Cambridge Assessment International Education

Practical Booklet 11
Invesitgating biodiversity of an ecosystem

Cambridge International AS & A Level Biology 9700

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Introduction

Practical work is an essential part of science. Scientists use evidence gained from prior observations and experiments to build models and theories. Their predictions are tested with practical work to check that they are consistent with the behaviour of the real world. Learners who are well trained and experienced in practical skills will be more confident in their own abilities. The skills developed through practical work provide a good foundation for those wishing to pursue science further, as well as for those entering employment or a non-science career.

The science syllabuses address practical skills that contribute to the overall understanding of scientific methodology. Learners should be able to:

1. plan experiments and investigations

2. collect, record and present observations, measurements and estimates

3. analyse and interpret data to reach conclusions

4. evaluate methods and quality of data, and suggest improvements.

The practical skills established at AS Level are extended further in the full A Level. Learners will need to have practised basic skills from the AS Level experiments before using these skills to tackle the more demanding A Level exercises. Although A Level practical skills are assessed by a timetabled written paper, the best preparation for this paper is through extensive hands-on experience in the laboratory.

The example experiments suggested here can form the basis of a well-structured scheme of practical work for the teaching of AS and A Level science. The experiments have been carefully selected to reinforce theory and to develop learners' practical skills. The syllabus, scheme of work and past papers also provide a useful guide to the type of practical skills that learners might be expected to develop further. About 20% of teaching time should be allocated to practical work (not including the time spent observing teacher demonstrations), so this set of experiments provides only the starting point for a much more extensive scheme of practical work.

Guidance for teachers

Aim

To use a variety of techniques to study the distribution of species in an ecosystem, to estimate population size and consider any relationships between the distribution of species and specific environmental factors.

Outcomes

Syllabus sections 18.1 (d) (e) (f)

Skills included in the practical

A Level skills	How learners develop the skills
Analysis	To use correlation analysis of the distribution of a species in relation to an environmental factor
	To use chi-squared test to determine any significant differences in populations of the same species in different environments
	Calculate Spearman's rank correlation coefficient
Evaluation	Evaluate the methods used and the accuracy and reliability of their results.
Conclusions	Decide whether a hypothesis is supported by their data

- This practical provides an opportunity to build on essential skills introduced at AS Level.

AS Level skills	How learners develop the skills
MMO collection	Record quantitative results
PDO recording	Record quantitative results in appropriate tables

Method

- Biodiversity is concerned with the variety and numbers of different species that exist in particular ecosystems and the genetic variation within species. It can be studied at many different levels from the entire world to the underside of a stone on the bottom of a stream.

- The biodiversity of specific ecosystems such as an area of woodland, sand dunes of a coastal area, a desert, the surface of the sea could be studied. This could provide an opportunity for learners to discuss their understanding of an ecosystem and identify those that are local. It is also an opportunity to remind learners that humans are part of ecosystems and can have far reaching effects on biodiversity.

- To study an ecosystem can be very time consuming so if possible at least a complete day should be allowed for learners to use ecological sampling techniques and collect data. For population estimations at least 24 hours between sampling times is needed. Depending on the quantity of data collected it may take several hours to process the results and draw conclusions. An ideal situation would be to take learners to a specific ecosystem and stay in residential accommodation so that evenings can be used to follow up on data collected during the day. If an extended time cannot be arranged, the sampling techniques may have to be carried out at different times. There may be organised courses available where the field study instructors are familiar with the species in that ecosystem. Otherwise, learners will need field guides to help identify species and teachers need to be familiar with the area and its species.

Guidance for teachers, *continued*

- As the ecosystems studied will be very different, general principles only are considered here:

  - Learners should be familiar with the use of a transect line and how to decide where to lay a line. The location of the line will usually depend on the purpose of the study. In some ecosystems this may be horizontal, for example across grass land with a footpath or along a beach, parallel to the coast line. In other cases it may be vertical, for example down the side of a slope to study changes with the slope or at right angles to an estuary to study zonation (stratified sampling).

  - Transect lines can laid using a long tape, e.g. 20 m. A transect line can be made from thin rope or cord that is knotted at 1 m intervals.

- The use of transects can be practiced in a class room by giving learners a tape or transect line and asking them to lay it across the class room. It is likely that these will be crossed over each other, so learners should be able to work out that this means some organisms will appear in two places so their numbers may be overestimated. Learners should then be able to suggest that lines should be parallel to each other and equidistant. Learners can then try point sampling by recording every object that touches the transect line at each 1 m interval. Learners need to understand that only objects that touch at that point should be recorded. Using different numbers and coloured shapes to represent species and scattering them on the floor is one way of showing how individual species can be missed.

- Learners should also be familiar with the use of quadrats and how they can be used either as part of a belt transect or for random sampling within an area.

  - Quadrats can be metal or wooden frames and have sides of 0.5 m or 1 m.

  - Some quadrats can also have internal division forming 10 cm squares with the frame. These are useful when estimating abundance.
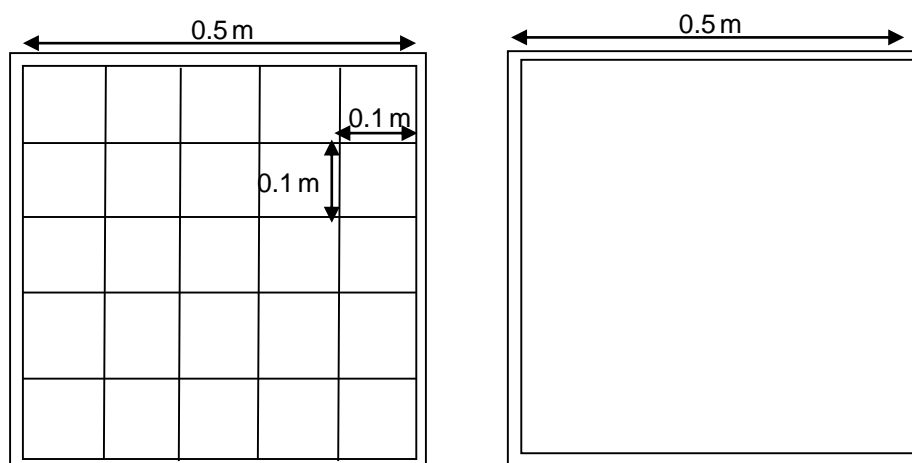
Guidance for teachers, *continued*

- The use of quadrats can also be practiced in the classroom, either with or without a transect line.

  - For random sampling learners can use random number tables, or calculators to generate random numbers. If these are not available then telephone numbers can be used. Learners stand in the middle of the room and use the first random number, e.g. 5, to walk 5 paces in one direction, then the second random number, e.g. 3, to walk 3 paces at right angles to the first direction. For most purposes this is sufficient, but up to 4 numbers can be used, walking in a different direction each time. The quadrat is then placed on the floor with one corner on the random point. The number of each object within the quadrat is counted and recorded. The use of random numbers can also be used to determine where a transect line is to be laid.

  - For systematic sampling the quadrat is placed at 1 m intervals along the transect line. If 1.0 m x 1.0 m quadrats are used, this will give a complete 'belt' along one side of the transect line. If 0.5 m x 0.5 m quadrats are used, there will be gaps. This provides an opportunity to discuss the different ways of using a belt transect and the advantages and disadvantages of each. For example a continuous transect is very time consuming so for a quick survey quadrats may be placed at 2 m intervals. For an extended survey, quadrats may be placed both sides of the transect line.

  - The use of subdivided quadrats for estimating percentage cover can also be demonstrated by learners counting the number of squares occupied by specific objects. This could include a large number of small shapes, e.g. cut out from a hole-punch, to represent abundant species like grasses or paper clips to represent lesser numbers of larger objects. This provides an opportunity to discuss what to do when 'species' overlap, or lie on top of each other.

- If the class room activities are used then learners can be asked to discuss how well the results represent the actual classroom. This should help learners to understand difficulties in getting reliable data about an ecosystem and the need for monitoring at intervals to get a truer picture.

- During a field activity learners should work in groups to make best use of the time and at the end share results. This enables several transects to be studied. Groups of three are the most efficient, one to position quadrats and identify species, one to the count/estimate species cover, one to record the data. Tasks can be rotated. Sampling of the abiotic factors can be taken at the same time, e.g. pH of soil / water, air / soil / water temperature, wind speed, light intensity. Soil and water samples can also be taken for laboratory testing, for example humus content of soil, mineral content of soil or water, biological oxygen demand of water. Kits for environmental sampling are available that have probes and chemical tests that can be carried out in the field.

- Learners should be instructed to collect data that will enable them to look for a correlation between the distribution of a species and an environmental factor. Unless there is plenty of time available it is best to decide before hand which correlations the learners are going to look for. With a large group of learners they could be split into groups and look at more than one correlation. The correlations will depend on the ecosystem being studied. On a slope a possible correlation is water content of soil and the numbers of a specific species of grass. In woodland it could be the percentage cover of leaf litter and the numbers of a detritivores in that ecosystem.

- Learners should also to carry out a chi-squared test. This can be done using data from random quadrats. Two species are chosen and the total numbers of each species in all the quadrats put into a 2 x 2 contingency table. These tables can be used to look for associations between species and for using the formula for the chi-squared test.

Guidance for teachers, *continued*

species **A**	species **B**		
	present	absent	totals
present			
absent			
totals			

- Estimations of animal populations need a least 24 hours between sampling times. It is easier to use a relatively small ground living invertebrate species that are easy to identify and have easy to find habitats. e.g. molluscs, crustacean, ground beetles, millipedes. Winged insects, birds and mammals require special trapping and marking methods. Learners should choose an inconspicuous place to mark the chosen species and a non-toxic marker. This provides an opportunity to discuss what parts of the chosen species is inconspicuous and how it might affect the results if the mark is easily visible. Learners should collect a sample from one area. This can be a randomly determined area of known dimensions e.g. 5 m x 5 m or a particular habitat e.g. under low growing bushes or a hedge. Learners could do this as a separate exercise in a garden or park. A sample of between 50 and 100 organisms are collected and marked. After 24 hours another 50 -100 organisms are collected and the number of marked organisms counted.

- **Safety**. When preparing for a field study, learners need to be aware of hazards which will vary according to the ecosystem studied, e.g. times of tides in coastal regions, steep slopes, marshy or muddy ground, dangerous plants or animals. General safety precautions should be discussed, e.g. not going away from the group, not running, not throwing quadrats. If the ecosystem is in an isolated area then a mobile telephone or radio telephone should be available in case of accidents.

Results

1. During the field study learners need to complete a data collection sheet that shows either distance along a transect line or quadrat number and the number or percentage cover of each species found. Bare soil / ground / rock within the quadrat should also be recorded. The most useful design is:

| species found	distance along transect / m **or** quadrat number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
number	2						1													
% cover																	30	70		

Species can be added as they are found.

Guidance for teachers, *continued*

2. Graphs showing distribution along a transect line can be drawn. The most useful type is a kite graph, particularly for species with a high percentage cover. An arbitrary scale can be used to convert % cover to a number or the 1 mm squares of a grid scaled. e.g.

percentage cover	value / arbitrary units
1-20	1
21-40	2
41-60	3
61-80	4
81-100	5

The independent variable is the distance along the transect line. The dependent variables are the percentage cover of each species, plotted as arbitrary values above and below a major grid line. Kite graphs allow changes in the distribution of species along a transect line to be easily seen.
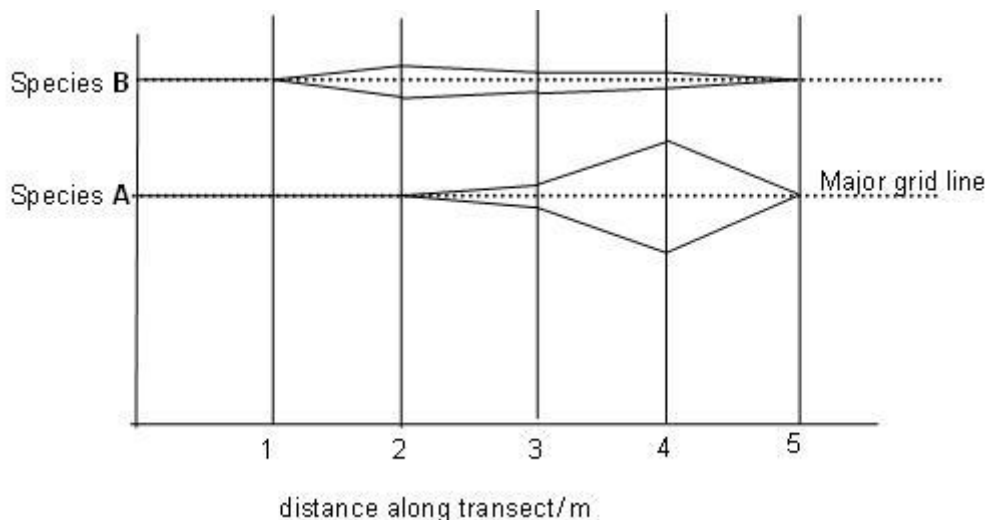
3. Simpsons Index of Diversity can be calculated using the data collected using the formula

$$D = 1 - \left(\Sigma \left(\frac{n}{N} \right)^2 \right)$$

n = number of individuals of each type present in the sample (types may be species and/or higher taxons such as genera, families, etc.)

N = the total number of all individuals of all types

4. Spearman's rank correlation coefficient should be calculated from the data collected for this purpose using the formula:

$$r_s = 1 - \left(\frac{6 \times \Sigma D^2}{n^3 - n} \right)$$

Where n is the number of pairs of items in the sample and D is the difference between each pair of ranked measurements.

Guidance for teachers, *continued*

5. Chi-squared should be carried out using the data collected into contingency tables using the formula:

$$x^2 = \Sigma \frac{(O - E)^2}{E} \qquad v = c - 1$$

6. Associations can also be considered from these tables. e.g.

species **A**	species **B**		
	present	absent	totals
present	80	95	170
absent	105	60	170
totals	185	155	340

- No association is present if the numbers are almost equal in both columns

- Positive association is when there are greater numbers in the present / present column and in the absent / absent column

- Negative association is when there are greater numbers in the present / absent column

7. Population size should be estimated using the Petersen or Lincoln index using mark-release-recapture data using the formula:

$$N = \frac{n_1 \times n_2}{m_2}$$

N = population estimate
$n1$ = number of marked individuals released
$n2$ = number of individuals (both marked and unmarked) captured
$m2$ = number of marked individuals recaptured

If population data is collected from two habitats then chi-squared test can be used to find out if the difference in population size is significant.

Guidance for teachers, *continued*

Interpretation and evaluation

Once all the data has been processed learners should describe and draw conclusions about the ecosystem studied. This should include:

- species diversity

- species distribution in relation to abiotic factors, e.g. light, temperature, pH, and biotic factors, e.g. predators, competition. Any human influences should also be considered, e.g. litter, trampling, fishing, bait collecting

- any correlations or associations between species

- population size.

Learners should also evaluate the methods used for obtaining results and the reliability of their results. Suggestions for improvements should also be made. They should be encouraged to consider the 'snap shot' idea of the results being only on that day at that time, so they may not be valid on another day. To make results more reliable, data has to be collected at different times over a long period of time.

Learners should also think about the accuracy as well as the reliability of the techniques, e.g. misidentification, not noticing rare species, miscounting the number of different species if males and females have different phenotypes, miscounting individual animals that move quickly.

Information for technicians

Each learner will require:

For a land-based field study you may require (depending on ecosystem sampled)

- transect line or tape
- frame quadrat
- clip board with a plastic bag cover if rain is likely
- 3 × recording sheets
- species identification guide
- pooter
- pitfall trap / jam jar and suitable cover to prevent water entry
- tray for hand sorting

For abiotic measurements:

- thermometer or temperature probe
- universal indicator paper or pH probe
- light meter
- 20 small plastic specimen tubes with lids, for soil or water samples
- marker pen

For laboratory measurements of soil water and humus:

- crucibles
- oven or incubator at a temperature of 80 °C. A Bunsen burner, tripod and gauze or heater can be used but care must be taken not to burn the soil.
- Bunsen burner, tripod and gauze or heater table to reach temperatures hot enough to burn soil
- balance

Additional instructions

Optional chemical tests for nitrate, chloride and other mineral ions can be carried out using standard laboratory chemicals. Methods for these tests can be obtained from the internet. Environmental testing kits can be purchased that contain all the equipment need for abiotic testing.

Worksheet

Due to the open-ended nature of this task, no worksheet is provided.