Population Ecology, a Simulation

Introduction

This program simulates the dynamics of population growth for two populations of sparrows, and a population of hawks as predators of sparrows. In this laboratory, you will perform simulations of experiments to investigate a variety of topics in population ecology including the relationships between competing species, exponential growth, resource-limited growth, population extinction, population cycles, competitive exclusion, resource partitioning and coexistence, predator-prey cycles, and predator-mediated coexistence.

Objectives & Goals

The purpose of this laboratory is to:

- Demonstrate important relationships between the many factors that influence population growth of a species.
- Simulate changing conditions such as life span, clutch size, competition, food availability, and predator-prey relationships, and investigate the effects of these conditions on population size and growth.
- Investigate how populations can adapt to changing conditions that influence population growth.

Before You Begin: Prerequisites

Before beginning PopEcoLab you should be familiar with the following concepts:

- Important characteristics of population ecology including population density, population dispersion, and intraspecies[delete comma] and interspecies interactions (see Campbell, N. A., Reece, J. B., and Mitchell, L. G. Biology 5/e, and Campbell, N. A., Reece, J. B., Biology 6/e, chapters 52 and 53).
- Factors that affect population growth such as limiting resources, birth rate, mortality, and sex ratios (chapter 52).
- How interactions between different species, and predation can result in changes in population density and population size (chapters 52 and 53).
- An understanding of how competition (competitive exclusion principle) can influence population size (chapter 53).
Background Information

Even if you have never studied ecology before, it is likely that you have frequently observed important characteristics of population ecology in your daily life. For example, have you ever noticed an abundance of a particular species of animal such as birds, squirrels, geese, deer, or fish in certain locations around the area where you live while in other seemingly similar areas this animal appears nonexistent? Have you ever seen one species chasing, attacking, or feeding on another species? Understanding conditions that influence the abundance of organisms in a particular area and the interactions between both organisms of the same species and organisms of different species that share the same habitat is a primary interest of population ecologists.

For any population, a wide range of conditions can influence the number of individuals in the population and result in changes in population size and population growth. Some of these conditions include environmental changes such as weather, habitat quality, and food availability. Other conditions involve interactions between competing populations of the same or different species, and predator-prey relationships.

One reason population size is influenced by environmental factors is that most populations exist within defined boundaries of habitat. A population's boundaries may be vast, covering large areas of forest or ocean, yet the overall growth and health of the population's individuals is directly influenced by the geographical boundaries of the population. This is true in part because the boundaries of habitat in which a population resides define a finite carrying capacity-the maximum population size that a geographical area can support-dictated by available resources such as food and shelter. If the food supply of a geographical area is inadequate to support a population, organisms have several options. They may be forced to leave the area in search of a richer food supply, they may learn to obtain nourishment from another food source, or population size will diminish over time if the population is unable to adapt to changing conditions in resources. In some cases, exceeding carrying capacity can lead to extinction of a species.

In many ecosystems, competition for a common food supply from populations coexisting in an area can greatly influence the population size of all organisms relying on the common food source. Two species competing for the same limited resources ultimately cannot coexist. This concept is known as the competitive exclusion principle. In interspecific competition, populations of different species compete for resources within a community. However, competition between two populations is not an absolute requirement for depleting a food supply. Even if there is no competition for food from another population, the size of a single population of organisms may become too large, resulting in competition for a limited amount of food among individuals in the same population. Eventually this population may exceed its carrying capacity. This is an example of intraspecific competition.

Human actions and seasonal variations in weather can also wreak havoc on populations. Natural and manmade events that result in the destruction of habitat are frequently called disturbances. Disturbances such as fire, floods, damming rivers, habitat destruction due
to construction, and drought—even if these disasters occur infrequently—can drastically affect population size by destroying habitat that a population relies on for necessities such as feeding, nesting, reproducing, resting, and hibernating. Natural disasters may greatly reduce population size and growth for some organisms while providing new opportunities for increased growth by other populations. As an example, a severe flood may kill populations of wild and domestic animals but the remains of these animals and the spread of nutrients over a wide area can provide new breeding habitats for bacteria and mosquitoes.

In addition to competition and disturbance, population growth can be restricted by biological events that exert strong effects on population size. Birth rate, the number of offspring produced by a population over a period of time, can affect populations both by increasing population size when birth rates are high and by decreasing population size when birth rates are low. Similarly, mortality rate—the number of deaths over a period of time—can greatly affect population size even when changes in mortality rate are small. Obviously, organisms that live longer (low mortality rate) have the potential to breed more frequently than organisms with a high mortality rate; thus, the potential for population growth is likely to be increased for a population with a low mortality rate compared to a population with a high mortality rate.

Even under conditions of adequate population size, adequate habitat and food supply, and ideal birth rates and mortality rates, many populations must deal with predation—an interaction that typically benefits the predator and is harmful to the population size of the prey. Predator-prey relationships can influence both the prey and the predator. Prey species are not always harmed by predation, nor do predator species always benefit from predation. For example, population size of prey can be controlled favorably through predation by preventing the prey population from exceeding carrying capacity. Population size for a predator species can be decreased when there is insufficient prey.

Population ecologists are often interested in studying patterns of population growth to prevent the likelihood of conditions that might cause a population to decline. As a result, population ecologists frequently use mathematical and computer modeling similar to PopEcoLab as a way of predicting how populations will be influenced in the future by current data they are collecting. For example, one may predict a model of exponential growth whereby a population may show an unlimited increase in size if resources are not limiting and mortality is not a problem. Through developing models, it is sometimes possible to predict when a population will exceed its carrying capacity and make choices about how to help prevent this from occurring. For example, in many areas of the northeastern United States, controlled harvests of white-tailed deer are frequently used to modulate population numbers in geographical areas that may be close to exceeding carrying capacity. For other animals, relocation of individuals to less populated areas is another strategy that can be used to maintain adequate population size.

You will use PopEcoLab to study important aspects of population ecology in two simulated populations of sparrows, brown sparrows and blue sparrows. In this hypothetical model, brown sparrows rely on seeds for their nutritional requirements and
their carrying capacity is limited by seed density. Blue sparrows rely on insects to satisfy their nutritional requirements and their carrying capacity is limited by insect density. By manipulating seed density and insect density as important resources, the carrying capacity for each population of sparrows can be varied. These two sparrows are also potential competitors because brown sparrows can also eat insects and blue sparrows can also eat seeds. Hawks are potential predators on both types of sparrows. The ability of sparrows to avoid predation depends on their flight speed—at the highest flight speed, sparrows can avoid being killed by hawks.

You can also use PopEcoLab to control reproductive rates for all three species by varying clutch size, and mortality rates can be manipulated by varying the life span of each species. The experiments that you set up and analyze in PopEcoLab will provide you with an important understanding of the many intricate factors that influence population growth in two competing species and will enable you to study the effects of relationships in a predator-prey community.

References