

## ACTIVITY BRIEF

# Distribution and abundance of species

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### The science at work

Ecologists often need to compare where living organisms are found and how many of them there are in these locations. When investigating populations in different areas and over periods of time, they monitor:

- the distribution of organisms (where they are)
- the abundance of organisms (how many there are).

There are many reasons for needing this information. For example, ecologists may wish to control pest species like slugs or locusts, or undertake conservation measures such as improving conditions for endangered species such as the British water vole, or recovering land used for landfill waste disposal.

The techniques used depend on the mobility of the species being monitored. In other words, how free they are to move about.

### Your brief

Ecologists base their work on a number of basic ecological concepts and terminology. Before you start work on this activity, make sure you are familiar with the following list.

Definitions of:

<i>species</i>	<i>niche</i>	<i>habitat</i>	<i>ecosystem</i>
<i>population</i>	<i>community</i>	<i>abundance</i>	<i>distribution</i>

Types of sampling techniques and measurements:

<i>random sampling</i>	<i>systematic sampling</i>	<i>line and belt transects</i>
<i>point and frame quadrats</i>	<i>frequency</i>	<i>percentage cover and density</i>

Test yourself by jotting down definitions and explanations of these terms, giving examples for each.

Swap and check your answers with a partner. You might use textbooks, the Internet (check sources are reliable) or your teacher to cover gaps in your knowledge.

Keep a glossary of terms in your portfolio.

### **Task 1 Non-mobile species**

Techniques used by ecologists to monitor distributions and abundances of non-mobile species can be modelled using a simulation. Use *Practical sheet: Simulating investigations of the distribution and abundance of non-mobile species* to help you learn how to plan and carry out sampling procedures in the field. Non-mobile or slow moving species include plants, seaweeds, anemones or gastropods (slugs, snails, limpets, whelks and so on). Similar methods can also be used for organisms that live in the soil. In this case, organisms are extracted, before being identified and counted.

Using this model, you will have the advantage of knowing the true population. You can investigate the effect of sample size on how close you get to the true value.

### **Task 2 Mobile species**

Investigate the use of the mark-release-recapture technique for mobile species such as beetles, voles, fish in a lake or birds by using another simulation exercise. *Practical sheet: Simulating the mark-release-recapture technique (Lincoln Index) for estimating population sizes of mobile species* will guide you.

This task will help you learn how to plan and carry out a sampling procedure to investigate the abundance of mobile animal species that mix freely with each other in the field. You will use a 'population' of counters, beads, pasta shapes or similar to investigate the effect of sample size on your population estimates.

## PRACTICAL SHEET

# Simulating investigations of the distribution and abundance of non-mobile species

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### The model

You will use randomly printed sheets of paper to set out the positions of individual organisms on a table or bench top. This represents how a species is distributed in its habitat or ecosystem. You can then investigate and compare a variety of sampling techniques, to determine how they can be best applied in the field.

### Total count or sampling?

In some cases, sampling to make estimates of population size is unnecessary. If organisms under investigation are easily visible and/or an area is of limited size and individuals are present in moderate numbers, a total count may be possible. It depends on the species and the area.

For example, all trees species in a small woodland may be identified and counted if the area and numbers are not too great.

On the other hand, even a mobile species like African elephants can be counted over a large, open area from an aircraft. More often, it is impossible or very time-consuming to obtain total counts. In such cases, representative samples are used.

'Representative' means that they reflect the total situation. Your task is to determine how small a sample (and how little work) is necessary to give a true overall picture.

This model can be used to investigate the advantages and disadvantages of a variety of sampling techniques.

### You will need

- pre-printed habitat sheets or computer with Excel, printer and paper
- acetate sheets and permanent acetate pen
- glue stick
- large table or bench top
- scissors
- 30 cm ruler
- metre rules
- string or thread
- *Blu-tack*

### Procedure

- 1 Work in pairs or a small group, according to your teacher's instructions.
- 2 Prepare your simulated habitat.
  - Determine how many A4 sheets of paper you will need to cover the bench or table top that you will use. Either measure and calculate the area or cover the area with A4 sheets.

- Your teacher may provide you with pre-printed simulation sheets. If not, you can prepare and print your own. Co-operate with other groups to print and swap extra sheets, to give you the correct number you need. In these instructions, “click” means use the **left** mouse button. If the **right** mouse button is needed “right click” is used.
  - Open *Excel* and save a blank spreadsheet using a suitable file name.
  - Click cell A1, type: =RANDBETWEEN(0,95) and *enter* (press return key ↵)
  - A randomly generated number between 0 and 95 should appear.[If #NAME? appears, carry out the following steps:
  - Obtain *Tools* menu (click *Tools* at top of screen), click *Add-Ins...*
  - A list of *Add-Ins available* should appear, select *Analysis ToolPak* by clicking the box on the left to give a tick (☑) then clicking the OK button. You may need to restart Excel.

If the *Analysis ToolPak* is not available, you will need to ask your teacher how to generate random numbers another way and add them to your spreadsheet, e.g. using random number tables or a suitable calculator.]

- Click and drag cell A1 down to A25 as follows.
  - Click cell A1 and point the cursor at the small black square (tag) that appears at the bottom right of the cell so that the hollow cross becomes a solid black cross.
  - Hold down the left mouse button and drag down to A25.
  - Release the mouse button, a column of 25 random numbers should appear.
- Click and drag the highlighted column over to column B (using the tag at the bottom as before), a second column of 25 random numbers should appear.
- The pairs of random numbers can now be used as random coordinates for points in a scattergram. These will be used to map the positions of the species in your simulated habitats:
  - With the two columns highlighted (if necessary, click and drag cursor from one corner to the opposing corner, e.g. B25 to A1), click the chart wizard icon (coloured bars) at the top of the screen (or use *Insert* and *Chart* from drop down menu).
  - Step 1: in *Chart type*, click *XY(Scatter)* and double click the image of a chart with points and no lines in *Chart sub-type* (or click once to highlight and then click *Next*).
  - Step 2: check that *Columns* is selected (dot in circle) and click *Next*.
  - Step 3: select each option in turn
    - *Titles*, leave boxes blank
    - *Axes*, click to remove ticks from *Value* boxes (removes numbers from axes)
    - *Gridlines*, click to remove tick from *Major gridlines* (and any others)
    - *Legend*, click to remove tick from *Show legend*
    - When chart contains only markers for plots, click *Next*
  - Step 4: Check that *As object in* is selected (dot in circle) then click *Finish*. The chart will appear on the spreadsheet page.

- Right click *twice* on the chart (not on a data point) to obtain a border round the chart; a menu will appear.
  - Select *Format Plot Area* (click).
  - In the box that appears, select *None* for **both** *Border* and *Area* (click to obtain black dot on circles), then click *OK* button. The shading on the chart should have been removed.
  - *Optional* : you can replace the data markers with pictures using *Copy* and *Paste*. For example, open a *Word* document and use *Insert, Picture, Clip Art, Search* to obtain a suitable image. In this case you could use 'dandelions' to create a simulated lawn or field. Click the image, then click and drag a corner tag to reduce the picture to a small size. Try going to the smallest size then increase to next size up. *Copy* to the clipboard, click on a data point on the chart so that some are highlighted, then *Paste* to a data point on the chart. Click *Print preview* (icon with rectangle and magnifying glass or use *File* menu) to check the size of your pictures.
    - If not all of the data points change to pictures, repeat the highlighting and pasting process using another data point.
    - If the size of the image is not appropriate, go back to the Word document and resize, then recopy and re-paste your picture.
  - If you use the existing markers, you need to increase their size. Right click (may need two clicks) on a data point; some of the points should be highlighted and a menu will appear. Select *Format Data Series* (click) and in the *Patterns* menu *Marker* box, increase the *Size* to 36 (you can also change *Style* if you wish) and click *OK*.
  - Finally, reset the chart margins: go to *Print preview* (icon with rectangle and magnifying glass or use *File* menu) then use *Setup* in *Margins* to set *Top* and *Right* to 1.5 and all other boxes to 0.
  - Still in *Print preview*, you can now print your habitat by using the print button at the top of the screen. Print one for yourself and for any other groups you are sharing with.
  - Close the print preview and *Save* .
  - Create and print as many other model sheets as you need. You can change the random distribution of the 'organisms' by clicking on any empty cell, then using the delete key. Each time you do this, the columns of random co-ordinates and the chart will automatically change to give you a new distribution of the species. Click the chart to be able to print it separately from the spreadsheet.
  - Set out the sheets to cover your table or bench top, using glue to stick the blank top and right hand sides under neighbouring sheets. If necessary, cut away any excess. You now have a simulation of the distribution of a species in its habitat, e.g. dandelions in a field.
- 3 Now try out a variety of sampling techniques. You can use points or grids drawn on acetate and rulers and pieces of string to model the point and frame quadrats, tape measures and ropes that you would use in the field. Your teacher will give you guidance about which ones to try.

## **For discussion**

Discuss and make some notes on the following:

- When should you measure:
  - frequency?
  - percentage cover?
  - density?
  
- When should you use:
  - random or systematic sampling?
  - point or frame quadrats?
  - transects?
  - line or belt transects?
  - continuous or interrupted belt transects?
  
- How can you find out:
  - what size sample to use?
  - what size quadrat to use?
  - the total population of a species in the habitat under consideration?

## PRACTICAL SHEET

# Simulating the mark–release–recapture technique (Lincoln Index) for estimating population sizes of mobile species

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### The model

With this simulation you learn how to plan and carry out a sampling procedure to investigate the abundance of mobile animal species that mix freely with each other in the field. You will use a 'population' of counters, beads, pasta shapes or similar to investigate the effect of sample size on your population estimates.

Using this model, you will have the advantage of knowing the true population. You can investigate the effect of sample size on how close you get to the true value.

### Total count or sampling?

In some cases, sampling to make estimates of population size is unnecessary. If organisms under investigation are easily visible and/or an area is of limited size and individuals are present in moderate numbers, a total count may be possible. It depends on the species and the area. For example, African elephants can be counted over a large, open area from an aircraft. Sometimes organisms are contained in an area and can be captured and counted. Fish in a stream may be electrically stunned, then netted when they float on the surface. After identification and counting, they recover rapidly and are returned to the water. More often, it is impossible to find or capture all the organisms or to cover the whole of a large area.

### You will need

- small objects for counting, e.g. plastic counters, beads, pasta shapes, polystyrene packing shapes, dried peas or beans (to give 400-500 shapes)
- two cardboard boxes, plastic trays or beakers (large enough to hold the shapes and to be able to mix them up freely)
- permanent marking pen (or second set of coloured or marked shapes)

### Procedure

Work in pairs or a small group, according to your teacher's instructions.

- 1 Pour the shapes into the container. You are going to estimate the total number by 'capture-mark-recapture' method (also called the Lincoln Index after the person who popularised the method).
- 2 Copy the table on the next page to record your results.

Trial	Capture sample, S1	Second sample, S2	Recaptured (previously marked), R	Population estimate, P
1	10	10		
2	25	25		
3	50	50		
4	100	100		
5	200	200		

- 3 Remove 10 shapes. This is the capture sample.
- 4 Mark them clearly with the pen. (Alternatively, replace them with similar shapes of a different colour.)
- 5 Replace the marked sample into the population in the container. Mix them thoroughly.
- 6 Remove a second sample of 10 shapes at random (put your hand in the container and remove them without looking at them). You may recapture some marked shapes in this sample. Record this number in your table.
- 7 Replace the marked shapes in the container.
- 8 Mark 15 more unmarked shapes and mix them in. (You now have 25 marked shapes mixed in the population)
- 9 Remove another second sample, this time of 25 shapes.
- 10 Record the number of recaptured marked shapes.
- 11 Continue to complete the table by adding new marked shapes and removing samples for sample sizes of 50, 100 and 200.
- 12 Now count and record the number of shapes, so that you know the *true* population size. At the same time, separate the marked and unmarked shapes, so they can be used again.
- 13 Calculate the population estimates for each of your samples.

The method assumes that marked animals mix completely freely with the rest of the population, so that they are completely evenly distributed. This means that the fraction of marked animals in the total population should be the same as the fraction found in any sample.

For example, if 50 animals are captured and marked from a population of 500 you would expect 50/500 or 1 in 10 of any sample to be marked, i.e. 5 in a sample of 50. The ratio of animals marked in Sample 1 (S1) to the total population (P) is the same as the ratio of recaptured marked animals (R) to Sample 2 (S2):

$$\frac{S1}{P} = \frac{R}{S2} \quad \text{therefore, } P = \frac{(S1 \times S2)}{R}$$

In our example, if you found 1 in 10 marked animals in a second sample of 50,

$$S1 = 50 \text{ and } P = \frac{50 \times 50}{5} = 500$$



- 14 Calculate the population estimates to complete your table. Plot a graph of population estimate against sample size. Add a horizontal line to show the true population, to see how sample size can affect the validity of the population estimate.
- 15 If time permits, repeat some of the sample sizes and plot the new results on your graph.
- 16 Make a note of the conclusions that you can draw from this investigation.

### **For discussion**

Discuss and make some notes on the following:

- When you carry out an investigation in the field, what will determine the size of the samples you use? (Think about different animals that you may be investigating).
- How can you decide that you have a good enough estimate of a population size?

### **Further work**

Find out about trapping and capture techniques, so that you are able to plan the investigation of a particular type of area to suit the types of animals that you might be investigating.

## Teacher notes

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### Overview

- *Practical sheet: Simulating investigations of the distribution and abundance of non-mobile species*

This sets out a method for using Excel to generate printed sheets with markers that can be used to build a table-top simulation of the distribution of non-mobile organisms such as dandelions in a field.

Images (including photographs) can be used instead of the normal Excel markers.

The simulated small scale classroom habitats can be used to teach or try out a variety of sampling methods before students use them in the field. Large amounts of data for analysis can be generated quickly and easily.

- *Practical sheet: Simulating the mark–release–recapture technique (Lincoln Index) for estimating population sizes of mobile species*

This provides a simple and rapid simulation of the use of the Lincoln Index to estimate populations of mobile organisms such as fish, insects, gastropods, amphibians and birds.

### Aims

Students use sampling techniques to determine the distribution and abundance of organisms in a simulated habitat. They should be able to:

- gain an appreciation of the use of transects to establish variation in the pattern of the distribution of species in an area
- recognise that abundance estimates in evenly spread populations can most easily be determined using relatively few large quadrats
- understand that smaller quadrats can be used more effectively for species that show aggregated distribution, by covering a wide area rapidly
- design and carry out an investigation to determine the distribution and abundance of selected species in an ecosystem
- justify the choice of sampling techniques and sample sizes used in an ecological investigation
- evaluate the techniques used, the data obtained and the conclusions formed in an ecological investigation.

### Related specification requirements

#### OCR Unit 14: Ecology and managing the environment

Relevant sections from the unit specification include:

##### *14.2 WHAT YOU NEED TO LEARN*

*You need to learn about:*

- *investigating ecosystems*

#### *14.2.1 Investigation of Ecosystems*

*You need to examine the range of methods ecologists use and apply them in a selected ecosystem to carry out a detailed study. You then need to use your findings to try to explain the relationships between the organisms and their physical environment.*

*When measuring the distribution of organisms making up the biological environment, it is not usually practical to count every organism in an ecosystem, so ecologists use sampling techniques.*

*You need to:*

- *describe the methods available to measure the distribution of organisms using appropriate sampling techniques (quadrats, sampling randomly and along a line or belt transect) and counting methods (species density, species cover) throughout the ecosystem studied*
- *relate the suitability of the methods used to collect data to the particular habitat and the organisms being studied*
- *evaluate the validity of the data based on the monitoring methods used*

#### *14.4.1 Guidance on delivery*

*This unit focuses on the principles of ecology – the relationships of organisms with their biological and physical environment. Candidates use a range of ecological methods to examine and make measurements of one ecosystem in detail and apply these principles to their findings. It is suggested that candidates review and practise the techniques available before carrying out the study.*

#### ***Investigating ecosystems***

*The investigation of the ecosystem comprises the major part of this sub-section, but it is essential for candidates to examine all the techniques available to the ecologist for making measurements within ecosystems before they can plan and carry out their investigation. The investigation itself, and the subsequent analysis, needs to comprise just over one third of the allotted time for this unit. With preliminary work it will comprise around half the unit in total.*

**Note:** these extracts need to be placed into the context of the unit as a whole.

### **AQA Unit 16: Ecology, conservation and recycling**

Relevant sections from the unit specification include:

*In this unit you will learn about:*

*Conducting an ecological survey and how to estimate the distribution and/or number of organisms in a habitat*

*Your portfolio of evidence should comprise:*

*A. details of an ecological survey, including food chains, food webs and energy flow within a chosen habitat including:*

- *an account of research undertaken in relation to the ecological survey. This will include a explanation of techniques which could be used*
- *the use of a suitable sampling technique, to estimate the distribution and/or numbers of organisms and use this information to estimate population size*

**Note:** these extracts need to be placed into the context of the unit as a whole.

## **Practical sheet: Simulating investigations of the distribution and abundance of non-mobile species**

### **Using the 'field' simulations**

A model of a habitat and the distribution of a non-mobile species can be constructed using the simulation sheets printed using Excel spreadsheets. Bench or table tops can be cleared and sufficient sheets printed to cover the entire area. The sheets are designed to overlap and so can be glued together. The perimeter edges may be trimmed to fit or to form more interesting shaped boundaries. Students can use string for line transects and acetate marked with points or squares can be used to simulate the use of point and frame quadrats. Random and systematic sampling and the effects of varying sample size and quadrat size can be investigated. Students should be given guidance on what to investigate according to the specific needs of any proposed field work.

Students can be given the task of creating their own spreadsheets, or pre-printed sheets can be prepared in advance for them to use. If time permits, generation of their own spreadsheets allows them to explore the use of Excel in greater depth than may normally be possible for those not following IT courses.

Two ready-for-use Excel spreadsheets:

- *Distribution of dandelions*
- *Distribution of dandelions (less dense)*

are provided on the CD ROM. *Distribution of dandelions* will give dandelions at a density of 25 plants per A4 sheet. *Distribution of dandelions (less dense)* will give dandelions at a density of 10 plants per A4 sheet (occasionally fewer when random plots coincide). These densities can be altered by deleting cells or clicking and dragging to add more cells.

Note: In the interests of economy, the A4 shape has been retained for the charting to reduce the waste of paper. As the sheets are rectangular rather than square, the distributions occur more densely along the shorter axis than along the longer axis. This will affect population estimates obtained either using transects in these opposing directions, or if random quadrats are laid out over a rectangular area. This should not be a problem for the purposes of teaching the techniques. If more comprehensive data or detailed analysis are desired, this can be avoided if the charts are made square (equal axes) before printing.

Comparison of measurements to find frequency, percentage cover and density of, e.g. 'dandelions' may be carried out using an area made solely from sheets of the first type. Randomly interspersed sheets of the second type can be used to give an area with less evenly distributed plants.

A scale should be decided on to relate distances and quadrat sizes to real measurements. These could be based on the area of the model and any area that might be investigated (such as a school sports field). The size of the 'dandelions' in the spreadsheets can be altered to be more realistic, but this is not essential and students can be asked to discuss the limitations of the model.

Point frame simulation can be achieved by simply using a line of 10 evenly spaced dots on a piece of acetate. These can be scaled to be at '5 cm' intervals on a '50 cm' line. Frame quadrats can be scaled to and chosen from '10 cm', '25 cm', '50 cm' and '1m' sides and may have 'cross wires' for estimating percentage cover.

Plots of cumulative means at 5 sample intervals can be used to show the effect of sample size on the consistency of abundance estimates. Curves should plateau out and a rough estimate of the reliability of the measurement can be made by determining the limits within which the estimate varies for a given range of sample sizes. A decision can be made concerning the smallest sample size (and therefore time expended) to give the precision needed for the study (e.g. plants  $\text{m}^{-2} \pm 5\%$ ).

Students should be able to gain an appreciation of the use of transects to establish variation in the pattern of distribution of species in an area. They should be able to recognise that abundance estimates in evenly spread populations can most easily be determined using relatively few large quadrats, but that a larger number of small quadrats can be used to cover a wider area more rapidly, if it is necessary to account for variation in distribution.

### Other habitat simulations

Three other Excel spreadsheets that can be used for other activities are also provided on the CD ROM:

- *Distribution of daisies*
- *Distribution of daisies and dandelions*
- *Distribution of brown seaweeds*

These can be modified or adapted for a variety of uses. In particular, the daisy distribution is designed to mimic the clumping and difficulty of distinguishing individual plants found in real life and the seaweed distribution models zonation found on a rocky shore. The former provides an example where the use of frequency or percentage cover has an advantage over density as a measure of abundance. The latter can be used to introduce the use of transects to reveal zonation and to generate data for construction of a kite diagram. One sheet is enough to explore this. If multiple sheets are used, they must be placed side by side. The chart can be modified to include the gridlines before printing, which can then be used as belt transects. (Major and minor gridlines may be added to other sheets as an alternative method for investing sampling and sample sizes).

The combined distribution of daisies and dandelions can be used to investigate whether the two species tend to occur together (i.e. show a positive or negative association). Additional sheets with only daisies or dandelions could be created and interspersed with these by deleting columns A and B (for dandelions) or B and C for daisies.

Note: The spreadsheets require the use of the RANDBETWEEN function. If #NAME? appears, carry out the following steps:

- Obtain *Tools* menu (click *T*ools at top of screen), click *Add-Ins...*
- A list of *Add-Ins available* should appear, select *Analysis ToolPak* by clicking the box on the left to give a tick () then clicking the *OK* button. You may need to restart Excel.

If the *Analysis ToolPak* is not available, it will be necessary to generate random numbers another way and add them to the spreadsheets, e.g. using random number tables or a suitable calculator.

The spreadsheets can be used to create and print as many different model sheets as you need. You can change the random distribution of the 'organisms' by clicking on an empty cell, then using the delete key. Each time you do this, the columns of random co-ordinates

and the chart will automatically change to give you a new distribution of the species. Click on the chart to be able to print it separately from the spreadsheet.

### **Practical sheet: Simulating the mark–release–recapture technique (Lincoln Index) for estimating population sizes of mobile species**

The practical sheet gives instructions for a simulation mixing shapes in a container, such as beads in a large plastic beaker. A wide variety of objects can be used, including beads, pasta shapes and polystyrene packaging shapes. A permanent marker or different coloured shapes can be used (to be substituted as marked 'animals'). An alternative method could use packs of cards which can be shuffled to mix (e.g. substitute *clubs* as 'marked' *spades*). This simulation explores the effect of changing sample size on the population estimate obtained. It therefore allows students to practise the calculation and consider factors affecting the design of a real investigation. Remember to ensure that students sort marked from unmarked, if shapes are to be reused.

Students are asked to plot graphs of population size against sample size and to discuss practical issues associated with using the technique.

Follow-up work can be related to potential investigations and consider capture and marking techniques relevant to actual species that may be sampled.

### **General comments**

The timing of ecological units depends on the fieldwork investigations planned and the occurrence of the organisms to be studied. Much work can be carried out throughout the year, for example on the distribution of dandelions and daisies on a school sports field or of brown seaweeds on a rocky shore. Although conditions for working outdoors may be unpleasant at any time in the UK, the chances of more extreme weather increase during and close to the winter months. The abundance of many species also increases during the warmer months. This makes it a better time for, for example, freshwater studies. Hence, there is more flexibility if the work is undertaken at the very beginning of the second year, but it may be possible to start work in the period following the summer examination series of the first year. The units also offer the ideal opportunity for residential trips, both at home and abroad.

These simulations offer the opportunity for students to become familiar with sampling techniques that can be used to investigate the distribution and abundance of organisms, before applying the techniques in the field. They are offered as techniques which can be used in a variety of ways depending on the needs of the students concerned, i.e. the specification and the ecosystem and species to be investigated.

For the 'field' simulation for non-mobile species, enough data and ideas can be generated in a double session (1-2 hours) with a follow-up discussion in a single session (30 minutes – 1 hour). A longer double session or an additional single period will be necessary if students use Excel to print their own sheets. This is a good exercise to develop skills in the use of Excel, which may be used later in the writing up of their ecology investigation and for any project work that they may undertake. Students can be asked to prepare ideas and charts for the follow up discussion in their own time. The capture-mark-recapture exercise can be completed and discussed in a double session.

More class time may be spent on this work if students are aiming for higher grades and need to develop concepts to be able to meet requirements for justifying and evaluating their work.