Definition of Population Dynamics

What exactly is meant when using the term population dynamics in biology?

A *population* is a convergence of individuals of the same species who live, interact, and reproduce in the same geographic region.

The word *dynamics* means forces that produce change. Combine the two and we get population dynamics!

The definition of population dynamics is as follows.

Population dynamics is the study of the fluctuations of a population's size over time, as observed through rates of birth, death, immigration, and emigration.
Before we start our discussion on population dynamics, we should review some terminology to better visualize the interactions of a population with its surroundings (Fig. 1).

A community is all the diverse species populations that cohabitate a geographic region.

An ecosystem is defined by all the communities in a geographic region, and that region's abiotic factors.

Abiotic factors are non-living parts of the environment, such as water, air, rock, soil, or sunlight.

Biotic factors are living parts of the environment, within the community. They are interactions between organisms, such as predation, competition, social hierarchy, mating, or illness. They can occur within the population, or with a population of another species.

Population Characteristics

Population *dynamics* observes the changes in the *static* physical properties of populations. Here are the main observable characteristics of populations:

- Size
- Density
- Dispersion
- Sex distribution
- Age distribution

Size

Size is the count of individuals within a population. This count represents a specific and unique point in time. When observing population dynamics, we thus need at least two data points at time

A and time B. In population ecology, the common symbol for population size is the uppercase letter 'N'.

Density

Density is the number of individuals of a population per region.

For example, a very dense population of squirrels may have one individual per square meter, whereas a more scattered population may have one individual per square kilometer.

The denser the population, the higher the level of competition. The multiple squirrels in the square meter may all have to tussle for the same acorn. Density is strongly correlated with biotic factors affecting population growth.

Dispersion

Dispersion describes the geographic distribution, or clustering, of the individuals in a population (Fig. 2).

This property is like density, but subtly distinct. For example, a woodpecker living in beech-maple forest lives in the entire forest, but may cluster around the location of maple trees because of their soft bark.

Sex distribution

Sex distribution is used to describe the quantity of individuals in a population who are male and female.

In population dynamics, counting individuals of each sex are in a population can help determine the maximum potential birth rate. By extrapolating the number of breeding females, population growth can be predicted.

Sex distribution is succinctly described by using a sex ratio, which is a fraction representing the number of individuals of one sex (e.g., females) to individuals of the other sex (e.g., males).

Age distribution

Age distribution is used to describe the quantity of individuals of a population within a specific age group, as sorted in classes, or cohorts. A cohort is a group of individuals in a population born within the same time frame. Population dynamics uses cohorts to observe whether a population is young or old, booming or busting.

Population Dynamics Models

Age-Structure Diagrams

During population growth studies, you may see age-structure diagrams. Age-structure diagrams (Fig. 3) are vertical histograms representing the cohorts of a population, separated by age group and sex.

Often, the shape of this model is indicative of a population growth trend. For example, a pyramid shaped age structure diagram shows a boom of young individuals, whereas another model that is narrowest at the base is indicative of an aging population with low population growth.

Survivorship Curve

Survivorship curves are another model which efficiently displays population dynamics. Survivorship curves plot a population's number of (surviving) individuals on the y-axis and the age of the individuals on the x-axis (Fig. 4).

Population growth in survivorship curves tend to follow one of three trends:

- Type I: A population with a high mortality rate in old age. Type I species are typically associated with strong parenting.
- Type II: A population with similar mortality throughout its life span.
- Type III: A population with a high mortality rate in young age. Type III species typically perform little to no parenting, preferring instead quantity over quality. Species that lay multiple eggs, like frog populations, are an example of a Type III species.

Growth Rate Curves

Population size can either increase, through birth or immigration, or decrease, through death or emigration.

When discussing *population dynamics*, the observations are being made with a sense of time as a scale. These four factors are known as the vital rates of population dynamics. Therefore, we can calculate population growth using these vital rates:

- Birth rate is the number of individuals entering a population by birth, per unit time.

- Death rate is the number of individuals exiting a population by death, per unit time.
- Immigration rate is the number of individuals entering a population geographically, per unit time.
- Emigration rate is the number of individuals exiting a population geographically, per unit time.

The general equation to find the population growth rate, symbolized by a lowercase r, is:

$$growthrate=(birthrate+immigrationrate)-(deathrate+emigrationrate)$$

or

$$r=(B+I)-(D+E)$$

In population dynamics, graphing the size of a population over time is an efficient model for displaying the biotic potential of a population. Biotic potential is the idealized maximum population growth rate, with little to no death or emigration. The resulting population dynamics model is a “J-shaped” graph representing the exponential growth curve (Fig. 5). In equation form, the exponential growth curve is expressed as such:

$$dN/dt=rN$$

where N = size, t = time and r = growth rate.
Realistically, a population will reach such a large size that the population's ecosystem can no longer support it. The maximum population size is limited by an ecosystem's abiotic and biotic factors, called the carrying capacity (K).

Carrying capacity (K) is the maximum population size an ecosystem can sustain, as imposed by limiting abiotic and biotic factors.
In population dynamics, there is a model of population growth rate that takes carrying capacity into consideration. The logistic growth curve (Fig. 6) is a population dynamics model with an “S-shaped” curve, where the carrying capacity (K) is represented as the population's ceiling, or maximum population growth rate.

In equation form, the exponential growth curve is expressed as such:

$$dN/dt=rNK-N/K$$

where N = size, t = time and r = growth rate, and K = carrying capacity.

Population Dynamics in Ecology

Population dynamics has many practical applications in ecology. Fish and game departments monitor populations to ensure healthy and fishing and hunting. Agricultural organizations track pest populations to protect their crops. Environmental protection groups ensure the survival of endangered, threatened or vulnerable species by observing shifts in population sizes.

For populations to be able to survive in their ecosystems, they have to adapt to the biotic and abiotic factors in their environment. When population and community density is high, then there is a lot of competition, and resources are scarce. Some species excel at winning when competing for resources. They spend a lot of energy doing so, and spend less energy reproducing. Thus, they experience slow population growth and rarely exceed the carrying capacity. A K-selected species carry fewer offspring and experiences slow population growth that follows the logistic growth curve. Elephants, tortoises, and bears are examples of K-selected species.

On the other hand, some species aren't good competitors. To compensate, these species have developed rapid population growth during periods of abundant resources, when competition is less necessary. These r-selected species carry large numbers of offspring and experience fast population growth in the shape of an exponential growth curve, exceeding the ecosystem's carrying capacity temporarily. The r-selected species typically experience population growth events known as booms, and then crashes. Swarms of mice during bountiful growing seasons or salmon spawning during the breeding season are examples of r-selected species.

Human Population Dynamics

The concepts of population dynamics extends to every species, even human populations! Demography is the application of population dynamics to the human species. In fact, demographics are extensively used in many other sciences, such as sociology, political science, anthropology, or geography. Demography uses its unique terminology when describing population dynamics.
Crude birth rate (CBR): Total number of birth per 1000 individuals.

Crude death rate (CDR): Total number of death per 1000 individuals.

Total fertility rate (TFR): Average number of birth per woman of child-bearing age.
Demography uses a demographic transition model (Fig. 7) to observe how human population growth patterns over long periods of time. Most often, these graphs are used to compare the human populations of two or more countries.

Population Dynamics Worksheet

Recall the following equations for population growth rates curves.

$dN/dt=rN$ $dN/dt=rN(K-N/K)$

The two population dynamics models being represented by these equations are the exponential growth curve and the logistic growth curve, respectively. In this worksheet, we will explore how a population dynamics model can be extracted from population size data. For 12 weeks, a population dynamics scientist counted the population of two species of insects, Study Bugs and Smarter Bugs. The data is compiled in the table below. From this data, you will derive a population growth rate (r).

This worksheet may be easier to complete if the table is printed out, or copied to a spreadsheet application.

Time (t) (weeks)	Study Bug Population # (N)	$dNdt$	Growth Rate (r)	Smarter Bug Population # (N)	$dNdt$	Growth Rate (r)
0	20	—		5	—	
1	63			26		
2	177			128		
3	534			669		
4	1 583			3 300		
5	4 695			16 911		
6	13 501			84 352		

7	35 353			422 777		
8	68 375			2 189 299		
9	64 800			10 546 547		
10	68 500			51 734 594		
11	68 356			263 672 108		
12	68 734			1 318 359 564		

1) Calculate the change in population (N) over the change in time (t), or dN/dt. Fill out the corresponding column. Can you determine which population whose population growth rate is affected by the carrying capacity (K)? Why?

Hint: For week 1, $dN_1 = N_1 - N_0 = 63 - 20 = 43$, and $dt_1 = t_1 - t_0 = 1 - 0 = 1$.

2) For the species in question 1, can you determine what the carrying capacity (K) appears to be?

3) Do Study bugs appear to follow a population dynamics model in the shape of an exponential growth curve or a logistic growth curve?

4) Do Smarter bugs appear to follow a population dynamics model in the shape of an exponential growth curve or a logistic growth curve?

5) Using the equation from your answer to question 4, determine the population growth rate (r) and fill out the corresponding column. (Note: the answer for "r" will not be exactly equal in each row, but all resulting calculations should be close to a single value)

Hint: If $rN_0 = dN_1 / dt_1$, then $r = (dN_1 / dt_1) / N_0$

6) A separate experiment in population dynamics determined the true value of K at 10 000 individuals. Using the equation from your answer to question 3, determine the population growth

rate (r) and fill out the corresponding column. (Note: again, the values for "r" will diverge slightly.)

Hint: If r * [(K-N_0) / K] = dN_1/dt_1, then r = (dN_1/dt_1) / [(K-N_0) / K]

Worksheet answers:

1) Study bug. The population growth *d*N/*d*t decreases and approaches zero as time increases.

2) The maximum population appears to slow down at about 70000 individuals.

3) Logistic growth curve

4) Exponential growth curve

5) r = 4

6) r = 3

Population Dynamics - Key takeaways

- Population dynamics is the study of the fluctuations of a population's size over time, as observed through rates of birth, death, immigration, and emigration.
- Important characteristics of a population are size, density, dispersion, sex distribution and age distribution.
- The four vital rates of population dynamics for measuring population growth are birth, death, immigration, and emigration.
- Carrying capacity (K) is the maximum population size an ecosystem can sustain, as imposed by limiting abiotic and biotic factors.
- Species' life strategies can be classified as r-selected, with numerous offspring and rapid growth, or K-selected, with few offspring and slow, steady growth.

Frequently Asked Questions about Population Dynamics

What is population dynamics?

Population dynamics is the study of the fluctuations of a population's size over time as observed through rates of birth, death, immigration, and emigration.

What are the 3 characteristics of population dynamics?

The 3 main characteristics of population dynamics are birth rate, death rate, and migration rate.

What is the importance of population dynamics?

Population dynamics are important because it can demonstrate whether a population is growing or shrinking.

What are the major components of population dynamics?

The major components of population dynamics, called the vital rates, are birth rate, death rate, immigration rate and emigration rate.

How does population dynamics affect the environment?

Population dynamics is used to observe if a population is growing at a rate that would exceed its carrying capacity. A population above carrying capacity would be indicative of an unsustainable ecosystem because it is being drained of its resources.

Population Dynamics

A population is a collection of individual organisms of the same species that occupy some specific area. The term "population dynamics" refers to how the number of individuals in a population changes over time. Biologists study the factors that affect population dynamics because they are interested in topics such as conservation of endangered species (for example, the Florida panther) and management of fish and wildlife. In addition, basic knowledge about the processes that affect population dynamics can be used to predict future patterns of human population growth.

How Do Biologists Characterize Populations?

Biologists distinguish between two main types of populations: unstructured and structured. In an unstructured population, all individuals are subject to the same general ecological pressures. That is, the rates of growth, reproduction, and mortality are roughly the same for all individuals in the population. A bacterial colony is a good example of an unstructured population. Conversely, in structured populations, individuals can differ from one another in ways that make some individuals more susceptible to mortality or more likely to reproduce than others. Examples of structured populations include many insects, sea turtles, trees, and fish. In these cases, mortality is often much higher for younger (and/or smaller) individuals. In addition, reproduction is often delayed until individuals are older (and/or larger).

How Does Resource Abundance Affect Population Dynamics?

The abundance of environmental resources such as food, water, and space determines how population abundance changes over time. In the presence of unlimited resources, populations grow exponentially. If one plots the number of individuals in an exponentially growing population over time, one finds a J-shaped curve where the slope gets ever steeper. This curve is described by the following equation:

$N_t = N_0 e^{rt}$

Where N_0 is the initial number of individuals, N_t is the number of individuals at a future time, r is the rate of increase, t is time, and e is the base of the natural logarithm (roughly 2.718). The rate of increase (r) is determined by the difference between birth and death rates of the population. In 1999 the U.S. Bureau of the Census estimated the rate of population increase (r) for the world human population to be 0.0129 (or 1.29 percent) per year. Few natural populations grow at exponential rates for extended periods of time because resources typically become limiting when population abundance is very high.

In an environment where resources become limited, populations exhibit a pattern of growth called logistic growth. In this case, if one plots the number of individuals in the population over time, one finds a sigmoidal, or S-shaped curve. When population abundance is low, the population grows exponentially. However, as population size increases, resources become limited, the population growth rate slows, and the population abundance curve flattens. The number of individuals present in the population when the growth rate slows to zero is referred to as *K*, the carrying capacity. The carrying capacity is the theoretical maximum number of individuals that the environment can support. Although estimates of *K* for humans are controversial, most are around 12 billion.

Using concepts from basic population biology, biologists have distinguished two strategies for population growth. Some species have characteristics that allow them to grow rapidly when an environment with abundant resources is newly created (for example, a new clearing in a forest). These species are referred to as *r* -selected species and typically reproduce at a young age and produce many offspring. Other species, called *K* -selected species, have characteristics that make them well suited for life in environments where there is intense competition for limited resources. These species are often strong competitors, reproduce later in life, and produce fewer offspring than *r* -selected species.

How Does Variability In Environmental Conditions Affect Population Dynamics?

A key assumption of the logistic population growth model for environments where resources are limiting is that environmental conditions are constant. In nature, environmental conditions may vary substantially over time. In such variable environments, the abundance of individuals in a population may also fluctuate over time. Some populations cycle in a predictable manner. Populations that fluctuate widely or have low abundance are especially vulnerable to extinction, an event in which population abundance declines to zero. Extinctions may be local (a population in a particular area is lost) or global (all populations of a species decline to zero and there are no living individuals of the species left on the planet). For example, the passenger pigeon, which was once one of the most numerous birds on Earth, went globally extinct in 1914 due to overhunting and habitat loss.

How Do Physical And Biological Factors Regulate Population Dynamics?

Patterns of population abundance are affected by a variety of biological and physical factors. For example, the abundance of a given species (for example, snails) might be controlled by the abundance of organisms that have a negative effect on the species of interest, such as competitors, predators, and diseases. Similarly, population abundance could be limited by the abundance of organisms that benefit the species of interest (for example, algae consumed by the snails).

In fact, some organisms require the presence of other species called **symbionts** with whom they live in direct contact. For example, corals use food molecules synthesized by symbiotic zooxanthellae (a type of algae), and zooxanthellae receive nutrients and protection from corals. However, not all populations are regulated by biological factors involving interactions with other species. Physical factors like water availability and temperature can control population abundance of some species.

Which type of factor (biological or physical) has a stronger effect on population dynamics? As one might suspect, the answer depends largely on the population that is studied. Some populations are regulated mostly by biological factors, others are controlled by physical factors, and most populations are affected by both biological and physical factors.

population dynamics The study of factors that influence the size, form, and fluctuations of populations. Emphasis is placed on change, energy flow, and nutrient cycling, with particular reference to homoeostatic controls. Key factors for study are those influencing natality, mortality, immigration, and emigration. See demography.

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