Population dynamics

Let's consider the major volcanic catastrophe at Mount Saint Helens on the west coast of the United States in 1980. After the massive eruption, little was left of the forest and rivers which once abounded on and around the mountain. The blast from the eruption knocked over massive adult trees as if they were toothpicks.

Fires and hot gases burned everything in sight. Volcanic ash rained down smothering the destroyed forest and covering the carcasses of the animals which died there. Countless species which could escape, fled the area. Although thousands of people had been evacuated, a handful of people perished that day, some of whom were photographers trying to get the photo of a lifetime.

And yet, within months of the total destruction and eradication of populations, life was back. Seeds dropped from birds or blown by the wind germinated in the fertile volcanic ash. Little by little, insects then birds then small mammals moved in. Within a couple of decades, a grassland and shrub ecosystem had reappeared.

From this example, it can be deduced that there are four main factors which affect population size:

- *natality* – the number of new members of the species due to reproduction;
- *mortality* – the number of deaths;
- *immigration* – members arriving from other places;
- *emigration* – members leaving the population.

In the example of Mount Saint Helens, the massive mortality rate due to the eruption caused the populations of birds, trees, elk and just about everything else at close range to be reset to zero. Emigration before and immediately following the eruption greatly decreased populations in the wider vicinity surrounding the volcano. But immigration and natality are improving the numbers dramatically today.

Carrying capacity (K)

No habitat can accommodate an unlimited number of organisms – populations cannot continue to grow and grow forever. As you have just seen, there comes a time in the growth of a population when its numbers stabilize. This number, the maximum number of individuals that a particular habitat can support, is called the carrying capacity and it is represented by the letter K (see Figure 5.5, page 131).

Consider, for example, a given area of soil in a forest. There is a maximum number of trees which can grow there. This number is attained when enough trees are present to catch all the sunlight, leaving every square metre of the forest floor in shade. New tree seedlings trying to grow under the adult trees, will have difficulty getting sunlight.

But many young trees store up energy for years with very little vertical growth until a big tree dies, leaving a hole in the canopy. The young trees then race up towards the opening to take the old tree's place. Those that lose the race usually die. In any case, for a young tree to join the population, an old one must die and give up a space.

Limiting factors, which define the carrying capacity of a habitat include:

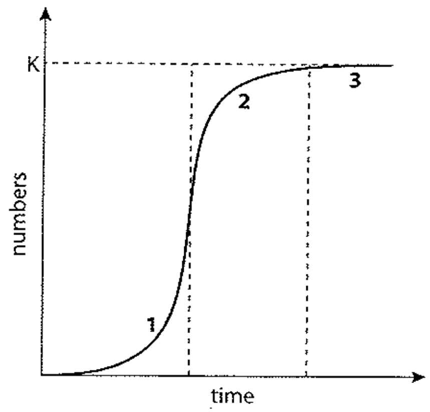
- availability of resources such as water, food, sunlight, shelter, space, or oxygen (notably in aquatic habitats);
- build-up of waste such as excrement or excess carbon dioxide;
- predation;
- disease.

Many biologists, environmental groups, economists and governments wonder what the carrying capacity of planet Earth is for the human population. Will the number of people continue its exponential growth phase or will diseases, climate change or competition for resources lead to a transitional phase or a plateau?
Only time will tell.

Population growth curve

The case of Mount Saint Helens shows that even from a non-existent or very small population of individuals, there can soon be a dramatic increase in numbers. Over the years, the number of trees and birds near Mount Saint Helens will rise at ever-growing rates as the organisms reproduce and occupy the available space.

Eventually, when a complete forest has grown again and all habitats are occupied, the numbers of organisms will stabilize and not get any bigger (see Figure 5.5).



The sigmoid (S-shaped) curve of the graph in Figure 5.5 shows three stages in population growth.

1 The *exponential growth phase*, also called the logarithmic phase, in which the number of individuals increases at a faster and faster rate.

2 The *transitional phase*, in which the growth rate slows down considerably – the population is still increasing but at a slower and slower rate.

3 The *plateau phase* or stationary phase, in which the number of individuals has stabilized – there is no more growth.

Note: The letter K at the top left of Figure 5.5 is the carrying capacity and is explained on the next page.

So what causes the phases of the population curve?

Causes of the exponential phase

In ideal conditions, a population can double on a regular basis. Not counting mortality, for example, a population of bacteria can theoretically double its population every few hours: 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, and so on. Without predators, introduced species, such as cane toads in Australia, have taken over habitats with uncontrolled population growth. The reasons for this first phase of exponential growth are:

- plentiful resources such as food, space or light;
- little or no competition from other inhabitants;
- favourable abiotic factors such as temperature or dissolved oxygen levels;
- little or no predation or disease.

Causes of the transitional phase

Eventually, after the exponential increase in the number of individuals of a population, some of the factors listed above are no longer true. This leads to the transitional phase. The causes of the transitional phase are:

- with so many individuals in the population, there is increasing competition for resources;
- predators, attracted by a growing food supply, start to move in to the area;
- because of large numbers of individuals living together in a limited space, opportunities for diseases to spread within the population increase.

Causes of the plateau phase

Consider the land around Mount Saint Helens slowly being taken over by vegetation. Once all the fertile ground is covered with plants, the space available will be occupied to its maximum. Thus, there is gradually less and less available space for seeds, which the plants produce, to germinate and the number of plants stabilizes.

With increasing numbers of herbivores, there is a limited supply of food. In response to limited food supplies, animals tend to have smaller numbers of offspring.

Predators and disease increase mortality and the growth curve tends to level off.

In this phase, the number of births plus the number of immigrations is balanced with the number of deaths plus the number of emigrations.

Distinguishing r-strategy from K-strategy

You will recall that zebra mussels are small molluscs which have invaded the Great Lakes region of the US. Zebras are hoofed mammals that live in the savannahs of Africa. Which of these two organisms is most likely to survive an ecological disaster? Suppose an asteroid hit the Earth and caused extreme changes in both the terrestrial and aquatic ecosystems. Which of these two organisms would be the most likely to survive?

Did you pick zebra mussel? When looking at the life cycle of the zebra mussel, we can see that its strategy is 'disposable'. It lays thousands of eggs which hatch into free-swimming larvae. The larvae swim around until they find a spot to attach. Most of the eggs are 'disposable' and get eaten, but hundreds can survive and grow into new zebra mussels. This is an inexpensive way to get lots of offspring. Given a natural disaster and a changed environment, a few of the thousands of eggs are quite likely to survive.

The zebra is not likely to survive a catastrophe that drastically changed the terrestrial environment. The zebra requires a stable environment. It has a long gestation period. During gestation, the mother needs good nutrition from the grasses of the savannah. After a young zebra is born, it needs maternal care. The savannah must have enough food for the nursing mother so that she can make milk for her offspring. She is protected by the herd which is also grazing in the savannah. A disaster which destroys the savannah would greatly reduce the herd. The few offspring produced would not survive.

These two strategies are the extremes of a continuum across the animal and plant kingdoms. The strategy of disposable offspring is called the r-strategy. The strategy of nurturing is called the K-strategy. Most invertebrates like insects and spiders follow the r-strategy. Larger animals follow the K-strategy. Larger animals will have few young and spend considerable time and energy caring for them. Most mammals have adopted this strategy.

Some animals, such as ducks, are intermediate on the continuum between r-strategy and K-strategy. Duck eggs do not require the length of development of a mammal but do need parental care. Some of the eggs can be lost to predators which is why there is more than one. The young ducklings also require some parental care. Even within the world of bird species, there is a continuum. Some birds lay only one egg and spend lots of energy caring for it, such as penguins in the Antarctic. Some birds produce lots of eggs and do not spend nearly as much energy in parental care.

This table compares the life histories of r-strategy species and K-strategy species.

Characteristic	r-strategy	K-strategy
life span	short	long
number of offspring	many	few
onset of maturity	early	late – after a long period of parental care
body size	small	large
reproduction	once during lifetime	more than once during lifetime
parental care	none	very likely
environment	unstable	stable

Environmental conditions of r-strategists and K-strategists

In an unstable environment, it is better to produce many offspring as quickly as possible. This is the r-strategy. In an unstable environment, lots of offspring are lost to unpredictable forces. The few that remain can reproduce and carry on the genes of the organism. You can imagine that weeds have this strategy. Weeds survive well in 'disturbed ground', like the side of a road that is constantly mowed, or the edge of a farm field or a drainage ditch. Weeds produce thousands of seeds and grow quickly to take advantage of these unstable places. In sand dune succession, the plants that grow on the foredune where shifting sand and salt spray cause unstable conditions, are r-strategists. They grow quickly extending roots deep in the sand to attempt to stabilize the unstable dune. If they are successful, the next plants which grow there can count on more stable conditions. The dunes that are more inland have a larger proportion of K-strategy plants and animals.

In a stable environment, the K-strategist flourishes. A mature dune is a stable community which has been built over hundreds of years of ecological succession. If there is no human encroachment to destabilize the mature dune, the plants and animals that live there can be K-strategists. The dune is located far from the coast and is not susceptible to the winds and salt spray, unlike the younger dunes which are closer to the coast. Soil has built up over hundreds of years. It contains humus which holds both mineral nutrients and water. K-strategists such as oak trees flourish in this stable environment. Deer and raccoons which are also K-strategists are common. When a habitat becomes diverse and is filled with a large collection of species, they will be K-strategists.