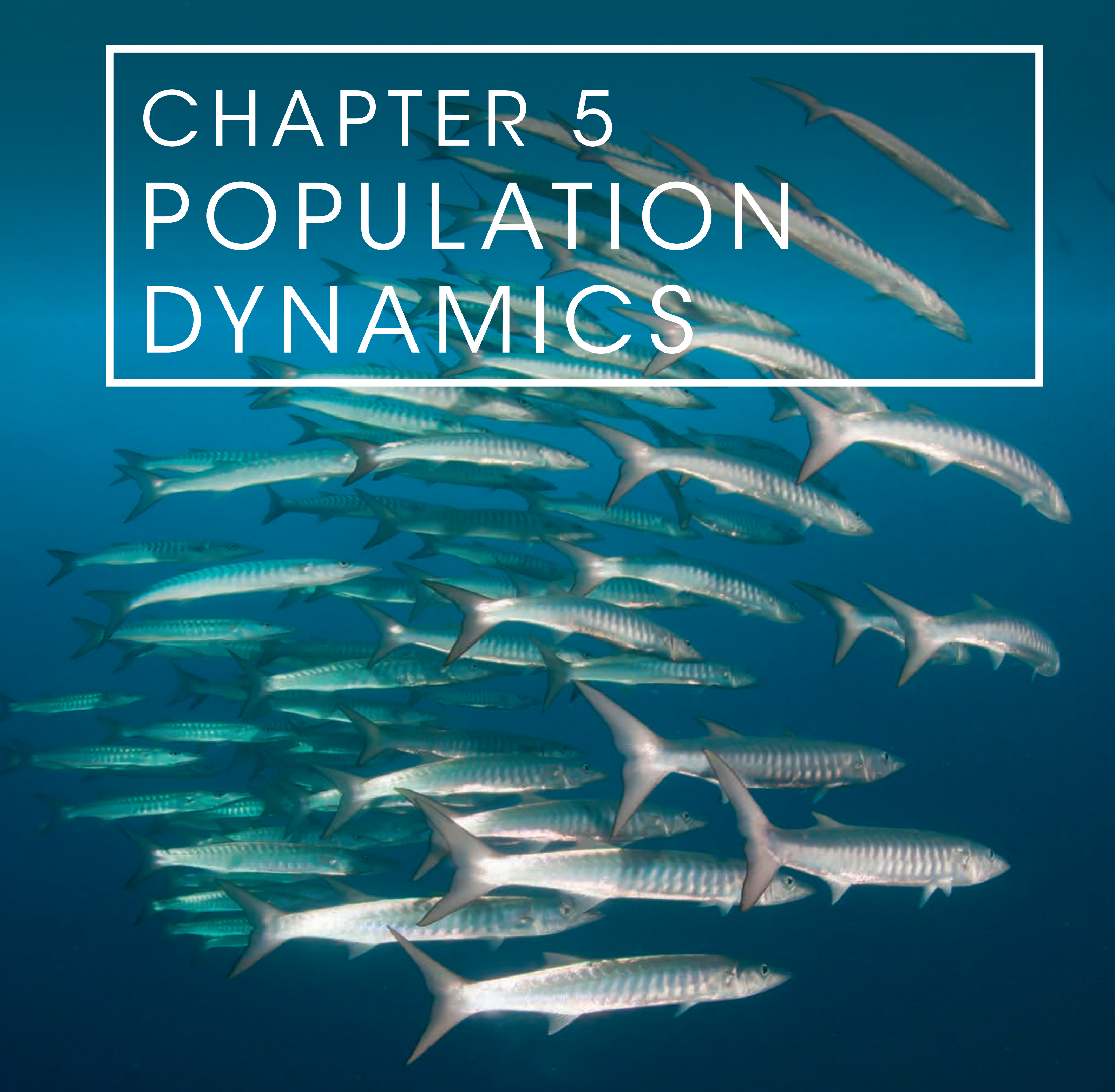
CHAPTER 5 POPULATION DYNAMICS



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By the end of this chapter you will have covered the following material.

Science Understanding

- Ecosystems have carrying capacities that limit the number of organisms (within populations) they support, and can be impacted by changes to abiotic and biotic factors, including climatic events (ACSBL025)
- Models of ecosystem interactions (for example, food webs, successional models) can be used to predict the impact of change and are based on interpretation of and extrapolation from sample data (for example, data derived from ecosystem surveying techniques); the reliability of the model is determined by the representativeness of the sampling (ACSBL029)

Figure 5.1 ▲ The grey-headed flying fox, *Pteropus poliocephalus*

In 1981, grey-headed flying foxes (*Pteropus poliocephalus*) established a permanent colony at Melbourne's Royal Botanic Gardens. Up until that time, the population had been seasonal with very few individuals present during the cooler months. The population then exploded over the next 20 years, reaching a total of 30 000 individuals in the summer of 2001. Though the population size continued to vary seasonally, a very large population was in permanent residence at the site. The size of any such colony is dependent on available food and roosting sites. The flying foxes' diet of nectar, pollen and fruit, specifically from eucalypts, banksias and melaleucas, also included occasional rainforest fruit and flowers. All these were readily available within or near the Botanic Gardens. This established population grew until it could not be sustained within the confines of the Botanic Gardens. Why did these individuals immigrate to the Melbourne site? Why do populations change? How can we measure and control populations if we want to manage them?

What is a population?

Populations are defined as members of a **species** in one place at one time. Knowing the figures helps scientists and ecologists understand the habits and needs of organisms. This enables humans to sustain and ensure that vulnerable species persist and contribute to the planet's **biodiversity**. Determining the size of various populations addresses many needs, whether it is to help understand how a vulnerable species such as Leadbeater's possum is able to survive any sort of logging activity in its already highly reduced habitat, or to determine how many minke whales Iceland may hunt in one season and still sustain a viable population. What determines whether a population is thriving, surviving or on the brink of extinction? What is the critical population size and what needs to be considered when working to ensure that Earth's biodiversity is maintained? The factors that would require consideration vary greatly between species. For example, a minke whale population in any area may be as small as 6 animals or as large as 50–100 animals where food is plentiful. Even the 6 are enough to maintain the population consisting of 2 mature females, 1 mature adult male and 2–3 immature animals. For krill (the food of many baleen whales, such as the minke), a population size of less than one million individuals is considered at risk.

Populations in unstable environments

In unstable, unpredictable ecosystems, such as after a fire or land-clearing, opportunistic species move in and colonise as quickly as they are able. In these environmental conditions, population explosions of these colonisers follows. This pattern of rapid increase then decline (or crash) is called **r-selection**, where the maximum reproductive potential of the species is reached. In order to survive, these so-called **r-selected species** must colonise new environments quickly, and be able to reproduce rapidly and in relatively large numbers. As a result, they are characterised by smaller size, short life cycles and a lack of parental care for young (in animals). Examples of r-selected species include mice, rats, frogs, toads, weeds and oysters.

Unfortunately, as the environmental resources are diminished, the numbers will drop off just as rapidly as they began and these species are replaced with competitors. Locusts and other swarming insects are an example of r-selected species.

Populations in stable environments

In stable ecosystems, slow and steady life strategies are more successful. Larger, longer-lived species like elephants, whales, gorillas, oak trees or eucalypts outcompete the smaller, faster growing species over time. They have a more controlled population growth pattern. They can exist close to the **carrying capacity** of their environment. The carrying capacity describes the maximum population size of a species that can be supported in a given environment. For example, the female red kangaroo is able to manage the number of young that are born at any one time. At times when water and food are plentiful, the female may have up to three young at various stages of development: a joey that has mostly left the pouch and is no longer reliant on the mother for nourishment, a young that is firmly attached to a nipple in the pouch while it completes development, and a third embryo whose development and birth have been suspended till there is room in the pouch. If food or other requirements for life become scarce at any stage, the female is able to abandon any one of the three. Without her protection they most certainly perish. A harsh reality; however, the maintenance of a sustainable population size is assured. This is defined as **K-selection**, and over the long term offers stability to the ecosystem and equilibrium to the populations that exist within it. **K-selected species** live longer, breed later in life, have fewer offspring and devote their lives to ensuring the survival of the offspring to reproductive maturity.

Sturt's desert pea (*Swainsona formosa*) is the floral emblem of South Australia, and it has a relatively short flowering season. Its natural habitat includes open desert areas and dry woodlands. It is often described as an opportunistic ephemeral plant because it is short-lived, particularly after heavy rains when conditions become temporarily suitable for its growth and reproduction. Most of its life is spent as a seed with a tough, water-resistant coat. Only after drenching rains will the seeds germinate, flower and then set seed all within a matter of days. In its specific habitat, this ensures survival of the species. However, when conditions become less suitable, the initial population explosion is quickly followed by a crash when resources (such as available water) are used or other **abiotic** conditions alter. This limits the numbers of the plant that can be sustained. Their use of existing resources is highly efficient and ensures their ongoing survival in an environment to which they are best suited. Is this an example of r-selection or K-selection?

QUESTION SET 5.1

Remembering

1 Define 'population'.

2 Explain why r-selected species are often described as opportunists.

Understanding

3 K-selected species are described as competitor species. Explain why.

4 Biodiversity is a measure of an ecosystem's health. How is this so?

Measuring populations

Platypus numbers in the eastern states of Australia have fluctuated over recent times. The most recent method of determining their numbers included enlisting the help of the public in reporting any sightings to a national database. The information gathered has been used to determine the health and sustainability issues for existing populations. The biggest impact on numbers in water bodies between northern New South Wales and Apollo Bay in western Victoria is the activities of humans, specifically dumping of rubbish anywhere that ultimately finds its way into the waterways and freshwater habitats of the platypus. Relationships between organisms can change. At the same time that humans are assisting in the data collection, their activities are impacting directly on the numbers. Studying populations can help us predict such changes to their numbers and the far-reaching consequences to the ecosystem they inhabit.

Ecologists describe the total number of a particular species in a particular place at a particular time as the population – for example, the number of manna gums (*Eucalyptus viminalis*) in a heathland community, the number of straw-necked ibises (*Threskiornis spinicollis*) in a wetland in a particular month, or even the number of possums in an urban area. Populations in an ecosystem are dynamic. Maybe you have noticed changes in the number and kind of plants or insects in your neighbourhood from one season to another or from year to year.

Growth of populations

The black swan (*Cygnus atratus*) is a nomadic species of waterbird native to the waterways of Australia, including fresh water, brackish (briny) water and seawater. In times of plentiful rain, adult swans will migrate to areas that have received the heaviest rain and will reproduce here. These areas often have a small resident population, which will quickly increase in number due to the migration. When the environmental conditions return to their previous levels, the swans will emigrate leading to a decrease in the local population size. This is an example of an open ecosystem, where migration between populations of animals (and occasionally plants) can occur. This migration will affect overall numbers in the ecosystems involved, their **distribution**, and, in the longer term, birth and death rates.

In the Queensland rainforests, located between Townsville and Cooktown, a small number of bird species exist that are not found in any other areas. All of their survival and reproductive needs must be met within this rainforest habitat. The Victoria's riflebird (*Ptiloris victoriae*) is one such species. The population is in decline as its growth rate depends only on birth and death rates. There is no migration as other members of the species will not move into an area where their species is under threat. The decline is also a reflection of habitat loss and hunting pressures. However, the species is abundant throughout its range. This is an example of a closed ecosystem, where migration does not impact at all on population size. A population is therefore increasing if the birth rate and/or immigration rate exceeds the death rate and/or emigration rate. Rate refers to the number of individuals per hundred, per thousand or whatever unit is appropriate.

Conversely, a population decreases when the death and emigration rates exceed birth and immigration rates. The decline in the numbers of the common sparrow in Indian urban settings is one such example. As the wetland habitat of these birds is reduced due to increased urbanisation, emigration may occur in the first instance, but the carrying capacity is reached at their destination and therefore the birds just die. The reduction in abiotic and **biotic** factors in its habitat impacts on many aspects of the sparrow's needs including availability of nesting sites, food, water and shelter, which together lead to a reduced birth rate. Interestingly, the sparrow is also an indicator of urban ecosystem health. Urban ecosystems are defined as ecosystems of towns and cities – essentially those constructed by humans. They can impact on the surrounding ecosystems of the natural world both positively and negatively. After initial establishment issues, wildlife, in particular, have been able to adapt and thrive in these environments. How well they integrate into the setting helps determine the general health and growth of this human-made ecosystem. Therefore, the decrease in sparrow numbers does not bode well for the future of this specific ecosystem.

Figure 5.2 ▼ The house sparrow at a bird feeder

Shutterstock.com/Jgade

$$\text{Population growth rate} = (\text{birth rate} + \text{immigration rate}) - (\text{death rate} + \text{emigration rate})$$
$$= (br + ir) - (dr + er)$$

WORKED EXAMPLE 5.1

Calculate the growth rate of a population of 1000 individuals where, every year, 100 individuals are born, 65 individuals immigrate into the population, 37 individuals die and 25 individuals emigrate to another population. (4 marks)

Answer	Logic	
growth rate = (*br* + *ir*) − (*dr* + *er*)	Devise formula	1 mark
growth rate = (100 per 1000 + 65 per 1000) − (37 per 1000 + 25 per 1000)	Substitute	2 marks
= 103	Calculate answer	1 mark

Therefore, the population has grown by 103 individuals per 1000. Growth rates can also be expressed as a percentage: +10.3% if there is an increase or −10.3% if there is a decrease.

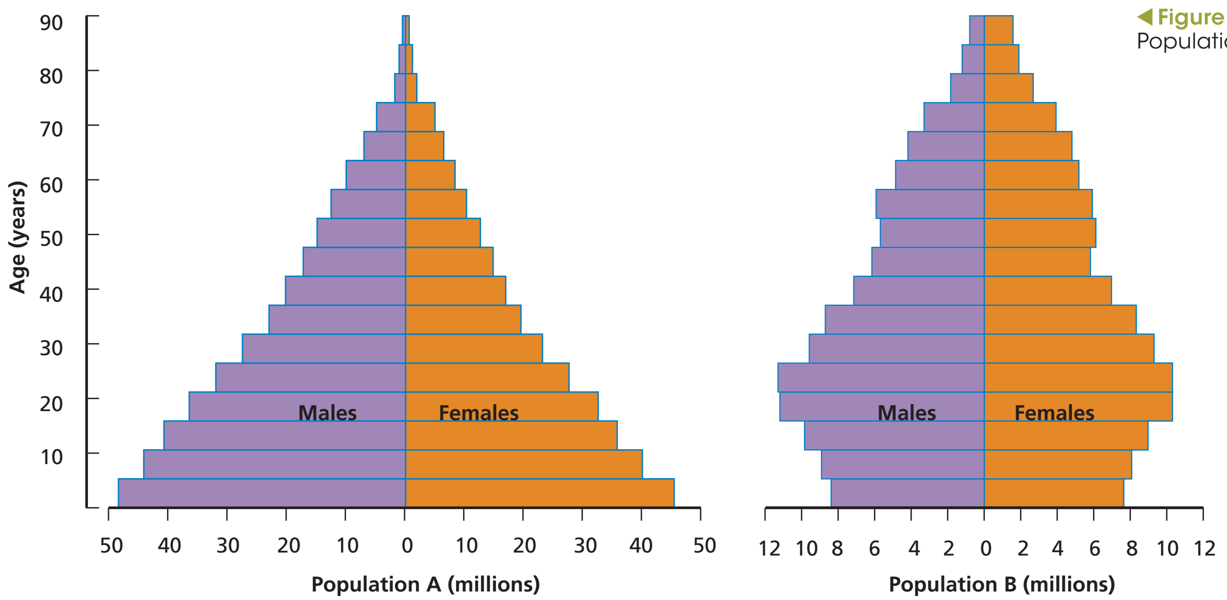
Try these yourself

1 Calculate the growth rate of a population if, for every 1000 individuals, there are 59 born, 105 immigrants, 86 deaths and 40 emigrants. (4 marks)

2 Calculate the growth rate of a population if, for every 1000 individuals, there are 150 born, 59 immigrants, 29 deaths and 30 emigrants. (4 marks)

Determining growth

Information that is provided by population studies is useful for monitoring ecosystems. Knowing the age structure of a population is significant in predicting future growth trends. A population with individuals predominantly below reproductive age will limit the ability of that species to reproduce and maintain its numbers in challenging situations, as well as in favourable conditions. Similarly, populations with individuals too old to reproduce will impact on the rate of replacement following death or emigration. A useful method of representing collected data is the construction of population pyramids. Figure 5.3 shows population pyramids for two different human populations. You can see that the pyramid for population A is wider at the bottom, indicating a healthy future reproduction rate because the number of children is quite high. Population A has a greater proportion of children than does population B. What is the significance of this?



◀ **Figure 5.3** Population pyramids

Scientific data about age distribution and sex ratios can assist in the management of populations. Each year, federal, state and local governments collect and collate information on the state of wild fish stocks. This information is used to determine the level of both recreational and commercial sustainable fishing. Sustainability ensures that overfishing does not drain the stocks, and that young (smaller) fish are able to contribute to the populations in the future. This information can be used to plan how to ensure sufficient numbers of young live to reach reproductive age, how to develop strategies for protecting endangered species and maintaining ecosystems, and how to restore degraded ones.

Measuring distribution

Understanding how populations operate takes more than knowing what kinds of species are a part of the system or how they relate to each other. It is also important to know their distribution: exactly where in the physical space members of the different species are found.

Members of a population are seldom spread evenly throughout the entire ecosystem. There are patterns in the way populations are distributed.

- **Random distribution**: organisms are spaced irregularly; the location of an organism does not affect the location of another (more common for plants than for animals).
- **Uniform (continuous) distribution**: organisms are evenly spaced; the presence of one organism determines how close or distant another will be. It is common in relatively high-density populations of some animals that set up breeding territories.
- **Clumped (grouped) distribution**: a number of individuals are grouped together and the groups make up the population as a whole. This is sometimes to do with social behaviour as in schools of fish, or clumping of vegetation in mini-habitats where biotic and/or abiotic factors are favourable.

Knowing the distribution and **abundance** (how many) of a species can help keep track of populations of significance. Knowledge of particular plant species can give clues about the distribution and abundance of animals that depend on them. The forestry industry needs to know about the distribution and abundance of valuable tree species, and the fishing industry needs to know about fish stocks. Keeping track of pest and plague species, such as mice and locusts, gives forewarning of potential outbreaks that would require management.

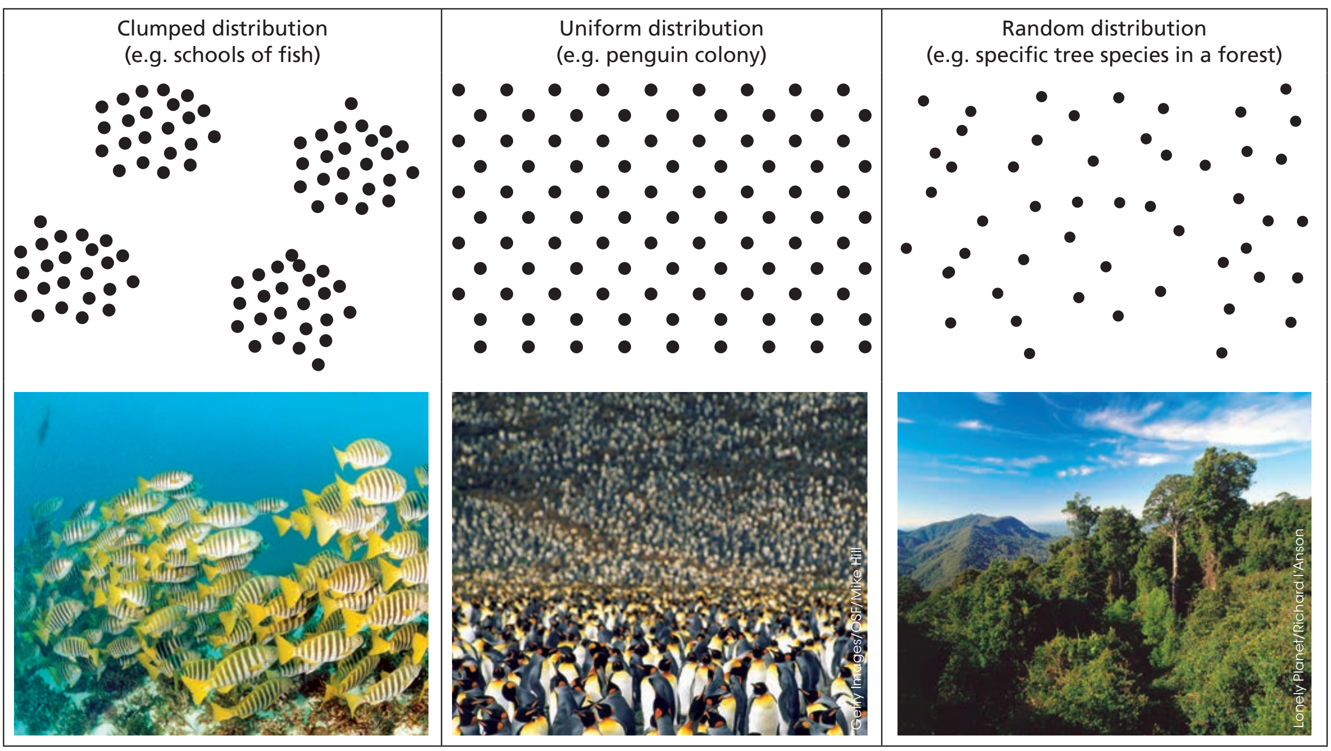


Figure 5.4 ▼ Distribution patterns: clumped, uniform and random

Techniques used to determine distribution and abundance depend upon the species or community under investigation. Essentially plants are stationary, so methods are used to determine location, numbers and distribution. Animals are mobile and so different techniques are used. The method that gathers the most pertinent data for management of populations within ecosystems should always be selected. For example, a small population of a rare orchid species may be able to be counted individually, whereas counting a colony of penguins or oceanic tuna will require different methodology.

Measuring abundance

It is not always possible to determine the population size of a species. Birds and insects are constantly on the move, and some animals move too fast to count, however, there are still techniques that can be used to make estimates. It may be difficult to work out what actually makes up an individual organism. How do you count individual plants of grass?

Direct observation

Making **direct observations** and recording sightings at particular intervals might be possible but it is time-consuming, and in the case of male fur seals in the breeding season on windswept shores, quite dangerous. Satellite images have been used to determine percentage vegetation cover in relatively inaccessible regions. In aquatic ecosystems, plankton nets are used to 'sweep' or **sample** the organisms, and aircraft traverse areas to count kangaroos and other large mammals like musk ox in the Arctic and antelope on African savannahs.

Even when it is possible, it may not be necessary to count all members of a given population. Various sampling techniques can provide estimates of a population. A sample is a small group of organisms selected from the total population in a given area or volume. This sample represents the whole population.

When determining population numbers of nocturnal species, slight variations need to be employed. In New Zealand, scientists have been using spotlights with a red filter to determine the number of fish in a measured and netted area of a river. The filter reduces the impact on the fish and counting can be carried out reliably.

Choosing a particular site because it is easy to get to or is more interesting, or selecting only two sample specimens, reduces the reliability of the data obtained. It does not give a true picture of the whole population. To represent the population as a whole reliably, the samples must be collected in an unbiased way.

Quadrat and transect

For organisms that are fixed or do not move very much, the **quadrat** method of sampling can be used to estimate distribution and abundance. A quadrat is a square, the size of which is determined according to the organism being studied, measured at ground level. It is most often used when measuring plant **density** because they are stationary. It is also a relevant method along shorelines when recording sedentary marine species that may be exposed as the tide varies. It can also be used to calculate density of a population.

CSIRO Division of Plant Industry

Figure 5.5 Quadrat sampling is often used to estimate plant population size.

If sufficient quadrats are chosen, and they are representative of the area under study, results can be used to estimate total population size. For each quadrat:

- the number of individuals of each species is counted and recorded, or
- the relative numbers of each species is estimated using a scale from abundant (3) to absent (0), or
- percentage cover is estimated, and
- the totals of the quadrats are averaged.

A simple mathematical calculation can give the total number or percentage cover for each species in the whole area. The density can also be calculated.

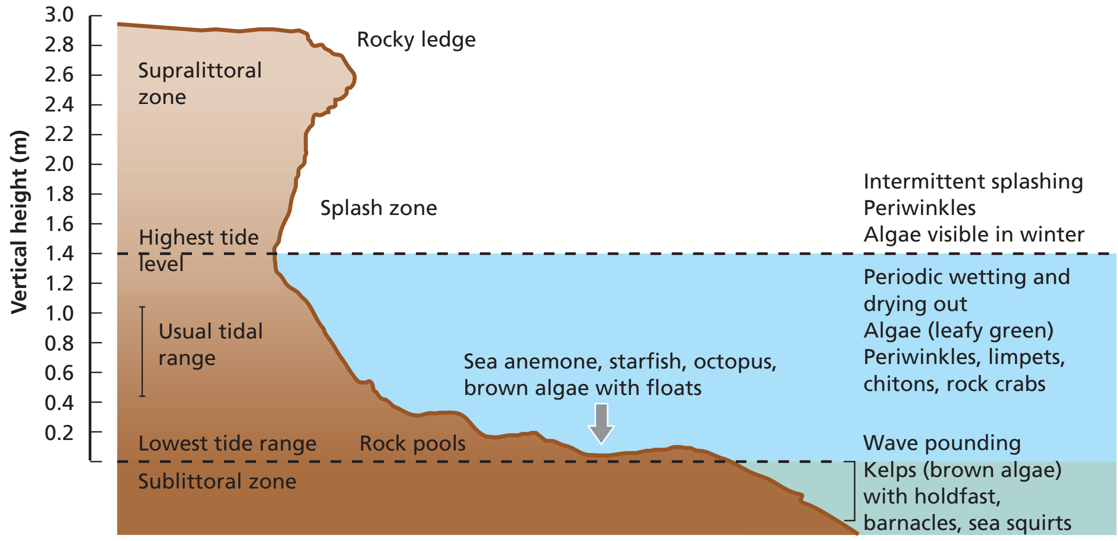
Estimating total population size of area under study

average density of members of species (estimated)

= total number of individuals counted ÷ area of each quadrat × number of quadrats

A **transect** ('trans' = across, 'sect' = section) is a line drawn through a community and the information gathered is used to determine the distribution of species within that community. Again, this is a useful method when species are fixed in place, such as plants and fungi. In order to improve the data collected, quadrats may also be placed at intervals along the transect line and thus data on density in specific locations may also be recorded.

Figure 5.6 ▶ Transect profile of a marine rock platform



WORKED EXAMPLE 5.2

If 35 individuals have been counted in 10 × 1 m^2 quadrats, what is the average density of that species? (3 marks)

Answer	Logic	
35 ÷ 1 m^2 × 10	Formula as above. Enter values	2 marks
= 3.5 individuals per m^2	Calculate answer	1 mark

Try these yourself

1 Complete the following to determine the average density.

a 65 individuals in 24 × 2 m^2 quadrats (3 marks)

b 110 individuals in 12 × 5 m^2 quadrats (3 marks)

When an area has been selected for study and the data needed has been nominated, the transect line is measured out. It may be 10 m long with regular segments (every metre) where information regarding changes in distribution is recorded as one moves along a tidal zone towards land. It may also provide information on vertical features such as the canopy of the forest, as well as the species present. It may need to be a kilometre in length if studying changes in the distribution of organisms because abiotic factors change with altitude along a mountainside.

The line transect method is best to use if environmental factors such as soil type, pH and salinity change along the distance to be sampled. Gradual changes like this are referred to as environmental gradients. Distribution of species can be correlated with changes in these abiotic factors. Vertical transects can show vertical distribution of species. Different conditions at different levels result in stratification; for example, in forests. Environmental factors change across a tidal mudflat or a marine rock platform. In these cases a profile can be drawn.

In order to gain a full picture of population distribution and specific abundance patterns in environments, a combination of methodologies is best. Data gathered using transects offers fairly accurate information regarding distribution of individuals and/or species, whereas quadrats offer a comprehensive picture of species abundance, but not distribution.

EXPERIMENT 5.1

DISTRIBUTION AND ABUNDANCE: HOW MANY PLANTS?

Determining plant numbers and species is a lot easier than determining animal numbers and species present. Plants don't move! There are two sampling strategies that work well. One is used to determine the density and total number of plants in a given area. Another method allows you to determine the distribution of a range of species within a defined space. You will be using both in this experiment.

Aim

To investigate the distribution and abundance of local plants

Materials

- 10 m tape measure
- three 1-m rulers
- pencil and eraser
- note pad

What are the risks in doing this experiment	How can you manage these risks to stay safe?
Insects or spiders living in the natural environment may bite.	Wear gloves when touching plants or soil.

Procedure

1 Select two sites to investigate: one will be a school oval, the other a forested area at least 10 m in length.

2 a On the oval: collect data about the number of plants on the total oval surface using a 1 m^2 quadrat.

b In forested area: collect data about the type and distribution of plants along a 10 m transect.

Results

1 Using your collected data, determine species type and number.

2 Research to determine the needs of each species.

3 Record your results in a table.

Conclusion

Make sure your conclusion includes quantitative data that relates directly to the measureable quantities you mentioned in your aim. If possible, make an estimate of the uncertainty in your results.

Corbis/Jonathan Blair

Figure 5.7 ▲ Playing tag: tagging a turtle

Capture–mark–recapture

The **capture–mark–recapture** method is commonly used to sample mobile species. A random sample of individuals of a species is taken and an overall estimation of the abundance of the species is made.

Step 1 Capture: animals are caught randomly and in such a way that they are unhurt. Small animals are trapped in cages or pitfalls in the ground, birds are trapped in fine nets and some animals are caught easily when they 'freeze' in spotlights. Flying insects are attracted to light traps.

Step 2 Mark and release: each captured animal is marked so that the mark is not obvious to predators or harmful to the organism. Insects are usually marked with a blob of paint, whereas birds are tagged on the leg or wing. The animals are returned to their habitat and left to mix with the unmarked individuals.

Step 3 Recapture: later, a random sample is taken and the number of marked individuals counted. The timing of recapture needs to be appropriate to again capture a random mixture of individuals, but without leaving it so long that many of the original marked individuals have died. From this information the total population can be estimated. The procedure has to be planned carefully so that the chances of each individual being caught are equal. Sometimes 'trap happy' individuals will be sampled over and over.

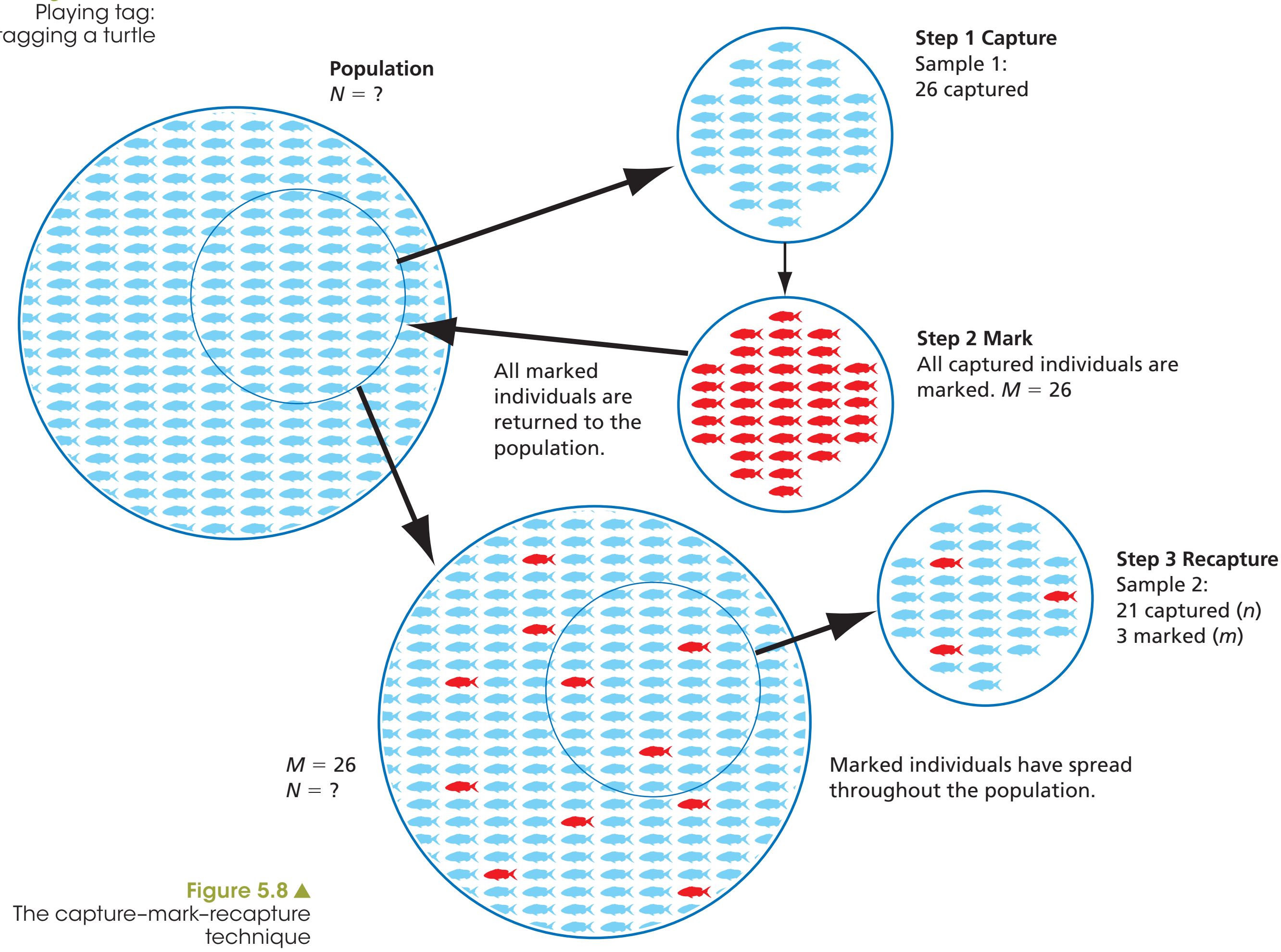


Figure 5.8 ▲ The capture–mark–recapture technique

WORKED EXAMPLE 5.3

In the first sample, 20 individuals were marked. In the second sample, 50 individuals were recaptured and of these recaptured animals 10 were marked. What is the total population? (3 marks)

Total population (N) = no. marked in first sample (M) × total number of animals recaptured (n) ÷ no. of recaptured animals that are marked (m)

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

Answer	Logic	
Total population $= \frac{20 \times 50}{10}$	Substitute into the formula above	2 marks
$= \frac{1000}{10}$		
= 100 individuals in the total population	Calculate the answer	1 mark

Try these yourself

1 In the first sample, 30 individuals were marked. In the second sample, 50 individuals were recaptured and 10 of these were marked. What is the total population? (3 marks)

2 In the first sample, 100 individuals were marked. In the second sample, 200 individuals were recaptured and 50 of these were marked. What is the total population? (3 marks)

EXPERIMENT 5.2

ESTIMATION OF POPULATION SIZE

When you are studying a population of organisms, whether it is a school of fish or a population of wombats in a certain area, it is not possible or even necessary to count all members of a given population. Estimates of numbers within the population are therefore made on the basis of various sampling techniques. A sample is a small group of organisms, selected from the total population, which is representative of the whole population. But just how reliable are these methods of estimating population size?

Aim

To estimate the size of a non-living population using the 'capture–mark–recapture' method and to comment on its reliability as a technique

Materials

Each student will require:

- 140 white or black buttons (beads or matches may be substituted)
- plastic cup to mix or shake the buttons

Procedure

1 Using a texta, mark 20 of the buttons with an 'X'. Alternatively, you could use buttons that are differently coloured from the rest; for example, 20 yellow buttons among all the black/white ones.

2 Thoroughly mix the marked buttons with the rest of the population of buttons by shaking them in the cup.

3 Take out a sample size of 20 of the buttons and count the number of marked ones among the number of unmarked.

4 We assume that if the sample taken is representative of the whole population, then the ratio of marked objects will be the same in both the sample and in the whole population:

$$\frac{\text{Total marked}}{\text{Total population (marked \& unmarked)}} = \frac{\text{Number marked in sample}}{\text{Number (marked \& unmarked) in sample}}$$

Thus:

$$\frac{\text{40 marked}}{\text{out of 160 total}} \text{ should produce } \frac{\text{5 marked}}{\text{out of 20 in a sample}}$$

$$\text{The formula for the total number} = \frac{\text{Number in sample}}{\text{Number marked in sample}} \times \text{Total number marked}$$

$$\text{In this example, the total} = \frac{20}{5} \times 40$$

$$= 160$$

5 Calculate your estimate of the population in your Results.
6 Repeat the procedure an additional nine times, each time returning the sample and mixing to get a reasonable average. You should now have 10 populations estimates based on 10 samples.
7 Draw a table and record your results.
8 Finally, count all the objects in your population.

Results

1 Record your calculations: 10 estimates of population size.
2 Record your table of results.
3 Write your average estimated population size.

Discussion

1 Based on your calculations, explain how reliable this method is at estimating population size.
2 Can you suggest any ways of improving the accuracy of this method in this experiment? Explain.
3 Discuss the advantages and disadvantages of using the capture–mark–recapture method to estimate a wild population of mice or blue whales.

Conclusion

Refer back to the aim of this experiment. Have you achieved this aim? Write a conclusion based on what you have learned.

Telemetry (remote tracking)

The management and conservation of species, whether native, endemic or pest species, is increasingly reliant on information gathered by the means described in previous sections and other methods that employ technology. The use of **species distribution modelling** to predict future needs and resource management is a more recent technology that has provided another means of achieving this aim. Increasingly, the impact of climate change is an environmental issue that raises many concerns for the wellbeing of many species, and this tool is vital in providing all necessary data.

In order to collect data used in species distribution modelling, individuals within a population need to be tracked. In Victoria, information regarding the foraging habits of little penguins throughout Port Phillip Bay during the non-breeding winter period was gathered when 21 little penguins were fitted with GPS (global positioning system) transmitters in July 2008. The data gathered indicated that the penguins went on short trips of 1–2 days around Phillip Island and then on longer foraging trips from 10–50 days out into Port Phillip Bay. The winter foraging trips appeared to be driven by the location of food sources such as anchovy, which are known to spawn in Port Phillip Bay during winter. This information was used to inform conservation groups on what areas needed to be monitored for human aquatic activity such as shipping, fishing and trawling, ensuring the survival of the penguins during these months.

Fairfax Syndication/The Age/Wayne Taylor

Figure 5.9 ▲
A little penguin fitted with a transmitter

Scientific literacy: Sea Shepherd campaigners leave to save whales from slaughter in Japan

Sea Shepherd campaigners left for their tenth annual campaign to prevent Japan's slaughter of whales in the Southern Ocean today, with three vessels departing Australia for Antarctic waters.

The Bob Barker, which was once a Norwegian whaling ship, steamed out of Hobart on the mission which aims to harass the Japanese fleet as they harpoon the giant animals and prevent them from taking their full quota.

Captain Peter Hammarstedt said it was his ninth campaign protecting whales, which have at times included high-seas clashes between the conservationists and the Japanese.

'The Japanese whaling fleet intends to kill 1035 whales of which 50 are endangered fin whales and 50 are endangered humpback whales, the very same whales that frequent the shores here off Australia,' he said.

'Our intention is to once again intercept the Japanese whaling fleet in the Southern Ocean whale sanctuary and to do everything that we can.' Sea Shepherd Australia said its two other boats the Steve Irwin and Sam Simon left Melbourne on Wednesday for the annual campaign it took over from the US-based Sea Shepherd Conservation Society in late 2012.

The Australian government, which strongly opposes Japanese whaling, is expected to announce later this week that a Customs vessel will monitor the hunt. 'The government's commitment to monitoring in the Southern Ocean remains undiminished,' a spokesman for Environment Minister Greg Hunt said in an email.

Australia wants Japan's annual whale hunt in the southern hemisphere summer to stop and has taken the matter to the UN's top court the International Court of Justice. A decision is expected in early 2014.

Japan says it conducts vital scientific research using a loophole in an international ban on whaling, but makes no secret of the fact that the mammals ultimately end up as food.

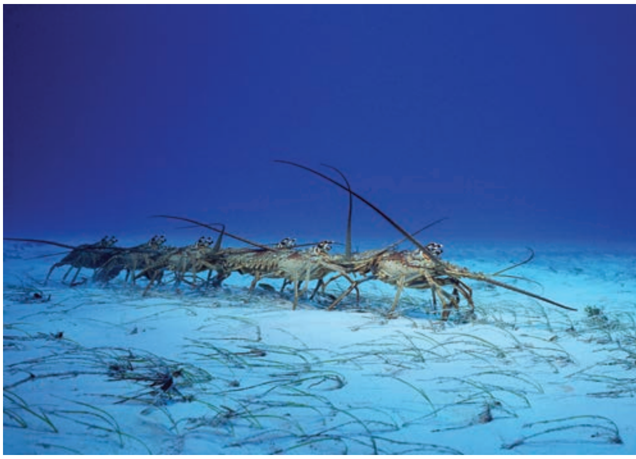
news.com.au (2013) 'Sea Shepherd campaigners leave to save whales from slaughter in Japan'. 18 December.

Questions

1. Identify the main message of this news article.
2. The Australian government, Japanese government and the United Nations International Court of Justice are all involved in the issue of whaling. In your opinion, who should have the final say? Justify your response.
3. Suggest some of the difficulties involved in monitoring and managing the remaining population sizes of whale species.
4. All whale species have a K-selected life strategy. Identify their K-selected characteristics and outline how each of these will affect the ability of their population to recover after unregulated numbers are removed.

GPS tracking is also used to track the movements of migrating animals such as birds and caribou, and is most efficient when tracking water animals such as whales, sharks, sea turtles and many sea birds. The signal is received by a satellite that ensures the animals are tracked when not in sight.

Radio tracking is an older technology than the GPS tracking systems. In this instance, the signal is transmitted from the unit attached to the animal to a receiver, much like a home transistor radio. The animals are physically followed by the scientists who will have the receiver in a car, truck or aeroplane. The data collected determines the movements of the animals and their destination. The information is then used to determine the best management strategy to ensure the safe movement of the animals involved.



Corbis/Doug Perrine/Nature Picture Library

▲ Figure 5.10 Migrating lobsters being tracked by GPS

In summary, the measuring tools used to determine the abundance of organisms in a population are dependent on a number of factors including the size of the population, the size of the organisms, whether the location is easily accessible, the life cycle of the organisms, migratory patterns, activity times and previous population information including the likelihood of population explosions or declines. They should also be relevant to the species being studied; for example, there is no point in attaching a solar transmitter to a nocturnal animal that spends its daylight hours in burrows deep beneath the Earth's surface!

WOW

Animal GPS

Recent refinements in the use of GPS trackers have reduced intrusions into the lives of the animals being tracked. Some devices are now lighter and can be used on smaller animals, or can be loaded with extra batteries that last longer on larger animals. Some transmitters on elks can last up to eight years. But the most innovative is the use of solar cells to power the transmitters used on birds, thus limiting the need for scientists to venture into the field and disturbing the natural behaviour of the birds under study.

RADIO TRACKING IN NATIONAL PARKS

Prepare a debate on the question: 'Is radio tracking a worthwhile exercise in national parks?'

Population density

Studying the density of populations in an ecosystem is useful in certain situations. Density refers to the number of individuals in a given area, such as the number of kangaroos per hectare. Sometimes it is difficult to distinguish individual plants, as with grass. In that case, density is the amount of biomass (dry) per unit area (for example, 0.6 kg of grass per m^2). In the case of diatoms in a pond, density is the number per unit volume (for example, 300 per mL).

Carrying capacity

Populations rely on balanced relationships between their biotic and abiotic components. The abiotic aspects have been studied previously. The biotic aspects are the focus of this chapter and are based primarily around communities and their component populations. So when studying a specific ecosystem, its relative health may be measured by the populations that are supported. The size of a population that an ecosystem can support is described as the carrying capacity of that ecosystem.

Knowing the density of populations can help assess an ecosystem's ability to provide sufficient resources to support its populations. This is the carrying capacity of the ecosystem and it can change from time to time as environmental conditions change.

For example, it has been estimated that 100 km^2 of moist tall eucalypt forest is the minimum area possible to support 10 000 sugar gliders as a viable population. Information such as this acts a guide to the minimum size a park or any closed ecosystem needs to be to conserve animals. Critically, the area needs to be sufficient for a significant number of top carnivores to survive. While this may be a less important consideration for Australian ecosystems where there are few large carnivores, it is still a valid point when considering how much continuous land must remain undisturbed.

Chapter 3 also discusses the abiotic and biotic aspects of ecosystems.

QUESTION SET 5.2

Understanding

1 What characteristics of populations are usually studied when analysing ecosystems?

2 Describe three basic patterns of distribution of populations of organisms.

3 Using examples, explain the differences between abundance and geographic distribution, and density and carrying capacity.

Analysing

4 Ecosystems can be open or closed to particular species. What effect does this have on growth of a population?

5 A particular population of kangaroos has 1000 births during the year; 72 individuals also join the population while 108 leave. There are 345 deaths. Work out the growth rate for this population of kangaroos for the year.

Evaluating

6 Copy and complete the table below summarising methods of estimating distribution and abundance of populations of organisms.

Method	Brief description	Best used for

Population regulation

When a few members of a species colonise a new and favourable habitat, its population increases rapidly. However, this population growth cannot be sustained; resources are used and the population begins to level off. Despite minor fluctuations in populations, there tends to be upper and lower limits. For a given species in a particular habitat, there is a certain equilibrium population that the ecosystem can support.

The population numbers of the Canada lynx and the snowshoe hare of northern Canada depend on the population sizes of the other species. Every 8–10 years the number of hares increases exponentially. The cause for this explosion is still under investigation. The lynx hunts the hare and, because there are so many hares, the lynx population also increases. This then puts pressure on the hare population and a slump in numbers follows. The stress of waiting to be hunted impacts on the health of the hares and illness spreads through the hare population. This then impacts on the lynx population, even though the lynx is able to hunt and feed on other small animals such as squirrels, grouse and white-tailed deer. For the lynx, hunting other prey takes its toll and its numbers decrease.

WOW

Population explosions

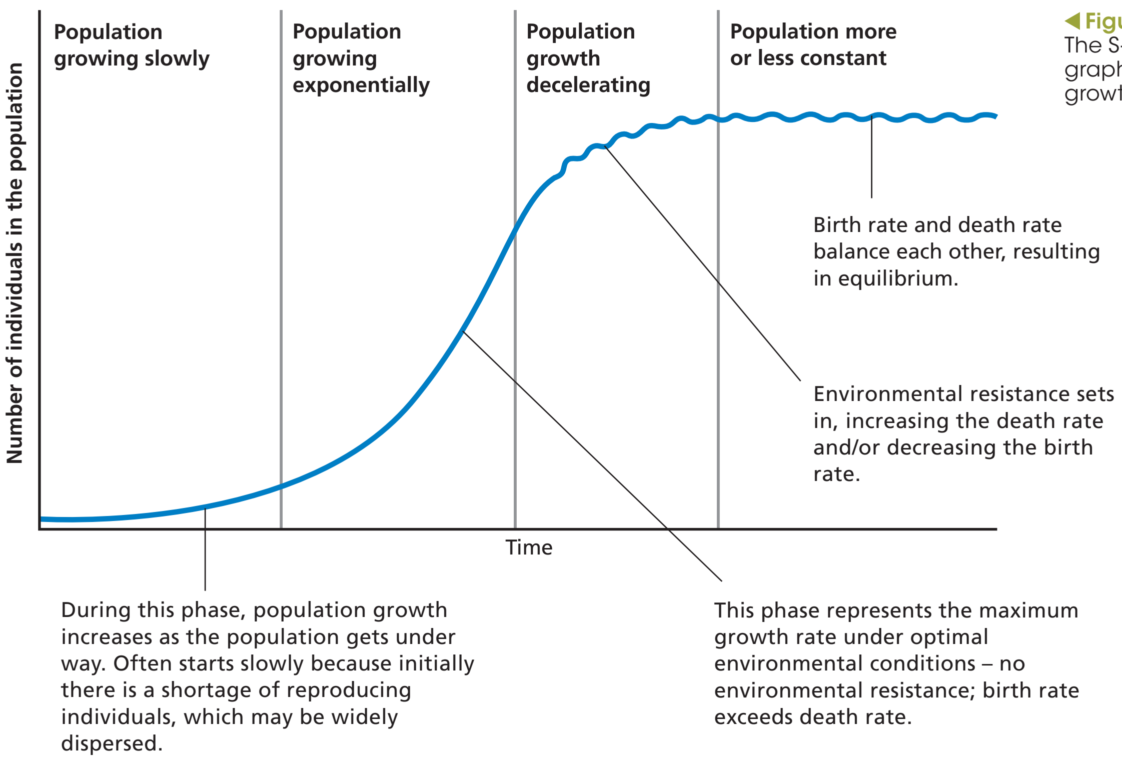
Population explosions are defined as rapid increases in populations, quite often after a catastrophic event. They are characterised by accelerated birthrate, decreasing infant mortality and extended life expectancy. Human populations are a prime example such as that seen at the end of World War II with the rise of the Baby Boomer generation.

Shutterstock.com/Dennis Donohue

Shutterstock.com/Howard Sandler

◀ **Figure 5.11**
a) A Canada lynx; b) A snowshoe hare. Their population increases and decreases are cyclic.

Factors in the environment, collectively referred to as environmental resistance, act on a population. If the population rises above the equilibrium or set point, competition for resources such as food and space begins to take effect. The increased ability of disease-causing organisms and parasites to spread also increases deaths and possibly reduces breeding. This could be to such



◀ **Figure 5.12**
The S-curve: generalised graph of population growth

Roberts, M., Reiss, M. & Monger, G. (1993) Biology: Principles and Processes, Thomas Nelson. New edition released as Advanced Biology (Nelson Thornes, 2000), © Micheal Roberts, Michael Reiss and Grace Monger 1993, 2000. Reprinted by permission of Oxford University Press.

an extent that the population falls. If it falls below the set point, there is less competition and the population begins to rise again. This kind of negative feedback process, or homeostatic control, keeps the population more or less constant (Figure 5.13). Is this scenario an example of K-selection or r-selection?

The factors mentioned above are **density-dependent factors**. The greater the density of a population, the more individuals die or fail to reproduce. **Density-independent factors**, such as severe weather conditions, volcanic activity or habitat destruction by clearing or fire, are those that affect all individuals in a population regardless of age or stage. These factors are seen vividly following a catastrophic event such as a bushfire or flooding. Populations of all living things usually decrease quite drastically due to either death or emigration to a habitat that is better able to meet their needs. Many human communities were devastated by the floods of Brisbane and south east Queensland from December 2010 to January 2011. Floods and fires, however, are part of nature's cycle and even though immediate effects to the environment and all communities within them are drastic, in the long term they redistribute sediment, seeds and animals to new areas.

Figure 5.13 ▶ Homeostatic mechanism of population control

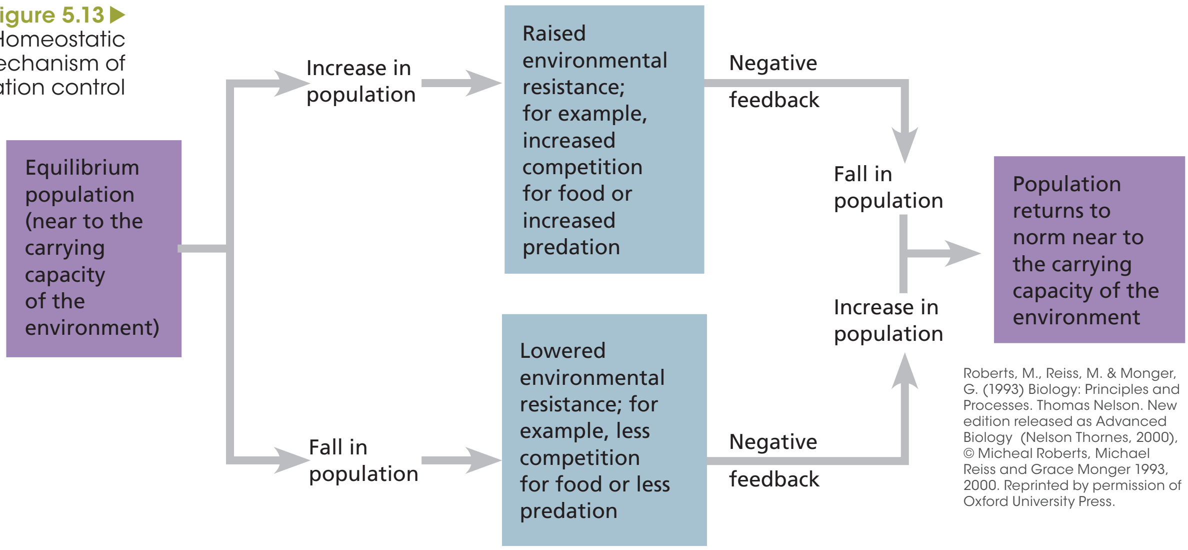


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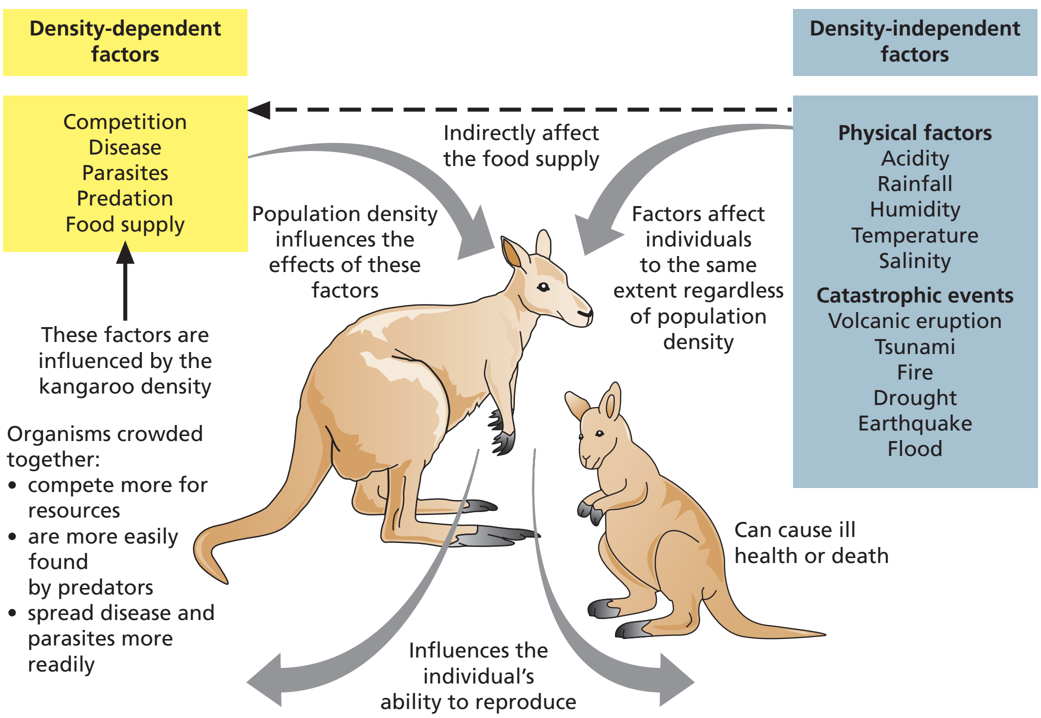
Figure 5.14 ▶ Populations are regulated by density-dependent and density-independent factors.



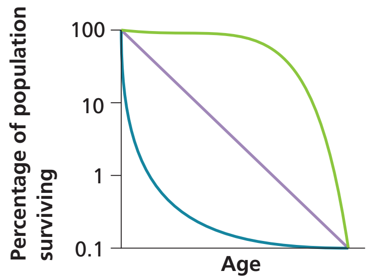
Adapted from BIOZONE International (Year 11 Biology - Student Workbook)

In some cases, populations of species are not able to recover from such extreme environmental resistance and disappear from that ecosystem. This may eventually result in widespread extinction if numbers are continually reduced with little chance of viable population growth.

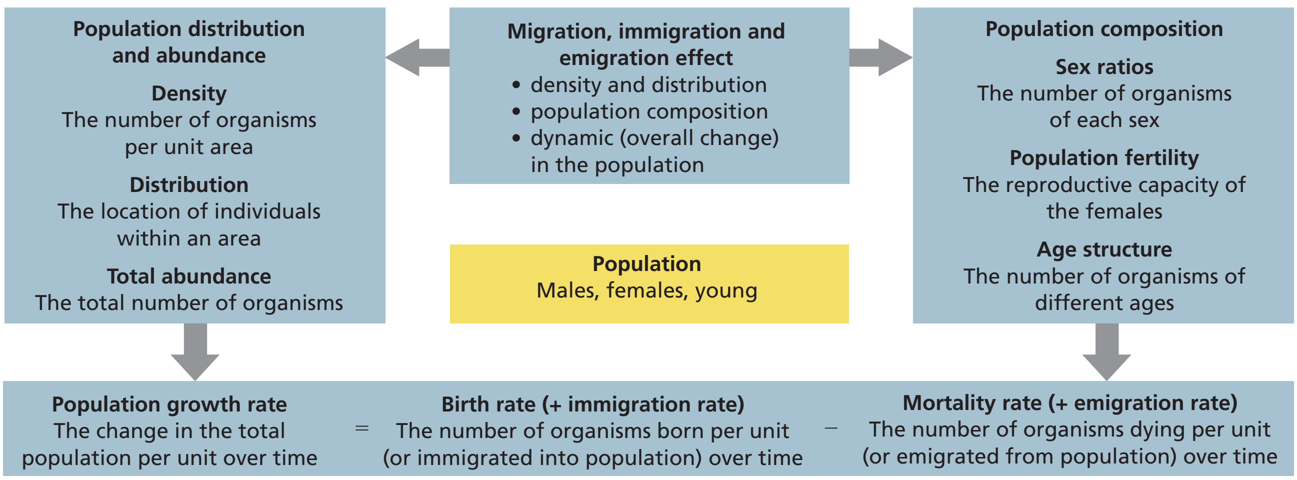
A combination of factors working together determines the survival of populations. If we examine survivorship of various species, patterns emerge. Species can be classified according to their probability of survival. This can be represented in a graph (Figure 5.15).

Table 5.1 Probability of survival of species

Classification	Description	Examples
Early loss	Species that produce many offspring. Many, even thousands, of young are produced but the probability of survival is low in early life. Probability increases with age.	Fish, frogs and many plants
Constant loss	Species whose probability of survival of individuals does not change with age. There is a fairly constant loss at all ages.	Many bird species
Late loss	Survival of individuals decreases with age.	Humans, elephants



▲ **Figure 5.15**
Survivorship curves



▲ **Figure 5.16**
Features of populations

QUESTION SET 5.3

Understanding

1 Draw a simple annotated diagram that summarises homeostatic control of populations.
2 Explain 'environmental resistance'.
3 What do survivorship curves show about the survival of populations?

Case study

Breeding, releasing and succeeding

Scientists have, for many years, mastered the concept of captive-breeding programs of endangered species. For example, remnant populations of native wildlife are kept and bred within controlled environments in an effort to restore numbers to a level where they will survive in their natural habitat. However, the projects may hit a snag when the carefully bred individuals are released back into the wild and within months there are few left. One such example is the 15-year project to breed and then return the brush-tailed rock wallaby (*Petrogale penicillata*) to western Victoria. The project is on hold as foxes are eating the released animals faster than they can breed.

The project run co-operatively by the Department of Environment and Primary Industries (DEPI), Parks Victoria, Melbourne Zoo, Adelaide Zoo, University of Melbourne researchers and ACT Parks decided to suspend the release of further animals pending a review of their procedures.

The breeding program began at Adelaide Zoo in 1998. Since that time, a total of 39 wallabies have been released into the Grampians in Victoria, and only seven have survived. According to Dr David Schultz of Adelaide Zoo veterinary department:

'Our biggest problem has been that the pouch young that have been born in the wild don't appear to have survived. We're not getting young surviving into adulthood, and that's mostly due to predation.'

Three years prior to the commencement of the breeding and release program, Parks Victoria ran a massive fox-baiting program. Other methods used included soft-jaw trapping as well as experienced, professional shooters. Remote digital camera surveillance and animal-feet tracking was also used to bring rapid field staff responses. The idea was to turn the Grampians into a fox-free haven for the wallaby, as well as other threatened species such as the long-nosed potoroo, Southern brown bandicoot, smoky mouse and heath mouse. But still the fox prevailed.

Dr Schultz says predator evasion lessons are being tested at the Tidbindilla nature reserve in the ACT. Captive-bred wallabies from Adelaide and Melbourne Zoos are sent to Tidbindilla or to a property in Dunkeld, Victoria, for 'hardening up' to living in the wild. Predator wariness training is now part of that process.

Another suggestion is the control of the fox population by Tasmanian devils. The devil vanished from mainland Australia about 600 years ago. According to Dr Schultz, 'the devils would root through the fox dens and knock off the pups'.

Adapted from Elder, J. (2013) 'Brush-tailed wallaby breeding program outfoxed'. *The Sunday Age*, 14 July.

Questions

1. Propose the type of evidence you would expect to find to indicate that foxes were mainly responsible for the deaths of the released wallabies.
2. Outline the purpose of captive breeding programs. Evaluate the value of this specific program. Discuss your reasons for your assessment.
3. Suggest the implications for other captive breeding programs in Australia, considering the result in this case.

Restoring populations

Although the rate of species loss worldwide is alarming, there are many examples of endangered populations of species being restored. Some of the recovery is due to natural cycles of population change, but many are the result of careful management and legal protection of species.

Whale species, for example, are staging extraordinary recoveries after being hunted to the verge of extinction. By 2050 it is predicted that the population of southern right whales in Australian waters may approach their pre-whaling numbers. Populations of humpback whales are expanding in the north Atlantic, north Pacific and off Western Australia.

Controlling populations

When does a living thing become a pest? Sometimes populations of species increase enormously at the expense of others when environmental conditions change. The development of particular agricultural practices, the introduction of species accidentally or deliberately and the concentration of people in urban environments have created excellent conditions for certain plants and animals to exploit.

Many fungi and insects, without natural predators, have been able to wreak havoc on crops of all kinds. Consider the mouse plagues common in Australia since European settlement or the invasive weed, Paterson's curse, which lives up to its name. Paterson's curse, also referred to as Salvation Jane, is a hardy European annual plant with a tap root that enables it to survive drought conditions. Individual plants produce many thousand seeds through late spring. When germination occurs, they are fast growing plants that quickly take over complete pastures. The name Salvation Jane was coined when, during drought, pasture animals were able to feed and survive, though a prolonged diet exclusively of the plant could lead to liver problems due to toxins present in the plant.

Chemical and biological control

The use of chemical pesticides (**chemical control**) is a quick and effective method of getting rid of pests, but there is a down side: the pesticides can be ecologically damaging as well as costly. Scientists now favour the use of **biological control** agents, which exploit relationships between organisms, or an integrated approach when rapid response is needed in the early stages to manage a problem. This may also be known as integrated pest management, which encourages the use of biological measures to control pests and limits the use of chemicals to narrow-spectrum agents that target specific species. Even biological control measures have their limitations.

There are four kinds of biological control agents:

1. **general predators**: organisms that consume a great variety of pest species; for example, ladybirds target aphids, caterpillars, mites and small beetles
2. **specialised predators**: organisms that target one pest species, such as the way dragonflies target all life stages of mosquitoes
3. **parasites**: organisms such as wasps or flies that lay their eggs in the bodies of hosts. When the eggs hatch, the larvae feed on the body of the host (moths and caterpillars) causing the host's death.
4. **microbial diseases**: caused by bacteria, fungi and viruses that target species and cause death through illness. Examples include *Myxomatosis*, which was introduced to control rabbit populations.

Almost all ecological disasters resulting from biological control have been due to the first method. For example, cane toads were introduced in north-eastern Queensland to control cane sugar beetle pests. Cane toads have rapidly expanded their range to the north and south of the original site, and are now found in the Northern Territory and into southern New South Wales.

Introduced plant weeds, some escaped from gardens or dumped from aquariums, choke many waterways. The plants grow freely, without any environmental control, and impact on the local animal and plant populations negatively. Too many weeds limits the populations of other species that native animals require for food and shelter. A small South American weevil, the natural predator of the water weed *Salvinia*, was released in 1980 with great success in many areas. Moths and flea beetles, introduced in 1977, are reducing the impact of the alligator weed. Another beetle from South America is controlling water hyacinth. There tends to be a balanced relationship now between the control agents and the plants.

Wasps are being used to control the native stem-girdler moths that can decimate macadamia and pecan crops in Queensland. The wasps lay their eggs in the moth eggs, which are then consumed by the wasp larvae. Many other wasps have been harnessed to control a range of pests, such as the *Heliothis* moth that feeds on cotton plants. Recent research has shown that green ants are a cost-effective method of controlling most pests that attack mangoes. Growers are being encouraged to introduce the ferocious predators into their mango orchards!

'Myco-insecticides' ('myco' = fungi) are showing promise as control agents. Many species of fungi in the soil attack grubs (larvae) that gnaw away at the roots of plants, including pasture grasses, sugar cane, potatoes and other crops. Selected fungi are now being used as biological control agents of scarab beetles and other target insects. Beetles carry diseases that affect plants, such as Dutch elm disease. This is a fungal infection that leads to the death of the tree, not limited but most commonly occurring in elm trees. The fungus is carried by beetles that infect each tree on which they feed. One way of combating the infection in the trees is to target the beetles. This is achieved by the action of fungi that infect the beetle's digestive system and prevent the beetle from gaining adequate nutrition, thus dying off.

WOW

Ladybirds: ecowarriors

Ladybirds have been introduced to battle aphids on citrus trees. This reduces the use of expensive chemical pesticides and limits the impact of these chemicals on other species.

Alamy/Graphic Science

Figure 5.17 ▶ A ladybird feeding on citrus aphids

Culling

The thought of **culling** populations of particular species that are pushing their ecosystem beyond its carrying capacity can cause strong reactions in people. Populations of some species of kangaroos have increased and expanded enormously since Europeans arrived. Land use was changed in such a way that it affected many endemic species of plants and animals. Six kangaroo species, for example, have become extinct. There are 7 kangaroo species that are endangered but the remaining 35 species are viable in their rangelands.

The Australian red and grey kangaroos have thrived in those areas where permanent water is made available for cattle. As populations of kangaroos have increased, there has been increased competition for resources. Each year, more than 2 million kangaroos are culled under strict regulations. The kangaroo industry is worth more than $200 million each year. A small proportion of the meat is processed for human consumption, most of it for export.

In 2013, conservationists called for the culling of the wild horse population of Victoria's alpine areas as it threatened the health of the alpine environment. The wild horse (brumby) population was estimated at 10 000 strong. Australian environments suffer from the effects of these hooved animals. Grasses are trampled, leading to soil erosion and the prospect of long-term rehabilitation of the area a reality. In the process, the habitats of many native flora and fauna are compromised. In some areas, where smaller populations of the brumby survived, co-existence with native species was possible.

To cull or not to cull?

Kangaroo Island, off the coast of South Australia in the Great Australian Bight, has been the home of large koala populations over the years. The year 1997 saw the introduction of the Kangaroo Island Koala Management Program to reduce the negative effects the large koala population was having on some eucalypt species on which the animals were selectively feeding. At the time, culling koalas was one option under discussion. Ultimately, this option was not pursued and two other programs were implemented. The first was the sterilisation of 9500 koalas. This reduced the rate of reproduction to a sustainable level. The second strategy was the translocation of 3800 individuals to their historic range in south-east South Australia. Both these strategies have resulted in positive outcomes for both the animals and the trees. The trees have returned to a healthy state that can be sustained with the current numbers of koalas. The koala numbers have been controlled without needing to cull existing populations. This is a win–win situation for all involved.

KANGAROO CULLING

Using the information given, prepare a report on the merits of kangaroo culling in Australia.

Reintroducing populations

The devastation that has occurred to native populations has often followed on from the invasion of introduced species. These species have been able to populate and then overrun habitats unchecked. So what defines a pest? One useful definition is any species causing harm or death to other organisms. It is also a species that can feed and reproduce to such an extent that local populations do not have any chance when competing for the same resources. One example worthy of study is the *Galaxias* genus. Galaxias are native freshwater fish whose numbers have suffered since the introduction and proliferation of the mosquitofish, which does very little to impact the mosquito numbers. Galaxias do not lay eggs – they give birth to live young that are easily devoured by the pest species. The numbers of galaxias have dropped to such low levels that numbers in the wild are no longer self-sustaining in some areas. However, they are relatively easy to breed in captivity. In order to re-introduce galaxias to the wild, the mosquitofish needs to be eradicated, or the same cycle that led to decreased numbers of galaxias will still exist. Eradication is a difficult process, so currently the only means of introducing galaxias back into the wild is through the location of uninfested waterways or artificially created ponds that have no migratory possibilities with infested ponds, lakes, streams or rivers. The reduction in numbers of galaxias has led to associated drops in the population numbers of native frogs and other aquatic species such as native insects.

Alamy/Diarmuid Toman

Figure 5.18 *Galaxias* genus fish are native freshwater fish whose populations decreased when mosquitofish were introduced.

Other species suffering similar decreases in numbers due largely to predation by introduced pest species, face the same issues. They can be bred in captivity. For land animals such as bandicoots, wallabies, quolls and marsupial mice, the threat is from feral cats, dogs and foxes. Their successful reintroduction requires safe release areas such as those with pest-proof fencing, which is then another expense that impacts on the success of any such captive-breeding program.

QUESTION SET 5.4

Understanding

1 a Under what circumstances does an organism become a pest?
  b Provide advantages and disadvantages regarding the use of chemicals to control pests.

Analysing

2 Draw up a table that summarises methods of biological control. Include examples of control relationships.

Evaluating

3 Use an annotated diagram to summarise ways to restore the balance of populations of species in an ecosystem.

CHAPTER SUMMARY

- Population numbers of native populations, whether plant or animal, are dependent on interactions between biotic and abiotic factors.
- Biotic factors include relationships between endemic and introduced species, available food resources and reproduction rates.
- Abiotic factors, which are generally measurable and mostly predictable, include water, soil and air quality, and availability of nesting sites.
- r-selection occurs when conditions are ideal for a rapid population increase and decrease, such as occurs with locusts.
- K-selection is found in species that mature slowly and breed later with fewer offspring that benefit from prolonged parental care, such as primates and elephants.

- Methods of recording populations within their environments varies according to the species being observed, and includes direct observation, GPS and satellite monitoring, capture-mark–recapture techniques, and transect and quadrat recording methods.
- Population regulation may involve human interference using methods such as culling and pest control through either chemical or biological means.
- Population size is determined by the increasing effects of birth and immigration rates, and decreasing effects of death and emigration rates.
- Carrying capacity indicates the maximum population supported in an environment, and all other factors listed above assist in determining this.

CHAPTER GLOSSARY

abiotic the non-living components of an ecosystem

abundance how many; the number of a species in a population

biodiversity the full range of different living things in a particular area or region; it can be described at various levels, including the range of different species, genetic diversity, or the diversity of ecosystems present in a larger area

biological control when living organisms are used to control pest species

biotic the living components of an ecosystem

capture–mark–recapture an ecological surveying technique used to measure animal populations, in which individual animals are captured, marked and released; after a time, the population is re-sampled and the number of marked animals caught gives an indication of population size

carrying capacity the maximum population size of a species that can be supported in a given environment

chemical control the chemical pesticides used to control pest species; quick and effective, but can be ecologically damaging and costly

clumped (grouped) distribution describes the situation in which individuals in a population are grouped together where biotic and/or abiotic factors are favourable; can be social (e.g. schools of fish) or clumping of vegetation

culling reducing the abundance of a particular species that is pushing the ecosystem beyond its carrying capacity

density the number of individuals in a given area; can use biomass or volume for smaller individuals

density-dependent factor the greater the density of a population, the more individuals die or fail to reproduce; e.g. disease-causing organisms and parasites

density-independent factor a factor that affects all individuals and usually leads to a drastic decline in population due to death or emigration; e.g. severe weather conditions, volcanic activity and habitat destruction by clearing or fire

direct observation a method used to measure abundance; e.g. recording sightings at particular intervals; can be time-consuming and dangerous

distribution the places in the ecosystem where individuals of species are found; usually this is not evenly spread

general predator an organism that consumes a variety of other species

K-selected species a slow-growing, long-lived species typical of those in a climax community

K-selection describes population growth; while some individuals may not survive initially, over the long term a sustainable population can be maintained

microbial disease a biological control agent that leads to death by illness; e.g. the myxomatosis disease introduced to control rabbit populations

parasite an organism, such as a bacterium, virus, fungi, worm or arthropod, that lives on or in another organism and causes death

population a group of individuals belonging to the same species living in a particular area at the same time

quadrat the method used in population sampling where a square is placed on the ground to count each individual of a species and determine their density; useful for stationary organisms

random distribution a measurement of distribution; organisms are spaced irregularly

r-selected species a fast-growing and reproducing organism, often the first to occupy unused resources and living space

r-selection describes population growth; opportunistic species quickly colonise an unstable ecosystem, leading to a pattern of rapid population increase and decrease (or crash), and eventual take over by competitors

sample a small group of organisms selected from the total population; is representative of the whole population

specialised predator a biological control agent that targets one pest species specifically

species a group of organisms that share a gene pool; all members of the same species have the capacity to interbreed to produce fertile offspring as long as they are not prevented by any physical barrier

species distribution modelling an attempt to predict future needs and resource management using computer technology

transect a method used in population sampling where a line is drawn through a community to determine the distribution of species; can be used in conjunction with quadrats and is useful for stationary organisms

uniform (continuous) distribution a measurement of distribution where organisms are evenly spaced

CHAPTER REVIEW QUESTIONS

Remembering

1 Define the types of population growth: K-selection and r-selection.

2 Describe the differences between density-dependent and density-independent factors.

3 In what ways are resources distributed that lead to each of the population distribution patterns?

Understanding

4 Capture–mark–recapture is one method used to determine the age structure of mobile populations. What problems may arise if too much time is left between the initial capture and the second recapture?

Applying

5 In the following examples, determine the resource that is impacting most on the population distribution.

- a Heath plants in clumps in a field
- b Penguins distributed evenly across an ice sheet
- c Alpine grasses randomly spread along the side of a hill

Analysing

6 a Draw a graph to show what would happen to a population of rabbits if there were no predators in the areas where the rabbits lived.

- b Introduce a predator such as a fox into your population and show on your graph what may be expected to happen to the rabbit population.

7 Using Figure 5.6 on page 108, determine the abiotic features that are vital for species found in the following environments.

- a Rock pools
- b Zone above the splash zone
- c The sublittoral zone

8 Describe the attributes that would indicate that a population is increasing in size.

9 How does the age structure of a human population indicate future growth patterns? What age group would need to show a steady growth to indicate a healthy overall population growth?

10 A student is asked to estimate the population size and density of beetles in an area shown in Figure 5.19. She collected data from 10 randomly placed quadrats each 10 cm x 10 cm in size (as shown).

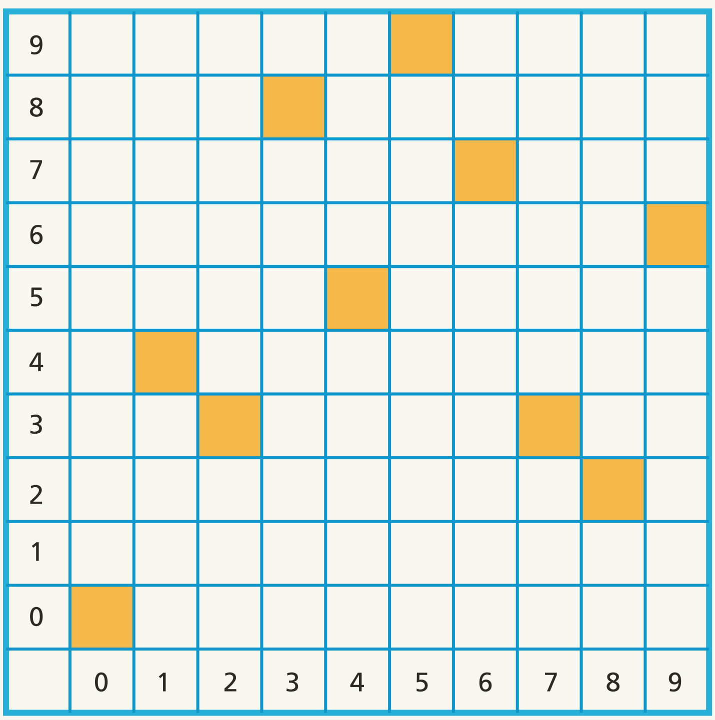


Figure 5.19
Quadrat samples

Table 5.2 Summary of results

Quadrat coordinate	Number of beetles	Quadrat coordinate	Number of beetles
(0,0)	10	(5,9)	14
(1,4)	0	(6,7)	3
(2,3)	45	(7,3)	6
(3,8)	32	(8,2)	12
(4,5)	48	(9,6)	16

a Calculate the population size and density of the beetles in the total area.
b Investigate two methods that could have been used to obtain the count of beetles.

11 Two populations of different species within an area are measured at 3-year intervals. Over that time, the numbers of the two species vary as shown in Table 5.3.

Table 5.3

Time	Number of species 1	Number of species 2
Year 0	25	85
Year 3	50	50
Year 6	30	75
Year 9	60	70

a Graph the results on one set of axes.
b Describe the trend you see with the two species.
c One species preys on the other. Explain which species you think is the predator and why.

Evaluating

12 A brown moth, so small it is barely visible and with a preference for chardonnay, threatened to become the Victorian wine industry's greatest scourge. The light brown apple moth caterpillar is capable of devouring up to 10 shoots out of every 100 throughout the growing season. Winemakers in the past resorted to chemical spraying, but they now rely on the native *Trichogramma* wasp. The wasps lay their own eggs inside the moth eggs and, as they hatch, the wasp larvae eat the moth caterpillars.
a What are the advantages and disadvantages of chemical spraying?
b What kind of relationships is being made use of to control the moths? Identify the partners.
c Draw a simple graph to show what happens to the population of apple moths and the population of *Trichogramma* wasps over time. Label your graph carefully.

Creating

13 How does population sampling assist in each of the following situations?
a Maintaining a population of an endangered species of wallaby
b Maintaining bird populations during the duck shooting season

14 Australia has about 700 endemic species of grasshoppers and locusts, but the one that usually hits the headlines is the Australian plague locust, *Chortoicetes terminifera*. Locust populations increase enormously in favourable climatic conditions, usually following periods of rainfall. Many minor plagues occur regularly but there have been five major plagues in the past 60 years. Densities of 1000 per m^2 have been recorded.
a Outline the abiotic and biotic conditions that may give rise to locust outbreaks.
b Are locusts r-selected species or K-selected species? Which features help you determine this?
c Predict the impact of a locust plague on other species, including humans.
d Suggest three ways to combat locust plagues in Australia.