Population Demographics and Dynamics

Inquire: Population Demographics and Dynamics

Overview

Populations are individuals of a species that live in a particular habitat. Populations are dynamic life forms. Their size and composition change in response to many factors, including seasonal and yearly changes in the environment, natural disasters such as forest fires and volcanic eruptions, and competition for resources between and within species. Ecologists measure characteristics of populations: size, density, and distribution pattern. Life tables are useful to calculate life expectancies of individual population members. Survivorship curves show the number of individuals surviving at each age interval plotted versus time.

Big Question: How do ecologists measure population size and density?

Watch: Estimating Population Size

The most accurate way to determine population size is to count all of the individuals within the area. However, this method is usually not logistically feasible. So, scientists study populations by taking a sample of each habitat and use this sample to make inferences about the population as a whole.

For immobile organisms such as plants, or for very small and slow-moving organisms, a quadrat may be used. A quadrat is a wood, plastic, or metal square that is randomly located on the ground and used to count the number of individuals that lie within its boundaries. To obtain an accurate count using this method, the square must be placed at random locations within the habitat enough times to produce an accurate estimate. This counting method will provide an estimate of both population size and density. The number and size of quadrat samples depends on the type of organisms and the nature of their distribution.

To estimate population size for smaller mobile organisms, such as mammals, a technique called mark and recapture is often used. This method involves marking a sample of captured animals in some way and releasing them back into the environment to mix with the rest of the population; then, a new sample is captured and scientists determine how many of the marked animals are in the new sample. This method assumes that the larger the population, the lower the percentage of marked organisms that will be recaptured since they will have mixed with more unmarked individuals. For example, if 80 field mice are captured, marked, and released into the forest, then a second trapping of 100 field mice are captured and 20 of them are marked, the population size ($N$) can be determined using the following equation:
We multiply the number marked in the first catch by the total number in the second catch. The result is then divided by the number marked in the second catch.

\[
\frac{\text{number marked first catch} \times \text{total number second catch}}{\text{number marked second catch}} = N
\]

Using our example, the population size would be 400. We multiply 80 and 100. This equals 8,000. We divide 8,000 by 20 equaling 400.

\[
\frac{80 \times 100}{20} = 400
\]

These results give us an estimate of 400 total individuals in the original population. The true number usually will be a bit different from this because of chance errors and possible bias caused by the sampling methods.

Read: Population Demographics and Dynamics

Overview

Populations are dynamic life forms. Their size and composition change in response to many factors, including seasonal and yearly changes in the environment, natural disasters such as forest fires and volcanic eruptions, and competition for resources between and within species.

The statistical study of populations is called **demography**: a set of mathematical tools designed to describe populations and investigate how they change. Many of these tools were actually designed to study human populations. For example, **life tables**, which detail the life expectancy of individuals within a population, were initially developed by life insurance companies to set insurance rates. In fact, while the term “demographics” is sometimes assumed to mean a study of human populations, all living populations can be studied using this approach.

Population Size and Density

Populations are characterized by their **population size** (total number of individuals) and their **population density** (number of individuals per unit area). A population may have a large number of individuals that are distributed densely, or sparsely. There are also populations with small numbers of individuals that may be dense or very sparsely distributed in a local area. Population size can affect potential for adaptation because it affects the amount of genetic variation present in the population. Density can have effects on interactions within a population such as competition for food and the ability of individuals to find a mate. Smaller organisms tend to be more densely distributed than larger organisms.

Estimating Population Size

The most accurate way to determine population size is to count all the individuals within the area. However, this method is usually not logistically or economically feasible, especially when studying large areas. Thus, scientists usually study populations by sampling a portion of each habitat and use this sample to make inferences about the population as a whole. The methods used to sample populations to determine their size and density are typically tailored to the characteristics of the organism being studied. For immobile organisms such as plants, or for very small and slow-moving organisms, a quadrat may be used. A **quadrat** is a wood, plastic, or metal square that is randomly located on the ground and used to
count the number of individuals that lie within its boundaries. To obtain an accurate count using this method, the square must be placed at random locations within the habitat enough times to produce an accurate estimate. This counting method will provide an estimate of both population size and density. The number and size of quadrat samples depends on the type of organisms and the nature of their distribution.

For smaller mobile organisms, such as mammals, a technique called **mark and recapture** is often used. This method involves marking a sample of captured animals in some way and releasing them back into the environment to mix with the rest of the population; then, a new sample is captured and scientists determine how many of the marked animals are in the new sample. This method assumes that the larger the population, the lower the percentage of marked organisms that will be recaptured since they will have mixed with more unmarked individuals. For example, if 80 field mice are captured, marked, and released into the forest, then a second trapping of 100 field mice are captured and 20 of them are marked, the population size can be determined using a mathematical equation.

The result gives us an estimate of total individuals in the original population. The true number usually will be a bit different from this because of chance errors and possible bias caused by the sampling methods.

**Species Distribution**

In addition to measuring density, further information about a population can be obtained by looking at the distribution of the individuals throughout their range. A **species distribution pattern** is the distribution of individuals within a habitat at a particular point in time — broad categories of patterns are used to describe them.

Individuals within a population can be distributed at random, in groups, or equally spaced apart (more or less). These are known as random, clumped, and uniform distribution patterns, respectively. Different distributions reflect important aspects of the biology of the species; they also affect the mathematical methods required to estimate population sizes. An example of random distribution occurs with dandelions and other plants that have wind-dispersed seeds that germinate wherever they happen to fall in favorable environments. A clumped distribution may be seen in plants that drop their seeds straight to the ground, such as oak trees; it can also be seen in animals that live in social groups (schools of fish or herds of elephants). Uniform distribution is observed in plants that secrete substances inhibiting the growth of nearby individuals (such as the release of toxic chemicals by sage plants). It is also seen in territorial animal species, such as penguins that maintain a defined territory for nesting. The territorial defensive behaviors of each individual create a regular pattern of distribution of similar-sized territories and individuals within those territories. Thus, the distribution of the individuals within a population provides more information about how they interact with each other than does a simple density measurement. Just as lower density species might have more difficulty finding a mate, solitary species with a random distribution might have a similar difficulty when compared to social species clumped together in groups.
Reflect: Survivorship Curves

Poll
Survivorship curves show the distribution of individuals in a population according to age. Humans and most mammals have a type I survivorship curve because death primarily occurs in the older years. Birds have a type II survivorship curve as death at any age is equally probable. Trees have a type III survivorship curve because very few survive the younger years, but after a certain age, individuals are much more likely to survive.

What other animals do you think would follow the type II survivorship curve?
- Frogs
- Turtles
- Insects
- Mice
- Rabbits

Expand: Demography

Discover
While population size and density describe a population at one particular point in time, scientists must use demography to study the dynamics of a population. Demography is the statistical study of population changes over time: birth rates, death rates, and life expectancies. These population characteristics are often displayed in a life table.

Life Tables
Life tables provide important information about the life history of an organism and the life expectancy of individuals at each age. They are modeled after actuarial tables used by the insurance industry for estimating human life expectancy. Life tables may include the probability of each age group dying before their next birthday, the percentage of surviving individuals dying at a particular age interval (their mortality rate, and their life expectancy at each interval).

Survivorship Curves
Another tool used by population ecologists is a survivorship curve, which is a graph of the number of individuals surviving at each age interval versus time. These curves allow us to compare the life histories of different populations. There are three types of survivorship curves. In a type I curve, mortality is low in the early and middle years and occurs mostly in older individuals. Organisms exhibiting a type I survivorship typically produce few offspring and provide good care to the offspring increasing the likelihood of their survival. Humans and most mammals exhibit a type I survivorship curve. In type II curves, mortality is relatively constant throughout the entire life span, and mortality is equally likely to occur at any point in the life span. Many bird populations provide examples of an intermediate or type II survivorship curve. In type III survivorship curves, early ages experience the highest mortality with much
lower mortality rates for organisms that make it to advanced years. Type III organisms typically produce
large numbers of offspring, but provide very little or no care for them. Trees and marine invertebrates
exhibit a type III survivorship curve because very few of these organisms survive their younger years, but
those that do make it to an old age are more likely to survive for a relatively long period of time.

Lesson Toolbox

Additional Resources and Readings

NetLogo
● An interactive activity estimating population, with the instructions listed under “Model Info”

NetLogo
● An interactive activity to practice mark and recapture, with the instructions listed under “Model
Info”
● http://virtualbiologylab.org/NetWebHTML_FilesJan2016/MarkRecaptureModel.html

PopulationEurope
● A video explaining demography
● https://www.youtube.com/watch?v=pCuW6FUBIEA

Lesson Glossary

demography: the statistical study of changes in populations over time
life tables: tables showing the life expectancy of a population member based on its age
mark and recapture: a method used to determine population size in mobile organisms
mortality rate: the proportion of population surviving to the beginning of an age interval that dies during
that age interval
population density: the number of population members divided by the area being measured
population size: the number of individuals in a population
quadrat: a square within which a count of individuals is made that is combined with other such counts to
determine population size and density in slow moving or stationary organisms
species distribution pattern: the distribution of individuals within a habitat at a given point in time
survivorship curve: a graph of the number of surviving population members versus the relative age of
the member

Check Your Knowledge

1. Density can have effects on interactions within a population such as competition for food and the
ability of individuals to find a mate.
   A. True
   B. False

2. Mark and recapture is a method used to determine population size in mobile organisms.
   A. True
   B. False
3. Life tables were initially developed by life insurance companies to set insurance rates.
   A. True
   B. False

Answer Key:
1. A  2. A  3. A

Citations

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