Population Characteristics

White-tailed deer (*Odocoileus virginianus*) are becoming more and more common in some cities in southern Ontario. Urban infringement on natural habitats, increased traffic, and changes in agricultural land-use practices have all increased interactions between the deer and humans (**Figure 1**). The increasing presence of white-tailed deer within city limits is problematic for both the deer and humans. Crop damage and a growing number of collisions between deer and drivers have encouraged government and wildlife officials to initiate strategies to maintain healthy deer populations (groups of the same species living in a particular geographic area at the same time) and reduce conflicts between the deer and humans.

Some people see the deer as destructive because the deer may damage crops or create a hazard on roadways. They believe that culling the population (selectively removing some of its members) is necessary. This was accomplished, in part, by a selective harvest system that was implemented in the 1980s to maintain healthy, sustainable deer populations. However, other people recognize that interactions with the deer are part of our relationship with nature. They believe that we should value the integrity and beauty of nature, rather than regard nature as something to manage.

Monitoring wildlife and protecting the rich biodiversity of the province while providing ecological resources is part of the mandate of the Ontario Ministry of Natural Resources. Wildlife officers monitor populations to determine if a species is invasive or if it is a native species expanding its range because of human activities. They need to decide what population size is ideal for a particular habitat and know when a population has reached this ideal size. They must also maintain healthy, sustainable population levels, using the many wildlife management options that are available.

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Population ecology is the study of populations, particularly their size, density, distribution, and changes over time. Population ecologists monitor, evaluate, and model changes in populations. By doing this, they are able to gather data that can help them predict growth trends in populations. The data can also help them determine the health of the different species and the ecosystems in which the species live. This information then allows scientists to manage the size of the populations. Research in ecology is often linked to work in genetics, physiology, anatomy, behaviour, palaeontology, and evolution, as well as geology, geography, and environmental science. Many ecological phenomena, such as climate change, occur over huge areas and long time spans, so ecologists must devise ways to determine how environments influence organisms and how organisms change the environments in which they live.

The Distribution of Populations

The distribution of a population is described by three key factors: its geographic range, defined by various boundaries; its population size and density; and the way that individuals are dispersed through the area.

Geographic Range

The **geographic range** is the total area that is occupied by a population. Geographic ranges vary enormously. The lakeside daisy (*Hymenoxys herbacea*), for example, is a rare species in the aster family that lives only in the Great Lakes region. It is found in Michigan, Ohio, Illinois, and southern Ontario. In Ontario, 38 populations of this species are found in the southern part of Manitoulin Island and on the Bruce Peninsula. Conversely, the tamarack larch (*Larix laricina*) has a very extensive geographic range. This tree is native to northern North America and can be found in all the provinces and territories of Canada.

A **habitat** is a specific environment in which an organism lives. It is characterized by its biotic and abiotic features. The common blue violet (*Viola sororia*), for example, grows in shaded fertile habitats, where moist soil is prevalent. Since the violet grows

Figure 1 White-tailed deer are becoming more common in urban areas. Fish and wildlife officers monitor deer populations to maintain healthy, sustainable levels.

population ecology a sub-field of ecology that focuses on the dynamics of populations and how populations interact with their environment

geographic range the overall spatial boundaries within which a population lives

habitat the place where an organism normally lives

low to the ground, it tends to creep into lawns and gardens. Despite its pretty blooms, it is often considered to be a weed. In contrast, the lakeside daisy is mainly found in alvar habitats (limestone bedrock with thin or no soil). These habitats are threatened by quarry and cottage development, as well as increased recreational usage. This flower has been designated as a threatened species in an effort to stop its population from declining.

Population Size and Density

Biologists are interested in **population size (N_t)**: the number of individuals that make up a population at a specified time. They are also interested in **population density (D)**: the number of individuals per unit area or per unit volume of their habitat. Species with a large body size generally have a lower population density than species with a small body size (**Figure 2**). For example, moose (*Alces alces*), a large herbivore that may weigh as much as 700 kg, may have a home range between 5 and 40 km². In comparison, a snowshoe hare (*Lepus americanus*), a small herbivore that may weigh up to 2 kg, may have a home range of just 0.1 km². Thus, a single moose can use the same amount of habitat as more than 400 snowshoe hares. Large animals require more space than smaller animals because of their body size and food requirements.
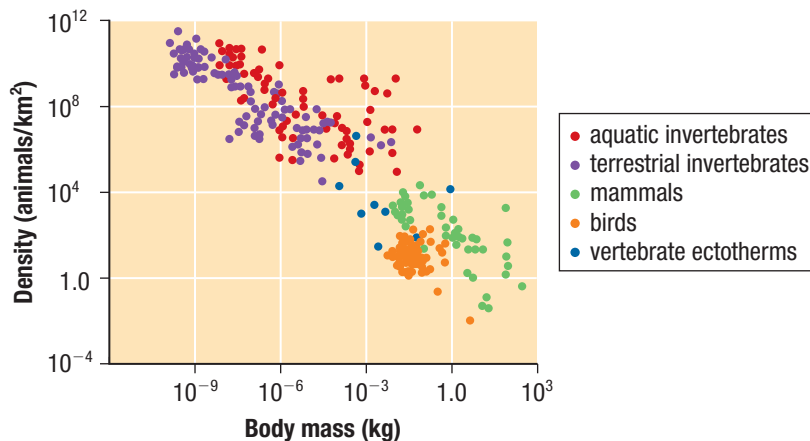
population size (N_t) the number of individuals of a specific species that occupies a given area or volume at a given time

population density (D) the number of individuals of the same species that occurs per unit area or volume

Figure 2 As the body size of animals increases, the number of animals per unit area tends to decrease.

The measure of population density can be misleading because of the unused or unusable space within a habitat. Therefore, ecologists differentiate between the number of individuals within an entire habitat (the **crude density**) and the number of individuals per unit area that is actually used (the **ecological density**).

Although population size and density are related measures, knowing the density of a population provides more information about the population's relationship to the resources it uses. Population density is calculated by dividing the total number of individuals in the population (N) by the space occupied by the population (S):

crude density population density measured in terms of the number of organisms of the same species within the total area of the entire habitat

ecological density population density measured in terms of the number of individuals of the same species per unit area or volume that is actually used by the individuals

$$D = \frac{N}{S}$$

For example, researchers identified 860 mature sugar maple trees (*Acer saccharum*) growing in a 4 ha (hectare) forested area of central Ontario. The density of the trees can be calculated as follows:

$$\frac{860 \text{ trees}}{4 \text{ ha}} = 215 \text{ trees/ha}$$

In the same study, the researchers estimated that there were 75 000 maple seedlings in a 0.5 ha plot. The density of the seedlings is

$$\frac{75\,000 \text{ seedlings}}{0.5 \text{ ha}} = 150\,000 \text{ seedlings/ha}$$

A hectare is an area of 10 000 m², so this value represents an average density of 15 seedlings per square metre. Clearly, the population of mature trees is less dense than the population of seedlings. However, as the seedlings grow and compete with each other and other species for nutrients, their density will more closely mirror the density of the mature trees.

In addition to measuring the population densities of the mature sugar maples and seedlings, the researchers also gathered data on red oak and beech trees in the same area. By comparing the densities of different species over many years, the researchers were able to document changes in the makeup of the entire ecosystem.

Dispersion of Populations

dispersion the pattern of distribution in which a population exists; may be clumped, random, or uniform

Populations can vary in their population **dispersion**, which is the spatial distribution of individuals within a geographic range. Ecologists define three theoretical patterns of dispersion: clumped, random, and uniform (**Figure 3**). Clumped dispersion is a pattern in which individuals in a population are more concentrated in certain parts of the habitat. It is a common pattern and occurs in three situations:

- Suitable living conditions are often distributed in patches. Cattails demonstrate clumped dispersion because they are only able to grow in wet conditions, on the edge of a lake or pond, or in wet soil.
- Populations of some social animals are clumped because mates are easy to locate within groups. The animals may cooperate in rearing offspring, finding food, and defending themselves from predators.
- Populations can be clumped due to limited seed dispersal or asexual reproduction. For example, some species reproduce by asexual clones that remain attached to the parents. Aspen trees exhibit clumped dispersion when they originate asexually from a single plant. Clumping may also occur in species in which seeds, eggs, or larvae lack dispersal mechanisms, such as the ability to move on their own, travel in wind, or float on water. Therefore, offspring grow and settle near their parents, forming clumps.
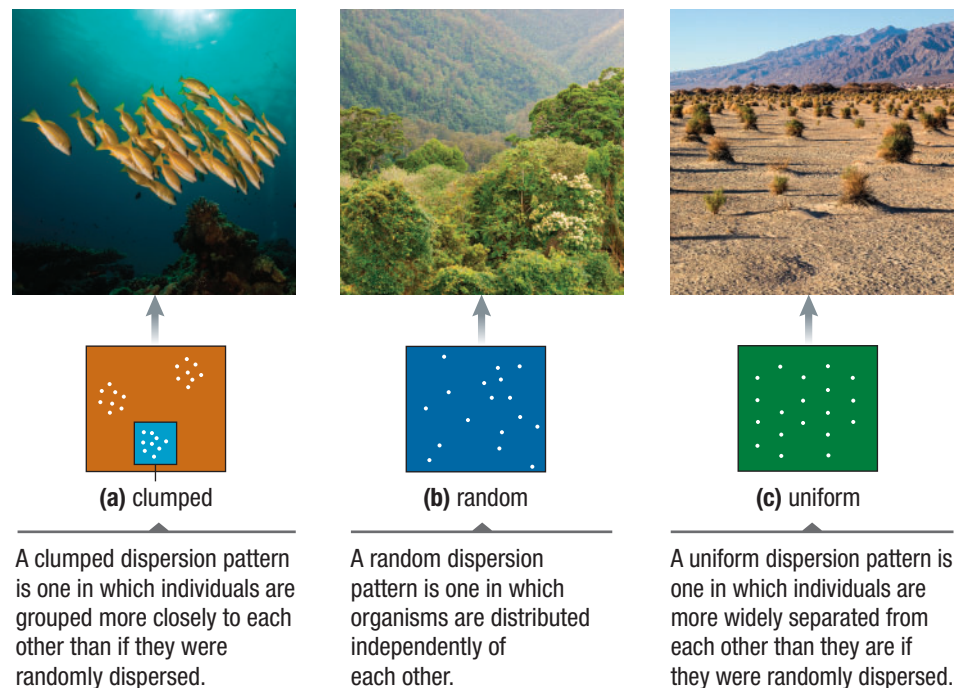

(a) clumped

A clumped dispersion pattern is one in which individuals are grouped more closely to each other than if they were randomly dispersed.

(b) random

A random dispersion pattern is one in which organisms are distributed independently of each other.

(c) uniform

A uniform dispersion pattern is one in which individuals are more widely separated from each other than they are if they were randomly dispersed.

Figure 3 (a) A clumped pattern of dispersion is evident in fish that live in social groups. (b) A random pattern of dispersion, seen here in an Australian rainforest, is rare in nature. This pattern serves as a yardstick for evaluating other dispersion patterns. (c) A nearly uniform pattern is demonstrated by creosote bushes (*Larrea tridentata*) near Death Valley, California.

Random dispersion occurs when environmental conditions do not vary greatly within a habitat and individuals are neither attracted to nor repelled by others of their species. In random dispersion, individuals are distributed unpredictably, and ecologists use statistics to determine when the distribution of a population is random. Some spiders, burrowing clams, and rainforest trees exhibit random dispersion.

In contrast, individuals can be equally spaced throughout a habitat. This is called uniform dispersion, and it may occur when individuals compete for food, breeding, or nesting grounds. Creosote bushes are uniformly distributed in the dry scrub deserts of the southwestern United States. Mature bushes deplete the surrounding soil of water and secrete toxic chemicals, making it impossible for seedlings to grow. Territorial behaviour, the defence of an area and its resources, can also produce uniform dispersion in some species of animals, such as in colonies of nesting birds.

Whether the spatial dispersion of a population is clumped, random, or uniform depends partly on the size of the organisms and the size of the study area being examined. Oak seedlings may be randomly dispersed on a spatial scale of a few square metres. However, over an entire mixed hardwood forest that covers many hectares, they are clumped under the parent trees. Therefore, dispersion of a population depends partly on the researcher's scale of observation. 🌐 CAREER LINK

The dispersion of an animal population often varies through time in response to natural environmental changes. Few habitats provide a constant supply of resources, such as food, throughout the year. Many animals move from one habitat to another on a seasonal cycle, based on the distribution of resources. Tropical birds and mammals are often widely dispersed in deciduous forests during the wet season, when food is widely available. During the dry season, these species crowd into narrow "gallery forests" along watercourses, where evergreen trees provide food and shelter.

Studying Populations

Biologists measure population size and density to understand more about population dynamics and to monitor and manage populations of endangered species, economically important species, and agricultural pests. For species of large animals, a simple count of the number of individuals can provide accurate information. For example, ecologists survey the size and density of populations of large African animals (such as lions, wildebeest, and elephants) by aerial counting (flying over in an airplane) **(Figure 4(a))**. This can be difficult, however, if the animals are camouflaged or concealed by trees **(Figure 4(b))**.
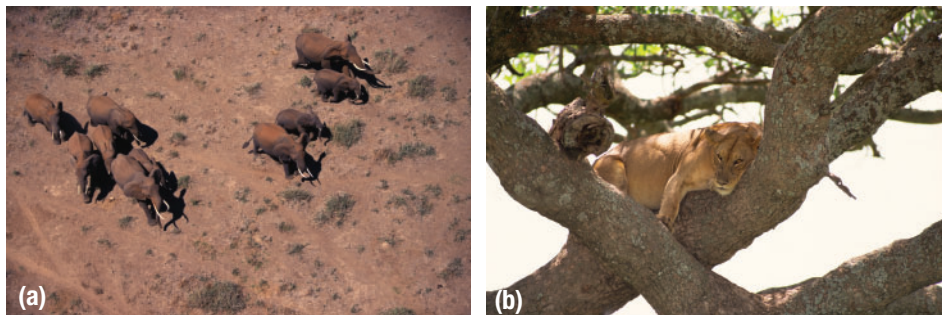

Figure 4 (a) Ecologists study populations of large African animals, such as elephants, using aerial counting. (b) However, counting animals from the air can be difficult if they spend their time under or in trees.

Often, the characteristics of a population make an accurate count impossible. Many populations are dynamic, and their number and geographic location can change over time. For these populations, scientists use sample data and their own observations to estimate population size and density. For other populations, an estimate of size can be made with indirect indicators, such as tracks, nests, or fecal droppings. However, when accurate estimates of population size are important, or when biologists are faced

with the challenge of populations that are mobile within their habitat or not readily observable, such as populations of aquatic organisms, ecological sampling methods are used. 🌐 CAREER LINK

Sampling Populations

Population size and density are important population characteristics, but they are often difficult to measure accurately. Many sampling techniques have been designed for measuring populations. Each technique has its own strengths and weaknesses, depending on the type of population that is sampled. A common and effective sampling technique for estimating population size and density of small or immobile organisms is **quadrat** sampling.

quadrat a sampling frame that is used for estimating population size; the frame can be real or virtual

A quadrat is a square made of wood, plastic, or metal that is used to isolate a sample (**Figure 5**). The size of the quadrat depends on the size of the population being sampled. For example, if a researcher wanted to estimate the population size of dandelions growing in a meadow, the quadrat would likely be 1 m². However, if the individuals in the population were much larger, the size of the quadrat would increase.

Quadrats must be placed randomly in the area being sampled to avoid bias. They must also be representative of the entire area in question. If a biologist who was determining the density and size of plants in a schoolyard placed quadrats only along a path, for example, the samples would not be random and therefore not representative of the entire population. Bias such as this can be avoided if the quadrats are placed at randomly chosen coordinates. In the tutorial below, you will practise using quadrats to estimate population density.

Figure 5 Quadrats are used to sample populations.

Tutorial 1 | Estimating Population Density

Quadrat sampling is one of the most convenient techniques for measuring the abundance of organisms in a specific area.

Sample Problem 1: Using Quadrats to Estimate Density

A biologist wants to estimate the population size and density of snails on a beach. The beach measures 100 m by 50 m. The biologist randomly places four 1.0 m by 1.0 m quadrats on the beach. Estimate the population size and density if the biologist counts 55, 13, 42, and 35 snails in the four quadrats.

Solution

You can estimate the population density of the snail by calculating the average density of the sampled quadrats.

$$\text{estimated population density} = \frac{\text{total number of individuals}}{\text{sampling area}}$$

$$= \frac{55 + 13 + 42 + 35}{(1.0 \text{ m}^2) + (1.0 \text{ m}^2) + (1.0 \text{ m}^2) + (1.0 \text{ m}^2)}$$

$$= 36.2 \text{ snails/m}^2$$

Assuming that the sample is representative of the total study area, the estimated population density of the snails is 36.2 snails/m².

You can estimate the population size by multiplying the estimated population density by the total study area.

$$\text{estimated population size} = (\text{estimated population density}) (\text{total size of study area})$$

$$= (36.2 \text{ snails/m}^2)(5000 \text{ m}^2)$$

$$= 181\ 000 \text{ snails}$$

MARK-RECAPTURE SAMPLING

Some animal species continually move around, seeking protection, food, and shelter in hard-to-see areas. These species are difficult, if not impossible, to count. One common sampling technique that is used to estimate the population size of these species is the **mark-recapture method**. A specific number of animals in the natural population is captured, marked, or tagged in some way and then released back to the population. After a period of time, when the marked animals have mixed with the unmarked animals, another sample is captured. Biologists use the proportion of marked to unmarked animals in the second sample to estimate the size of the entire population.

The accuracy of this method is dependent on five assumptions:

mark-recapture method a sampling technique for estimating population size and density by comparing the proportion of marked and unmarked animals that are captured in a given area; sometimes called the capture-recapture method

- The chances for each individual in the population to be caught are equal and constant for both the initial capture and the recapture. Marked individuals must not be or become easier or more difficult to catch.
- The proportion of marked to unmarked animals remains the same between captures. No new individuals can enter the population through birth or immigration, and no individuals can leave through death or emigration.
- Enough time is allowed between the initial capture and subsequent recapture for all the marked individuals to disperse randomly throughout the population.
- The captured animals are not adversely affected by their marks.
- The marked animals do not lose their marks.

Based on these assumptions, the estimated population size can be calculated as follows:

$$\frac{\text{total number marked } (M)}{\text{total population } (N)} = \frac{\text{number of recaptures } (m)}{\text{size of second sample } (n)}$$

or

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

where

N = estimate of the total population size
M = total number of animals captured, marked, and released on the first visit
n = total number of animals captured on the second visit
m = number of marked animals that were recaptured on the second visit

In the following tutorial, you will estimate population sizes based on data from mark-recapture sampling.

Tutorial 2 | Estimating Population Size

The mark-recapture sampling method is used to measure the population size of large or highly mobile animals.

Sample Problem 1: Mark-Recapture Sampling

Biologists were studying a saw-whet owl population of unknown size. They captured, banded, and released 30 individuals. They waited until they assumed that the released

individuals had moved randomly through the population. Then they captured a second sample of 80 individuals and found that 12 individuals were marked. Use these values to estimate the population size.

We can assume that the ratio of marked individuals to the size of the total population equals the ratio of marked individuals recaptured in the second sample.

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

$$N = \frac{30 \times 80}{12}$$

$$N = 200$$

Therefore, the estimated population size is 200.

Practice

1. Biologists captured 75 red foxes in a forested area and marked them with ear tags. Exactly 10 days later, they recaptured 45 red foxes and found that 15 had ear tags. Estimate the red fox population in this area. [ans: 225 red foxes]

2. In a northern Ontario lake, 208 lake trout were captured and marked with a tag on one fin. Two weeks later, 185 lake trout were recaptured and 13 had tags. Estimate the lake trout population in this lake during the study period. [ans: 2960 lake trout]

3. Imagine that you capture a sample of 180 butterflies in a park, mark them, and then release them. A week later, you recapture 210 butterflies and find that 30 are marked. Determine the estimated butterfly population in the park during the study period. [ans: 1260 butterflies]

Tracking Populations

Tracking animals provides useful information about their behaviour. Animals can be tracked with special transmitters using Global Positioning System (GPS) technology and satellites. They can also be tracked with DNA sampling, by collecting and testing their droppings and other biological materials. Biologists have been able to learn a great deal about the range, distribution, and population density of various species with these techniques. For example, satellite tracking of 25 female sea turtles showed that their migrations followed three major routes from Gabon in Africa (**Figure 6**). This research was vital for determining which conservation strategies should be used for the sea turtles. 🌐 WEB LINK
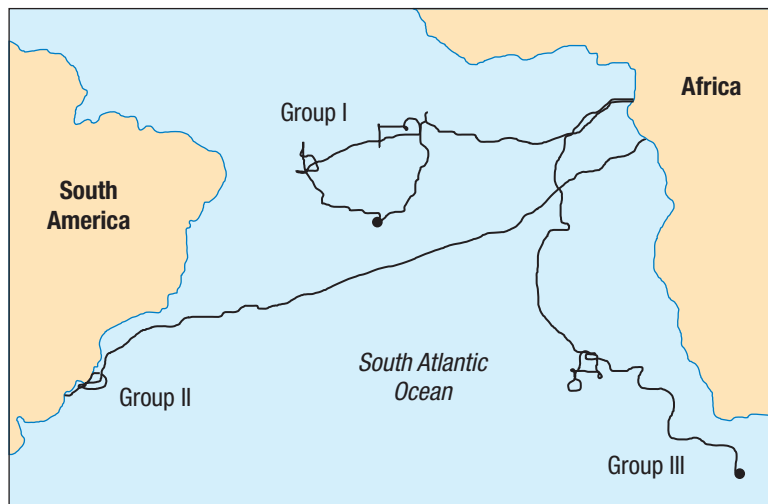

Figure 6 Satellite tracking of sea turtle migrations off the western coast of Africa

Another study, called the Y2Y project (for "Yukon to Yellowstone"), started with a female wolf nicknamed "Pluie" (after the French word for "rain"). She was collared by researchers in June of 1991 in Alberta's Peter Lougheed Provincial Park and tracked for two years. Satellite locations recorded Pluie's travels. In a nine-month period, she wandered over 103 000 km^2, an area 15 times as large as Banff National Park, and she spent time with five different wolf packs. In her travels, she passed through three states, two provinces, private lands, and First Nations, Inuit, and Métis lands (**Figure 7**).
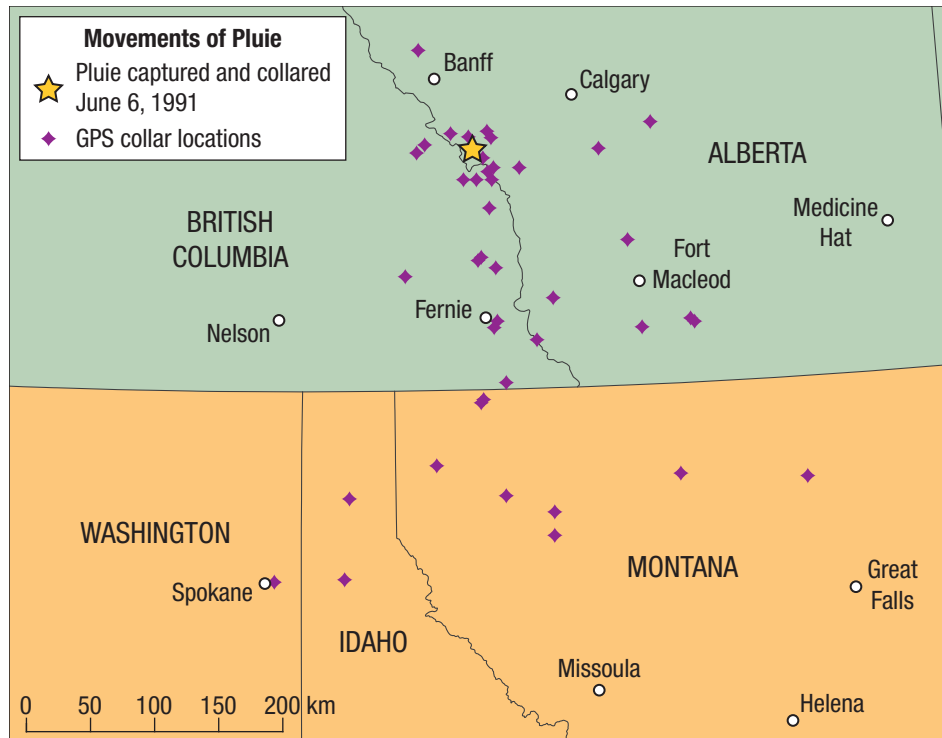
Figure 7 Pluie travelled through Banff National Park into southwest British Columbia, then into Montana, Idaho, and Washington state before returning to British Columbia.

The Ethics of Studying Populations

Marking and tracking can be excellent techniques for monitoring and sampling a population. However, there is an ethical debate about their potential impact on the animals involved. Some scientists have expressed concern that the handling of animals during data collection for population density and size may alter their behaviour after their release or reduce their reproductive ability. Other scientists are concerned that trapping methods may be harmful. The long-term effects of repeated tranquilizing of large animals are not known, nor are the effects of collars and tags. The effects of pursuing, capturing, and marking animals are also not known. However, a recently published 10-year study of banded King penguins by French researchers has shown that banding the penguins on a flipper has reduced their lifespan and their reproductive fitness.

The Canadian Council on Animal Care (CCAC) is in the process of developing a set of guidelines for ethical wildlife research. The CCAC is encouraging researchers to reduce their use of animals in studies as much as possible, to support and develop techniques that will minimize pain and distress in animals, and to replace trapping with computer estimations wherever possible.

Measuring and estimating population size are necessary for developing population management strategies and reducing the effects of environmental stressors, whether natural or human-made. However, efforts should be made to ensure that the use of animals in research is valid, humane, justifiable, and considerate.

Summary

- Biologists use measurements, such as population size and population density, to describe and monitor populations. These measurements also help biologists manage species.
- Populations in a given geographical range show one of three dispersion patterns: clumped, uniform, or random.
- Biologists use quadrat sampling and mark-recapture sampling to estimate population size and density.
- Satellite and other technology can be used to track animals that migrate or move over long distances.
- Ethical issues and concerns need to be considered when studying and monitoring wildlife populations.

Questions

1. (a) What are the three types of dispersion?
   (b) Do dispersion patterns of populations always stay the same? Why or why not? K/U

2. Use the Internet to find satellite tracking data for a species of wildlife, and answer the following questions. Be sure to include the URL of the site you used to answer the questions. 🌐 T/I A
   (a) What animals are being tracked?
   (b) How far did the animals travel?
   (c) Where were they located?
   (d) How are the data being used by scientists?
   (e) How can such data help to protect endangered species?

3. Using a Venn diagram or t-chart, compare and contrast quadrat sampling and mark-recapture sampling for estimating population size. What underlying assumptions must be made for each technique to be effective? K/U C

4. Research the invasive plant species called garlic mustard (*Alliaria petiolata*) and the impact it is having in Ontario. 🌐 T/I
   (a) When and how was garlic mustard introduced into North America?
   (b) Identify the major problem(s) it causes for native species.
   (c) What, if anything, is being done to stop its spread?

5. Researchers captured 18 black bears in a large forested area. They marked and released the bears. In a second trial, they captured 16 black bears and found that 5 had been marked. Estimate the overall population of black bears in this area. T/I

6. To estimate the size of a dandelion population in a schoolyard, a biology student randomly placed five 1.0 m by 1.0 m quadrats in a site that measured 40.0 m by 40.0 m. The numbers of dandelions in the quadrats were 6, 10, 2, 4, and 7. K/U T/I
   (a) Estimate the density and size of the dandelion population in this study site.
   (b) What assumptions did the student have to make when estimating the density and size of the population?

7. A biologist wanted to estimate the density and size of a burrowing prairie dog population in a grassland habitat. The biologist had to choose between quadrat sampling and mark-recapture sampling. T/I A
   (a) Which sampling technique do you think would be easier to implement, and why?
   (b) Which sampling technique do you think would be more effective, and why?

8. A team of wildlife researchers plans to study caribou that live in the Arctic tundra using mark-recapture sampling. T/I
   (a) What challenges might the researchers experience when estimating the density and size of the caribou population? Is there a better sampling technique that could be used for this population?
   (b) What are the possible potential short-term and long-term effects of studying the caribou population?

🌐 WEB LINK