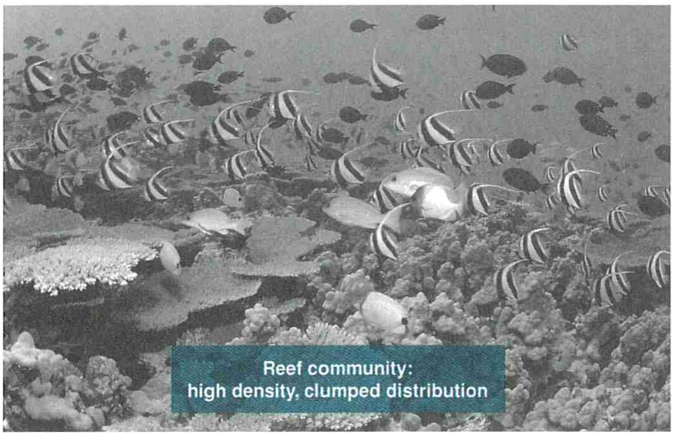
Sampling Populations

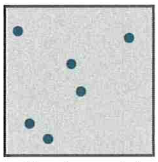
In most ecological studies, it is not possible to measure or count all the members of a population. Instead, information is obtained through **sampling** in a manner that provides a fair (unbiased) representation of the organisms present and their distribution. This is usually achieved through **random sampling**, a technique in which every possible sample of a given size has the same chance of selection. Most practical exercises in community ecology involve the collection or census of living organisms, with a view to identifying the species and quantifying their abundance and other population features of interest. Sampling techniques must be appropriate to the community being studied and the information you wish to obtain. Any field study must also consider the time and equipment available, the organisms involved, and the impact of the sampling method on the environment. Often indicator species and **species diversity indices** are used as a way of quantifying biodiversity and ecosystem "health". Such indicators can be particularly useful when monitoring ecosystem change and looking for causative factors in species loss.

Quantifying the Diversity of Ecosystems

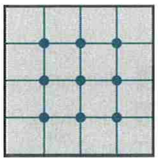


Reef community:
high density, clumped distribution

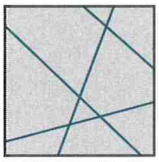
The methods we use to sample communities and their constituent populations must be appropriate to the ecosystem being investigated. Communities in which the populations are at low density and have a random or clumped distribution will require a different sampling strategy to those where the populations are uniformly distributed and at higher density. There are many sampling options, each with advantages and drawbacks for particular communities. How would you assess aspects (e.g. species richness, abundance, or distribution) of the reef community above?



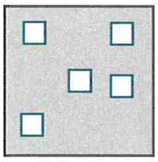
Random point sampling



Point sampling: systematic grid



Line and belt transects



Random quadrats

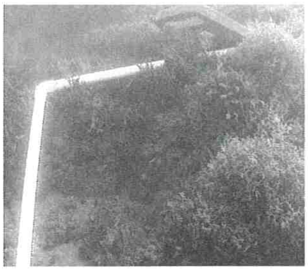
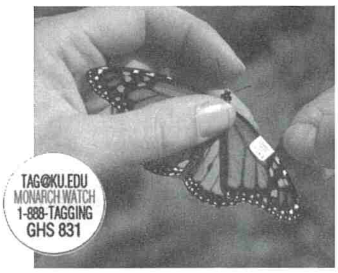


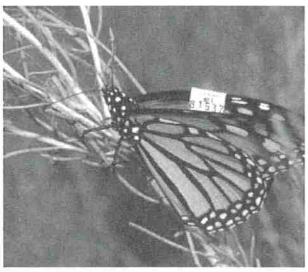
Photo: www.coastal planning.net

Marine ecologists use quadrat sampling to estimate biodiversity prior to works such as dredging.

RA

Line transects are appropriate to estimate biodiversity along an environmental gradient.





Tagging has been used for more than 30 years to follow the migration of monarch butterflies. The photograph here depicts an older tagging method, which has largely been replaced by a tag on the underside of the hindwing (inset). The newer method results in better survival and recapture rates and interferes less with flight.

Which Sampling Method?

Field biologists take a number of factors into consideration when deciding on a sampling method for a chosen population or community. The benefits and drawbacks of some common methods are outlined below:

Point sampling is time efficient and good for determining species abundance and community composition. However, organisms in low abundance may be missed.

Transects are well suited to determining changes in community composition along an environmental gradient but can be time consuming to do well.

Quadrats are also good for assessments of community diversity and composition but are largely restricted to plants and immobile animals. Quadrat size must also be appropriate for the organisms being sampled.

Mark and recapture is useful for highly mobile species which are otherwise difficult to record. However, it is time consuming to do well. **Radiotracking** offers an alternative to mark and recapture and is now widely used in conservation to study the movements of both threatened species and pests.

Sensors and Measures

Various meters can be used to quantify aspects of the physical environment, including the pH, temperature, light levels, and turbidity. Meters that measure single factors have now largely been replaced by multi-purpose meters.

Total dissolved solids (TDS) meter: Measures the content of dissolved solids (as ions) in water in mgL^{-1} giving an indication of water quality. The probe measures the conductivity of the water to approximate the level of TDS. TDS can also be measured gravimetrically by evaporating a sample leaving the residue behind.

Quantum light meter: Measures light intensity levels but not light quality (wavelength). Light levels can change dramatically from a forest floor to its canopy. A light meter provides a quantitative measure of these changes, many of which are not detectable with our own visual systems.

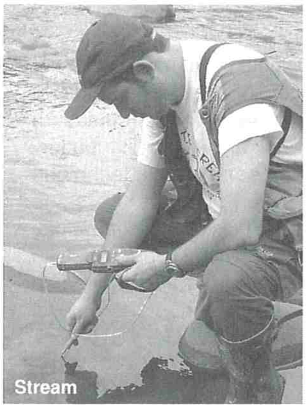
All photos: Campus photography University of Waikato

Dissolved oxygen meter: This measures the amount of oxygen dissolved in water (as mgL^{-1}), which gives and indication of water quality and suitability to support organisms such as fish. The **Winkler** method uses a titration of $MnSO_4$, KI, and $K_2S_2O_3$ to determine the concentration of O_2.

Using Dataloggers in Field Studies

Usually, when we collect information about populations in the field, we also collect information about the physical environment. This provides important information about the local habitat and can be useful in assessing habitat preference. With the advent of **dataloggers**, collecting this information is straightforward.

Dataloggers are electronic instruments that record measurements over time. They are equipped with a microprocessor, data storage facility, and sensor. Different sensors are used to measure a range of variables in water or air. The datalogger is connected to a computer, and software is used to set the limits of operation (e.g. the sampling interval) and initiate the logger. The logger is then disconnected and used remotely to record and store data. When reconnected to the computer, the data are downloaded, viewed, and plotted. Dataloggers make data collection quick and accurate, and they enable prompt data analysis.



Datalogger photos courtesy of PASCO

Dataloggers fitted with sensors are portable and easy to use in a wide range of aquatic (left) and terrestrial (right) environments. Different variables can be measured by changing the sensor attached to the logger.

1. Explain why we **sample** populations: ______________________

2. Describe a sampling technique that would be appropriate for determining each of the following:

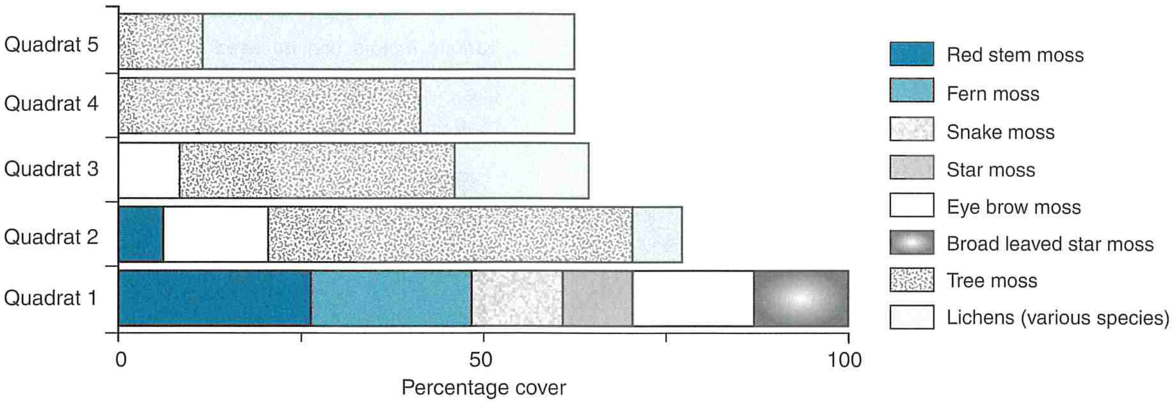
   (a) The percentage cover of a plant species in pasture: ______________________

   (b) The density and age structure of a plankton population: ______________________

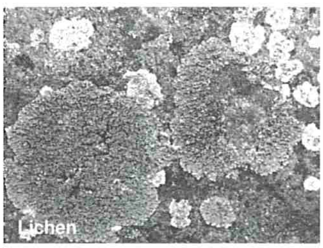
   (c) Change in community composition from low to high altitude on a mountain: ______________________

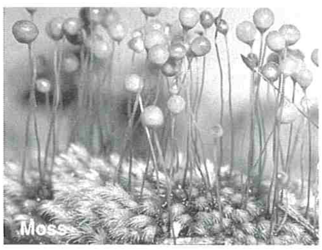
3. Explain why it is common practice to also collect information about the physical environment when sampling populations:

____



QUADRAT	1	2	3	4	5
Height / m	0.4	0.8	1.2	1.6	2.0
Light / arbitrary units	40	56	68	72	72
Humidity / percent	99	88	80	76	78
Temperature / °C	12.1	12.2	13	14.3	14.2





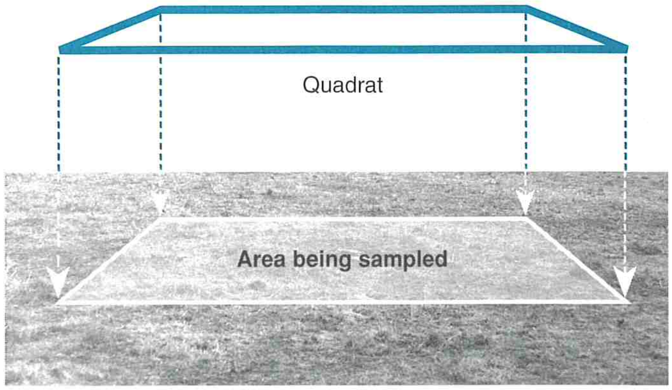
4. The figure (above) shows the changes in vegetation cover along a 2 m vertical transect up the trunk of an oak tree (*Quercus*). Changes in the physical factors light, humidity, and temperature along the same transect were also recorded. From what you know about the ecology of mosses and lichens, account for the observed vegetation distribution:

____

Quadrat Sampling

Quadrat sampling is a method by which organisms in a certain proportion (sample) of the habitat are counted directly. As with all sampling methods, it is used to estimate population parameters when the organisms present are too numerous to count in total. It can be used to estimate population **abundance** (number), **density**, **frequency of occurrence**, and **distribution**. Quadrats may be used without a transect when studying a relatively uniform habitat. In this case, the quadrat positions are chosen randomly using a random number table.

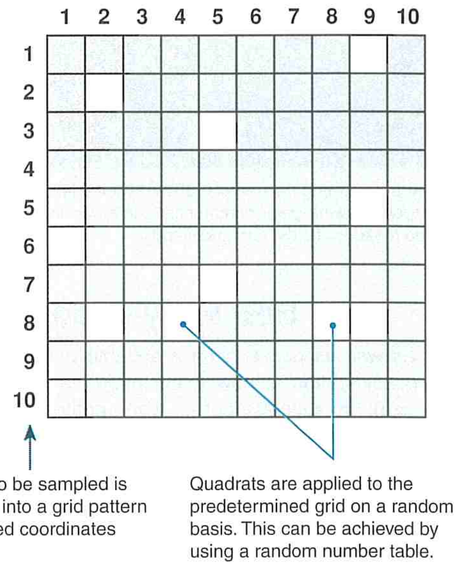
The general procedure is to count all the individuals (or estimate their percentage cover) in a number of quadrats of known size and to use this information to work out the abundance or percentage cover value for the whole area. The number of quadrats used and their size should be appropriate to the type of organism involved (e.g. grass vs tree).



$$\text{Estimated average density} = \frac{\text{Total number of individuals counted}}{\text{Number of quadrats} \times \text{area of each quadrat}}$$

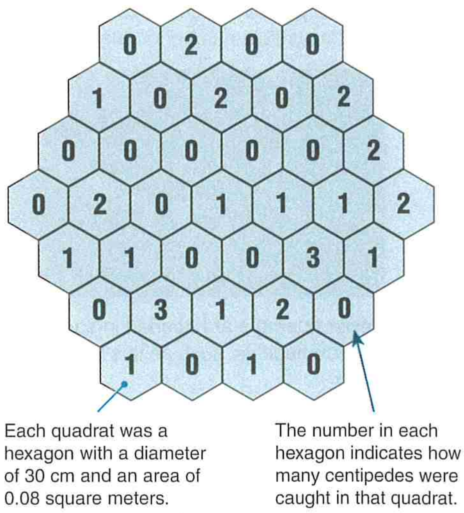
Guidelines for Quadrat Use:

1. The **area of each quadrat** must be known exactly and ideally quadrats should be the same shape. The quadrat does not have to be square (it may be rectangular, hexagonal etc.).
2. **Enough quadrat samples** must be taken to provide results that are representative of the total population.
3. The **population of each quadrat** must be known exactly. Species must be distinguishable from each other, even if they have to be identified at a later date. It has to be decided beforehand what the count procedure will be and how organisms over the quadrat boundary will be counted.
4. The size of the quadrat should be appropriate to the organisms and habitat, e.g. a large size quadrat for trees.
5. The quadrats must be **representative of the whole area**. This is usually achieved by **random sampling** (right).



Sampling a centipede population

A researcher by the name of Lloyd (1967) sampled centipedes in Wytham Woods, near Oxford in England. A total of 37 hexagon–shaped quadrats were used, each with a diameter of 30 cm (see diagram on right). These were arranged in a pattern so that they were all touching each other. Use the data in the diagram to answer the following questions.



1. Determine the average number of centipedes captured per quadrat:

____

2. Calculate the estimated average density of centipedes per square meter (remember that each quadrat is 0.08 square meters in area):

____

3. Looking at the data for individual quadrats, describe in general terms the distribution of the centipedes in the sample area:

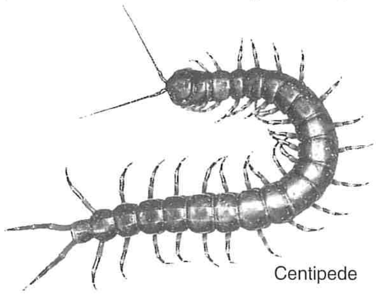
____

____

4. Describe one factor that might account for the distribution pattern:

____

____



Quadrat-Based Estimates

The simplest description of a plant community in a habitat is a list of the species that are present. This qualitative assessment of the community has the limitation of not providing any information about the **relative abundance** of the species present. Quick estimates can be made using **abundance scales**, such as the ACFOR scale described below. Estimates of percentage cover provide similar information. These methods require the use of **quadrats**. Quadrats are used extensively in plant ecology. This activity outlines some of the common considerations when using quadrats to sample plant communities.

What Size Quadrat?

Quadrats are usually square, and cover 0.25 m^2 (0.5 m x 0.5 m) or 1 m^2, but they can be of any size or shape, even a single point. The quadrats used to sample plant communities are often 0.25 m^2. This size is ideal for low-growing vegetation, but quadrat size needs to be adjusted to habitat type. The quadrat must be large enough to be representative of the community, but not so large as to take a very long time to use.

A quadrat covering an area of 0.25 m^2 is suitable for most low growing plant communities, such as this alpine meadow, fields, and grasslands.

Larger quadrats (e.g. 1 m^2) are needed for communities with shrubs and trees. Quadrats as large as 4 m x 4 m may be needed in woodlands.

Small quadrats (0.01 m^2 or 100 mm x 100 mm) are appropriate for lichens and mosses on rock faces and tree trunks.

How Many Quadrats?

As well as deciding on a suitable quadrat size, the other consideration is how many quadrats to take (the sample size). In species-poor or very homogeneous habitats, a small number of quadrats will be sufficient. In species-rich or heterogeneous habitats, more quadrats will be needed to ensure that all species are represented adequately.

Determining the number of quadrats needed

- Plot the cumulative number of species recorded (on the *y* axis) against the number of quadrats already taken (on the *x* axis).
- The point at which the curve levels off indicates the suitable number of quadrats required.

Fewer quadrats are needed in species-poor or very uniform habitats, such as this bluebell woodland.

Describing Vegetation

Density (number of individuals per unit area) is a useful measure of abundance for animal populations, but can be problematic in plant communities where it can be difficult to determine where one plant ends and another begins. For this reason, plant abundance is often assessed using **percentage cover**. Here, the percentage of each quadrat covered by each species is recorded, either as a numerical value or using an abundance scale such as the ACFOR scale.

The ACFOR Abundance Scale

A = Abundant (30% +)

C = Common (20-29%)

F = Frequent (10-19%)

O = Occasional (5-9%)

R = Rare (1-4%)

The ACFOR scale could be used to assess the abundance of species in this wildflower meadow. Abundance scales are subjective, but it is not difficult to determine which abundance category each species falls into.

1. Describe one difference between the methods used to assess species abundance in plant and in animal communities:

____

2. Identify the main consideration when determining appropriate quadrat size: _______________

3. Identify the main consideration when determining number of quadrats: _______________

4. Explain two main disadvantages of using the ACFOR abundance scale to record information about a plant community:

(a) _______________

(b) _______________

Sampling a Leaf Litter Population

The diagram on the following page represents an area of leaf litter from a forest floor with a resident population of organisms. The distribution of four animal species as well as the arrangement of leaf litter is illustrated. Leaf litter comprises leaves and debris that have dropped off trees to form a layer of detritus. This exercise is designed to practice the steps required in planning and carrying out a sampling of a natural population. It is desirable, but not essential, that students work in groups of 2–4.

1. Decide on the sampling method

For the purpose of this exercise, it has been decided that the populations to be investigated are too large to be counted directly and a quadrat sampling method is to be used to estimate the average density of the four animal species as well as that of the leaf litter.

2. Mark out a grid pattern

Use a ruler to mark out 3 cm intervals along each side of the sampling area (area of quadrat = 0.03 x 0.03 m). **Draw lines** between these marks to create a 6 x 6 grid pattern (total area = 0.18 x 0.18 m). This will provide a total of 36 quadrats that can be investigated.

3. Number the axes of the grid

Only a small proportion of the possible quadrat positions are going to be sampled. It is necessary to select the quadrats in a random manner. It is not sufficient to simply guess or choose your own on a 'gut feeling'. The best way to choose the quadrats randomly is to create a numbering system for the grid pattern and then select the quadrats from a random number table. Starting at the *top left hand corner*, **number the columns** and **rows** from 1 to 6 on each axis.

4. Choose quadrats randomly

To select the required number of quadrats randomly, use random numbers from a random number table. The random numbers are used as an index to the grid coordinates. Choose 6 quadrats from the total of 36 using table of random numbers provided for you at the bottom of the next page. Make a note of which column of random numbers you choose. Each member of your group should choose a different set of random numbers (i.e. different column: A–D) so that you can compare the effectiveness of the sampling method.

Column of random numbers chosen: ______

NOTE: Highlight the boundary of each selected quadrat with coloured pen/highlighter.

5. Decide on the counting criteria

Before the counting of the individuals for each species is carried out, the criteria for counting need to be established.

There may be some problems here. You must decide before sampling begins as to what to do about individuals that are only partly inside the quadrat. Possible answers include:

(a) Only counting individuals if they are completely inside the quadrat.

(b) Only counting individuals that have a clearly defined part of their body inside the quadrat (such as the head).

(c) Allowing for 'half individuals' in the data (e.g. 3.5 snails).

(d) Counting an individual that is inside the quadrat by half or more as one complete individual.

Discuss the merits and problems of the suggestions above with other members of the class (or group). You may even have counting criteria of your own. Think about other factors that could cause problems with your counting.

6. Carry out the sampling

Carefully examine each selected quadrat and **count the number of individuals** of each species present. Record your data in the spaces provided on the following page.

7. Calculate the population density

Use the combined data TOTALS for the sampled quadrats to estimate the average density for each species by using the formula:

$$\textbf{Density} = \frac{\textbf{Total number in all quadrats sampled}}{\textbf{Number of quadrats sampled} \times \textbf{area of a quadrat}}$$

Remember that a total of 6 quadrats are sampled and each has an area of 0.0009 m^2. The density should be expressed as the number of individuals *per square meter (no. m^{-2})*.

Woodlouse: [ ] False scorpion: [ ]

Centipede: [ ] Leaf: [ ]

Springtail: [ ]

8. (a) In this example the animals are not moving. Describe the problems associated with sampling moving organisms. Explain how you would cope with sampling these same animals if they were really alive and very active:

______

______

______

(b) Carry out a direct count of all 4 animal species and the leaf litter for the whole sample area (all 36 quadrats). Apply the data from your direct count to the equation given in (7) above to calculate the actual population density (remember that the number of quadrats in this case = 36):

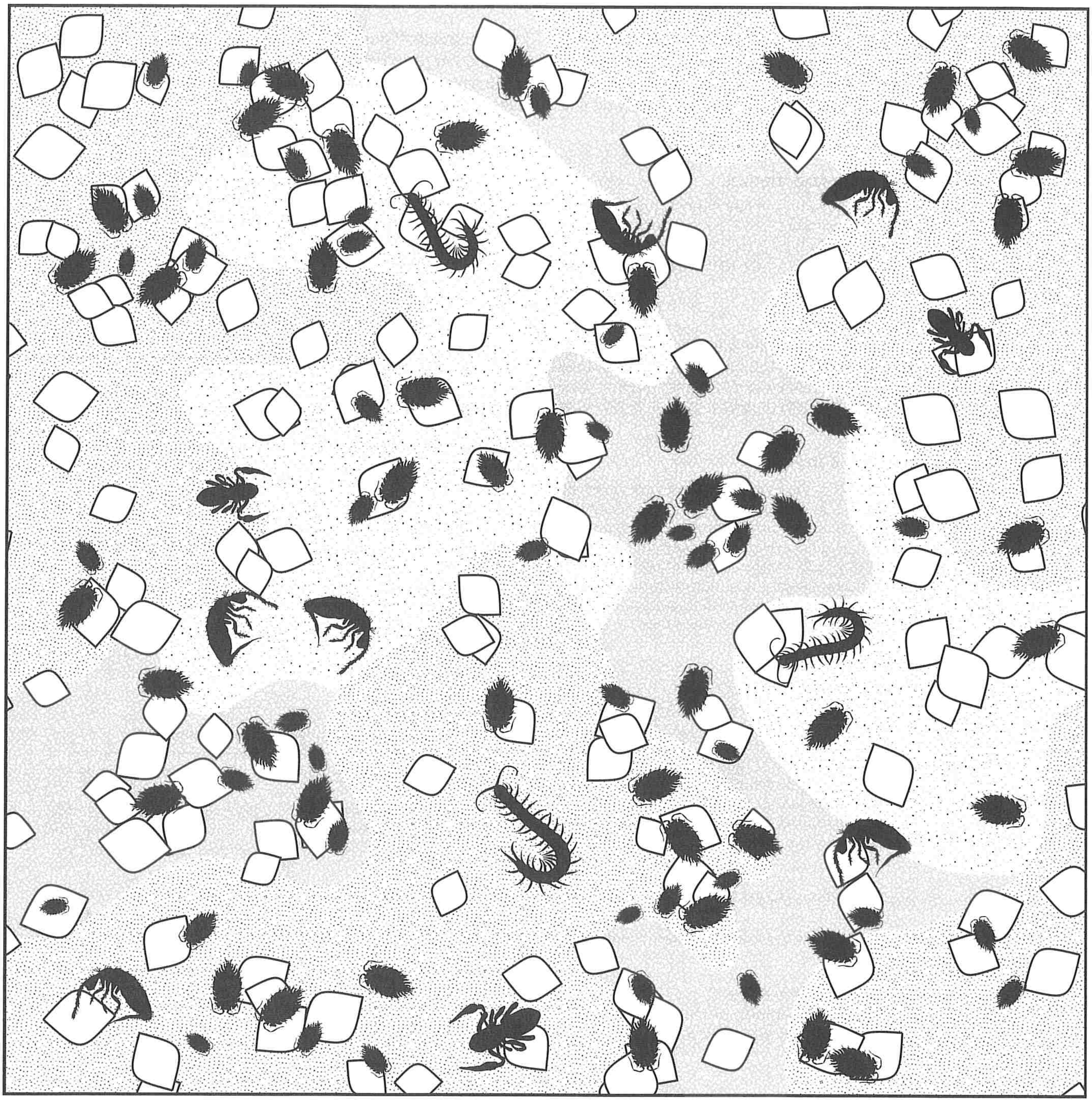
Woodlouse: [ ] Centipede: [ ] False scorpion: [ ] Springtail: [ ] Leaf: [ ]

Compare your estimated population density to the actual population density for each species:

______

______

______



Coordinates for each quadrat	Woodlouse	Centipede	False scorpion	Springtail	Leaf
1:					
2:					
3:					
4:					
5:					
6:					
TOTAL					

Table of random numbers

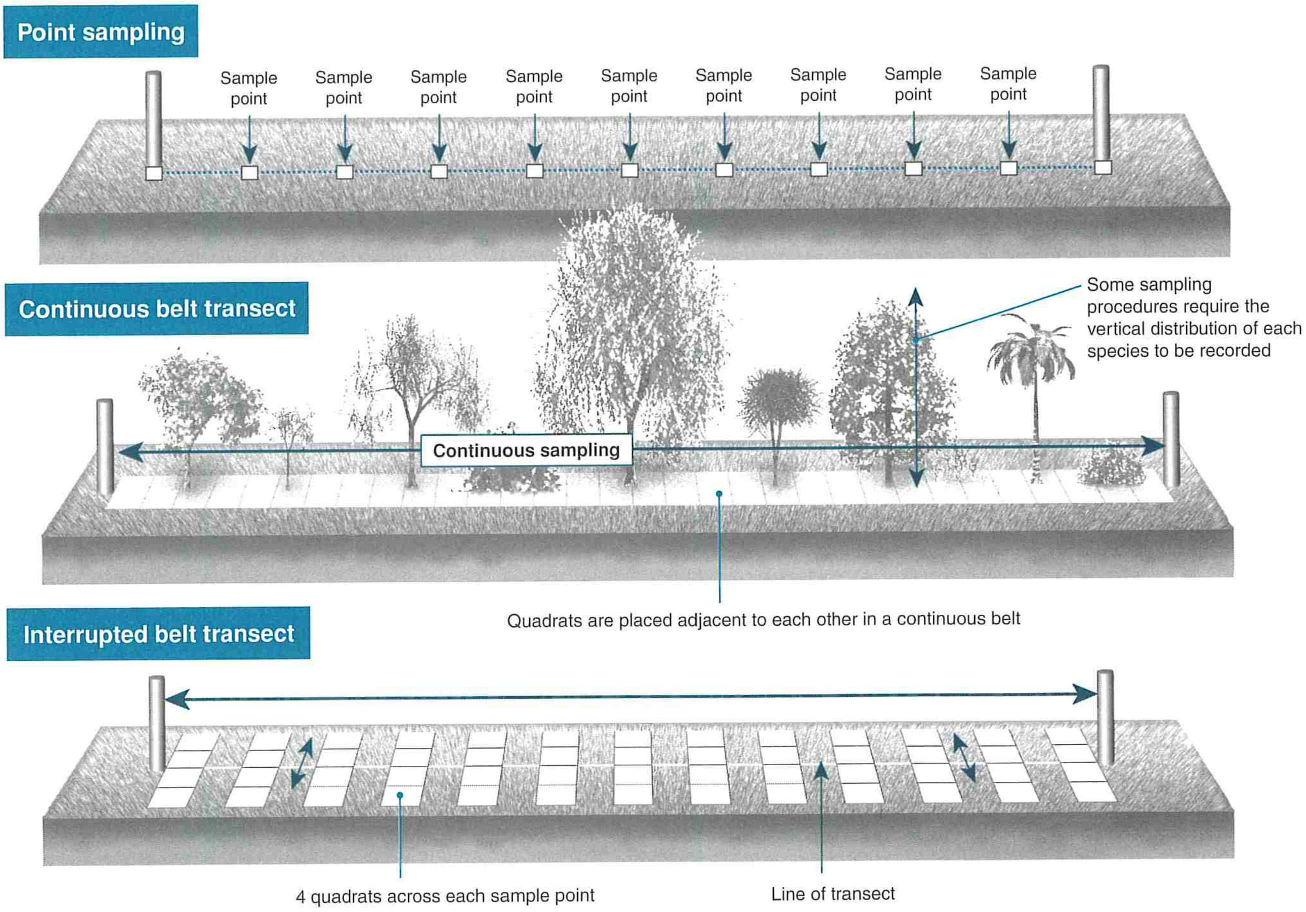
A	B	C	D
2 2	3 1	6 2	2 2
3 2	1 5	6 3	4 3
3 1	5 6	3 6	6 4
4 6	3 6	1 3	4 5
4 3	4 2	4 5	3 5
5 6	1 4	3 1	1 4

The table above has been adapted from a table of random numbers from a statistics book. Use this table to select quadrats randomly from the grid above. Choose one of the columns (A to D) and use the numbers in that column as an index to the grid. The first digit refers to the row number and the second digit refers to the column number. To locate each of the 6 quadrats, find where the row and column intersect, as shown below:

Example: 5 2 refers to the 5th row and the 2nd column

Transect Sampling

A **transect** is a line placed across a community of organisms. Transects are usually carried out to provide information on the **distribution** of species in the community. This is of particular value in situations where environmental factors change over the sampled distance (**environmental gradient)** or in the transition area between one ecosystem and another (**ecotone**). The usual practice for small transects is to stretch a string between two markers. The string is marked off in measured distance intervals, and the species at each marked point are noted. The sampling points along the transect may also be used for the siting of quadrats, so that changes in density and community composition can be recorded. Belt transects are essentially a form of continuous quadrat sampling. They provide more information on community composition but can be difficult to carry out. Some transects provide information on the vertical, as well as horizontal, distribution of species (e.g. tree canopies in a forest).



1. Belt transect sampling uses quadrats placed along a line at marked intervals. In contrast, point sampling transects record only the species that are touched or covered by the line at the marked points.

   (a) Describe one disadvantage of belt transects: ______

   (b) Explain why line transects may give an unrealistic sample of the community in question: ______

   (c) Explain how belt transects overcome this problem: ______

   (d) Describe a situation where the use of transects to sample the community would be inappropriate: ______

2. Explain how you could test whether or not a transect sampling interval was sufficient to accurately sample a community: ______

Kite graphs are an ideal way in which to present distributional data from a belt transect (e.g. abundance or percentage cover along an environmental gradient. Usually, they involve plots for more than one species. This makes them good for highlighting probable differences in habitat preference between species. Kite graphs may also be used to show changes in distribution with time (e.g. with daily or seasonal cycles).

3. The data on the right were collected from a rocky shore field trip. Periwinkles from four common species of the genus *Littorina* were sampled in a continuous belt transect from the low water mark, to a height of 10 m above that level. The number of each of the four species in a 1 m^2 quadrat was recorded.

   Plot a **kite graph** of the data for all four species on the grid below. Be sure to choose a scale that takes account of the maximum number found at any one point and allows you to include all the species on the one plot. Include the scale on the diagram so that the number at each point on the kite can be calculated.

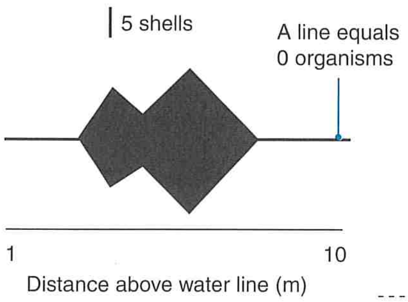
Field data notebook

Numbers of periwinkles (4 common species) showing vertical distribution on a rocky shore

Periwinkle species:

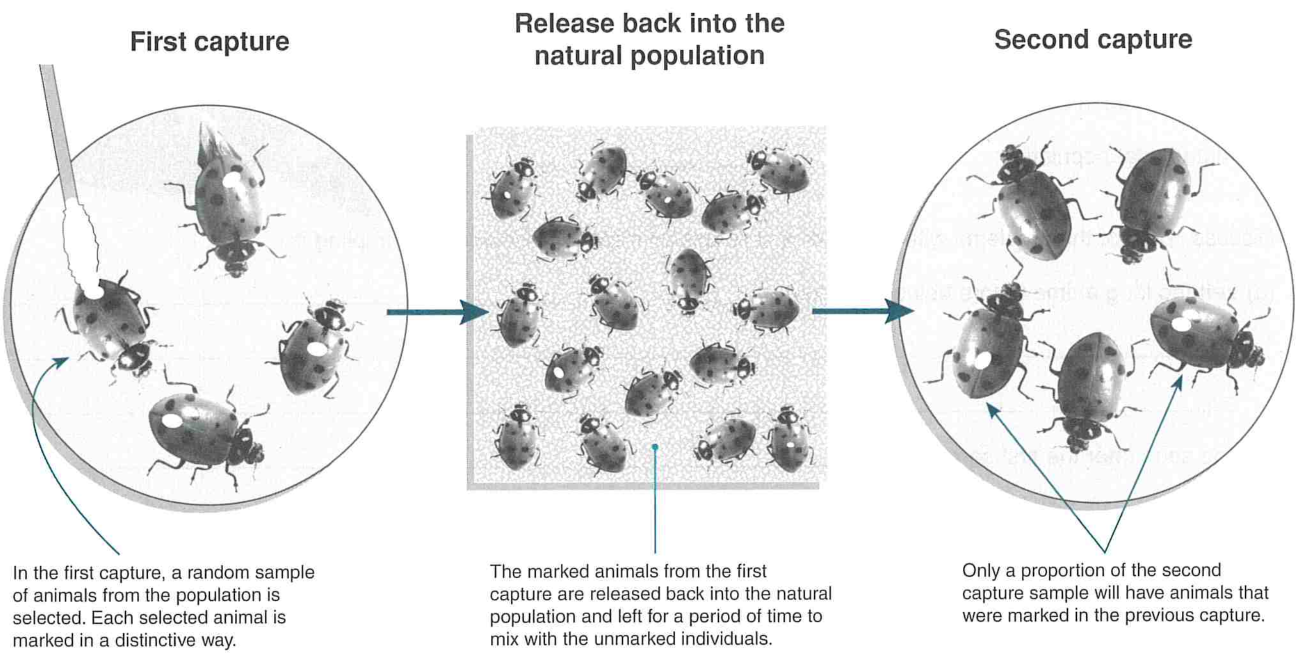
Height above low water (m)	*L. littorea*	*L. saxatalis*	*L. neritoides*	*L. littoralis*
0-1	0	0	0	0
1-2	1	0	0	3
2-3	3	0	0	17
3-4	9	3	0	12
4-5	15	12	0	1
5-6	5	24	0	0
6-7	2	9	2	0
7-8	0	2	11	0
8-9	0	0	47	0
9-10	0	0	59	0

An Example of a Kite Graph



Mark and Recapture Sampling

The mark and recapture method of estimating population size is used in the study of animal populations where individuals are highly mobile. It is of no value where animals do not move or move very little. The number of animals caught in each sample must be large enough to be valid. The technique is outlined in the diagram below.



The Lincoln Index

$$\text{Total population} = \frac{\text{No. of animals in 1st sample (all marked)} \times \text{Total no. of animals in 2nd sample}}{\text{Number of marked animals in the second sample (recaptured)}}$$

The mark and recapture technique comprises a number of simple steps:

1. The population is sampled by capturing as many of the individuals as possible and practical.
2. Each animal is marked in a way to distinguish it from unmarked animals (unique mark for each individual not required).
3. Return the animals to their habitat and leave them for a long enough period for complete mixing with the rest of the population to take place.
4. Take another sample of the population (this does not need to be the same sample size as the first sample, but it does have to be large enough to be valid).
5. Determine the numbers of marked to unmarked animals in this second sample. Use the equation above to estimate the size of the overall population.

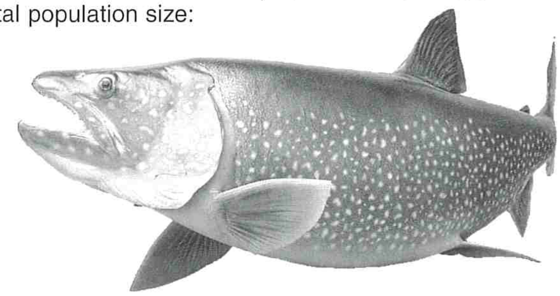
1. For this exercise you will need several boxes of matches and a pen. Work in a group of 2-3 students to 'sample' the population of matches in the full box by using the mark and recapture method. Each match will represent one animal.
   (a) Take out 10 matches from the box and mark them on 4 sides with a pen so that you will be able to recognize them from the other unmarked matches later.
   (b) Return the marked matches to the box and shake the box to mix the matches.
   (c) Take a sample of 20 matches from the same box and record the number of marked matches and unmarked matches.
   (d) Determine the total population size by using the equation above.
   (e) Repeat the sampling 4 more times (steps b-d above) and record your results:

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Estimated Population					

   (f) Count the actual number of matches in the matchbox : ____________________

   (g) Compare the actual number to your estimates and state by how much it differs: ____________________

2. In 1919 a researcher by the name of Dahl wanted to estimate the number of trout in a Norwegian lake. The trout were subject to fishing so it was important to know how big the population was in order to manage the fish stock. He captured and marked 109 trout in his first sample. A few days later, he caught 177 trout in his second sample, of which 57 were marked. Use the Lincoln index (on the previous page) to estimate the total population size:



Size of first sample: ______________________

Size of second sample: ______________________

Number marked in second sample: ______________________

Estimated total population: ______________________

3. Discuss some of the problems with the mark and recapture method if the second sampling is:

(a) Left too long a time before being repeated: ______________________

(b) Too soon after the first sampling: ______________________

4. Describe two important assumptions being made in this method of sampling, which would cause the method to fail if they were not true:

(a) ______________________

(b) ______________________

5. Some types of animal would be unsuitable for this method of population estimation (i.e. would not work).

(a) Name an animal for which this method of sampling would not be effective: ______________________

(b) Explain your answer above: ______________________

6. Describe three methods for marking animals for mark and recapture sampling. Take into account the possibility of animals shedding their skin, or being difficult to get close to again:

(a) ______________________

(b) ______________________

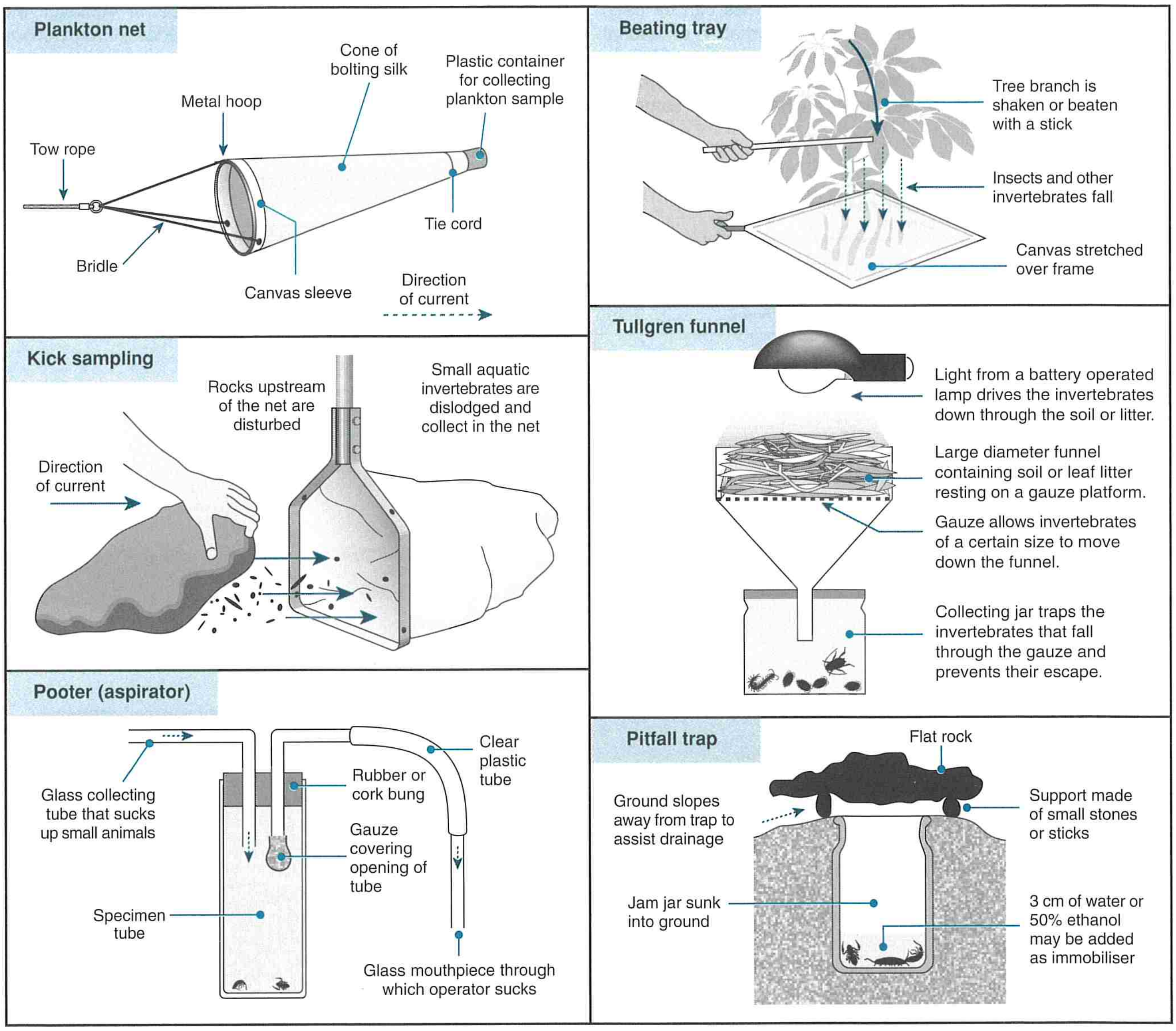
(c) ______________________

7. At various times since the 1950s, scientists in the UK and Canada have been involved in computerized tagging programmes for Northern cod (a species once abundant in Northern Hemisphere waters but now severely depleted). Describe the type of information that could be obtained through such tagging programmes:

____

Sampling Animal Populations

Unlike plants, most animals are highly mobile and present special challenges in terms of sampling them **quantitatively** to estimate their distribution and abundance. The equipment available for sampling animals ranges from various types of nets and traps (below), to more complex electronic devices, such as those used for radio-tracking large mobile species.



1. Describe which of the sampling techniques pictured above provides the best **quantitative** method for sampling invertebrates in vegetation. Explain your answer:

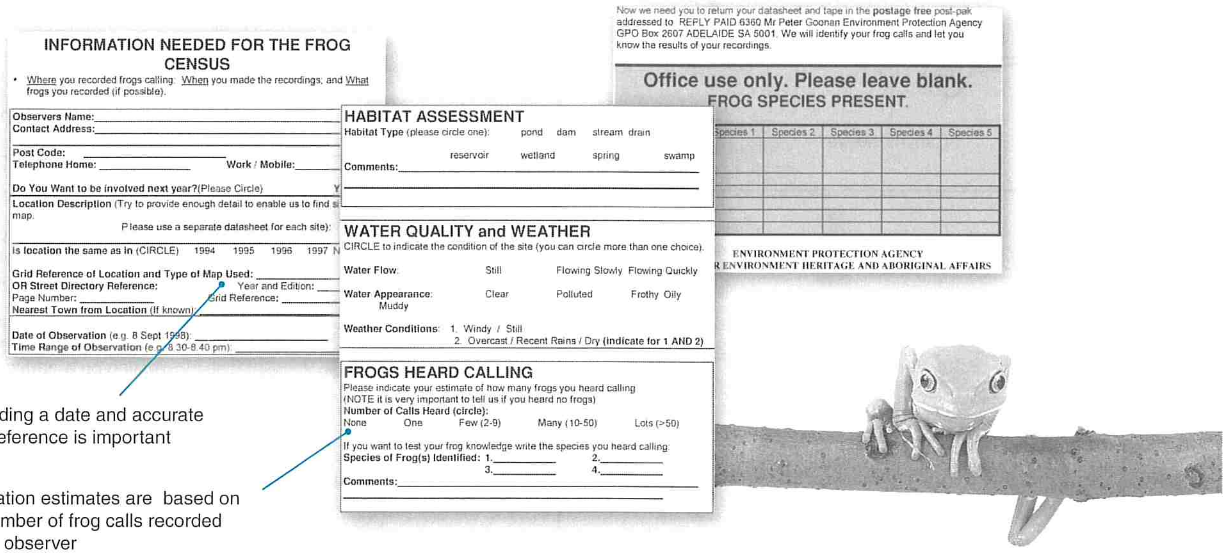
2. Explain why pitfall traps are not recommended for estimates of population density:

3. (a) Explain how mesh size could influence the sampling efficiency of a plankton net:

   (b) Explain how this would affect your choice of mesh size when sampling animals in a pond:

Indirect Sampling

If populations are small and easily recognized they may be monitored directly quite easily. However, direct measurement of elusive, easily disturbed, or widely dispersed populations is not always feasible. In these cases, indirect methods can be used to assess population abundance, provide information on habitat use and range, and enable biologists to link habitat quality to species presence or absence. Indirect sampling methods provide less reliable measures of abundance than direct sampling methods, such as mark and recapture, but are widely used nevertheless. They rely on recording the signs of a species, e.g. scat, calls, tracks, and rubbings or markings on vegetation, and using these to assess population abundance. In Australia, the Environmental Protection Agency (EPA) provides a Frog Census Datasheet (below) on which volunteers record details about frog populations and habitat quality in their area. This programme enables the EPA to gather information across Australia.



INFORMATION NEEDED FOR THE FROG CENSUS

- Where you recorded frogs calling: When you made the recordings; and What frogs you recorded (if possible).

Observers Name: ____
Contact Address: ____

Post Code: ____
Telephone Home: ____ Work / Mobile: ____

Do You Want to be involved next year?(Please Circle) Y

Location Description (Try to provide enough detail to enable us to find s[ite] map.
Please use a separate datasheet for each site):

Is location the same as in (CIRCLE) 1994 1995 1996 1997 N

Grid Reference of Location and Type of Map Used: ____
OR Street Directory Reference: Year and Edition: ____
Page Number: ____ Grid Reference: ____
Nearest Town from Location (If known): ____

Date of Observation (e.g. 8 Sept 1998): ____
Time Range of Observation (e.g. 8.30-8.40 pm): ____

HABITAT ASSESSMENT

Habitat Type (please circle one): pond dam stream drain reservoir wetland spring swamp

Comments: ____

WATER QUALITY and WEATHER

CIRCLE to indicate the condition of the site (you can circle more than one choice).

Water Flow: Still Flowing Slowly Flowing Quickly

Water Appearance: Clear Polluted Frothy Oily Muddy

Weather Conditions: 1. Windy / Still
2. Overcast / Recent Rains / Dry (indicate for 1 AND 2)

FROGS HEARD CALLING

Please indicate your estimate of how many frogs you heard calling
(NOTE it is very important to tell us if you heard no frogs)
Number of Calls Heard (circle):
None One Few (2-9) Many (10-50) Lots (>50)

If you want to test your frog knowledge write the species you heard calling:
Species of Frog(s) Identified: 1.____ 2.____ 3.____ 4.____

Comments: ____

Now we need you to return your datasheet and tape in the postage free post-pak addressed to REPLY PAID 6360 Mr Peter Goonan Environment Protection Agency GPO Box 2607 ADELAIDE SA 5001. We will identify your frog calls and let you know the results of your recordings.

Office use only. Please leave blank.
FROG SPECIES PRESENT.

Species 1	Species 2	Species 3	Species 4	Species 5

ENVIRONMENT PROTECTION AGENCY
[FO]R ENVIRONMENT HERITAGE AND ABORIGINAL AFFAIRS

Recording a date and accurate map reference is important

Population estimates are based on the number of frog calls recorded by the observer

COD

Electronic devices, such as the bat detector pictured above, can be used to estimate population density of nocturnal, highly mobile species, such as bats. In this case, the detector is tuned to the particular frequency of the hunting clicks emitted by specific bat species. The number of calls recorded per unit time can be used to estimate numbers per area.

The analysis of animal tracks allows wildlife biologists to identify habitats in which animals live and to conduct population surveys. Interpreting tracks accurately requires considerable skill as tracks may vary in appearance even when from the same individual. Tracks are particularly useful as a way to determine habitat use and preference.

Sam Banks

All animals leave scats (feces) which are species specific and readily identifiable. Scats can be a valuable tool by which to gather data from elusive, nocturnal, easily disturbed, or highly mobile species. Fecal analyses can provide information on diet, movements, population density, sex ratios, age structure, and even genetic diversity.

1. (a) Describe the kind of information that could be gathered from the Frog Census Datasheet:

   ____

   (b) Identify the benefits of linking a measure of abundance to habitat assessment: ____

   ____

2. Describe one other indirect method of population sampling and outline its advantages and drawbacks:

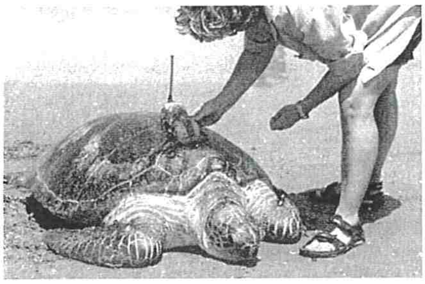
   ____

   ____

   ____

Radio-tracking

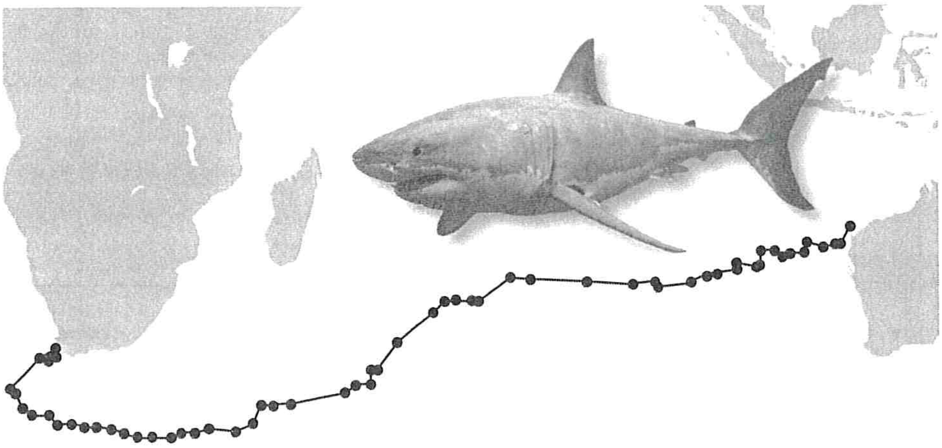
Field work involving difficult terrain, aquatic environments, or highly mobile, secretive, or easily disturbed species, has been greatly assisted in recent years by the use of radio-transmitter technology. Radio-tracking can be used to quickly obtain accurate information about an animal's home range and can provide information about dispersal, distribution, habitat use, and competitive relationships. Radio-tracking is particularly suited to population studies of threatened species (because it is relatively non-invasive) and of pests (because their dispersal and habitat use can be monitored). The information can be used to manage an endangered species effectively or to plan more efficient pest control operations. Satellite transmitters can be used to study migratory movements of large animals and marine species, which are more difficult to follow.



Radio-tracking technology is widely used in conservation work to study animal movements and habitat use. The information allows conservation organizations to develop better strategies for the management of species in the wild or follow the progress of reintroduced captive-bred animals.

A tracking antenna and receiver can be used to pinpoint the location of an animal. Antennae are directional and so can accurately fix an animal's position. They can be mounted on to light aircraft or off-road vehicles to provide mobile tracking over large areas. For work in inaccessible or difficult terrain, portable, hand-held antennae are used.

Australian brush-tailed possums are a major pest in New Zealand where they damage native forests, and prey on native birds. Radio-tracking is used on possums in critical conservation areas to determine dispersal rates, distribution, and habitat use. This allows pest control can be implemented more effectively.



From Bonfil *et al* 2005.

Tracking Migrations

During 2002 and 2003, a number of great white sharks were radio-tagged in South African waters. The data recovered showed the first ever recorded intercontinental migration by a great white. A female shark known as P12, swam 11,000 km from South Africa to Australia in 99 days with a minimum speed just under 5 kmh^{-1}. Within 9 months she had returned to South African waters, completing a round trip of more than 20,000 km.

1. Describe two applications of radio-tracking technology in endangered species management: ____________________

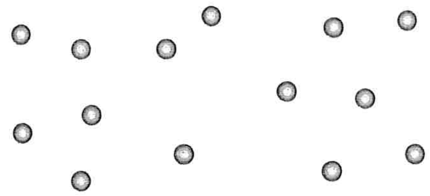
2. Explain why radio-tracking might be used to monitor pest species: ____________________

3. Explain how radio-tracking has increased our knowledge of the movement of marine animals: ____________________

Density and Distribution

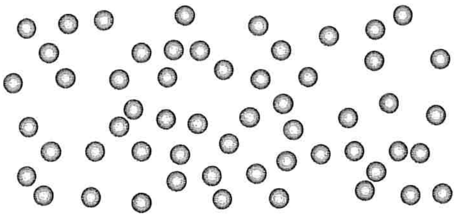
Distribution and density are two interrelated properties of populations. Population density is the number of individuals per unit area (for land organisms) or volume (for aquatic organisms). Careful observation and precise mapping can determine the distribution patterns for a species. The three basic distribution patterns are: random, clumped and uniform. In the diagram below, the circles represent individuals of the same species. It can also represent populations of different species.

Low Density



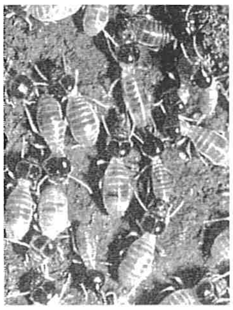
In low density populations, individuals are spaced well apart. There are only a few individuals per unit area or volume (e.g. highly territorial, solitary mammal species).

High Density



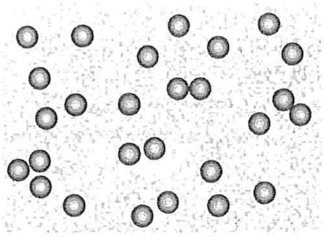
In high density populations, individuals are crowded together. There are many individuals per unit area or volume (e.g. colonial organisms, such as many corals).

Tigers are solitary animals, found at low densities.



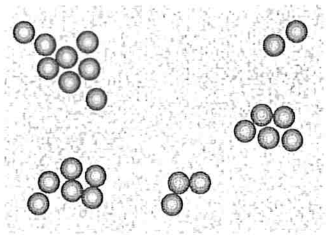
Termites form well organized, high density colonies.

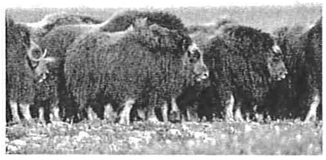
Random Distribution



Random distributions occur when the spacing between individuals is irregular. The presence of one individual does not directly affect the location of any other individual. Random distributions are uncommon in animals but are often seen in plants.

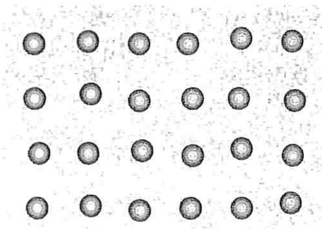
Clumped Distribution





Clumped distributions occur when individuals are grouped in patches (sometimes around a resource). The presence of one individual increases the probability of finding another close by. Such distributions occur in herding and highly social species.

Uniform Distribution



Regular distribution patterns occur when individuals are evenly spaced within the area. The presence of one individual decreases the probability of finding another individual very close by. The penguins illustrated above are also at a high density.

1. Describe why some organisms may exhibit a clumped distribution pattern because of:

   (a) Resources in the environment: ______________________________

   ____

   (b) A group social behavior: ______________________________

   ____

2. Describe a social behavior found in some animals that may encourage a uniform distribution:

   ____

3. Describe the type of environment that would encourage uniform distribution:

   ____

4. Describe an example of each of the following types of distribution pattern:

   (a) Clumped: ______________________________

   (b) Random (more or less): ______________________________

   (c) Uniform (more or less): ______________________________