investigation title: Investigating differences in soil characteristics between two contrasting areas.

Links to the specification

	Sampling techniques (ST)						Methodology (ME)					
	1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation
Scientific Principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical Skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.2 The physical environment 3.2.5 Soils 3.2.5.1 How human activities affect soil fertility 3.2.5.2 Causes of soil degradation and erosion 3.2.5.3 Soil management strategies to increase sustainability	
Maths skills	Arithmetic and numerical computation (0.3) Handling data (1.1, 1.4, 1.5,1.9) Algebra (2.3) Graphs (3.3)	
Subject specific vocabulary	Acidification Contour ploughing Monoculture Mulch Ploughing	Terracing Tied ridging Tillage Universal soil loss equation Windbreaks

Student sheet

Measuring edaphic characteristics

"Healthy soils are the basis for healthy food production." (FAO, 2015)

Soil is an essential component of ecosystems. Human activities influence the fertility of soils, and certain activities can cause soil degradation and erosion. Understanding soil characteristics is essential in informing sustainable management practices of soils and ecosystems. This investigation aims to consider different measures of soil characteristics and compare these between two contrasting areas. Your teacher will tell you what the two areas are, and how physical factors or management strategies differ between the two.

Investigation title: Investigating differences in soil characteristics between two contrasting areas.

Method

You are provided with the following

Fieldwork equipment:

- trowel, auger or spoon
- soil texture key
- knitting needle
- ruler
- 2 xtape measure
- random number generator.

Laboratory equipment:

- water
- distilled water
- crucible
- balance
- microwave
- test tube
- bung
- spatula
- barium sulphate
- universal indicator
- test tube rack
- bunsen burner
- tripod
- clay pipe triangle
- tongs.

You should read these instructions carefully before you start work, tasks have been identified as fieldwork or laboratory work.

1. You will be advised on the two contrasting areas of study.
2. Lay out tape measures at right angles to each other to define an area (10m x 10m).
3. Use a random number table to generate a pair of coordinates in the format (XX,YY), this will be the location of the sample site within the two areas.

A: Soil compaction (fieldwork)

1. Hold the knitting needle perpendicular to the ground at a height of 1m and let go.
2. Hold the knitting needle at the surface of the soil.
3. Pull out from the soil and measure the length of knitting needle (mm) that was embedded in the soil, record in Table 1.

B: Soil texture (fieldwork)

1. Use the trowel, auger or spoon to take a sample of soil at depth of 10cm
2. Use the soil texture key (Figure 1) to identify the soil type, record in Table 1

C: Soil water content (laboratory work from field sample)

1. Use the trowel, auger or spoon to take a sample of soil at depth of 10cm
2. Measure the mass (g) of the empty crucible (A), record in Table 2
3. Measure the mass (g) of the crucible with the sample of soil in (B), record in Table 2
4. Place the crucilble with soil in it in the microwave alongside a crucible filled with water – this will act as a control
5. Microwave on high power for 10 minutes
6. Check that the water in the control crucible has evaporated. If water remains, continue to microwave for 1 minute bursts until all of the water has evaporated
7. Measure the mass of the crucible with the dry soil in (C), record in Table 2
8. Use the equation below to calculate soil moisture as a % of dry mass, record in Table 1

$$Soil\ moisture\ as\ \%\ of\ dry\ mass = \frac{(B - C)}{(C - A)} \times 100$$

D: Soil pH (laboratory work from field sample)

1. Use the trowel, auger or spoon to take a sample of soil at depth of 10cm
2. Use a spatula place approximately 1cm^3 of soil in the test tube
3. Place a spatula full of Barium Sulphate into the test tube
4. Half fill the test tube with distilled water
5. Place a bung in the test tube and agitate the sample for 2 minutes
6. Place 3 drops of Universal Indicator solution into the sample
7. Rest the test tube in the test tube rack for 20 minutes
8. Use the colour key provided with the Universal Indicator solution to record the pH of the soil sample

E: Soil organic matter (laboratory work from field sample)

1. Use the dry sample of soil (C) from the soil moisture experiment, place the crucible with soil in onto the tripod and clay pipe triangle, above the Bunsen burner.
2. Light bunsen burner and heat the sample, maintain a red glow on the crucible for 30 minutes
3. Allow to cool, use tongs to handle the sample
4. Measure the mass of the crucible with the burned soil in (D), record in Table 2
5. Use the equation below to calculate soil organic content as a % of dry mass and record in Table 1

$$Soil\ organic\ content\ as\ \%\ of\ dry\ mass = \frac{(C - D)}{(C - A)} \times 100$$

Repeat all steps again in Area 2

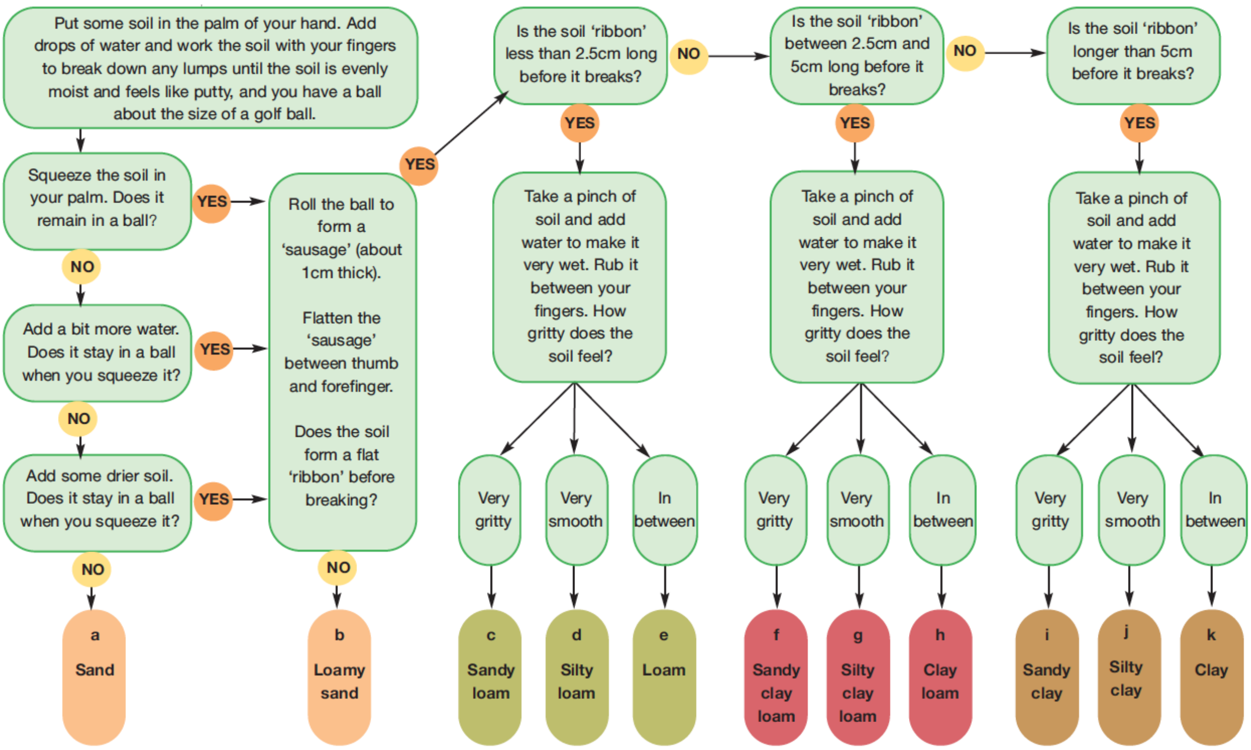
Table 2-Recording sheet

	Area 1	Area 2
Soil type		
Soil water content (%)		
Soil organic content (%)		
Soil pH		
Soil compaction (mm)		

Table 3-Calculating soil moisture and soil organic content

	Area 1	Area 2
(A) = Mass of crucible (g)		
(B)= Mass of crucible and soil (g)		
(C)= Mass of dry soil and crucible (g)		
Soil moisture as a % of dry mass		
(D)= Mass of burned soil and crucible (g)		

Figure 9-Soil texture key



Source: Field Studies Council

Teacher notes

Measuring edaphic characteristics

"Healthy soils are the basis for healthy food production." (FAO, 2015)

Investigation title: Investigating differences in soil characteristics between two contrasting areas.

Materials

Fieldwork equipment:

- trowel, auger or spoon
- soil texture key
- knitting needle
- ruler
- 2 x tape measure
- random number generator.

Laboratory equipment:

- water
- distilled water
- crucible
- balance
- microwave
- test tube
- bung
- spatula
- barium sulphate
- universal indicator
- test tube rack
- bunsen burner
- tripod
- clay pipe triangle
- tongs.

Technical information

Soil water content – The use of a microwave is a practical alternative if centres do not have access to a soil oven. Method for calculating soil moisture using a soil oven: 35°C for 24 hours then 110°C for 4 hours.

Soil Organic Content – The use of a Bunsen burner is a practical alternative if centres do not have access to a Muffle Furnace. Method for calculating soil organic content using a muffle furnace: 550°C for 4 hours.

Soil compaction – The use of a knitting needle is a practical alternative if centres do not have access to a soil penetrometer.

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

CLEAPSS Student Safety Sheet No. 42 – Barium Compounds

CLEAPSS Student Safety Sheet No. 70 – Dyes, stains and indicators

Trialling

This practical should be trialled before use with students

Additional notes

This practical includes a wide variety of measurements of the edaphic conditions in two contrasting areas, and both laboratory and field work timing and logistics of this practical are crucial. It is therefore recommended that all fieldwork (soil compaction and soil type) are completed first, before samples that are clearly marked are taken back into the lab (soil moisture, soil organic content, soil pH).

All groups can work on individual sample sites within 100m² in each Area. Students can then compare results, draw graphs and perform statistical analysis where appropriate on collated group data.

Teachers may wish to give each group a soil variable to compare using presentation and analysis techniques. Dispersion graphs and Mann-Whitney U statistical analysis can be carried out on group data (soil moisture and soil organic content) to see if there is a statistically significant difference between soil moisture/soil organic content and the two sample sites.

Alternatives to this practical

This practical can easily be adapted to suit a variety of contrasting environments.

- Ploughed and unploughed
- Flat land and cultivated step slopes
- Compacted (trampled) and uncompacted (untrampled)

Teachers may wish to extend this practical by investigating how the Universal Soil Loss Equation (USLE) can be used to estimate erosion rates in the two areas, based on fieldwork data and observations, references are provided below to inform the variables of the USLE equation.

This extension involves the equation:

$$A = R \times K \times L \times C \times P$$

A= mean annual soil loss (T ha^{-1} yr^{-1})

R= rainfall erosivity factor (MJ mm^{-1}) (ha^{-1} h^{-1} yr^{-1})

K= soil erodibility factor (T ha^{-1})

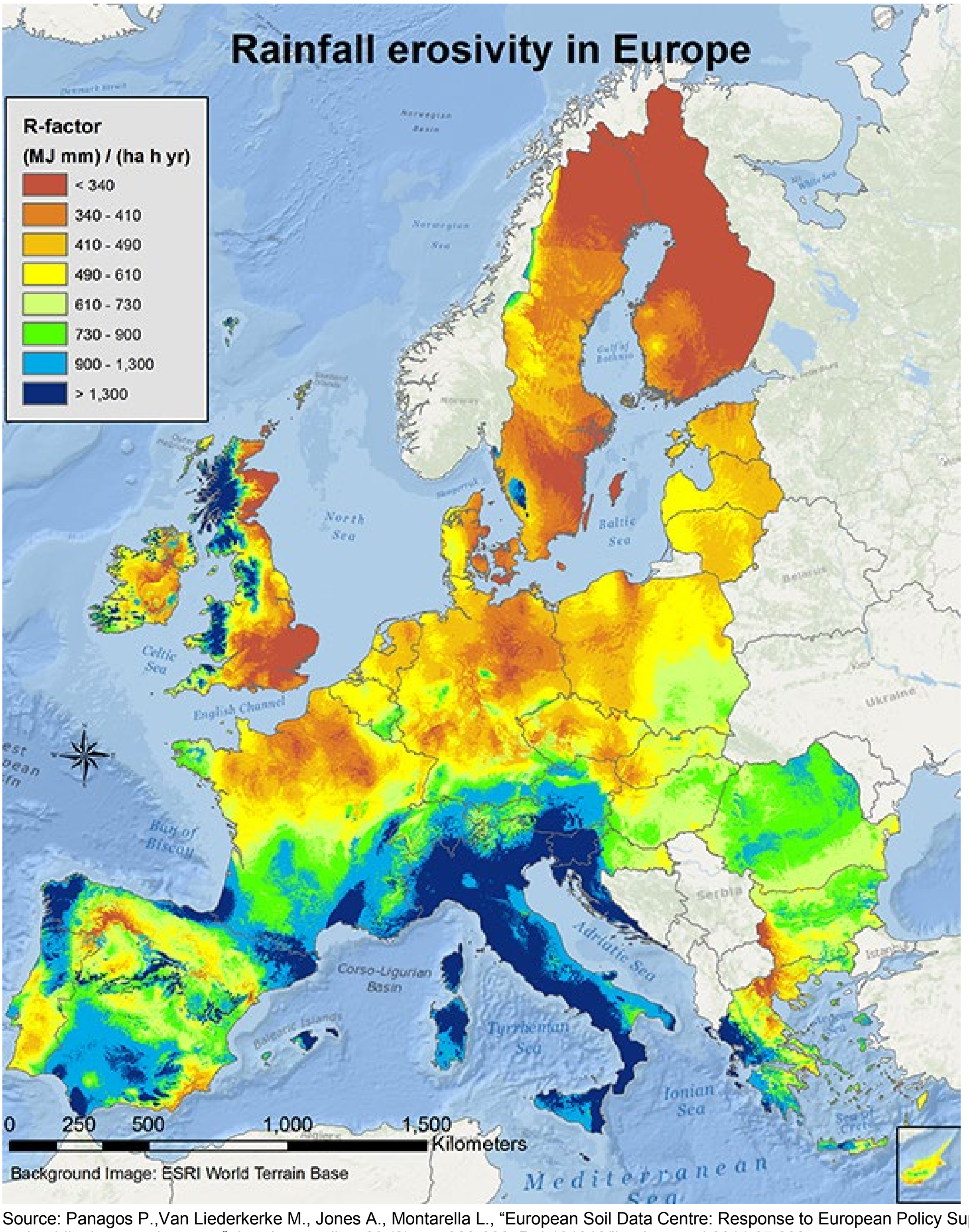
L= slope length factor (unitless)

C= cover and management factor (unitless)

P= support practice factor (unitless)

1. R=Rainfall erosivity factor

Figure 1-Map of R-factor across Europe, European Soil Data Centre (ESDAC, 2015)



Source: Panagos P.,Van Liederkerke M., Jones A., Montarella L., "European Soil Data Centre: Response to European Policy Support and public data requirements"; Land use policy. 29 (2), pp. 329-338. Doi:101016/jlandusepool.2011.07.003

European Soil Data Centre (ESDAC), esdac.jrc.ec.europa.eu,

European Commission, Joint Research Centre

2. K=Soil erodibility factor

Table 1 – Soil erodability factor for different soil types

Soil type	K factor (T ha^{-1})
Sand	0.04
Loamy sand	0.09
Sandy loam	0.29
Silty loam	0.85
Loam	0.67
Sandy clay loam	0.45
Silty clay loam	0.72
Clay loam	0.67
Sandy clay	0.63
Silty clay	0.58
Clay	0.49

3. L=slope length factor (unitless)

Two options for calculating L

3.1 Equation method

$$L = (0.065 + 0.0456\ (slope) + 0.006541\ (slope)^2)(slope\ length \div constant)^{NN}$$

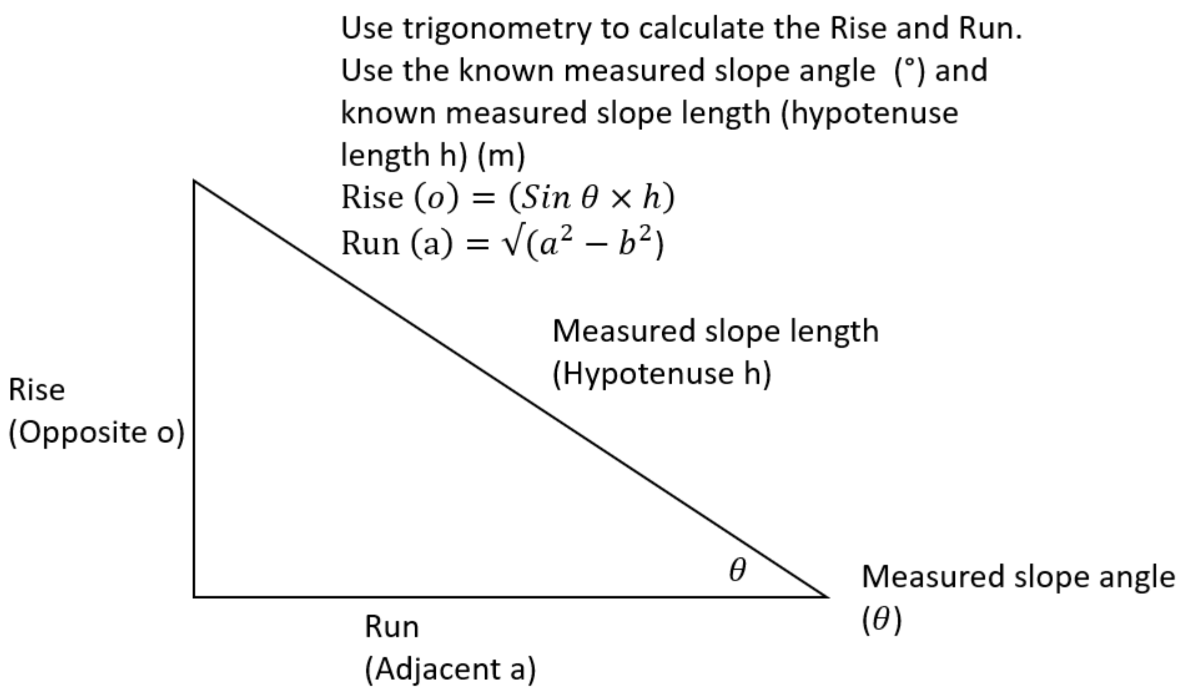
Slope = slope steepness in % (see Fig. 3 to calculate slope steepness in %)
Slope length = length of slope in m
Constant = 22.1m

Table 2 – Finding the constant NN using slope steepness (%)

Slope (%)	<1	1≤ Slope ≤ 3	3≤ Slope ≤ 5	≥ 5
NN	0.2	0.3	0.4	0.5

$$\boldsymbol{Slope\ steepness}\ \% = \left(\frac{\boldsymbol{Rise}}{\boldsymbol{Run}}\right) \times \mathbf{100}$$

Figure 2 – Calculating slope steepness



Source: Field Studies Council

3.2 Table of L values

Table 3 – Look up table for L factor

Slope length (m)	Slope %	L factor
30.5	10	1.38
	8	1.00
	6	0.67
	5	0.54
	4	0.40
	3	0.30
	2	0.20
	1	0.13
	0	0.07
61	10	1.95
	8	1.41
	6	0.95
	5	0.76
	4	0.53
	3	0.39
	2	0.25
	1	0.16
	0	0.08
122	10	2.76
	8	1.99
	6	1.35
	5	1.07
	4	0.70
	3	0.52
	2	0.30
	1	0.20
	0	0.09

4. C=cover and management factor (unitless)

Multiple crop type and tillage method values together for C factor

Table 4 – C factor values for different crop types

Crop type	Factor
Grain	0.40
Silage, beans	0.50
Cereals	0.35
Seasonal horticultural crops	0.50
Fruit trees	0.10
Hay and Pasture	0.02

Table 5 – C Factor for different tillage methods

Tillage Methods	Factor
Autumn ploughing	1.00
Spring ploughing	0.90
Mulch tillage	0.60
Ridge tillage	0.35
Zone tillage	0.25
No till	0.25

5. P=support practice factor (unitless)

Table 6 – P factor values for different support practices

Support practice	Factor
Up and down slope ploughing	1.00
Cross slope ploughing	0.75
Contour ploughing	0.50
Strip cropping, cross slope ploughing	0.37
Strip cropping, contour ploughing	0.25

The calculated ULSE values can be compared between contrasting sites and compared to the soil loss tolerance levels in Table 9.

Table 7 – Soil loss tolerance levels

Soil erosion class	Potential
Very low	≤ 6.7
Low	$6.7 < A \leq 11.2$
Moderate	$11.2 < A \leq 22.4$
High	$22.4 < A \leq 33.6$
Severe	>33.6

(Ministry of Agriculture, Food and Rural Affairs, ULSE Factsheet, 2019)
omafra.gov.on.ca/english/engineer/facts/

Sample results

	Area 1-Grazed	Area 2-Ungrazed
Soil type	Sandy clay loam	Sandy clay loam
Soil water content (%)	23.25	12.09
Soil organic content (%)	18.93	15.67
Soil pH	6.5	7.5
Soil compaction (mm)	9	36

Case study 6

Carbon sequestration

The Intergovernmental Panel on Climate Change (IPCC) said that if the world wanted to limit the rise to 1.5C by 2050, an extra 1bn hectares (2.4bn acres) of trees would be needed.

Investigation title: Investigating differences in carbon storage and sequestration between a coniferous and deciduous woodland.

Links to the specification

	Sampling techniques (ST)						Methodology (ME)					
	1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals.	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation
Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.2 The physical environment 3.2.4 Bio geochemical cycles 3.2.4.2 The carbon cycle including human influences
Maths skills	Arithmetic and numerical computation (0.1, 0.2, 0.3) Handling data (1.1, 1.2, 1.5, 1.6, 1.9) Algebra (2.3) Graphs (3.1, 3.5) Geometry and trigonometry (4.1)
Subject specific vocabulary	Afforestation Deforestation Carbon sequestration Dendrochronology

Student sheet

Carbon sequestration

The Intergovernmental Panel on Climate Change (IPCC) said that if the world wanted to limit the rise to 1.5C by 2050, an extra 1bn hectares (2.4bn acres) of trees would be needed.

Through photosynthesis, all plants remove carbon dioxide from the atmosphere. Due to their longevity, trees act as carbon stores, fixing large quantities of carbon within their root, trunk, and canopy biomass. Carbon stored in leaves is returned to the atmosphere annually through the decomposition of fallen leaves, but carbon stored in the woody parts of trees will be stored for much longer periods.

Approximately 50% of the biomass of a tree is carbon bound in organic compounds. Direct measurement of biomass and carbon content of trees is impractical and destructive, requiring felling, drying and burning.

Factors including tree species, planting density and tree age effect the amount of carbon stored per unit area of woodland and the quantity of carbon that can be sequestered annually.

In this investigation you will use referenced conversion tables to estimate biomass and carbon storage from measurements of tree volume. You will compare the amount of carbon stored within an area of deciduous woodland compared to an area of coniferous woodland.

Investigation title: Investigating differences in carbon storage and sequestration between a coniferous and deciduous woodland

Method

You are provided with the following:

- clinometer
- random number table
- tree ID guide
- tape measure.

You should read these instructions carefully before you start work:

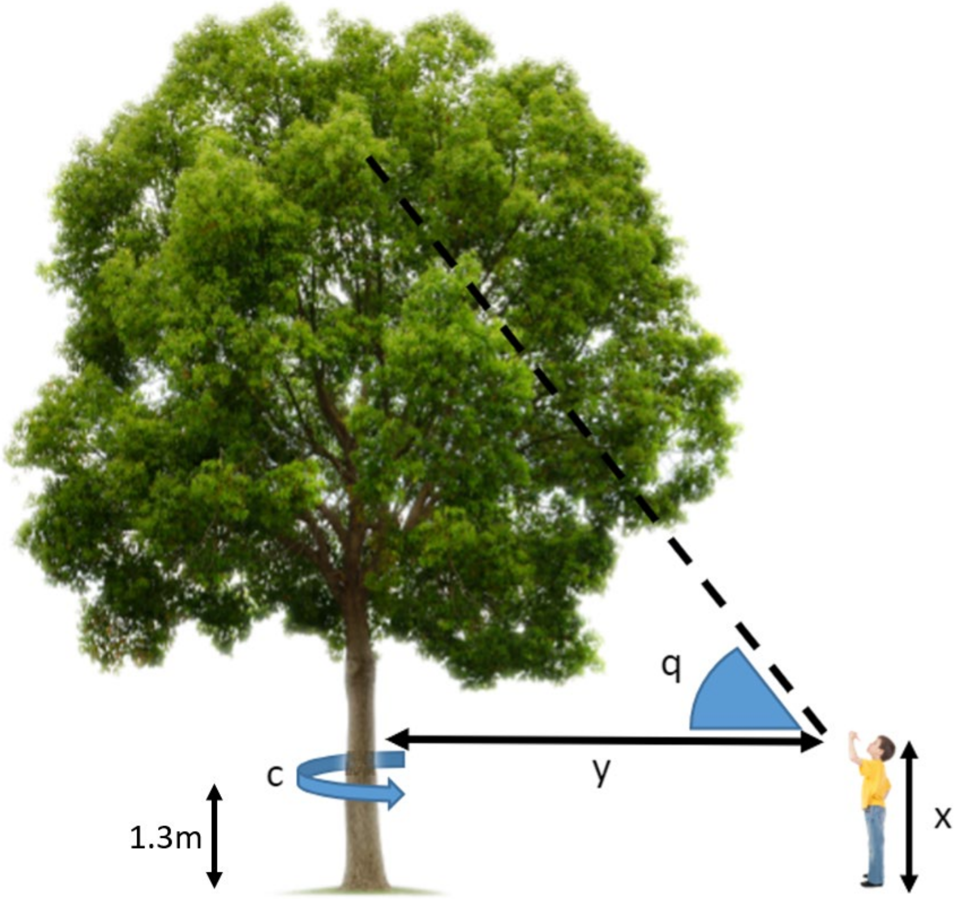
For this investigation you will be collecting field data to use as part of a class investigation, the data you collect will form part of a larger class data set. You will be told how many trees to measure in each of the two woodland areas.

1. In woodland area one lay out two tape measures at right angles to each other to form a grid (10m x 10m) (one per class)
2. Use a random number table to generate a set of random coordinates in the format (XX,YY). Record all data in Table 1
3. Select the tree closest to your random co-ordinates. Measure the circumference (m) of the trunk at 1.3m above the ground (c).
   (If the tree has a circumference <0.22m it is classed as a sapling, select the next nearest tree to your random coordinate.)
4. Calculate the radius (r) (m) of the trunk using the formula;
   $$r = \frac{c}{2\pi}$$
5. Stand away from the tree in a position where you can see the top of the trunk (known as the stem). From this position take the following measurements shown in Figure 1.
   a. Use the clinometer to measure the angle (°) to the top of the stem (q).

b. Measure your distance (m) from the base (y).
c. Measure the distance (m) from the ground to your eye level (x).

6. Calculate the height (m) of the stem (h) using the formula;
   $h = y\,(\tan q) + x$
7. Calculate the volume (m^3) of the stem (v) using the formula;
   $v = \pi r^2 \left(\frac{h}{3}\right)$
8. Calculate the diameter at breast height (DBH) (cm) using the formula;
   $DBH = 100(2r)$

Figure 10 – Measuring tree height and circumference.



Source: Field Studies Council

9. Use the Tree ID Chart to identify the species of tree.
10. Use **Conversion Chart 1** to look up the biomass (T) contained in the stem.
11. Use **Conversion Chart 2** to look up the biomass (T) contained in the crown.
12. Use **Conversion Chart 3** to look up the biomass (T) contained in the roots.
13. Calculate the total biomass (T) contained within the tree;
    $Tree\ biomass = stem\ biomass + crown\ biomass + roots\ biomass$
14. Halve the total biomass to give the tree's carbon content (tonnes);

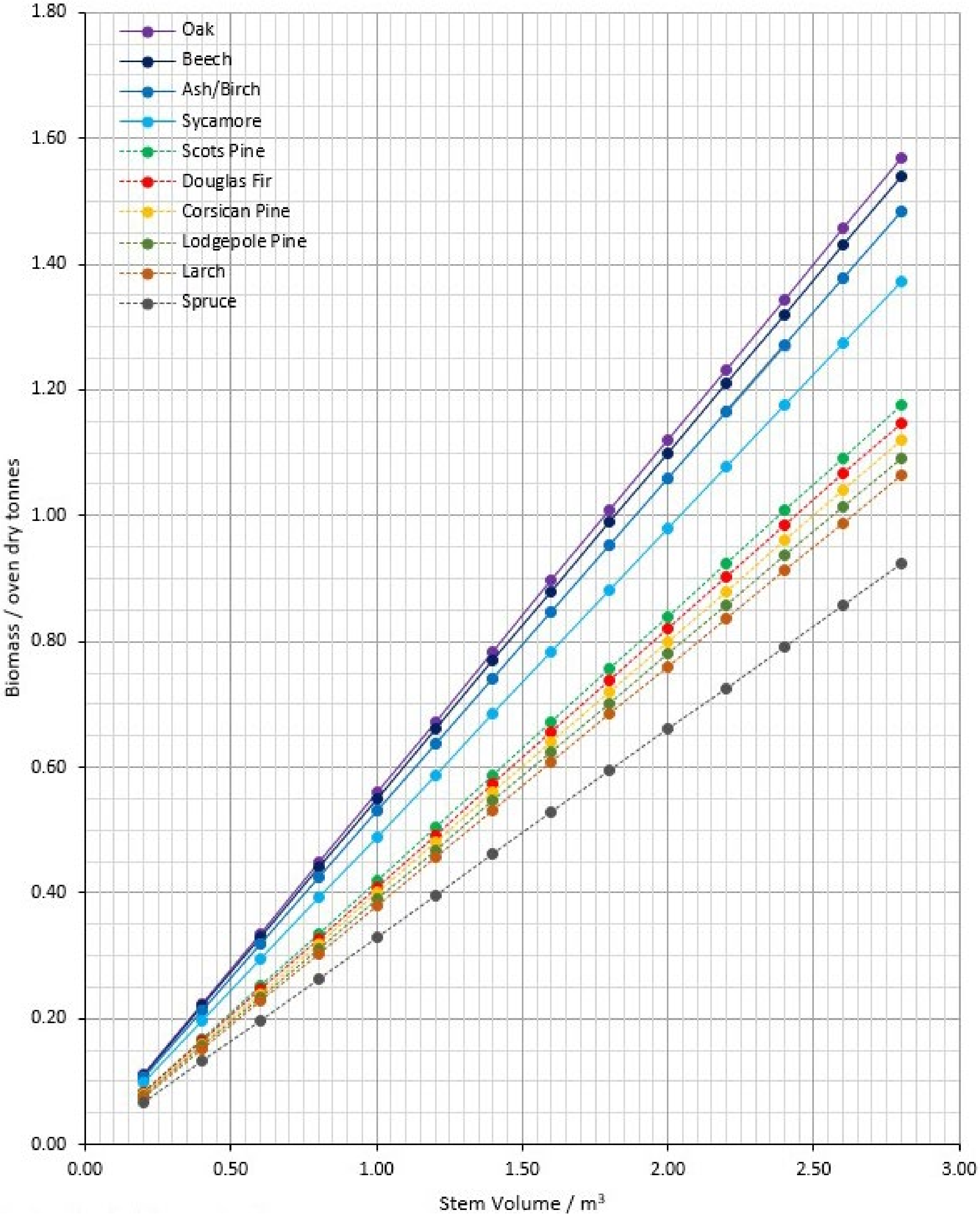
$$Carbon\ Storage\ (TC) = \frac{Tree\ Biomass\ (T)}{2}$$

15. Repeat steps 1-14 for the number of trees you need to measure.
16. Count the total number of trees in the 100m^2 area-multiply by 100 to estimate tree density (trees Ha^{-1}).
17. Repeat steps 1-16 in the coniferous woodland area.
18. Collate your carbon content values with the rest of the class to create a whole class data set.
19. Calculate the mean carbon (TC) stored in a tree in the deciduous woodland and a tree in the coniferous woodland.
20. Calculate carbon storage per hectare (TC ha^{-1}) values for deciduous woodland and for coniferous woodland by multiplying the mean carbon stored and the tree density for each woodland type.
21. Compare carbon storage per hectare (TC ha^{-1}) between the two areas.

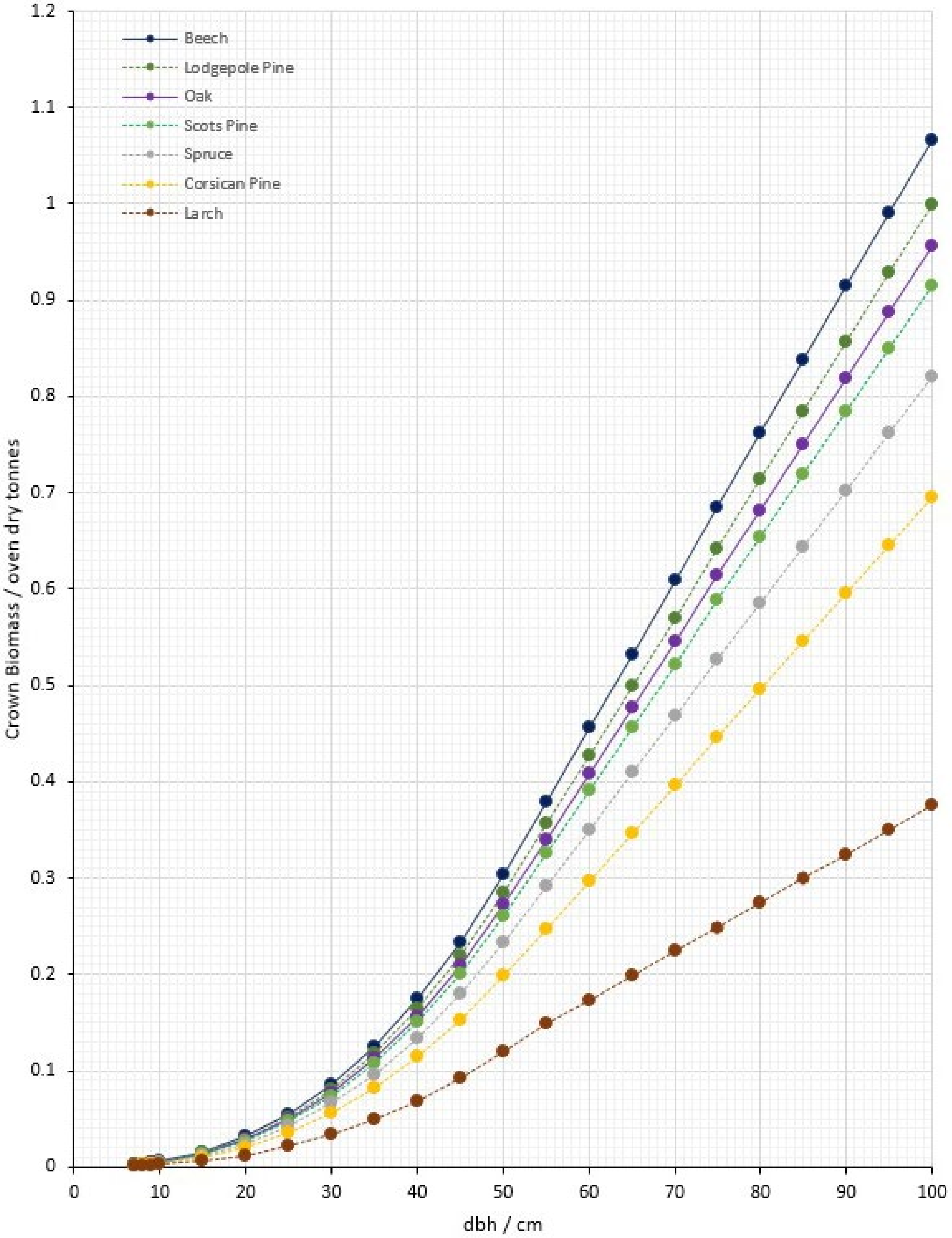
Table 4 – Recording sheet

		Field Measurements				Calculations				Conversion Chart 1	Conversion Chart 2	Conversion Chart 3	Calculations	
		y	*q*	*x*	*c*	*r*	*h*	*v*	*DBH*					
Woodland Area	Species	Distance from base (m)	Angle to top of tree (°)	Observers eye level (m)	Circumference of trunk (m)	Radius of trunk (m)	Height of stem (m)	Volume of stem (m)	Diameter at Breast Height (cm)	Stem biomass (tonnes)	Crown biomass (tonnes)	Root biomass (tonnes)	Total tree biomass (tonnes)	Carbon content (tonnes)

Conversion Chart 1 – Stem Volume to Biomass

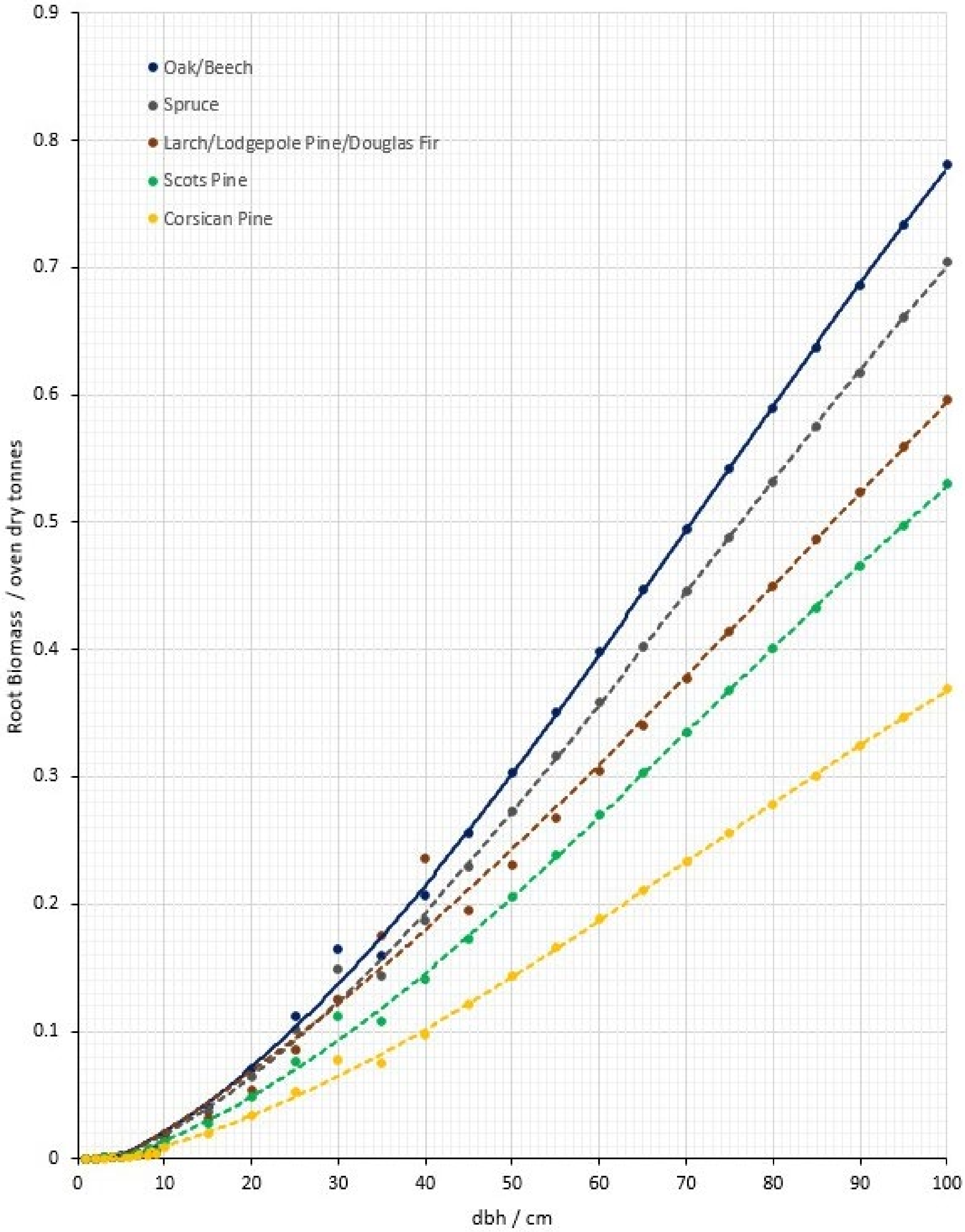


Conversion Chart 2 – Crown Biomass from dbh



For Sycamore, Ash, Birch and also Douglas Fir use the Oak line to read of Crown Biomass figures

Conversion Chart 3 – Root Biomass from dbh



Fewer data are available for Root Biomass estimates especially for deciduous trees.
All deciduous trees should be read from the line for Oak/Beech.

Source: Field Studies Council

Table 2

Equations for calculating stem (trunk) volume from: **D Zinnis et al.** (2005) Biomass and Stem Volume Equations for Tree Species in Europe **Silva Fennica, Monographs 4** (D = dbh, H = height). Biomass estimates for the listed species can be read directly from the graph or you can convert any Stem Volume to Biomass by multiplying the volume by the appropriate Nominal Specific Gravity for that species. Data from **T.A.R.Jenkins et al** (2011) FC Woodland Carbon Code: Carbon Assessment Protocol.

Stem Volume Equations		a	b	c	Nominal Specific Gravity
Ash	$a+b.D^2.H^c$	-0.012107	0.0000777	0.75	0.53
Beech	$a+b.D^2.H^c$	-0.014306	0.0000748	0.75	0.55
Birch	$a+b.D^2.H^c$	-0.009184	0.0000673	0.75	0.53
Corsican Pine	$D^a.H^b.e^c$	1.891920	0.953740	-2.725050	0.4
Douglas Fir	$D^a.H^b.e^c$	1.900530	0.807260	-2.431510	0.41
Larch	$D^a.H^b.e^c$	1.866700	1.081180	-3.048800	0.38
Lodepole Pine	$D^a.H^b.e^c$	1.893030	0.986670	-2.886140	0.39
Oak	$a+b.D^2.H^c$	-0.011724	0.0000765	0.75	0.56
Scots Pine	$D^a.H^b.e^c$	1.820750	1.074270	-2.885000	0.42
Spruce	$D^a.H^b.e^c$	1.783830	1.133970	-2.908930	0.33
Sycamore	$a+b.D^2.H^c$	-0.012668	0.0000737	0.75	0.49

Teacher notes

Carbon sequestration

The Intergovernmental Panel on Climate Change (IPCC) said that if the world wanted to limit the rise to 1.5C by 2050, an extra 1bn hectares (2.4bn acres) of trees would be needed.

Investigation title: Investigating differences in carbon storage and sequestration between a coniferous and deciduous woodland

Materials

Each pair of students need:

- clinometer
- random number table
- tape measure
- tree ID chart

Additional equipment for the group

- 2 x tape measures (per area)

Two additional tape measures are needed for setting up the (10m x 10m) area. These could be set up in advance – if doing so, two tape measures are required for each of the deciduous and coniferous areas. This has the benefit of clearly demarking the two areas, depending on proximity of the two areas and supervision, it may be possible to split the group across the two areas to limit the number of students working in each area at once.

Technical information

Simple clinometers can be purchased, or iOS and Android apps for smart phones can be downloaded by students prior to the practical (iOS may have clinometer built into existing compass app).

Accessible tree ID charts can be purchased from the Field Studies Council website (field-studies-council.org). The Woodland Trust has a free Tree ID app (for iOS and Android).

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Trialling

The practical should be trialled before use with students.

Additional notes

This practical is intended to be completed collectively, with students working in pairs to collect data that is combined into a class data set. Each pair should measure one tree in each of the two woodland areas. For small class sizes you may ask each pair of students to measure more than one tree in each area. This approach gives an opportunity to discuss the impact of larger sample sizes on reliability.

The differences between carbon storage in the two areas could be explored further using the class data set of carbon storage within individual trees, with opportunities for data presentation in the form of box and whisker plots, and for statistical analysis using the Mann-Whitney U Test.

If the approximate date of planting for each woodland is known, then tree age can be used to estimate carbon sequestration rates using the formula;

$$Sequestration\ Rate\ (T\ C\ yr^{-1}) = \frac{Total\ carbon\ stored\ (T\ C)}{Age\ of\ trees\ (yr)}$$

Alternatives to this practical

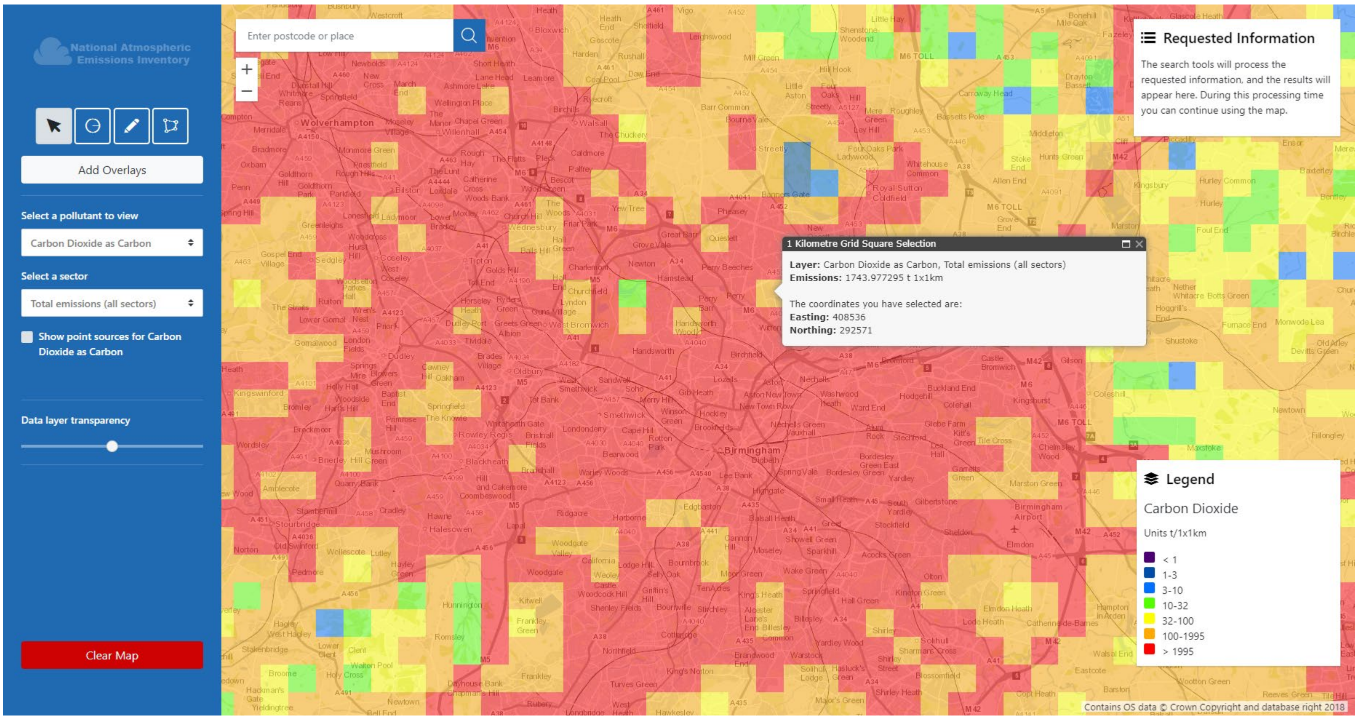
This practical can easily be adapted carbon storage and sequestration in different environments:

- managed and unmanaged woodland
- monoculture plantations and mixed woodlands.

This method of calculating carbon sequestration rate for trees in a given area can be used in conjunction with the national emissions map from the National Atmospheric Emissions Inventory to investigate questions around balancing the carbon budget, for example:

- what proportion of the annual co_2 emissions are sequestered by trees in this area
- how many more trees would need to be planted to balance carbon emissions and sequestration in this area?

Figure 1–NAEI Interactive Emissions Map



Source: Copyright rests with the European Commission; Acknowledgement: Produced by the University of Leicester, The Centre for Landscape and Climate Research and Specto Natura and supported by Defre and the European Environment Agency under Grant Agreement 3541/B2012/R0-G10/EEA.55055 with funding by the European Union.

Using the storage values calculated in this practical, students could create estimates of carbon storage on larger scales. The UK land cover atlas gives values for the area of deciduous and coniferous woodland at a number of different scales. Scaling up from a small field sample to a local authority, or national scale carries limitations – this process provides an opportunity for the discussion of the assumptions and limitations involved in creating large area estimates in this way.

Rae, Alasdair (2017): A Land Cover Atlas of the United Kingdom (Document).

figshare. Journal contribution. (Available online at figshare.com/articles/A_Land_Cover_Atlas_of_the_United_Kingdom_Document_/5266495

Sample data

Students measured 26 trees in an area of deciduous woodland.

The mass of carbon stored within each tree ranged from 0.011t to 0.09t.

The mean mass of carbon stored in each tree was 0.032t.

Students counted a mean of 7 trees per $100m^2$

A tree density of 700 Trees per hectare

A Carbon Storage Density of 22t C Ha^{-1}

Case study 7

Succession of plant communities

(Succession has) “relevance to studies of landscape ecology, ecosystem development, restoration ecology, and global change ecology.” (Chang and Turner, 2019)

Investigation title: Investigating how species presence, abundance and diversity changes over time.

Links to the specification

	Sampling techniques (ST)						Methodology (ME)					
	1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation
Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1
Specification links	3.1 The living environment 3.1.3 Life processes in the biosphere and conservation planning 3.1.3.2 Terminology to describe the roles of living organisms in their habitats and their interactions with the physical environment 3.1.3.3 The control of ecological succession in conserving plagioclimax habitats											
Maths skills	Arithmetic and numerical computation (0.3) Handling data (1.1, 1.4, 1.5, 1.7, 1.9) Algebra (2.3) Graphs (3.3)											

Subject specific vocabulary	Abiotic factors Biodiversity Climax community Community of species Deflected succession Ecological niche Ecosystem Habitat Legumes Pioneer species Plagioclimax Population Quadrat Secondary succession Sere Simpson's index of biodiversity Species Transect

Student sheet

Succession of plant communities

(Succession has) "relevance to studies of landscape ecology, ecosystem development, restoration ecology, and global change ecology." (Chang and Turner, 2019)

Ecological succession is a series of changes to an ecosystem over time, changes in plant communities create changes in the local abiotic factors, which in turn lead to further changes in the plan communities and abiotic factors. Seral stages are the progression from uncolonised bare ground to the climax community, through a process known as primary succession. Seres are named differently dependent on the conditions present at the beginning (Hydrosere – freshwater, Psammosere – sand dunes, Halosere – saltmarsh, Lithosere – bare rock.

Investigation title: Investigating how species presence, abundance and diversity changes over time.

Method

You are provided with the following:

- tape measure
- point frame quadrat
- plant identification key
- light meter
- anemometer
- soil moisture meter.

You should read these instructions carefully before you start work:

1. Measure the total distance of the environmental change across the sere eg psammosere
2. To find 10 sample sites which are an equal distance apart, divide the total distance measured by 11, this will be the interval between sample sites – systematic sampling.
3. At each sample site place the point frame quadrat (Figure 1)
4. Use the pointers in the point frame quadrat to record the presence of all species that are "hit" by the pointer. Use the plant identification key to help to identify the species.
   If the pointer hits bare ground, also record this. Record data in Table 1.
5. Repeat at each sample site 10 times, so 100 pointer samples have been taken at each sample site. (This step may be missed if you are collating data within a larger group.)
6. At each sample site also take abiotic measurements once. Record in Table 2
   a. Light Intensity: Hold the light-meter at the height of the vegetation, record light levels over a 1 minute period, note the maximum light level in this one-minute period (lux).
   b. Wind speed: Hold the anemometer at the height of the vegetation, record wind speeds over a 1 minute period, note the maximum wind speed in this 1 minute period ($m\ s^{-1}$).
   c. Soil Moisture: Use the soil moisture probe, insert into the ground to a depth of 5cm, record moisture levels from the relative soil moisture scale.
7. Calculate $\%\ vegetation = \frac{numberof\ hits\ on\ all\ vegetation}{total\ number\ of\ pins\ dropped} \times 100$
8. Calculate $\%\ bare\ ground = \frac{numberof\ hits\ on\ bare\ ground}{total\ number\ of\ pins\ dropped} \times 100$
9. Calculate $species\ diversity = \frac{N(N-1)}{\Sigma n(n-1)}$ Where N= Total number of organisms of all species and n= Total number of organisms of individual species.

10. Plot how distance travelled along the sand dunes transect (m) and species diversity correlate using a scatter graph.
11. Use Spearman’s Rank Correlation Coefficient to consider the correlation between distance travelled along the sand dune transect (m) and species diversity.

$$r_s = \frac{1 - 6\Sigma D^2}{n(n^2 - 1)}$$

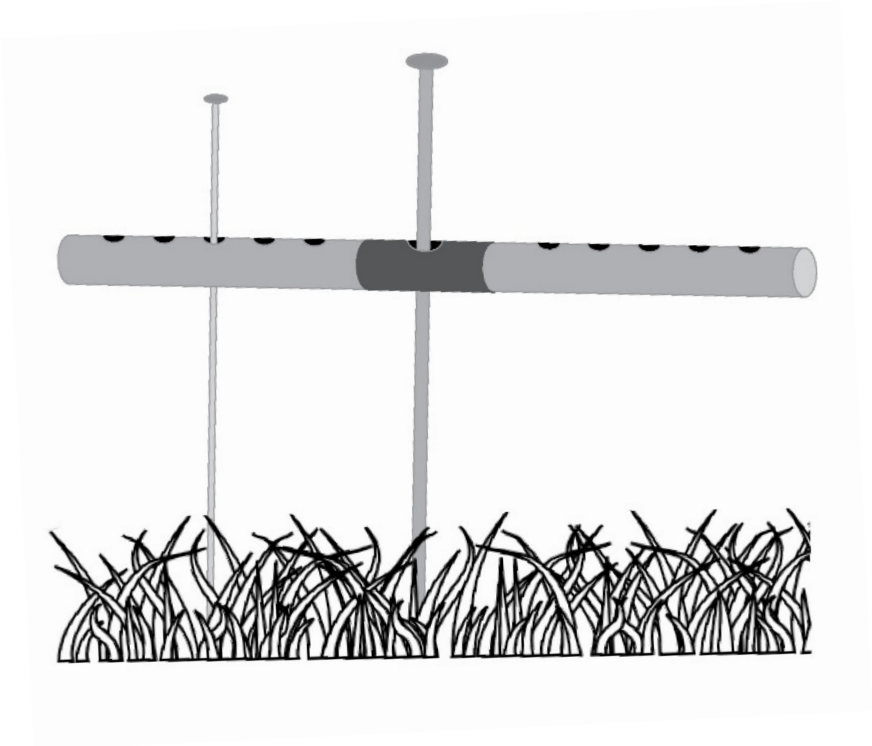
Table 5-Recording sheet (vegetation)

		Frequency tally of different vegetation									
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Species	A										
	B										
	C										
	D										
	Bare ground										

Table 6-Recording sheet (abiotic factors)

	Abiotic measurements									
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Wind speed ($m\ s^{-1}$)										
Max Light intensity (lux)										
Soil Moisture (1-10)										

Figure 1-Point frame quadrat



Source: Field Studies Council

Teacher notes

Succession of plant communities

(Succession has) "relevance to studies of landscape ecology, ecosystem development, restoration ecology, and global change ecology." (Chang and Turner, 2019)

Investigation title: Investigating how species presence, abundance and diversity changes over time.

Materials:

- tape measure
- point frame quadrat
- plant identification key
- light meter
- anemometer
- soil moisture meter

Technical information

Light meters can be purchased and vary in price (£15-£300). However, iOS and android apps can be downloaded by students prior to the practical beginning.

The following app is recommended at time of print.

Name of app	iOS/Android	Cost
Lux metre	Both	Free

Digital Anemometers can be easily purchased and vary in price (£12-£250)

Soil moisture meter can be easily purchased and vary in price (£8-£50)

Risk assessment

- Risk assessment and risk management are the responsibility of the centre.
- Depending on the location chosen for this study, specific locational risks must be identified and control measures put in place.

Trialling

This practical should be trialled before use with students.

Additional notes

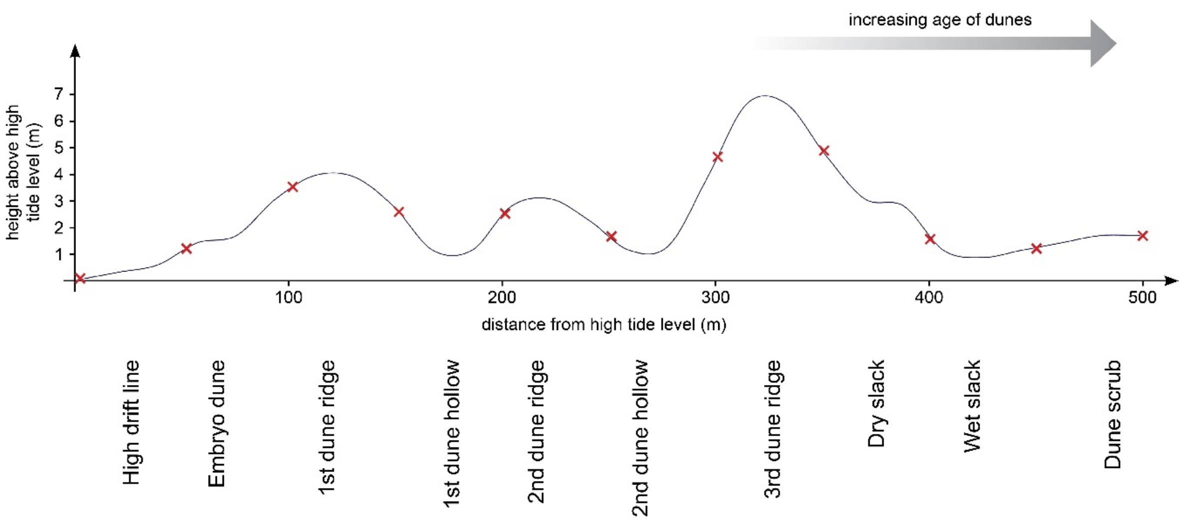
Measuring how plant communities change over time is impractical for A-level fieldwork, a transect across a habitat with an environmental gradient showcasing land formation such as a sand dune system can provide that opportunity. The transect can begin at the more recently formed land (embryo dune) and subsequently travels back to older land – fore, yellow, grey dunes, each with more established soil and plant communities.

Using this method of sampling across an environment such as a sand dune ecosystem, the presence and absence, alongside the relative abundance of certain pioneer species and plagioclimax communities, can all be identified. This showcases the change and development of plant communities over time. Figure 1 shows sampling along transect in a sand dune system.

Opportunities for discussion on interspecies competition and how species modify the environment, improving conditions for other species, can all be instigated based on the biotic, abiotic and edaphic measurements taken.

- Species diversity
- Abiotic and edaphic conditions more favourable for plant growth

Figure 1-Sand dune transect



Source: Field Studies Council

Alternatives to this practical

This sand dune succession practical can easily be adapted to for different habitats which show the process of succession, teachers may wish to alter the abiotic measurements to suit the different environments. Examples can include:

Hydroseral succession: Margins of lake (Soil moisture, Soil pH, wind speed)

Haloseral succession: Saltmarsh (Salinity, Soil pH, wind speed)

For some specific locations due to the extensive area of these habitats, conducting systematic sampling with ten samples will be impractical due to both access and distance to travel between samples. Any differences in plant communities along the transect could be missed if distances between samples are too large. Stratified random sampling is a suitable alternative eg stratified for dune type (embryo, fore, yellow, grey) and random sampling (10m x10m) for location of point frame quadrats. (ME1). Instead of conducting a Spearman's Rank Correlation Coefficient statistical test in this case a Chi-squared statistical test which would consider the association between dune type and frequency counts of different species would be appropriate.

An alternative to using the soil moisture meter which provides a relative measure of soil moisture could be to calculate absolute soil moisture levels using the method as outlined in Case Study 5 This could also be combined with calculations of organic matter from Case Study 5. This would fulfil ST 3.

Sample results

Total number of pins dropped (100 per site)		Frequency tally of different vegetation									
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Species	A Marram grass	27	94	41	53	52	70	35	47	29	5
	B Fescue grass	0	0	10	15	0	17	10	25	22	4
	C Other grass	0	0	0	0	50	41	35	51	58	90
	D Ladies Bedstraw	0	0	0	10	1	0	2	5	6	7
	E Dandelion	0	0	0	5	0	5	5	8	0	0
	F Bramble	0	0	13	14	34	25	7	1	0	6
	Bare ground	73	6	51	3	0	0	0	0	0	0
	% Vegetation Cover	27	94	64	97	137	158	94	137	115	112
	% Bare Ground	73	6	51	3	0	0	0	0	0	0

	Abiotic measurements									
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Wind speed (m s^{-1})	1.5	1.0	1.0	2.6	1.7	2.1	1	1.6	0.7	0.9
Max Light intensity (lux)	9000	9330	3400	5800	3700	6300	4400	2800	1400	1900
Soil Moisture (1-10)	1	1	3	3	7	7	6	8	7	7
Soil Moisture as a % of dry weight	6.57	20.96	14.76	42.74	44.65	52.35	25.66	44.17	48.90	36.36

Case study 8

Building energy conservation

"Around 75% of an industrial unit's heat is lost through the building fabric." (Carbon Trust, 2019)

Investigation title: Investigating building energy loss through different construction materials.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.3 Energy resources 3.3.4 Strategies to secure future energy supplies 3.3.4.2 New energy conservation 3.3.4.2.2. Building energy conservation
Maths skills	Handling data (1.1, 1.2, 1.3, 1.5, 1.6) Graphs (3.3)
Subject specific vocabulary	Albedo

Student sheet

Building energy conservation

"Around 75% of an industrial unit's heat is lost through the building fabric." (Carbon Trust, 2019)

Energy use in buildings makes up approximately 50% of the UK's energy use and 35% of national greenhouse gas emissions. The largest area of energy consumption in buildings is for heating spaces, comprising 61% of domestic energy use and 45% of energy use in the services sector which includes schools[1]. In order to reduce the overall heating demand of a building it is necessary to reduce heat losses through unwanted ventilation (draughts) and through the building fabric, such as walls, windows and roof. In this practical you will investigate the heat loss through different building materials.

[1] DECC (2014a) Energy Consumption in the UK: data tables, Department for Energy and Climate Change. Available at gov.uk/government/collections/energy-consumption-in-the-uk (Accessed 12 March 2019).

Investigation title: Assessing building energy loss through different construction materials.

Method

You are provided with the following:

- Infra-Red (IR) thermometer
- air thermometer
- map of your school grounds with locations of buildings shown.

You should read these instructions carefully before you start work:

A. Determine number of samples required.

1. Identify an external surface on the building that is uniform in its construction (a double-glazed window, a brick wall)
2. Use the IR thermometer to measure the temperature (°C) at three different points on the surface (consider using a systematic or random sampling strategy to choose these points.
3. Calculate the mean surface temperature.
4. Take an additional measurement of temperature and recalculate the mean using all measured values.
5. Repeat 4, increasing the sample size (n) until the mean value stabilises.
6. Identify the value of n required to achieve less than 5% variation in the mean surface temperature.

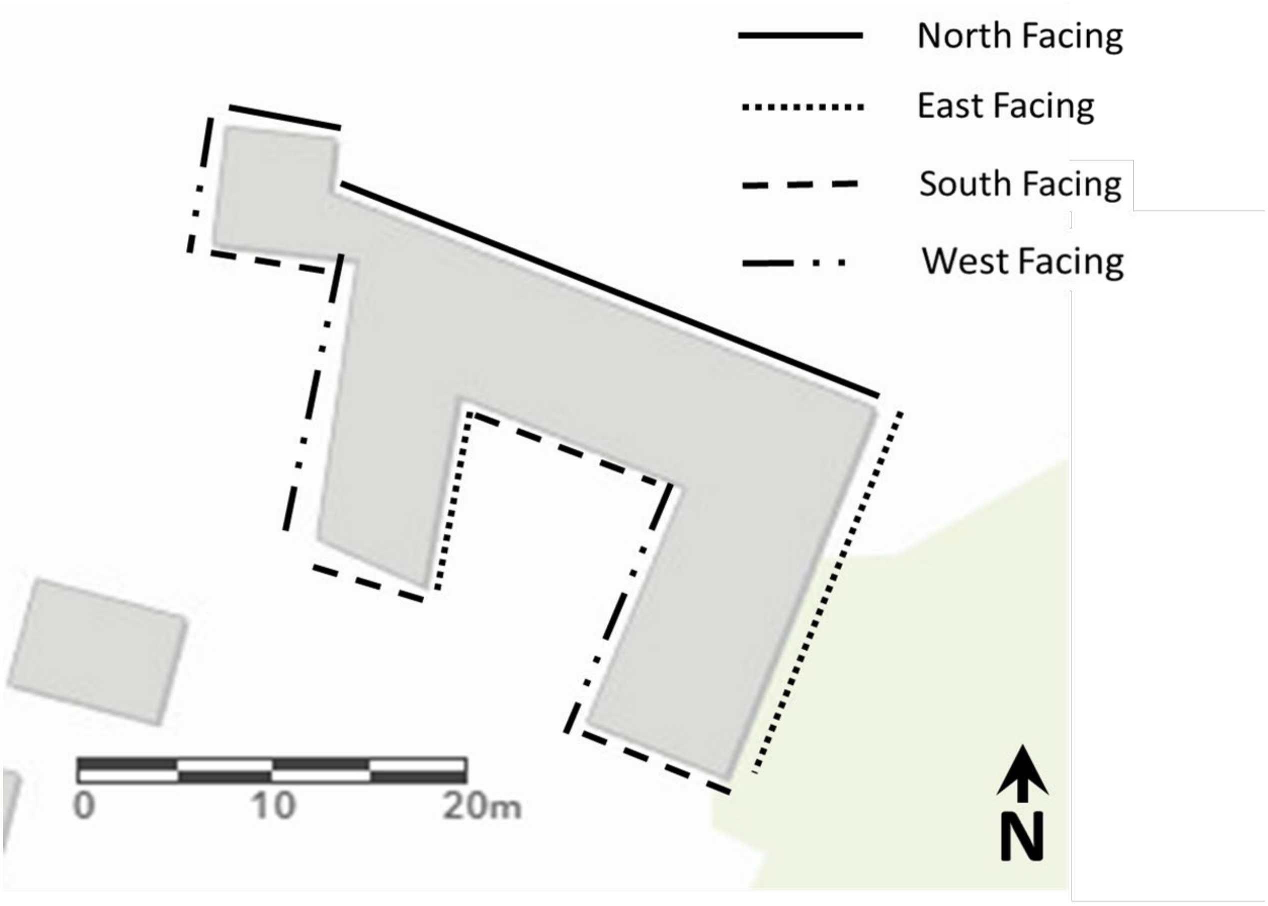
Plotting a scatter graph of n (x-axis) against mean surface temperature (y-axis) may help you identify the optimal value of n.

B. Compare heat loss through different building materials.

1. Use the map of your school to identify the aspect of building surfaces as North, South, East or West facing aspects (Figure 1). You will need to use aspect as a control variable.
2. Walk around the school buildings and mark on the locations of different building materials, eg single glazing, double glazing, bare brick wall, rendered wall, timber clad wall (Figure 2).
3. Identify the aspect with the widest variety of building materials – these will be the areas you compare.
4. For the first building material type, use the IR thermometer to measure the temperature (°C) on the external surface of the material (A).
5. Use the air thermometer to measure and record the ambient temperature (°C) outside (B).

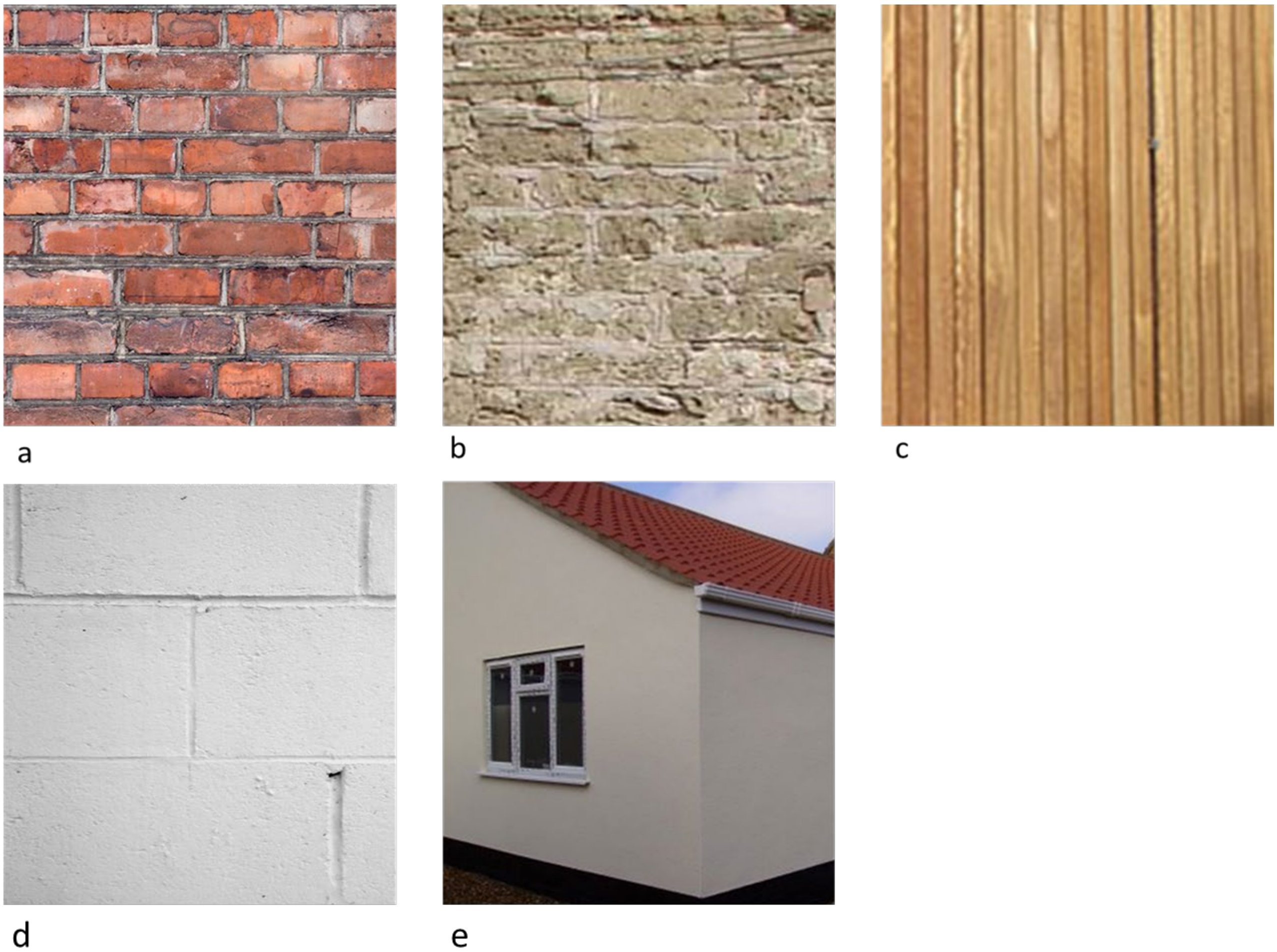
6. Go to the same location on the inside of that building and use the IR thermometer to measure and record the temperature (°C) on the internal surface (C).
7. Use the air thermometer to measure and record the ambient temperature inside (D).
8. Repeat steps 4-7 for each of the building surfaces you identified on your chosen aspect.
9. Calculate the difference between the temperatures on the internal and external surfaces
   $Difference\ in\ surface\ temperature\ (°C) = C - A$
10. Plot a bar graph showing the surface type and surface temperature difference.
11. Calculate the differences between the ambient temperatures (°C) inside and outside for each location.
    $Difference\ in\ surface\ temperature\ (°C) = B - D$
12. Plot a bar graph showing the difference in ambient temperatures (°C) for each location – consider this a control variable.
13. Identify the most effective building material at preventing heat loss.

Figure 11–Identifying aspect of building surfaces.



Source: Field Studies Council

Figure 12-A selection of building surfaces a. bare brick, b. stone wall, c.timber clad wall, d. painted breeze block wall, e. rendered wall.



Source: Field Studies Council

Teacher notes

Building energy conservation

"Around 75% of an industrial unit's heat is lost through the building fabric." (Carbon Trust, 2019)

Investigation title: Investigating building energy loss through different construction materials.

It is recommended that this practical is completed in the winter months when there will be greatest difference between internal and external temperatures and the impact of albedo on external surface temperatures minimised.

Materials:

- Infra-Red (IR) thermometer
- air thermometer
- map of your school grounds with locations of buildings shown.

Technical information

Infra-red thermometers measure the surface temperature of objects without requiring direct contact-this makes them useful for measuring temperatures on surfaces above head height. Prices from £10 upwards.

This practical investigates the relative insulation performance of different building materials. It is difficult for students to determine the internal structure and materials used within the buildings structure, so this practical relies on visible differences. In your school it may be possible to obtain detailed information on the materials and structure of the building. Where available these could be used to further identify different building fabric.

In the construction industry the thermal performance of any particular building element is specified by a U-value, the energy transfer per metre squared per degree difference in internal and external temperature ($W\ m^{-2}\ K^{-1}$). With a knowledge of all the elements of a buildings construction it is possible to calculate its overall heat loss coefficient.

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

IR thermometers use lasers and should not be shone into eyes.

Trialling

The practical should be trialled before use with students.

Alternatives to this practical

Compare the difference between the same building material on buildings of different ages.

Case study 9

Assessing noise pollution

> "Exposure to aircraft noise may be a risk factor for cardiovascular diseases." (Franssen et al. 2004)

Investigation title: Investigating how noise levels change with distance from the site of point source noise pollution.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.4 Pollution 3.4.3 Strategies to control pollutants based on their properties and features of the environment. 3.4.3.2 Selection of control technologies: to reduce production, reduce release and mitigate damage caused. 3.4.3.2.13 Noise
Maths skills	Handling data (1.1, 1.5, 1.7, 1.9) Algebra (2.3) Graphs (3.3)
Subject specific vocabulary	Abiotic factors Acoustic fatigue Active traffic management (ATM) Baffle mounds dB scale Transect

Student sheet

Assessing noise pollution

"Exposure to aircraft noise may be a risk factor for cardiovascular diseases." (Franssen et al. 2004)

Noise pollution can negatively impact humans and wildlife. It can also have an impact on buildings through acoustic fatigue and/or vibration damage. In humans noise pollution can cause hearing damage and stress related health problems such as high blood pressure. In wildlife feeding and breeding can be affected as well as inducing behavioural change in organisms. You will be directed to a local site of point source noise pollution eg factory, airport, busy intersection of road, and will investigate how noise levels change with increasing distance from this source.

Investigation title: Investigating how noise levels change with distance from the site of point source noise pollution.

Method

You are provided with the following:

- map of urban centre with transect lines depicted
- device to record noise levels (dB)
- device to record latitude and longitude
- a method of recording distance travelled
- compass
- watch/timing device.

You should read these instructions carefully before you start work

1. Ensure that you have synchronised watches with other groups in your class. Decide in advance the timing of each measurement at the sample sites.
2. Use a systematic sampling strategy-travel along the transect line, measure the distance travelled. At regular intervals (which your teacher will tell you) stop, these are your sample sites.
3. At your sample site, record the latitude and longitude.
4. Using the decibel meter monitor noise levels for two minutes at your sample site.
5. Record the maximum decibel reading (dB) in those two minutes.
6. Plot how distance from the source and noise levels (dB) correlate using a scatter graph.
7. Use Spearman's Rank Correlation Coefficient to assess the strength of correlation between distance travelled from source of noise pollution (m) and maximum noise level (dB)

$$r_s = 1 - \frac{6\Sigma D^2}{n(n^2 - 1)}$$

Teacher notes

Assessing noise pollution

"Exposure to aircraft noise may be a risk factor for cardiovascular diseases." (Franssen et al. 2004)

Investigation title: Investigating how noise levels change with distance from the site of point source noise pollution.

Materials

- map of urban centre with transect lines depicted
- device to record noise levels (dB)
- a method of recording distance travelled
- compass
- watches/timing devices

Technical information

Digital decibel meters can be purchased and vary in price (£16-50). However, iOS and Android apps can be downloaded by students onto their phones prior to the practical beginning.

Devices that record GPS co-ordinates can be purchased. However, iOS and Android apps can be downloaded by students onto their phones prior to the practical beginning.

The following apps are recommended at time of print.

Name of app	iOS/Android	Cost
Decibel X	Both	Free
Sound Meter	Android	Free
NIOSH Sound Level Meter	iOS	Free
OS Locate	Both	Free

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Teachers should have procedures in place to monitor students working in small groups away from permanent supervision of the teacher.

Trialling

This practical should be trialled before use with students.

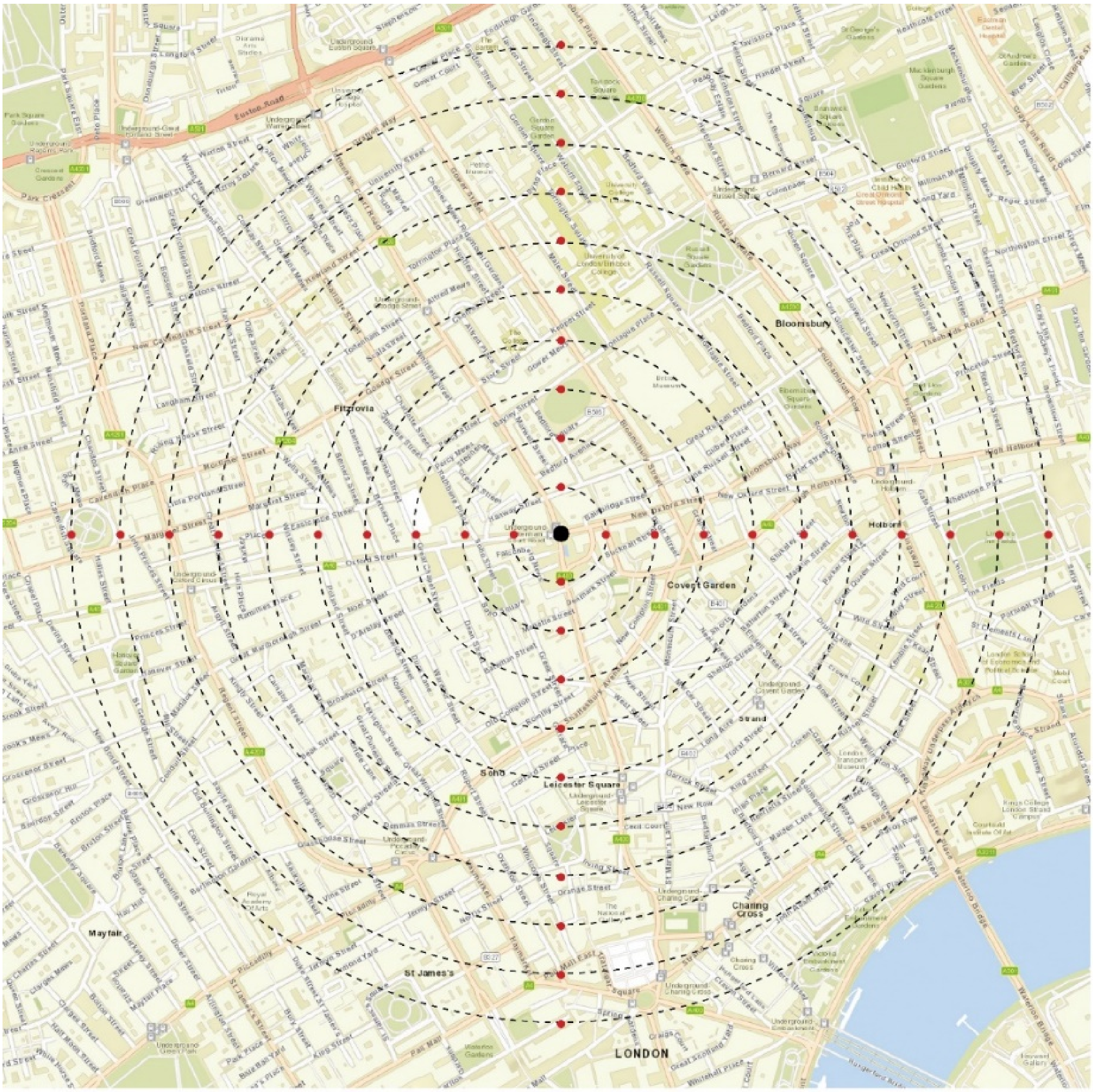
Additional notes

Mapping out the routes of the transects from the site of the source of noise pollution prior to the collection of field data is important. Site locations can be clearly marked on maps given to students. An example is shown in Figure 1.

A statistical analysis can be carried out on the data collected. Spearman's Rank Correlation Coefficient can be used to test for a correlation between distance travelled (m) (Independent Variable) and noise levels (dB) (Dependent Variable).

Tottenham Court Road is an example of Point Source Noise Pollution due to the extensive building works resulting from the construction of the Elizabeth Line and new underground station at this location.

Figure 13-Example transects and sample sites on Tottenham Court Road, London



Key

- ● Location of point source noise pollution
- ● Sample sites

Ensuring that students collect the data at increasing distance from the source at the same point in time is crucial to reduce the impact of temporal bias on the data collected. Pre-determining timings of measurements prior to the practical starting is important, taking into consideration the time to travel between sample sites.

Students should be encouraged to make any additional qualitative notes of sources of noise which may impact the data collected along their transect.

By collecting GPS co-ordinates of the locations of sample sites, decibel levels can be spatially mapped.

Alternatives to this practical

This practical can easily be adapted to investigate noise pollution from any point sources of noise pollution eg airports, train stations, industrial sites, football stadiums.

Sample results

Transect A

Site	Distance from source of noise	Maximum noise level over two-minute period (dB)
1	60	100
2	120	95
3	180	62
4	240	78
5	300	70
6	360	68
7	420	51
8	480	58
9	540	44
10	600	42

Case Study 10

Assessing air pollution

> "Although London's air often appears clear to the naked eye, the city has suffered from illegal levels of air pollution since 2010, with particularly dangerous levels of nitrogen dioxide, which comes mainly from diesel vehicles." (Financial Times, 2018)

Investigation title: Investigating air quality using a biotic index.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location-random sampling	2. Sample location-systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.4 Pollution 3.4.3 Strategies to control pollutants based on their properties and features of the environment 3.4.3.2 Selection of control technologies: to reduce production, reduce release and mitigate damage caused. 3.4.3.2.2 Acid precipitation
Maths skills (ms)	Handling data (1.1, 1.5, 1.7, 1.9) Algebra (2.3) Graphs (3.3)
Subject specific vocabulary	Bag filter Biotic Index Clean Air Act (1956) Photochemical smog Quadrat Smog Species Wet flue gas desulfurisation

Student sheet

Assessing air pollution

> “Although London’s air often appears clear to the naked eye, the city has suffered from illegal levels of air pollution since 2010, with particularly dangerous levels of nitrogen dioxide, which comes mainly from diesel vehicles.” (Financial Times, 2018)

A biotic index can be used as measure of pollution based on the presence, abundance and state of health of certain living organisms. Some lichen species which are nitrogen-sensitive, or nitrogen-loving can be used as measure of air quality. The biotic indices used in this investigation; tar spots and lichen; are useful in quantifying air pollution, as fluctuation in atmospheric concentrations of pollution particulates at various temporal scales makes it difficult to measure accurately.

Investigation title: Investigating the use of a biotic index to assess air quality.

Method

You are provided with the following:

- 3 x tape measures
- random number table
- flexible (0.5x0.5m) gridded quadrat
- lichen ID guide
- tree ID guide
- ruler.

You should read these instructions carefully before you start work

A: Choosing the size of quadrat

1. At the edge of a deciduous woodland, lay out tape measures at right angle to each other, to define an area (10m x 10m).
2. Use a random number table to generate a pair of coordinates in the format (XX,YY), this will be the location of the pilot into size of quadrat.
3. Locate the nearest tree (deciduous) to the coordinate. Exclude any trees with a circumference of less than 22cm at breast height (1.3m up from ground level)
4. Choose the side of the trunk with the most lichen present.
5. Place the flexible grid quadrat (0.5m x 0.5m) at breast height (1.3m up from ground level) See Figure 1.
6. Record the number of different lichen species recorded in 1 square of the gridded quadrat in Table 1.
7. Repeat for 4, 9, 16, 25, 36, 49, 64, 81, 100 squares of the (0.5m x 0.5 m gridded quadrat)
8. Use the information recorded in Table 1 to decide and justify the most appropriate size of quadrat to use for Part B of this investigation.

B: Biotic index-lichen

1. At the edge of a deciduous woodland, lay out tape measures at right angle to each other, to define an area (10m x 10m).
2. Use a random number table to generate 5 pairs of coordinates in the format (XX,YY), these will be the location of 5 sample sites within the 100m² area.
3. Locate the nearest tree (deciduous) to the coordinate. Excluding any trees with a circumference of less than 22cm at breast height (1.3m up from ground level)
4. Choose the side of the trunk with the most lichen present.
5. Place the flexible grid quadrat (0.5m x 0.5m) at breast height (1.3m up from ground level) See Figure 1.

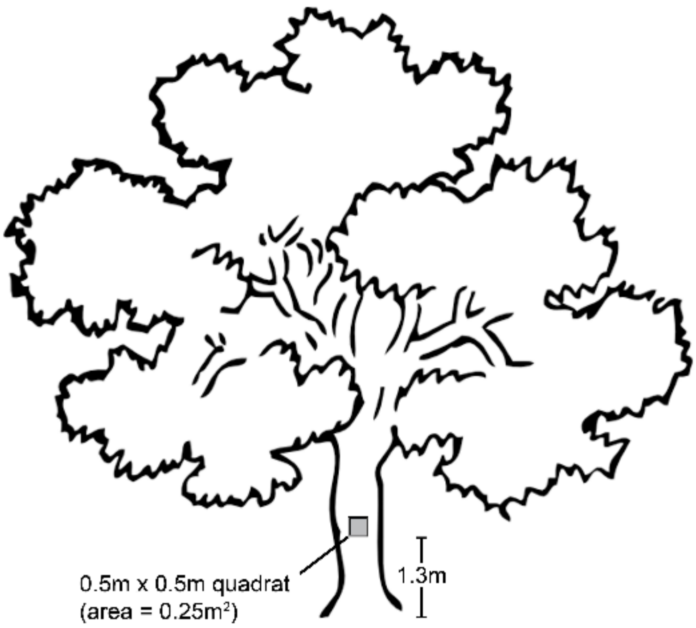
6. Use the Lichen ID key, to record the percentage (%) cover of each of the indicator lichen species. Record in Table 2.

C: Biotic index-tar spots

1. At the edge of a sycamore woodland, lay out tape measures at right angle to each other, to define an area (10m x 10m).
2. Use a random number table, to generate a pair of coordinates in the format (XX,YY), this will be the location of the sample site within the 100m² area.
3. Use the Tree ID key to locate the nearest sycamore tree.
4. Choose the 10 most easily accessible branches on the tree and select the largest accessible leaf on this branch.
5. Count the number of tar spots (which are larger than 15mm wide), see Figure 2. Record in Table 3.
6. Measure the longest length (mm) and width (mm) of the leaf. Record in Table 3.
7. Calculate an estimate of the leaf area (mm²).
8. Plot how leaf area and number of tar spots correlate using a scatter graph.
9. Repeat steps 1-7 in the centre of a woodland.
10. The area of leaf may affect the number of tar spots, use the equation below to calculate Spearman's Rank Correlation Coefficient to assess the strength of correlation between leaf area (mm²) and the number of tar spots. This can help inform whether it is leaf size or pollution that is determining the number of tar spots present.

$$r_s = 1 - \frac{6\Sigma D^2}{n(n^2 - 1)}$$

Figure 1-Quadrat placement



Source: Field Studies Council

Figure 14-Sycamore leaf with tar spots

Source: Field Studies Council

Table 7-Determining the size of quadrat

Size of quadrat-No. of squares	1	4	9	16	25	36	49	64	81	100
No. of Lichen Species present										

Table 8-Lichen as a biotic indicator of air pollution

		% cover of each lichen species				
		Tree 1	Tree 2	Tree 3	Tree 4	Tree 5
Nitrogen-sensitive	*Usnea*					
	Evernia					
	Hypogymnia					
Intermediate	*Melanelixia*					
	Flavoparmelia					
	Parmelia					
Nitrogen-loving	Leafy *Xanthoria*					
	Cushion *Xanthoria*					
	Physica					

Table 9-Tar spots as a biotic indicator of air pollution

	Longest width of leaf (mm)	Longest length of leaf (mm)	Area of leaf (mm^2)	Number of tar spots >15mm
Leaf 1				
Leaf 2				
Leaf 3				
Leaf 4				
Leaf 5				
Leaf 6				
Leaf 7				
Leaf 8				
Leaf 9				
Leaf 10				

Teacher notes

Assessing air pollution

"Although London's air often appears clear to the naked eye, the city has suffered from illegal levels of air pollution since 2010, with particularly dangerous levels of nitrogen dioxide, which comes mainly from diesel vehicles." (Financial Times, 2018)

Investigation title: Investigating the use of a biotic index to assess air quality.

Materials

- 3 x tape measures
- random number generator
- flexible (0.5x0.5m) gridded quadrat
- lichen ID guide
- tree ID guide
- ruler.

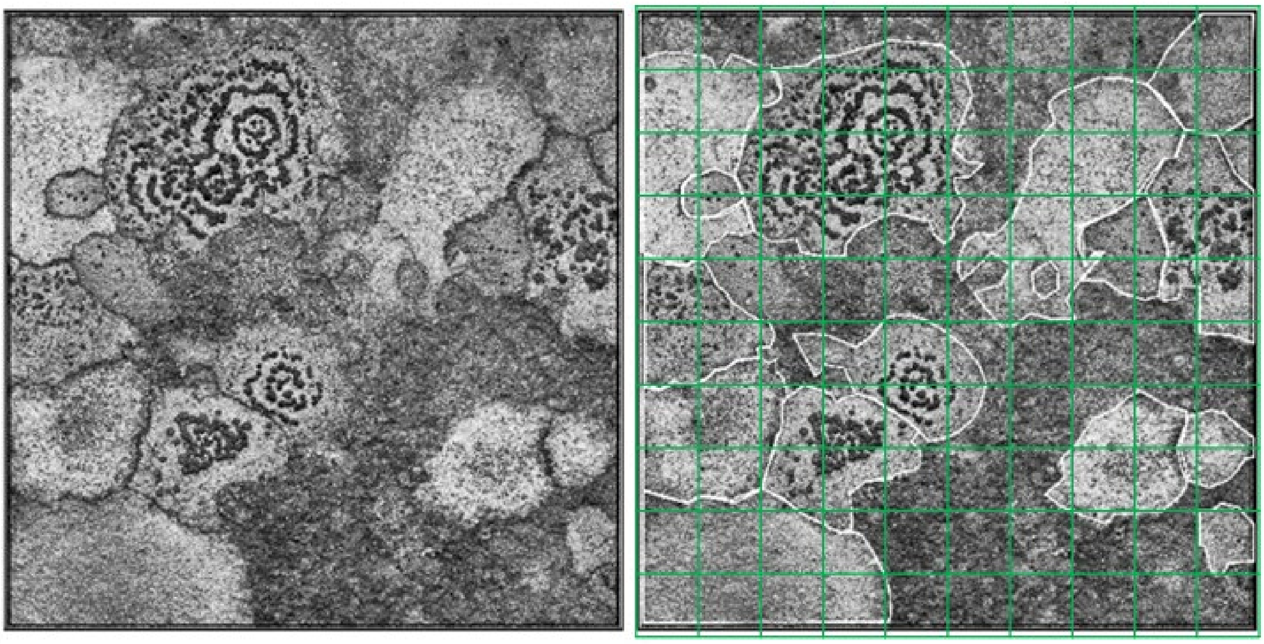
Technical information

Identifying lichens can be challenging, this free downloadable Lichen ID Guide can be used to help identify the lichens in this practical.

opalexplorenature.org/lichen-identification-guide

Identifying boundaries between close-growing individual lichen species can be challenging. Figure 1 shows an example of lichen on tree with boundaries identified, with an example gridded quadrat placed over the top. Students would need to assess percentage cover for each individual lichen species.

Figure 1-Lichen on a tree with boundaries identified



Source: Field Studies Council

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Trialling

This practical should be trialled before use with students.

Additional notes

Many cities monitor air pollution, and real-time data from fixed locations can be found. However, measuring air pollution as a practical activity in the field for students can be challenging as the equipment required is sophisticated, expensive and requires the set-up of long-term monitoring stations. The use of biotic indicators can provide an opportunity to assess air pollution through the impacts of air pollution on the presence and abundance of living organisms. This practical draws heavily on the work of the OPAL (Open Air Laboratories Programme) opalexplorenature.org Air Quality Survey and looks at the presence/abundance of lichens and tar spots, two bio indicators sensitive to nitrogen-containing air pollutants.

- Lichens-presence and abundance of nitrogen-sensitive and nitrogen-loving species.
- Tar spots-the number of tar spots (caused by a fungus) can be reduced by air pollution.

When selecting an area of deciduous woodland for students to work in for the lichen bio indicator investigation, avoid heavily shaded areas of woodland. Trees at the edge of a woodland work best, close to a potential site of pollution (road/urban centre).

The tar spot indicator investigation must be carried out on sycamore trees. This can either be a sycamore plantation (mono-culture) or in a mixed deciduous woodland. Two study sites will need to be selected, one at the edge of a sycamore woodland-close to a source of air pollution eg road, and one in the centre of a woodland, further away from the source.

Size of leaf may affect the number of tar spots found, by drawing a scatter graph and calculating a Spearman's Rank Correlation Coefficient, students will be able to find whether there is a significant correlation between leaf area (mm^2) (independent variable) and number of tar spots (dependent variable). This will then inform any conclusions they may draw between the number of tar spots on leaves at the edge of woodland and in the centre of woodland.

Cheap flexible gridded quadrats can be made by cutting plastic garden mesh screen to size (0.5 x 0.5m). It can be bought in rolls (0.5m x 5m-£10).

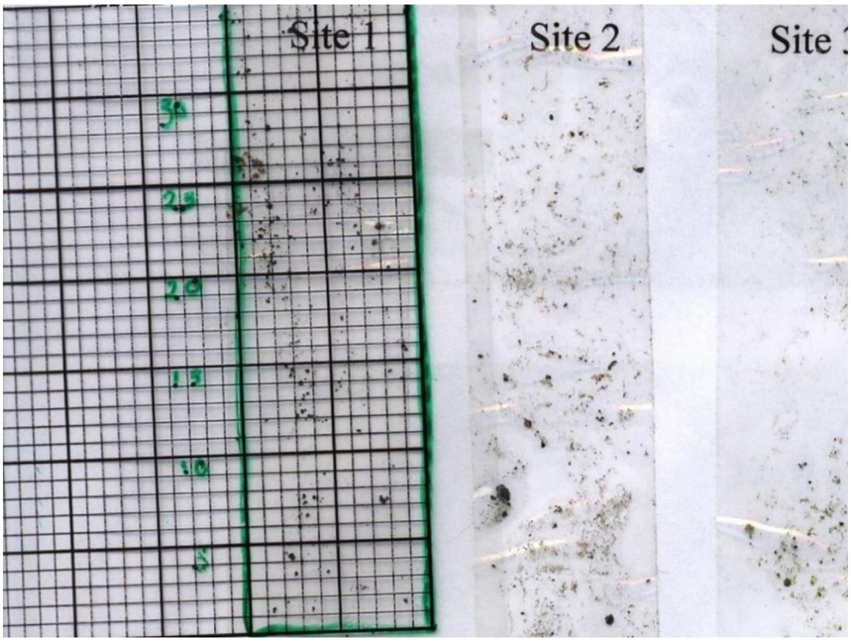
Justifying the size of quadrat in any experiment should always be informed by the size of the organisms, quadrat size should be large enough to be representative of the number of species found. Students should find that in Part A the number of lichen species will increase as quadrat size increases, but the number of lichen species present will stay the same at a certain point, this is the optimum size of quadrat to use for Part B.

Alternatives to this practical

Teachers may wish to extend this practical by investigating particulate pollution through using sticky tape peels.

This extension involves the presence and abundance of particulate pollution (eg soot) which may be present on surfaces close to a road. Sticky tape will remove the particulates, and the presence can be assessed using graph paper copied onto acetates and counting frequency of particulates. See Figure 2. More information can be found at opalexplorenature.org

Figure 2-Sticky tape peels to assess frequency of particulate pollution



Source: Field Studies Council

Students could be encouraged to explore the properties, source, wider potential impacts of air pollution and control strategies in their local area.

This could be achieved through completing a Critical Pathway Analysis (CPA) and a Critical Group Monitoring (CGM) task.

Case study 11

Assessing water quality

"More than 80% of the world's wastewater flows back into the environment without being treated or reused, according to the United Nations." (NDRC, 2019)

Investigation title: Investigating the use of a biotic index to assess water quality.

Links to the specification

	Sampling techniques (ST)						Methodology (ME)					
	1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals.	6. The use of aquatic sampling methods to measure biotic factors.	1. Sample location- random sampling	2. Sample location- systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation
Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.1.2.2 How humans influence biodiversity 3.2.4 Biochemical cycles 3.2.4.3 The nitrogen cycle 3.2.4.4 The phosphorus cycle 3.4 Pollution 3.4.3.2.9 Nutrient pollution
Maths skills (MS)	Handling data (1.1, 1.2, 1.6)
Subject specific vocabulary	Abiotic factors Aerobic process Anaerobic process Eutrophication

Student sheet

Assessing water quality

"More than 80% of the world's wastewater flows back into the environment without being treated or reused, according to the United Nations." (NDRC, 2019)

Organic pollution in freshwater habitats leads to eutrophication resulting in rapid plant growth. The decomposition of increased quantities of dead organic matter by microorganisms consumes oxygen, reducing the levels of dissolved oxygen in the water.

Measurements of the chemical and physical properties of the water, including turbidity, can be used to assess water quality. A biotic index can also be used as measure of pollution based on the presence and abundance or health of particular living organisms.

Some species of freshwater invertebrate are adapted to thrive in lower oxygen conditions, whilst others require very high levels of oxygen to survive-the presence or absence of these species can be used as an indicator of water quality. The Biological Monitoring Working Party (BMWP) Score, used in this investigation, is quick to respond to changes in water quality, owing to the sensitivity of indicator species to reduction in oxygen availability.

Investigation title: Investigating the use of a biotic index to assess water quality.

Method

You are provided with the following:

- access to a freshwater pond
- white tray
- pond net
- 2 x white paint palette
- plastic spoons
- identification chart
- magnifying glass
- dissolved oxygen probe
- 2 x beakers
- nitrate test strips
- phosphate test strips
- pH probe.

You should read these instructions carefully before you start work

1. Identify the same microhabitat within the freshwater pond that all groups will work in-ensure that all groups keep a standardised distance apart within that microhabitat.
2. Take measurements (or water samples) for abiotic factors first to avoid disturbing water and bed-this can cause mixing of water from the silty bed of the pond where there will be lower oxygen (or anoxic) conditions. Take care to minimise disturbance to the water as this can cause invertebrates to disperse.
    a. Use the dissolved oxygen (DO_2) probe to take three measurements at one third of the depth from the surface − calculate the mean DO_2
    b. Use the pH probe to take three measurements at one third of the depth from the surface − calculate the median pH.
    c. Take a water sample in a beaker, dip a nitrate test strip into the sample and use the colour chart to record nitrate concentration.

d. Take a water sample in a beaker, dip a phosphate test strip into the sample and use the colour chart to record phosphate concentration.

3. Part fill the white tray and paint palette with water and place in a convenient, flat location.
4. Place the bag of the net into the pond and carry out a sweep sample − draw a figure 8 in the water approximately shoulder width from side to side-continue this figure 8 pattern for 30 seconds.
5. Remove the net from the pond and turn inside out into the white tray-wash the net bag in the white tray taking care to ensure all invertebrates are removed from the net into the tray before laying the net to one side.
6. Wait a few minutes to allow any material to settle to the bottom of the tray-this will enable you to see invertebrates more easily in the tray.
7. Use the plastic spoons to transfer the invertebrates into the paint palettes, sorting invertebrates that look the same into the same portion of the palette.
8. Use the key to identify each organism-tick those present in your sample in Table 1.
9. Calculate the total BMWP score for organisms present in your sample.
10. Use Table 2 to interpret the water quality from the total BMWP score.

Table 10-recording sheet

Common name	Score	Present
Stonefly	10	
Burrowing Mayfly Nymph	10	
Flattened Mayfly Nymph	10	
Swimming Mayfly Nymph	10	
Dragonfly nymph	8	
Damselfly Nymph	7	
Cased Caddis	7	
Freshwater Shrimp	6	
Caseless caddis	5	
Cranefly Larvae	5	
Diving Beetle	5	
Diving Beetle Larvae	5	
Flatworm	5	
Freshwater Scorpion	5	
Greater Waterboatman	5	
Lesser Waterboatman	5	
Other Beetles	5	
Alderfly	4	
Leech	3	
Pond Snail	3	
Ramshorn Snail	3	
Water hoglouse	3	
Non-biting midge	2	
Worm	1	
Tubifex worm	1	
Total BMWP Score		

Table 11-Interpreting your BMWP score

BMWP score	Category	Interpretation
0-10	Very poor	Heavily polluted
11-40	Poor	Polluted or impacted
41-70	Moderate	Moderately impacted
71-100	Good	Clean but slightly impacted
>100	Very good	Unpolluted, un-impacted

Teacher notes

Assessing water quality

"More than 80% of the world's wastewater flows back into the environment without being treated or reused, according to the United Nations." (NDRC, 2019)

Investigation title: Investigating the use of a biotic index to assess water quality.

Materials

- access to a freshwater pond
- white tray
- pond net
- 2 x white paint palette
- plastic spoons
- identification chart
- magnifying glass
- dissolved oxygen probe
- 2 x beakers
- nitrate test strips
- phosphate test strips
- pH probe.

Technical information

White plastic paint palettes like the one shown below are ideal for sorting invertebrates and limiting their mobility.

Figure 1 – Paint palette

Plastic spoons are suggested for moving invertebrates from the large tray for sorting or ID, this is to reduce the likelihood of harming individuals whilst moving them.

Additional notes

Students must be briefed on the ethical treatment of organisms before this practical.

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Students should be aware, briefed and take precautions in response to outdoor diseases such as Weil's disease.

Specific risk management should be in place to manage groups working in and around freshwater environments.

Trialling

This practical should be trialled before use with students.

Alternatives to this practical

Whilst this practical is written for a freshwater pond it could equally be carried out in a freshwater stream.

If sampling in a shallow stream, the sweep sampling technique could be replaced with kick sampling or surber sampling which are more appropriate for flowing water environments.

The practical could be used to compare water quality between two freshwater sites, or to investigate changes in water quality relative to a point source of pollution. Sampling could be stratified, upstream and downstream of the pollution source, or systematically away from the pollution source.

This practical includes the collection of a range of abiotic measurements which have an impact on freshwater organisms, Table 1 includes additional abiotic measurements that could be included and alternative methods of data collection.

Table 1-Additional abiotic factors and alternative methods of data collection.

Abiotic Factor	Methods of data collection
Turbidity	Secchi Disk Turbidity Tube Turbidimeter
Oxygen	Dissolved oxygen probe Biological Oxygen Demand laboratory testing (Winkler Method)
Nitrates/Nitrites	Test dip strips provide quantitative results. Water sample tested using Nitrite and Nitrate aquarium testing kits.
pH	pH probe Water sample tested using Universal Indicator solution.

Sample results-Stagnant pool near farm

Common Name	Score	Present
Stonefly	10	
Burrowing Mayfly Nymph	10	
Flattened Mayfly Nymph	10	
Swimming Mayfly Nymph	10	
Dragonfly nymph	8	Y
Damselfly Nymph	7	Y
Cased Caddis	7	
Freshwater Shrimp	6	
Caseless caddis	5	
Cranefly Larvae	5	
Diving Beetle	5	Y
Diving Beetle Larvae	5	
Flatworm	5	
Freshwater Scorpion	5	
Greater Waterboatman	5	Y
Lesser Waterboatman	5	
Other Beetles	5	
Alderfly	4	
Leech	3	Y
Pond Snail	3	Y
Ramshorn Snail	3	Y
Water hoglouse	3	
Non-biting midge	2	Y
Worm	1	
Tubifex worm	1	Y
Total BMWP Score		37

Dissolved oxygen %	2.2
pH	5.9

Case study 12

Constructing new habitats

Habitat replacement or creation costs are undertaken when one or more of the following apply:

- there is a commitment to replace habitats lost as part of a wider scheme
- where a scheme promotes environmental aspects
- there is a commitment to provide habitat improvements as part of wider policy requirements

Habitat aspects may involve the restoration or re-establishment of existing habitat or the creation of entirely new habitat where previously none existed. (Environment Agency, Report –SC080039/R14, 2015)

Investigation title: Investigating how size and material type impacts the rate and abundance of colonisation in a freshwater environment.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location- random sampling	2. Sample location- systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12

Practical skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.1 The living environment 3.1.2 Conservation of biodiversity 3.1.2.3 Methods of conserving biodiversity 3.1.2.3.5 The importance of ecological monitoring in conservation planning. 3.1.3.1 How adaptation to the environment affects species' habitat requirements and influences conservation decision making. 3.1.3.2 Terminology to describe the roles of living organisms in their habitats and their interactions with the physical environment.

Maths skills	Arithmetic and numerical computation (0.3) Handling data (1.1, 1.4, 1.5) Algebra (2.3) Graphs (3.3)
Subject specific vocabulary	Abiotic factors Colonisation media Community of species Ecosystem Habitat Photoautotroph Quadrat Simpson's Index of Biodiversity Species Turbidity

Student sheet

Constructing new habitats

Habitat replacement or creation costs are undertaken when one or more of the following apply:

- there is a commitment to replace habitats lost as part of a wider scheme
- where a scheme promotes environmental aspects
- there is a commitment to provide habitat improvements as part of wider policy requirements

Habitat aspects may involve the restoration or re-establishment of existing habitat or the creation of entirely new habitat where previously none existed. (Environment Agency, Report –SC080039/R14, 2015)

The monitoring of species in a freshwater environment can be achieved by providing habitats that organisms can colonise. This experiment aims to consider how size of colonising media impacts upon rate of colonisation and diversity of the organisms; and how material type (surface area: volume ratio) impacts upon rate of colonisation and diversity of the organisms.

Investigation title: Investigating how size and material type impacts the rate and abundance of colonisation in a freshwater environment.

Method

You are provided with the following:

- access to a freshwater pond
- pan scourers
- shower loofas
- pre-cut lino
- freshwater organisms identification guide
- trays
- quadrat of appropriate size
- string.

You should read these instructions carefully before you start work:

Part A. Identifying how the sample size of colonising media impacts the rate and abundance of colonisation in a freshwater environment.

1. Identify the same microhabitat and depth within the freshwater pond that all groups will work in.
2. Assemble the four different sized colonisation media using the pan-scourers and string. See Figure 1.
3. Create a hole in the colonising media and attach string so that the media can be removed easily from the pond.
4. Immerse the four different sized (pan-scourers) colonising media in the freshwater environment.
5. Day 1: Remove colonising media from the pond, count the number of different species that have colonised the pan-scourer (Species Richness). Record in Table 1.
6. Repeat on Day 7, 14 and 21.
7. Plot on a line graph how species richness changes over time for the four different sizes of colonising media.
8. Based on these graphs, decide on the optimum size of colonising media to be used in part B.

Part B. Identifying how material type impacts the rate and abundance of colonisation in a freshwater environment.

1. Identify the same microhabitat within the freshwater pond that all groups will work in.
2. Assemble the three different colonising media material using string at the determined size (based on the previous investigation)
3. Create a hole in the colonising media and attach string so that the media can be removed easily from the pond.
4. Immerse the three-colonising media (of pre-determined sizes) in the freshwater environment.
5. Day 1: Remove the colonising media from the pond, quickly count the number of different species that have colonised the media (Species Richness). Record in Table 2.
   Using a gridded quadrat of appropriate size record the species present at each intersection of the gridded quadrat (Species Frequency). Record in Table 3, 4 and 5. Return the media to the water.
6. Calculate percentage frequency of organisms using the equation below
   $$percentage\ frequency\ of\ organisms = \frac{total\ number\ of\ organisms\ hit}{total\ number\ of\ intersection\ samples} \times 100$$
7. Calculate species diversity using the equation below
   $$species\ diversity = \frac{N(N-1)}{\Sigma n(n-1)}$$
   N= Total number of individuals of all species

   n= Number of individuals of a particular species

   The higher the number calculated the more diverse the site.
8. Repeat for the different material colonisation media.
9. Repeat on Day 7, 14 and 21

Figure 15 – Assembling the colonising media

Source: Field Studies Council

Table 12 – Recording sheet (optimum size of colonising media)

	Area of pan scourer			
	60cm² (1 scourer)	240cm² (4 scourers)	600cm² (9 scourers)	960cm² (16 scourers)
	Species richness			
Immerse-Day 0				
Sample 1-Day 1				
Sample 2-Day 7				
Sample 3-Day 14				
Sample 4-Day 21				

Table 13 – Recording sheet (optimum material for colonising media)

Determined area of media =			
	Pan scourer	Shower loofa	Lino
	Species richness		
Immerse-Day 0			
Sample 1-Day 1			
Sample 2-Day 7			
Sample 3-Day 14			
Sample 4-Day 21			

Table 14 – Recording Sheet (Species frequency-pan scourer)

Material = Pan scourer					
Frequency	Immerse-Day 0	Sample 1-Day 1	Sample 2-Day 7	Sample 3-Day 14	Sample 4-Day 21
Species A					
Species B					
Species C					
Species D					
Species E					

Table 15 – Recording Sheet (Species frequency- shower loofa)

Material = Shower loofa					
Frequency	Immerse-Day 0	Sample 1-Day 1	Sample 2-Day 7	Sample 3-Day 14	Sample 4-Day 21
Species A					
Species B					
Species C					
Species D					
Species E					

Table 16 – Recording Sheet (Species frequency- lino)

Material = Lino					
Frequency	Immerse-Day 0	Sample 1-Day 1	Sample 2-Day 7	Sample 3-Day 14	Sample 4-Day 21
Species A					
Species B					
Species C					
Species D					
Species E					

Teacher notes

Constructing new habitats

Habitat replacement or creation costs are undertaken when one or more of the following apply:

- there is a commitment to replace habitats lost as part of a wider scheme
- where a scheme promotes environmental aspects
- there is a commitment to provide habitat improvements as part of wider policy requirements

Habitat aspects may involve the restoration or re-establishment of existing habitat or the creation of entirely new habitat where previously none existed. (Environment Agency, Report –SC080039/R14, 2015)

Investigation titleInvestigating how size and material type impacts the rate and abundance of colonisation in a freshwater environment.

Materials:

- access to a freshwater pond
- pan scourers
- shower loofas
- pre-cut lino
- freshwater organisms identification guide
- trays
- quadrat of appropriate size
- string.

Technical information

Teachers/technicians may wish to pre-make the colonising media of different sizes and materials, to save time. If so, students can be directed to begin from Step 4 in each set of instructions in the practical.

Risk assessment

Risk assessments and risk management are the responsibility of the centre.

Students should be aware, briefed and precautions taken in response to outdoor diseases such as Weil's disease.

Specific risk management should be in place to manage groups working in and around freshwater environments.

Trialling

This practical should be trialled before use with students.

Additional notes

This is an ongoing practical over several weeks. Teachers may find it of benefit to structure this practical, as a starter or plenary alongside their class teaching. Teachers may wish to distribute sizes of colonising media and type of colonising material to different groups to reduce overall workload of students on this practical.

When choosing materials for the colonisation media, the degree of surface area is important, so teachers should ensure that the materials differ in their surface area (eg lino, pan-scourer, shower loofa).

Students must be briefed on the ethical implications of this experiment, and a procedure in place to ensure that organisms are kept in water during sampling and not harmed at the end of the experiment, or during the removal of the colonisation media at the end of the experiment.

Alternatives to this practical

Colonising media experiments can also be conducted on a rocky shore environment. Care should be taken to ensure that media are securely attached to the bedrock, to ensure the tide does not carry away material. Permission may need to be sought before attaching colonising media at the coastline.

A range of different materials can be chosen in the creation of colonisation media. Teachers may wish to consider expense, environmental impact (eg single-use plastics) when making this choice.

This practical can be complimented by the collection of relevant abiotic measurements. Table 1 lists abiotic measurements which have an impact on freshwater organisms and suggestions of methods of data collection.

Table 1 – Additional abiotic factors and alternative methods of data collection

Abiotic factor	Methods of data collection
Turbidity	Secchi Disk Turbidity Tube Turbidimeter
Oxygen	Dissolved Oxygen probe Dissolved Oxygen laboratory testing (Winkler Method)
Nitrates/Nitrites	Test dip strips provide quantitative results. Water sample tested using Nitrite and Nitrate aquarium testing kits.
pH	pH probe Water sample tested using Universal Indicator solution.

Sample results

	Area of pan scourer			
	60cm² (1 scourer)	240cm² (4 scourers)	600cm² (9 scourers)	960cm² (16 scourers)
	Species richness			
Immerse-Day 0	0	0	0	0
Sample 1-Day 1	0	0	0	0
Sample 2-Day 7	0	0	1	1
Sample 3-Day 14	0	0	1	3
Sample 4-Day 21	0	1	2	4

Determined area of media =			
	Pan scourer	Shower loofa	Lino
	Species richness		
Immerse-Day 0	0	0	0
Sample 1-Day 1	0	0	0
Sample 2-Day 7	2	2	0
Sample 3-Day 14	2	3	0
Sample 4-Day 21	3	5	1

Case Study 13

Sampling flying organisms

"Bye-bye dark sky: is light pollution costing us more than just the night-time?" (Lotzof K. 2018)

Investigation title: Investigating how temporal change impacts the populations of flying organisms.

Links to the specification

Sampling techniques (ST)						Methodology (ME)					
1. Measurement of abiotic factors	2. The use of quadrats to measure biotic factors	3. Measurement of edaphic factors	4. The use of methods to measure biotic factors related to animal taxa on the soil surfaces and in the soil	5. The use of methods to measure biotic factors related to animal taxa on foliage and flying animals	6. The use of aquatic sampling methods to measure biotic factors	1. Sample location- random sampling	2. Sample location- systematic sampling	3. Number of samples	4. Sample size	5. Sample timing	6. Standard deviation

Scientific Principles	6.5.1	6.5.2	6.5.3	6.5.4	6.5.5	6.5.6	6.5.7	6.5.8	6.5.9	6.5.10	6.5.11	6.5.12
Practical Skills	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1

Specification links	3.1 The living environment 3.1.2 Conservation of biodiversity 3.1.2.2 How humans influence biodiversity, with examples in a range of different context 3.1.2.3.5 The importance of ecological monitoring in conservation planning 3.1.2.3.6 The development of new technologies for ecological monitoring. 3.1.3 Life processes in the biosphere and conservation planning 3.1.3.1 How adaptation to the environment affects species' habitat requirements and influences conservation decision-making.
Maths skills	Handling data (1.1, 1.3, 1.4, 1.5, 1.9) Algebra (2.3)
Subject specific vocabulary	Abiotic factors Light traps Sweep nets

Student sheet

Sampling flying organisms

"Bye-bye dark sky: is light pollution costing us more than just the night-time?" (Lotzof K. 2018)

The timing of samples can have a big influence on the data collected. There are a wide range of temporal scales associated with sample timing.

- Short term **–** Influenced by weather conditions (cloud cover, wind gusts).
- Diurnal (Daily 24 hours) **–** Influenced by the rotation of the earth (temperature, light, tides).
- Seasonal **–** Axis of rotation and orbit around the sun produce changes across the year (temperature, presence of migratory species).
- Long-term **–** Other external factors can cause change (atmospheric CO_2 level)

This experiment will consider how the day to night transition impacts on the presence and abundance of various of flying organisms.

Investigation title: Investigating how temporal change impacts the populations of flying organisms.

Method

You are provided with the following:

- sweep net
- containers for storing moths and butterflies
- bat detector
- moth trap
- device to measure light intensity
- two tape measures
- clicker
- stopwatch.

You should read these instructions carefully before you start work.

1. Lay out tape measured at right angle to each other to define an area (20m x 20m)
2. Moths: Switch on the moth trap. Leave for 30 minutes.
3. Light Intensity: At a corner of the 400m² area hold the light-meter at the height of the vegetation, record light levels over a 1 minute period, note the maximum light level in this one-minute period (lux). Repeat in other 3 corners of grid. Record the maximum light level (lux) in Table 1.
4. Bees: Sit at the edge of the defined 400m² area. Count the total number of bees seen in the sample area in 5 minutes. Record in Table 1.
5. Damsel and Dragonflies: Sit at the edge of the defined 400m² area. Count the total number of Damsel or Dragonflies seen in the sample area in 5 minutes. Record in Table 1.
6. Butterflies: Use the sweep net, move the net in a figure of eight motion as you move around the sample site for 5 minutes. Count the number of Butterflies caught in the sweep-net. Record in Table 1.

7. Bats: Standing at the edge of the defined area, switch on the bat-detector. Move the bat-detector around in all directions. Record every time, a distinct noise is made which indicates the presence of a bat.
8. Moths: Go back to the moth trap (after 30 minutes) and record the total number of moths caught in the trap. Record in Table 1.
9. Repeat steps 3-8 at the other 3 times in the day.
10. Construct a stacked bar chart to show how the frequency of the different organisms change between the four different times of day.
11. Use Chi-squared statistical analysis to consider the association between frequency of the different organisms and time of day.

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

Table 17 – Recording sheet

	Time (24 hour clock)							
	12:00		15:00		18:00		21:00	
Indicator organisms	Present Yes/No	Number	Present Yes/No	Number	Present Yes/No	Number	Present Yes/No	Number
Damsel and Dragonflies								
Bees								
Butterflies								
Moths								
Bats								
Max Light intensity in 1 minute period (lux)								

Teacher notes

Sampling flying organisms

"Bye-bye dark sky: is light pollution costing us more than just the night-time?" (Lotzof K. 2018)

Investigation title: Investigating how temporal change impacts the populations of flying organisms.

This is an ongoing practical from lunchtime to early evening, logistically each recording at the four times should take around 30 minutes.

Materials:

- sweep net
- containers for storing moths and butterflies
- bat detector
- moth trap
- device to measure light intensity
- two tape measures
- clicker
- stopwatch.

Technical information

Light meters can be purchased and vary in price (£15-£300). However iOS and android apps can be downloaded by students prior to the practical beginning.

The following app is recommended at time of print.

Name of app	iOS/Android	Cost
Lux meter	Both	Free

Bat detectors can be purchased and vary in price (£60-£1600). The lowest priced bat detector on the market, will be sufficient for this practical. However centres are encouraged to approach their local bat group via bats.org.uk/support-bats/bat-groups or local Field Studies Council centre via field-studies-council.org who may be able to support in the loaning and use of bat detecting equipment.

A standard sweep net should have a strong calico bag to collect insects from long grass.

Moth traps come in three main basic types (Robinson, Skinner and Heath traps), decisions are often made based on balancing price, bulkiness of trap and its ability to attract and retain high frequencies of moths mothscount.org. A low cost alternative would be to can build your own LED moth trap, an instruction guide and equipment list can be found written by Paul Palmer fscbiodiversity.uk you may also wish to approach your local County Moth Recorder or Local Moth Group via butterfly-conservation.org

Risk assessment

Risk assessment and risk management are the responsibility of the centre.

Due to the risk of stings from bees, and any known or unknown allergies to stings, the counting of bees is carried out remotely by observation only.

Trialling

This practical should be trialled before use with students.

Additional notes

This practical will work best on warm, sunny days in the summer months.

The location of the survey site is important, the following are ideal environment conditions; tall meadow grass, source of water such as a pond close-by, away from loud sources of noise, away from bright sources of light.

Students must be briefed on the ethical implications of this experiment, and the careful correct handling of any organisms.

Alternatives to this practical

This practical does not require students to identify bees, dragonflies, damselflies, moths or bats down to a species level. However excellent picture and dichotomous keys are available should centres wish to explore these species further.

There are a variety of nationwide Citizen Science projects based on the species within this practical. The Bumblebee Conservation Trust and Butterfly Conservation are a good place to look for these. Centres may wish to extend this practical and take part, submitting data to these nationwide surveys.

Sample results

	Time (24 hour clock)							
	12:00		15:00		18:00		21:00	
Indicator organisms	Present Yes/No	Number	Present Yes/No	Number	Present Yes/No	Number	Present Yes/No	Number
Damsel and Dragonflies	Y	5	Y	3	Y	1	N	0
Bees	Y	3	Y	1	Y	4	N	0
Butterflies	Y	5	Y	3	N	1	N	0
Moths	N	0	Y	3	N	0	Y	25
Bats	N	0	N	0	N	0	Y	8
Max Light intensity in 1 minute period (lux)	3600		4800		2400		120	

Get help and support

Visit our website for information, guidance, support and resources at aqa.org.uk/7447

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