Module 04 Patterns of Population Distribution
Unit 02 Population Demography
Dall mountain sheep Study

An example of a life table from a study of Dall mountain sheep, a species native to north-western North America, is shown below. Notice that the population is divided into age intervals. The mortality rate (per 1000), is based on the number of individuals dying during the age interval divided by the number of individuals surviving at the beginning of the interval multiplied by 1000.

$$\text{Mortality rate} = \frac{\text{Number of individuals dying}}{\text{Number of individuals surviving}} \times 1000$$

For example, between ages three and four, 12 individuals die out of the 776 that were remaining from the original 1000 sheep. This number is then multiplied by 1000 to get the mortality rate per thousand.

$$\text{Mortality rate} = \frac{12}{776} \times 1000 = 15.5$$

As can be seen from the mortality rate data a high death rate occurred when the sheep were between 6 and 12 months old, and then increased even more from 8 to 12 years old, after which there were few survivors. The data indicate that if a sheep were to survive to age one, it could be expected to live another 7.7 years on average.

Age interval (years)	Number dying in age interval out of 1000 born	Number surviving at beginning of age interval out of 1000 born	Mortality rate per 1000 alive at beginning of age interval	Life expectancy or mean lifetime remaining to those attaining age interval
0-0.5	54	1000	54.0	7.06
0.5-1	145	946	153.3	--
1-2	12	801	15.0	7.7
2-3	13	789	16.5	6.8
3-4	12	776	15.5	5.9
4-5	30	764	39.3	5.0
5-6	46	734	62.7	4.2
6-7	48	688	69.8	3.4
7-8	69	640	107.8	2.6
8-9	132	571	231.2	1.9
9-10	187	439	426.0	1.3
10-11	156	252	619.0	0.9
11-12	90	96	937.5	0.6
12-13	3	6	500.0	1.2
13-14	3	3	1000	0.7

Data Adapted from Edward S. Deevey, Jr., Life Tables for Natural Populations of Animals, The Quarterly Review of Biology 22, no. 4 (December 1947): 283-314.

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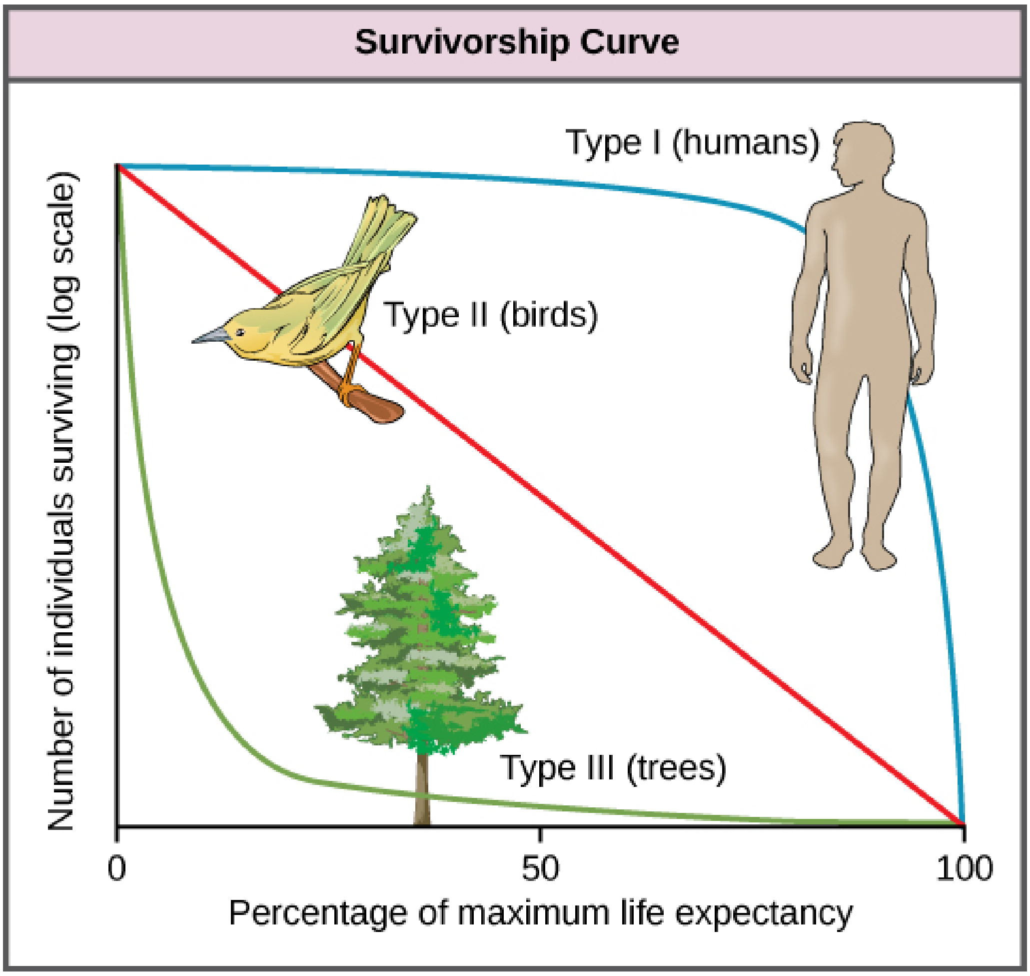
Survivorship Curve

Another tool used by population ecologists is a survivorship curve, which is a graph of the number of individuals surviving at each age interval plotted versus time (usually with data compiled from a life table).
These curves allow us to compare the life histories of different populations.



Exponential Growth

When calculating the growth rate of a population, the death rate (D) (number organisms that die during a particular time interval) is subtracted from the birth rate (B) (number organisms that are born during that interval). This is shown in the following formula:

$$\frac{\Delta N \text{ (change in number)}}{\Delta T \text{ (change in time)}} = B \text{ (birth rate)} - D \text{ (death rate)}$$

The birth rate is usually expressed on a per capita (for each individual) basis. Thus, B (birth rate) = bN (the per capita birth rate “b” multiplied by the number of individuals “N”) and D (death rate) =dN (the per capita death rate “d” multiplied by the number of individuals “N”).

$$\frac{dN}{dT} = bN - dN = (b - d)N$$

Notice that the “d” associated with the first term refers to the derivative (as the term is used in calculus) and is different from the death rate, also called “d.” The difference between birth and death rates is further simplified by substituting the term “r” (intrinsic rate of increase) for the relationship between birth and death rates:

$$\frac{dN}{dT} = rN$$

A further refinement of the formula recognizes that different species have inherent differences in their intrinsic rate of increase (often thought of as the potential for reproduction), even under ideal conditions. The maximal growth rate for a species is its biotic potential, or rmax, thus changing the equation to:

$$\frac{dN}{dT} = r_{max} N$$

Logistic Growth

Carrying Capacity and the Logistic Model

The formula we use to calculate logistic growth adds the carrying capacity as a moderating force in the growth rate. The expression "K - N" is indicative of how many individuals may be added to a population at a given stage, and "K - N" divided by "K" is the fraction of the carrying capacity available for further growth. Thus, the exponential growth model is restricted by this factor to generate the logistic growth equation:

$$\frac{dN}{dT} = r\,max\ \frac{dN}{dT} = r\,max\ N\ \frac{(K - N)}{N\,K}$$

Notice that when N is very small, (K-N)/K becomes close to K/K or 1, and the right side of the equation reduces to rmaxN, which means the population is growing exponentially and is not influenced by carrying capacity. On the other hand, when N is large, (K-N)/K come close to zero, which means that population growth will be slowed greatly or even stopped. Thus, population growth is greatly slowed in large populations by the carrying capacity K. This model also allows for the population of a negative population growth, or a population decline. This occurs when the number of individuals in the population exceeds the carrying capacity (because the value of (K-N)/K is negative.