# Mark-recapture

Teacher

## Science topics

Populations, sampling

## Maths topics

Rearranging equations, statistics, variance, standard deviation

## Age

14–18 years old

## Duration

45 minutes

## Learning outcomes

Students will be able to:

- Estimate population size using the mark-recapture principle
- Produce statistics including calculation of variance and standard deviation

## Keywords

Mark-recapture, population size, bees, habitats, pollination, pesticides, conservation, estimation, distribution, variance, variability, standard deviation

## What you will need

- Stack of bee cards (each set of bee cards must contain more than 10 cards and to work well should contain at least 20 bee cards)
- Small stickers to mark the cards
- Calculator
- Paper or a flipchart (to keep track of results and to work out means and variances)
- Question and answer sheets

## Prior learning

Students should be able to carry out multiplication, division and rearrange equations.

## Introducing the lesson

This lesson is designed to be delivered as either a maths or science lesson. The lesson is suitable for students taking GCSE statistics or as an extension lesson for maths or science.

Provide the students with the recent research information along with the activity sheets. Students can check their results using the answer sheets provided at the end.

The lesson first of all introduces both the concept of the mark-recapture technique used to estimate population size and the equation. Students are required to rearrange the equation to work out the number of bee cards they have been provided with.

The next stage of the lesson involves the students repeating this activity and calculating the variance and standard deviation of their results.

If the students are not sure about how to calculate the variance and standard deviation, first have a discussion about what they think they represent, and then show them how to calculate it.

## Plenary

Discuss the following questions with the students.

**Question 1** – Why do we say that we are estimating the number of bees in the field by mark–recapture methods? Why is the result uncertain, and not exact?

**Question 2** – What assumptions do we make when estimating the number of bees this way?

**Question 3** – What would happen to our estimate if bees discover that the traps are warm, safe, food-filled places to spend the night and they become 'trap-happy'?

**Question 4** – What would happen to our estimate if bees hate the traps, and avoid them after first being caught?

**Question 5** – What would happen to our estimate if some bees are caught by predators or die between the first and second round of trapping?

## Plenary question answers

**Answer 1.** We assume that the proportion of bees in the second round of trapping is equal to the proportion of bees in the field that are marked. However, this is unlikely to be exactly true. Statistically (subject to the assumptions below) the expected value of the marked proportion in the second round is the true proportion in the whole population (we say the estimate of the proportion is unbiased), but any one sample is likely to differ from this. We call this difference the sample error.

**Answer 2.** One important assumption is that, in both rounds of trapping, all bees in the field are equally likely to be caught. Only if this is true are we justified in our assumption that the proportion of bees caught in the second round that are marked is an unbiased estimate of the true proportion of marked bees in the whole population. In the exercise with cards, this assumption is met only if the cards are thoroughly shuffled.

**Answer 3.** This would be a violation of our assumption that all bees are always equally likely to be caught (previously caught bees are more likely to be caught again). We shall therefore overestimate the proportion of bees in the field that are marked, and so underestimate the total number.

**Answer 4.** This is also a violation of the assumption set out in (2) above. This time we shall tend to underestimate the marked proportion, and so overestimate the total number.

**Answer 5.** This highlights the importance of our assumption that we know how many bees are actually marked. The estimated proportion of bees that are marked is still an unbiased estimate of the true proportion. The total number of marked bees in the field will be smaller than we think (unless, for some reason, marked bees are never caught by predators), because some have been eaten by predators, and we will overestimate the population.

## DRAFT Science programme of study for Key Stage 4

### Ecosystems

- Levels of organisation: species, population, community, ecosystem, biome and biosphere
- Components of an ecosystem (abiotic factors and biotic community)
- Relationships among organisms in an ecosystem

### Human interactions with ecosystems

- The importance of biodiversity in ecosystems
- Identifying and classifying local species and using keys
- Measuring the distribution, frequency and abundance of species in a range of habitats and explaining outcomes in terms of abiotic and biotic factors
- Measuring changes in the distribution and abundance of organisms as a way of measuring and monitoring change in ecosystems
- Positive and negative human interactions with ecosystems
- The biological challenges of increasing food yield using fewer resources

## DRAFT Maths programme of study for Key Stage 4

### Number

- Apply systematic listing strategies, including use of the product rule for counting
- Estimate powers and roots of any given positive number
- Calculate with roots, and with integer and fractional indices

### Algebra

- Simplify and manipulate algebraic expressions (including those involving surds and algebraic fractions)

### Statistics

- Infer properties of populations or distributions from a sample, while knowing the limitations of sampling
- Apply statistics to describe a population

## Further reading and links

For more information on the application of mark-recapture methods
**www.pitt.edu/~yuc2/cr/main.htm**

## Research groups

Sustainable pollination services for UK crops – Dr Koos Biesmeijer, University of Leeds
**https://secure.fera.defra.gov.uk/beebase/downloadDocument.cfm?id=360**

Modelling systems for managing bee disease: the epidemiology of European foulbrood – Dr Giles Budge, Food and Environment Research Agency
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-budge.pdf**

Investigating the impact of habitat structure on queen and worker bumblebees in the field – Dr Claire Carvell, NERC Centre for Ecology and Hydrology
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-carvell.pdf**

An investigation into the synergistic impact of sublethal exposure to industrial chemicals on the learning capacity and performance of bees – Dr Chris Connolly, University of Dundee
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-connolly.pdf**

Linking agriculture and land use change to pollinator populations – Professor Bill Kunin, University of Leeds
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-kunin.pdf**

Urban pollinators: their ecology and conservation – Professor Jane Memmott, University of Bristol
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-memmott.pdf**

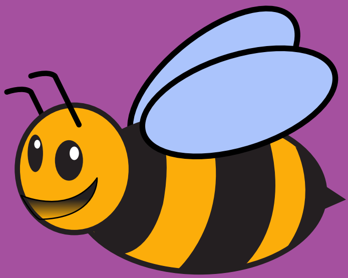
## Research groups

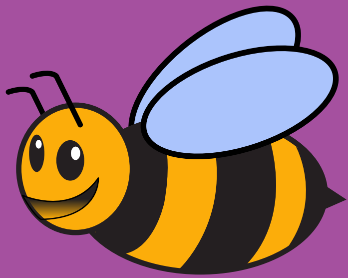
Impact and mitigation of emergent diseases on major UK insect pollinators – Dr Robert Paxton, Queen's University of Belfast
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-paxton.pdf**

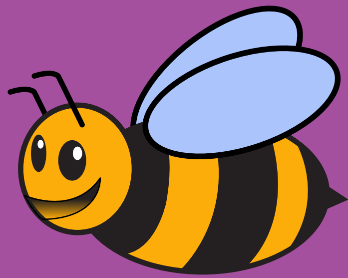
Unravelling the impact of the mite Varroa destructor on the interaction between the honeybee and its viruses – Dr Eugene Ryabov, The University of Warwick
**www.nerc.ac.uk/research/funded/programmes/pollinators/pollinators-ryabov.pdf**

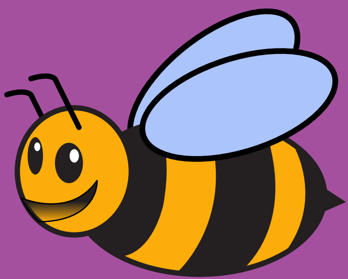
# Mark-recapture

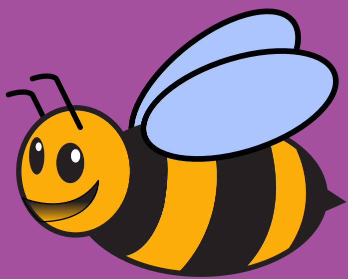
**Student**

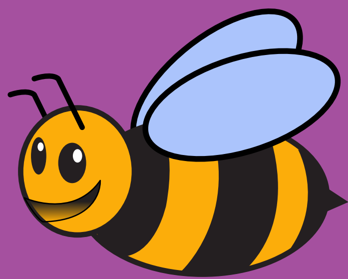












# Activity 1

**Student**

Biologists often need to estimate how many animals are in a particular place. This could be to see whether the numbers are declining because of a disease, to decide whether conservation methods are working or to find out whether one habitat can support more animals than another.

This is not always easy. Some large animals can be counted from aircraft. But how would you count the number of bees in a field?

A common method is called **mark-recapture.** Bees are caught live in traps, marked (e.g. with enamel paint), and then released. Then there is a second round of trapping. We assume that the proportion of the second group of trapped bees that are marked is equal to the proportion of marked bees in the whole population.

To get an idea how this technique works we can play a card game.

## Rules

### What you will need

- A pack of cards (each with a picture of a bee)
- Stickers

1. You are not allowed to count the number of cards in the pack (that's just cheating and would not be possible in real life).
2. Take the top 10 cards (these are the bees that you have caught), and mark each bee (add a sticker).
3. Shuffle the pack of cards thoroughly.
4. Take the top 10 cards again (these are the bees caught in the second round of trapping).
5. Count how many of the second set of caught bees were already marked with a sticker.

If we think about this technique mathematically we can write an equation to work out how many bees there are.

- The number of bees marked = $n$ (in this case 10)
- The number of marked bees caught in the second round of trapping = m (marked bees plus unmarked bees)
- Total number of marked bees in the field (we know this, because we marked them in the first round of trapping) = $M$
- The total number of cards (bees) = $N$

$$\frac{m}{n} = \frac{M}{N}$$

Can you rearrange this equation to estimate N from the numbers that you know?

Turn over for the answer.

## Answer

$$N = \frac{nM}{m}$$

From the numbers you know, estimate the total number of bees (cards in the pack).

**Estimated total number of bees (N) =** ______________________

**You are still not allowed to count the number of cards!**

## Variance and standard deviation

To get a better estimate you will need to repeat the mark-recapture technique a number of times and use some statistical techniques. You will learn how to work out the variance and standard deviation of your results.

Variance and the closely related standard deviation are measures of how spread out a set of results is. This is known as distribution (it is not how spread out the bees are in the environment). In other words, variance and standard deviation are measures of variability.

The variance ($\sigma^2$) is calculated as the average squared deviation of each number from its mean. For example, for the numbers 1, 2, and 3, the mean is 2 and the variance is:

$$\sigma^2 = \frac{(1-2)^2+(2-2)^2+(3-2)^2}{3} = 0.667$$

The formula (in summation notation) for the variance in a population is:

$$\sigma^2 = \frac{\sum(X-\mu)^2}{N}$$

- $\sum$ (summation) is the sum of all values in the range of the series
- $X$ represents each value in the range
- $\mu$ is the mean
- $N$ is the number of scores

The standard deviation is the square root of the variance.

$$\sqrt{\sigma^2}$$

## Variance and standard deviation continued

What are the advantages of variance and standard deviation? What effect does squaring have?

Squaring each difference makes them all positive numbers (to avoid negatives reducing the variance).

And it also makes the bigger differences stand out. For example $100^2 = 10,000$ which is a lot bigger than $50^2 = 2,500$.

But squaring them makes the final answer really big, and so un-squaring the variance (by taking the square root) makes the standard deviation a much more useful number.

## Activity 2: Repeating the mark-capture card game

1. Play the game as you did in Activity 1.
2. Repeat the game five times.
3. Record the estimated total number of bees (N) each time you repeat the game.
4. After five games calculate the mean estimate, the variance and the standard deviation of your estimate.

**Mean estimate =** ______________________________

**Variance =** ______________________________

**Standard deviation =** ______________________________

## Activity 3: Changing the sample size

- Change the number of cards that you mark and repeat the mark-recapture game five times.

How does the sample size affect your estimates?

Now you can count the number of cards.

**Total number of bees =** ______________________________

How close was your initial estimate to the actual number of bees?

# Glossary



**Bumblebee**
Any of the 250 species of large, hairy, social bees of the genus Bombus that nest underground.

**Conservation**
The protection, preservation, management, or restoration of wildlife and of natural resources.

**Habitat**
The area or environment where an organism or ecological community normally lives or occurs.

**Foraging**
The act of looking or searching for food.

**Mark-recapture**
Organisms are caught live in traps, marked (e.g. with enamel paint), and then released. Following a second round of trapping it is assumed that the proportion of the second group of trapped organisms that are marked is equal to the proportion of marked organisms in the whole population.

**Pesticide**
A chemical used to kill pests, especially insects.

**Pollinate**
To transfer pollen from an anther to the stigma of (a flower).

**Population**
All the organisms that constitute a specific group or occur in a specified habitat.

**Standard deviation**
A measure of dispersion in a frequency distribution, equal to the square root of the mean of the squares of the deviations from the arithmetic mean of the distribution.

**Variance**
A measure of distribution that is calculated as the square of the standard deviation.