# Population Growth

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Population Models An ecological population is a group of individuals of a single species living in an area at the same time. To persist, a population must either grow or maintain its size. Population ecology is the study of how population size and age distribution change over time through interactions with other species and the environment as well as with individuals of their own species. A particularly important feature that is studied by ecologists is the rate at which a population grows or declines. A population grows when its birth rate is greater than its death rate. That is, more offspring are being produced than individuals are dying. If the opposite is true and the death rate is greater than the birth rate, the population is in decline and if it continues to decrease it will eventually go extinct. Population ecologists build models to predict how the size of populations will change over time. Two simple models of population growth are exponential (geometric) growth models and logistic growth models. Exponential population models are density-independent, meaning that per capita birth rates and death rates will remain constant regardless of how many individuals are in the population, therefore these populations increase to infinity. However, logistic growth models are density-dependent, therefore the growth rate of the population is dependent on how many individuals are currently in the population. Geometric or exponential growth can only occur when resources are readily available and in unlimited supply. For example, under optimal growing conditions, bacteria follow an exponential growth pattern, with each organism producing two additional reproducing organisms in the next generation1. Exponential Growth For a population that follows an exponential growth pattern, population ecologists can estimate the number of individuals in the next generation based on the size of the initial population and the growth rate, which represents the proportion of new offspring produced per individual for each generation. With a growth rate of 0.05, 5% of individuals produce one offspring in the next generation. At this rate it would only take 23 generations to produce over a million offspring from 2 initial offspring under exponential growth. Some bacteria can grow and divide very rapidly, and thus would be able to reach large population numbers relatively quickly. For instance, Escherichia coli can double its population in approximately 20 minutes, whereas the rate for Syntrophobacter fumaroxidans is 140 hours2. Geometric or exponential growth cannot go on forever, as eventually resources like food or space will be exhausted, and organisms begin to die more quickly or slow reproduction. The maximum number of individuals in a population that can be supported based on the resources in the environment is known as the carrying capacity (K). When more individuals exist in an area than the area can support, the carrying capacity is said to be exceeded. Natural populations may exceed carrying capacity only briefly, before the lack of resources leads to increased death rates and/or decreased reproduction. Logistic Growth Populations of many species follow a logistic growth pattern, where the growth rate of the population is dependent on its current size. Therefore, the growth rate of the logistic growth is variable as opposed to the constant growth rate of the exponential model. As the population nears its carrying capacity, its growth begins to decrease, until the number of individuals reaches or briefly exceeds carrying capacity and subsequently maintains a size near carrying capacity. By incorporating a carrying capacity that represents the limiting resources of a population, logistic models consider a more realistic relationship between an organism and its environment. Population

Dynamics Sophisticated models of population dynamics include variables representing real-world interactions between distinct populations. One such example which represents two interacting populations is the predator-prey model that was independently developed by mathematicians Alfred J. Lotka and Vito Volterra in the 1920s. In fact, predator-prey models have been adapted for a variety of species interactions and continue to be used in adapted forms almost a century after they were developed. One population is a prey species, like hares, and the other is a predator, like wolves, that feed on the prey. The species are closely interacting, because the wolf requires the hare as a food source, thus their birth rate is dependent on the amount of prey they consume and how effectively they convert this food into producing new offspring. The prey populations are dependent on the predator population, because their death rate is dependent on the number of prey that are eaten by predators in a generation. The close interaction of the species can result in oscillating patterns shown between their populations. Models of population dynamics have a variety of applications in conservation biology. Altering models to predict the extinction risk of species is particularly important for helping to protect endangered species, since the loss of one species can result in losses to other species in the food web. The extinction of predator species worldwide is of great concern and can result in instability and extinctions of prey species. Sophisticated modeling and conservation planning will help to protect species in a changing world. The predator-prey models have also been adapted to study competitive interactions, in which multiple species are competing with each other for resources. These models can be used to predict which species will "win" competition interactions and have been applied to the spread of non-native species to predict if a species will be able to establish in a new area, and whether they are likely to become invasive. In most natural applications, models must consider many resources that are available to species, and a complex web of interactions between organisms. For example, lionfish which are native to the Indo-Pacific are invasive in the Atlantic and the Caribbean. Lionfish can reproduce all year long, have no natural predators, and can consume numerous native fish species at unsustainable rates which permanently alters the Atlantic and Caribbean ecosystems. Using population growth models has enabled scientists to determine that approximately a quarter of the entire lionfish population has to be removed from the ecosystem every month just to stunt population growth3. Population growth models have been adapted to fit human populations using demography, which is the study of birth rates, death rates, and statistics related to population sizes based on age groupings. The growth rate of countries and other political districts can be forecast using demographic data, and this is important for planning infrastructure in localities. Thus, application of population growth models is important to planning for the growth of the human population. Further, Lotka-Volterra model has also been applied to study and predict the competition of businesses, further demonstrating the versatility of the population growth models to fields outside of biology4. References Ghislain Y. Gangwe Nana, Camille Ripoll, Armelle Cabin-Flaman, David Gibouin, Anthony Delaune, Laurent Janniere, Gerard Grancher, Gaelle Chagny, Corinne Loutelier-Bourhis, Esther Lentzen, Patrick Grysan, Jean-Nicolas Audinot, Vic Norris. Division-Based, Growth Rate Diversity in Bacteria. Front Microbiol. 2018, Vol. 9, 849 (doi: 10.3389/fmicb.2018.00849). Beth Gibson, Daniel J. Wilson, Edward Feil, Adam Eyre-Walker. The distribution of bacterial doubling times in the wild. Proc Biol Sci. . 2018, Vol. 285, 1880 (20180789). Rice, James A. MorrisJr.Email authorKyle W. ShertzerJames A. A stage-based matrix population model of invasive lionfish with implications for control. Biological Invasions. 2011, Vol. 13, 1 (7-12). Ofer Malcai, Ofer Biham, Peter Richmond, and Sorin Solomon. Theoretical analysis and simulations of the generalized Lotka-Volterra model. Phys. Rev. E. 2002, Vol. 66, 3

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