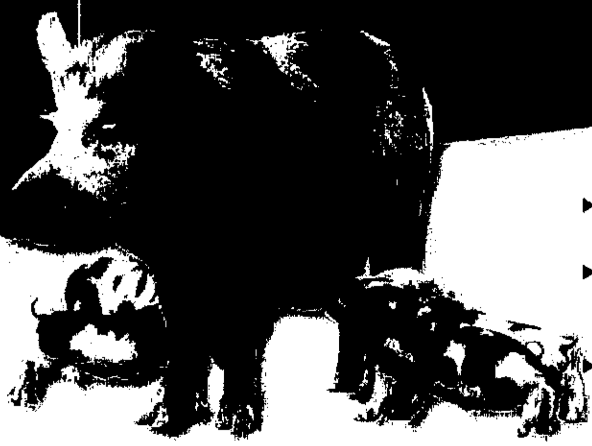
AP III a-b
IB Topic 2-3

Populations



Key concepts

- Populations are dynamic collections of interbreeding individuals.
- Populations exhibit attributes not shown by the individuals themselves, including natality, mortality, survivorship, and age structure.
- Population growth is regulated by density dependent and density independent factors.

Key terms

carrying capacity
community
competition
demographics
density
distribution
emigration
environmental resistance
exponential growth
immigration
K-selection
life tables
limiting factors
logistic growth
mortality
natality
population size
r-selection
sigmoidal growth
survivorship curve
urbanization

Learning Objectives

☐ 1. Use the **KEY TERMS** to compile a glossary for this topic.

Features of Populations — pages 88-92

☐ 2. Recall the difference between a **population** and a **community**.

☐ 3. Distinguish between **population density** and **population size**.

☐ 4. Use the terms **uniform, random**, and **clumped** to describe the **distribution** of individuals in a population. Describe factors governing these distributions.

☐ 5. Use the terms **density**, **distribution**, **natality** (birth rate), **mortality** (death rate), **age structure**, **survivorship**, and fecundity to describe a population.

Population Growth and Size — pages 93-104

☐ 6. Explain how births, deaths, **emigration** and **immigration** affect population size.

☐ 7. Explain how **survivorship curves** are used to analyze populations. Use examples to describe features of type I, II and, III survivorship curves.

☐ 8. Describe features of *r* and K selection and give examples of organisms with each strategy. Recognize *r* and K strategies as extremes of a continuum.

☐ 9. Explain the terms **carrying capacity** and **environmental resistance**.

☐ 10. Describe how carrying capacity, environmental resistance, and **limiting factors** affect population size. Distinguish between **density dependent factors** and **density independent factors** in population regulation.

☐ 11. Describe the characteristics of **exponential** and **sigmoidal** growth curves. Identify phases of growth in populations with sigmoidal growth and describe factors regulating growth at each stage.

☐ 12. Describe aspects of human population dynamics, including the:
- effect of **urbanization** on **demographics**
- environmental and economic impacts of an increasing human population.

Periodicals:
Listings for this chapter are on page 246

Weblinks:
www.thebiozone.com/weblink/EnvSci-3558.html

The Rise and Fall of Human Populations

Human populations are subject to rises and collapses in the same way as natural animal populations. Throughout history there have been a number of peaks of human civilization followed by collapse. These collapses have been triggered by various events but can generally be attributed either to the spread of disease or to the collapse of a food source (normally agriculture). Examples can be traced right back to the origins of humans.

Mitochondrial DNA analyses show that the human population may have been on the brink of extinction with only around 10,000 individuals alive 150,000 years ago. The population remained low for virtually the whole of human prehistory. When the first towns and cities were being built, around 10,000 years ago, the human population had reached barely 5 million. By around 700 AD, the human population had reached 150 million, and the first very large cities were developing. One such city was the Mayan city of Tikal.

TIKAL: At its peak around 800 AD, Tikal and the surrounding area, was inhabited by over 400,000 people. Extensive fields were used to cultivate crops and the total area of the city and its satellite towns and fields may have reached over 250 km^2. Eventually the carrying capacity of the tropical, nutrient-poor land was overextended and people began to starve. By 900 AD the city had been deserted and the surrounding area abandoned.

EASTER ISLAND: Similar events happened elsewhere. Easter Island is located 3,000 km from South America and 2,000 km from the nearest occupied land (the tiny, isolated Pitcairn Island). Easter Island has a mild climate and fertile volcanic soil, but when Europeans discovered it in the 1700s, it was covered in dry grassland, lacking trees or any vegetation above 1m high. Around 2,000 people survived on the island by subsistence farming, yet all around stood huge stone statues, some 30 m tall and weighing over 200 tonnes. Clearly a much larger more advanced society had been living on the island at some time in the past. Archaeological studies have found that populations reached 20,000 people prior to 1500AD. Exhaustion of the island's resources by the population was followed by war and civil unrest and the population fell to the subsistence levels found in the 1700s.

EUROPE: Despite isolated events, the world population continued to grow so that by 1350 AD it had reached around 450 million. As a result of the continued rise of urban populations, often living in squalid conditions, disease spread rapidly. The bubonic plague, which swept through Europe at this time, reduced its population almost by half, and reduced the world's population to 350 million. Despite further outbreaks of plague and the huge death tolls of various wars, the human population had reached 2.5 billion by 1950. By 1990 it was 5 billion and today it is around 6.5 billion. In slightly less than 60 years the human population has grown almost twice as much as it did in the whole of human history up until 1950. Much of this growth can be attributed to major advances in agriculture and medicine. However, signs are appearing that the human population are approaching maximum sustainable levels. Annual crop yields have ceased increasing and many common illnesses are becoming more difficult to treat. The rapid spread of modern pandemics, such as H1N1 swine flu, illustrates the vulnerability of modern human populations. Could it be, perhaps, that another great reduction in the human population is imminent?

1. Describe the general trend of human population growth over the last 100,000 years: ______________________

____

2. Explain why the human population has grown at such a increased rate in the last 60 years: ______________________

____

____

3. Discuss similarities between the events at Tikal and on the Easter Islands and how they can help us plan for the future:

____

____

____

____

____

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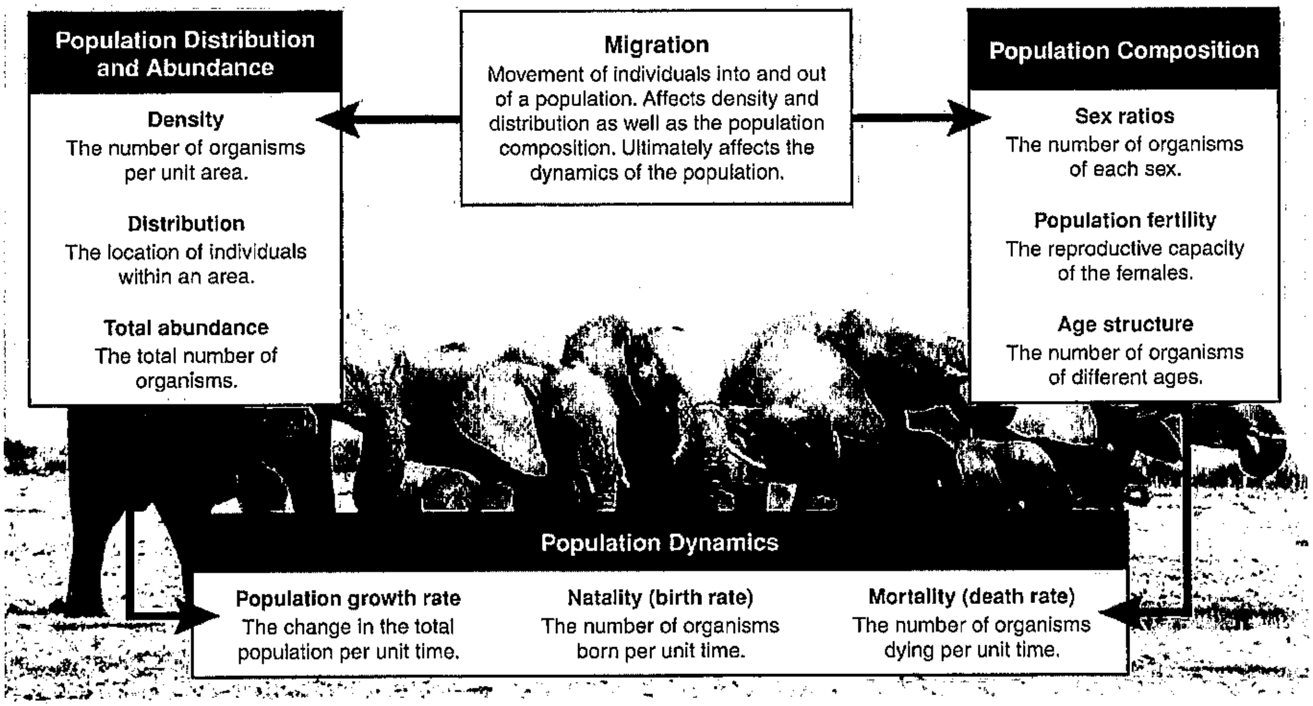
Features of Populations

Populations have a number of attributes that may be of interest. Usually, biologists wish to determine **population size** (the total number of organisms in the population). It is also useful to know the **population density** (the number of organisms per unit area). The density of a population is often a reflection of the **carrying capacity** of the environment, i.e. how many organisms an environment can support. Populations also have structure; particular ratios of different ages and sexes. These data enable us to determine whether the population is declining or increasing in size. We can also look at the **distribution** of organisms within their environment and so determine what particular aspects of the habitat are favored over others. One way to retrieve information from populations is to **sample** them. Sampling involves collecting data about features of the population from samples of that population (since populations are usually too large to examine in total). Sampling can be carried out directly (by sampling the population itself using appropriate equipment) or indirectly (e.g. by monitoring calls or looking for droppings or other signs). Some of the population attributes that we can measure or calculate are illustrated on the diagram below.



1. Describe one example of a population attribute that would be a good indicator of each of the following:

   (a) Whether the population is increasing or decreasing:

   (b) The ability of the environment to support the population:

2. (a) Identify the population attributes that can be measured directly from the population:

   (b) Identify the population attributes that must be calculated from the data collected:

3. Describe the value of population sampling for each of the following situations:

   (a) Conservation of a population of an endangered species:

   (b) Management of a fisheries resource:

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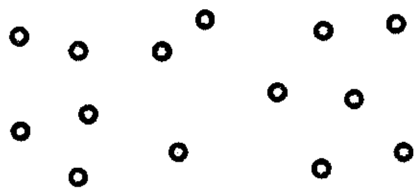
Density and Distribution

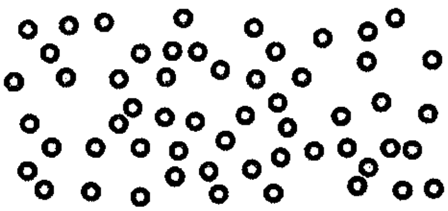
Distribution and density are two interrelated properties of populations. Population density is the number of individuals per unit area (for land organisms) or volume (for aquatic organisms). Careful observation and precise mapping can determine the distribution patterns for a species. The three basic distribution patterns are: random, clumped and uniform. In the diagram below, the circles represent individuals of the same species. It can also represent populations of different species.

Low Density



In low density populations, individuals are spaced well apart. There are only a few individuals per unit area or volume (e.g. highly territorial, solitary mammal species).

High Density

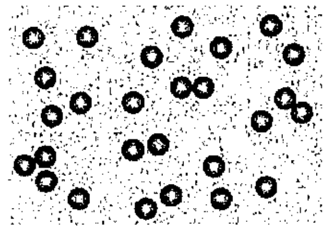


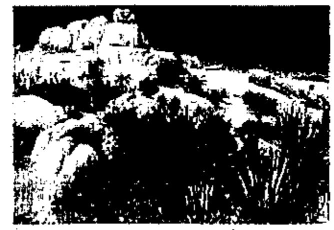
In high density populations, individuals are crowded together. There are many individuals per unit area or volume (e.g. colonial organisms, such as many corals).

Tigers are solitary animals, found at low densities.

Termites form well organized, high density colonies.

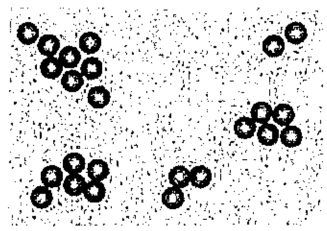
Random Distribution





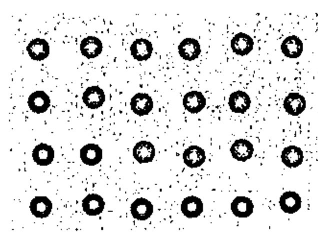
Random distributions occur when the spacing between individuals is irregular. The presence of one individual does not directly affect the location of any other individual. Random distributions are uncommon in animals but are often seen in plants.

Clumped Distribution



Clumped distributions occur when individuals are grouped in patches (sometimes around a resource). The presence of one individual increases the probability of finding another close by. Such distributions occur in herding and highly social species.

Uniform Distribution



Regular distribution patterns occur when individuals are evenly spaced within the area. The presence of one individual decreases the probability of finding another individual very close by. The penguins illustrated above are also at a high density.

1. Describe why some organisms may exhibit a clumped distribution pattern because of:

   (a) Resources in the environment: ______________________________

   ____

   (b) A group social behavior: ______________________________

   ____

2. Describe a social behavior found in some animals that may encourage a uniform distribution:

   ____

3. Describe the type of environment that would encourage uniform distribution:

   ____

4. Describe an example of each of the following types of distribution pattern:

   (a) Clumped: ______________________________

   (b) Random (more or less): ______________________________

   (c) Uniform (more or less): ______________________________

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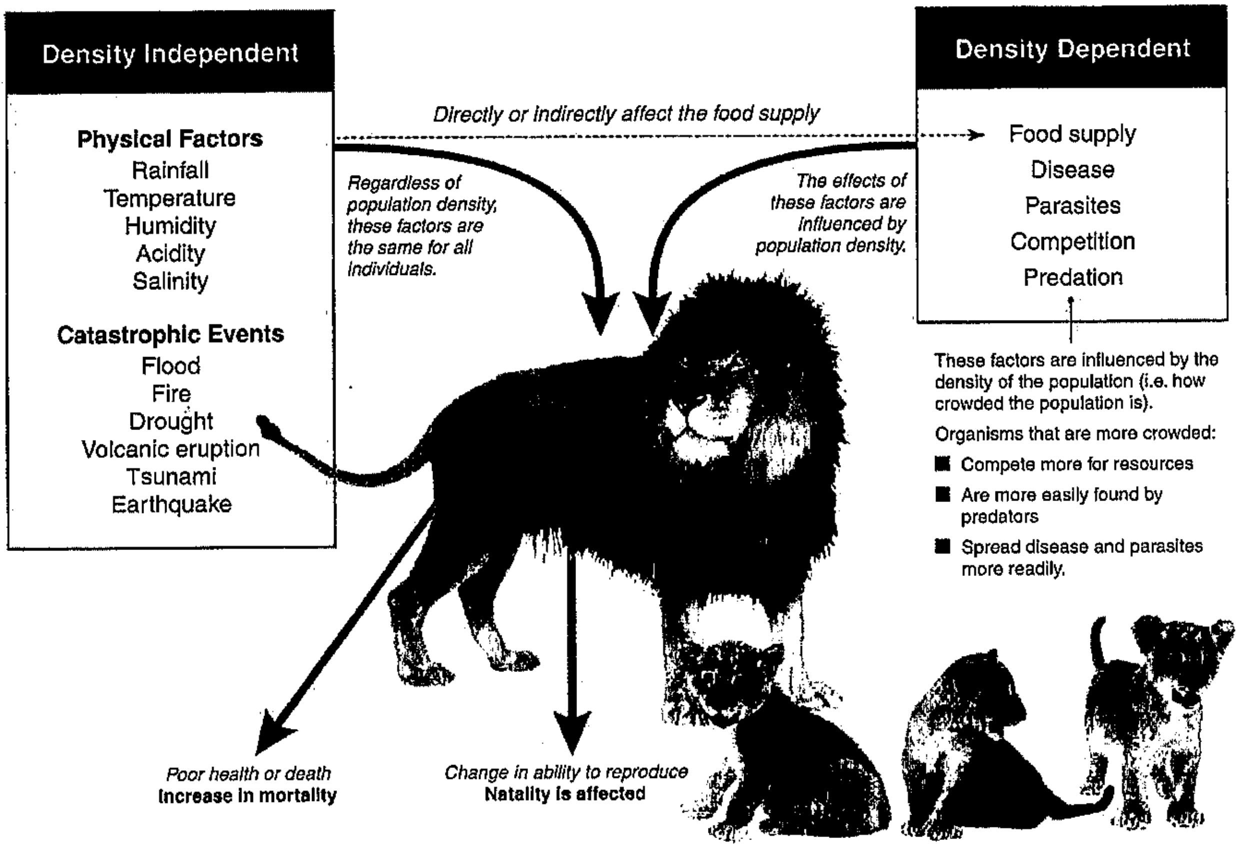
Population Regulation

Very few species show continued exponential growth. Population size is regulated by factors that limit population growth. The diagram below illustrates how population size can be regulated by environmental factors. **Density independent factors** may affect all individuals in a population equally. Some, however, may be better able to adjust to them. **Density dependent factors** have a greater affect when the population density is higher. They become less important when the population density is low.



1. Discuss the role of **density dependent factors** and **density independent factors** in population regulation. In your discussion, make it clear that you understand the meaning of each of these terms:

2. Explain how an increase in population density allows disease to have a greater influence in regulating population size:

3. In cooler climates, aphids go through a huge population increase during the summer months. In autumn, population numbers decline steeply. Describe a density dependent and a density independent factor regulating the population:

   (a) Density dependent:

   (b) Density independent:

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Population Growth

Organisms do not generally live alone. A **population** is a group of organisms of the same species living together in one geographical area. This area may be difficult to define as populations may comprise widely dispersed individuals that come together only infrequently (e.g. for mating). The number of individuals comprising a population may also fluctuate considerably over time. These changes make populations dynamic: populations gain individuals through births or immigration, and lose individuals through deaths and emigration. For a population in **equilibrium**, these factors balance out and there is no net change in the population abundance. When losses exceed gains, the population declines.

Births, deaths, immigrations (movements into the population) and emigrations (movements out of the population) are events that determine the numbers of individuals in a population. Population growth depends on the number of individuals added to the population from births and immigration, minus the number lost through deaths and emigration. This is expressed as:

Population growth =

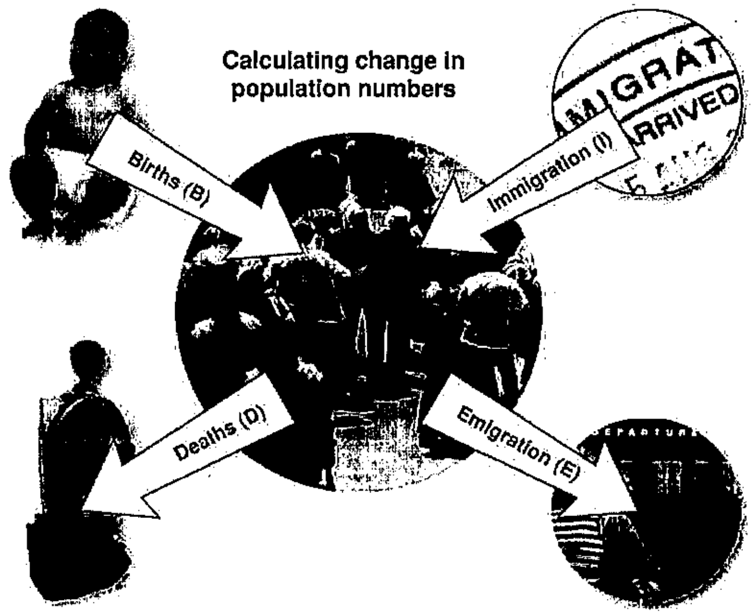
Births – Deaths + Immigration – Emigration
(B) (D) (I) (E)

The difference between immigration and emigration gives net migration. Ecologists usually measure the **rate** of these events. These rates are influenced by environmental factors (see below) and by the characteristics of the organisms themselves. Rates in population studies are commonly expressed in one of two ways:

- Numbers per unit time, e.g. 20,150 live births per year.
- Per capita rate (number per head of population), e.g. 122 live births per 1000 individuals per year (12.2%).

Limiting Factors

Population size is also affected by limiting factors; factors or resources that control a process such as organism growth, or population growth or distribution. Examples include availability of food, predation pressure, or available habitat.



Human populations often appear exempt from limiting factors as technology and efficiency solve many food and shelter problems. However as the last arable land is used and agriculture reaches its limits of efficiency, it is estimated that the human population will peak at around 9 billion by 2050.

1. Define the following terms used to describe changes in population numbers:

   (a) Death rate (mortality): ______________________

   (b) Birth rate (natality): ______________________

   (e) Net migration rate: ______________________

2. Using the terms, B, D, I, and E (above), construct equations to express the following (the first is completed for you):

   (a) A population in equilibrium: B + I = D + E

   (b) A declining population: ______________________

   (c) An increasing population: ______________________

3. The rate of population change can be expressed as the interaction of all these factors:

   Rate of population change = Birth rate – Death rate + Net migration rate (positive or negative)

   Using the formula above, determine the annual rate of population change for Mexico and the United States in 1972:

	USA	Mexico
Birth rate	1.73%	4.3%
Death rate	0.93%	1.0%
Net migration rate	+0.20%	0.0%

   Rate of population change for USA = ____________

   Rate of population change for Mexico = ____________

4. A population started with a total number of 100 individuals. Over the following year, population data were collected. Calculate birth rates, death rates, net migration rate, and rate of population change for the data below (as percentages):

   (a) Births = 14: Birth rate = ____________ (b) Net migration = +2: Net migration rate = ____________

   (c) Deaths = 20: Death rate = ____________ (d) Rate of population change = ____________

   (e) State whether the population is increasing or declining: ____________

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Survivorship Curves

The survivorship curve depicts age-specific mortality. It is obtained by plotting the number of individuals of a particular cohort against time. Survivorship curves are standardized to start at 1000 and, as the population ages, the number of survivors progressively declines. The shape of a survivorship curve thus shows graphically at which life stages the highest mortality occurs. Survivorship curves in many populations fall into one of three hypothetical patterns (below). Wherever the curve becomes steep, there is an increase in mortality. The convex Type I curve is typical of populations whose individuals tend to live out their physiological life span. Such populations usually produce fewer young and show some degree of parental care. Organisms that suffer high losses of the early life stages (a Type III curve) compensate by producing vast numbers of offspring. These curves are conceptual models only, against which real life curves can be compared. Many species exhibit a mix of two of the three basic types. Some birds have a high chick mortality (Type III) but adult mortality is fairly constant (Type II). Some invertebrates (e.g. crabs) have high mortality only when moulting and show a stepped curve. Typically, **K-selection** predominates in organisms with Type I survivorship and ***r*-selection** predominates in organisms with Type III survivorship.

Hypothetical Survivorship Curves

Type I

Late loss survivorship curve

Mortality (death rate) is very low in the infant and juvenile years, and throughout most of adult life. Mortality increases rapidly in old age. **Examples:** Humans (in developed countries) and many other large mammals (e.g. big cats, elephants).

Type II

Constant loss survivorship curve

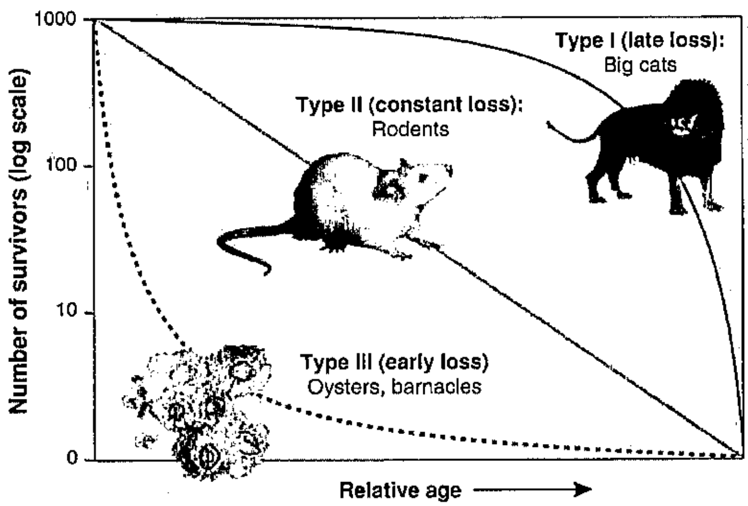
Mortality is relatively constant through all life stages (no one age is more susceptible than another). **Examples:** Some invertebrates such as *Hydra*, some birds, some annual plants, some lizards, and many rodents.

Type III

Early loss survivorship curve

Mortality is very high during early life stages, followed by a very low death rate for the few individuals reaching adulthood. **Examples:** Many fish (not mouth brooders) and most marine invertebrates (e.g. oysters, barnacles).

Graph of Age Specific Survival



Three basic types of survivorship curves and representative organisms for each type. The vertical axis may be scaled arithmetically or logarithmically.

Elephants have a close matriarchal society and a long period of parental care. Elephants are long-lived and females usually produce just one calf.

Rodents are well known for their large litters and prolific breeding capacity. Individuals are lost from the population at a more or less constant rate.

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Despite vigilant parental care, many birds suffer high juvenile losses (Type III). For those surviving to adulthood, deaths occur at a constant rate.

1. Match the following terms to the statements below: **A** Type I **B** Type II **C** Type III **D** Human **E** Oyster

   (a) Curve followed by organisms with high mortality rates early in life: ______

   (b) Human populations in developed countries follow this type of curve: ______

   (c) Organism which compensates for high juvenile mortality by producing large numbers of young: ______

2. Describe the features of a species with type I survivorship that aid in high juvenile survival: ______

3. Discuss the following statement: "There is no standard survivorship curve for a given species; the curve depicts the nature of a population at a particular time and place and under certain environmental conditions.": ______

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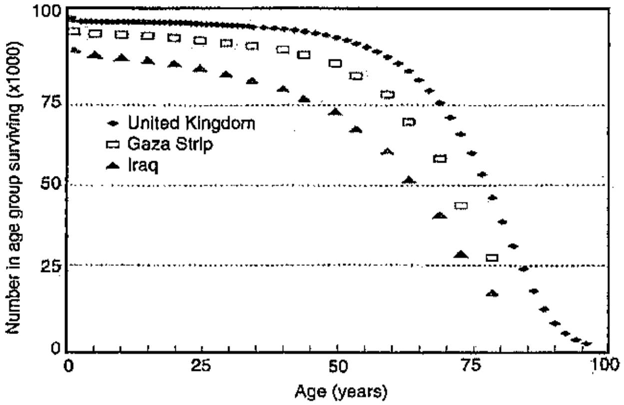
Life Expectancy and Survivorship

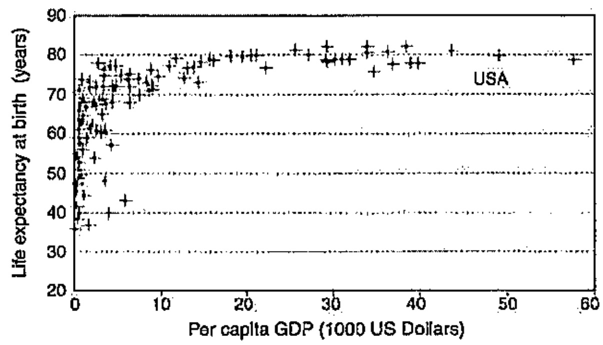
Life expectancy is the average number of years of life remaining when at any given age, and therefore changes as an individual ages. For example in the US, at birth a human has a life expectancy of around 78 years. However a 66 year old has a life expectancy of around 16 years meaning they should live to the age of 82. In human societies, life expectancy is heavily dependent on aspects of the socio-economic structure such as public health facilities, presence and treatment of endemic disease, and level of poverty. These factors are not static. Countries where war, famine or disease are common invariably have low life expectancies. Life expectancy is also affected by gender; international life expectancy for males is 64 compared with 68 for females.



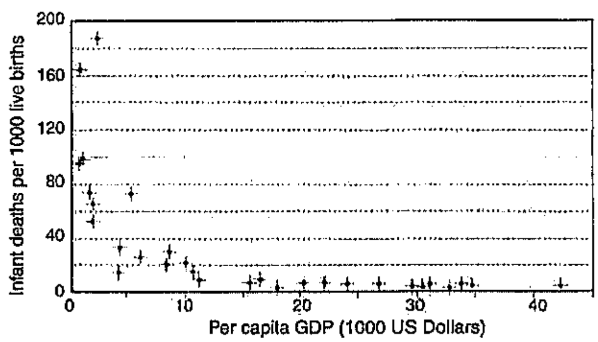
Human populations typically follow a type I survivorship curve. However, the average life expectancy can vary greatly between developed and developing nations. The average life expectancy can be estimated from the suvivorship curves above as being the age at which 50% of the people in the sample are still alive.

War, civil instability, poor infrastructure and social services, and poverty can greatly reduce life expectancy. Life expectancy in stable, industrialized nations, e.g. Japan, can be around 80 at birth, while war-torn, poor, or developing nations may have life expectancies as low as 39 at birth e.g. Swaziland.

Life Expectancy, Mortality and Wealth



Life expectancy is linked to many factors but in human society there is a close correlation between life expectancy and a country's per capita gross domestic product (GDP). Those countries with high GDP can be expected to have citizens with long life expectancies.



In developed nations, the **infant mortality rate** (IMR) is low because of better standards of living and advanced medical technology. People in developing countries often lack access to quality medical care and the IMR can be high, especially where there are high rates of endemic disease. However, populations in developing countries often have high birth rates so that population growth rates remain high despite a high IMR.

Life expectancy and survivorship of a population are closely linked to the wealth of the country they live in:

1. (a) Describe the relationship between a country's per capita GDP and life expectancy of its citizens: __________

(b) Explain why IMR might be linked to a nation's wealth: __________

(c) Identify some factors that lower life expectancy and survivorship of a country: __________

2. Explain why life expectancy changes as one ages: __________

3. Estimate average life expectancy for: (a) United Kingdom: _____ (b) Gaza Strip: _____ (c) Iraq: _____

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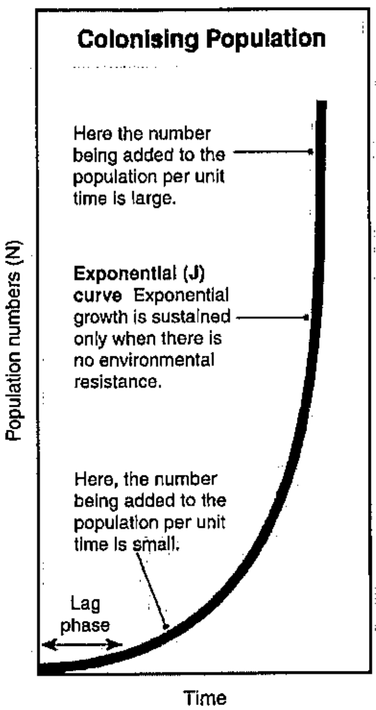
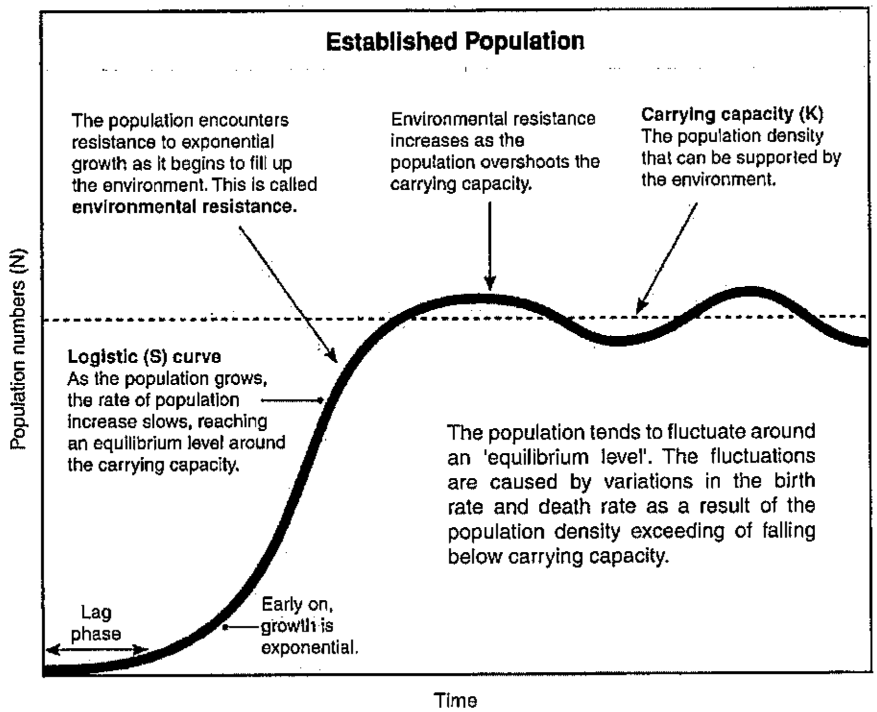
Population Growth Curves

Populations grow by increasing in numbers. Patterns of population growth fall into two main types: **exponential** or **logistic** (sigmoidal). These patterns are a reflection of the biological characteristics of the species and the environment. Exponential (J-shaped) growth (below, left) is typical of early **colonising populations**, but is not normally sustained indefinitely because the resources of the environment are limited. The populations of established communities tend to show logistic (S-shaped) growth (below, right), and stabilise at a level that can be supported by the environment. Logistic growth is determined by two things: how fast a species reproduces and the carrying capacity (saturation density) of the environment (represented by the letter **K**).





1. Explain why populations tend not to continue to increase exponentially in an environment: ____________________

2. Explain what is meant by environmental resistance: ____________________

3. (a) Explain what is meant by carrying capacity: ____________________

   (b) Explain the importance of **carrying capacity** to the growth and maintenance of population numbers: __________

4. Species that expand into a new area, such as rabbits did in areas of Australia, typically show a period of rapid population growth followed by a slowing of population growth as density dependent factors become more important and the population settles around a level that can be supported by the carrying capacity of the environment.

   (a) Explain why a newly introduced consumer (e.g. rabbit) would initially exhibit a period of exponential population growth:

   (b) Describe a likely outcome for a rabbit population after the initial rapid increase had slowed: __________

5. Describe the effect that introduced grazing species might have on the carrying capacity of the environment:

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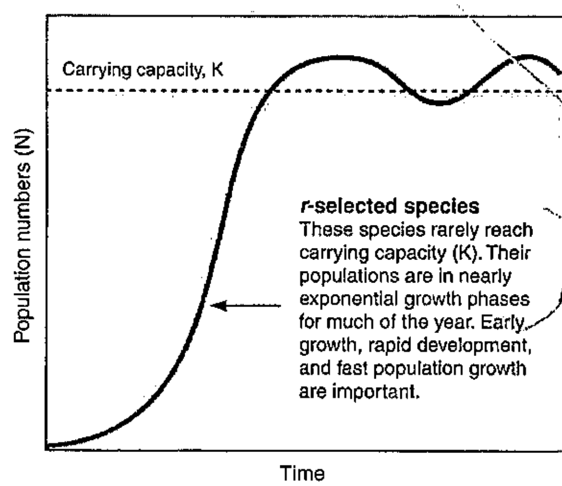
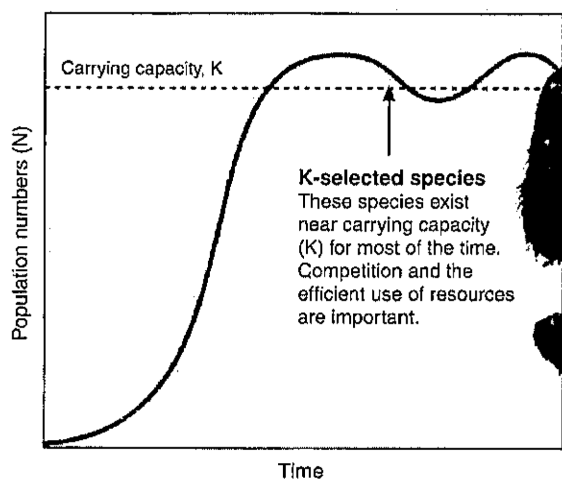
r and K Selection

The capacity of a species to increase in numbers is called its **biotic potential**. It is a measure of reproductive capacity and is assigned a set value (denoted by the letter *r*) that is specific to the organism involved. Species with a high biotic potential are called ***r*-selected species.** They include algae, bacteria, rodents, many insects, and most annual plants. These species show life history features associated with rapid growth in disturbed environments. To survive, they must continually invade new areas to compensate for being replaced by more competitive species. The population growth of species with lower biotic potential tends to depend on the carrying capacity of the environment (**K**). These species, which include most large mammals, birds of prey, and large, long-lived plants, exist near the carrying capacity of their environments and are forced, through their interactions with other species, to use resources more efficiently. These species have fewer offspring and longer lives, and put their energy into nurturing their young to reproductive age. Most organisms have reproductive patterns between these two extremes. Both *r*-selected species (crops) and K-selected species (livestock) are found in agriculture.



Features of *r*-Selected Species	
Climate	Variable and/or unpredictable
Mortality	Density independent
Survivorship	Large, early losses of offspring
Population size	Fluctuates wildly. Often below K
Competition	Variable, often lax. Generalist niche.
Selection favours	Rapid development, high biotic potential, early reproduction, small body size, single reproduction.
Length of life	Short (usually less than one year)
Leads to:	Productivity



Features of K-Selected Species	
Climate	Fairly constant and/or predictable
Mortality	Density dependent
Survivorship	Constant or late loss of older individuals
Population size	Fairly constant in time. Near equilibrium with the environment.
Competition	Usually keen. Specialist niche.
Selection favours	Slower development, larger body size, greater competitive ability, delayed reproduction, repeated reproduction.
Length of life	Longer (greater than one year)
Leads to:	Efficiency

1. Explain the significance of the *r* and the K notation when referring to *r* and **K selection:** ______

2. Giving an example, explain why *r*-selected species tend to be **opportunists**: ______

3. Describe some benefits of being a K selected species: ______

4. Suggest why many K-selected species are often vulnerable to extinction: ______

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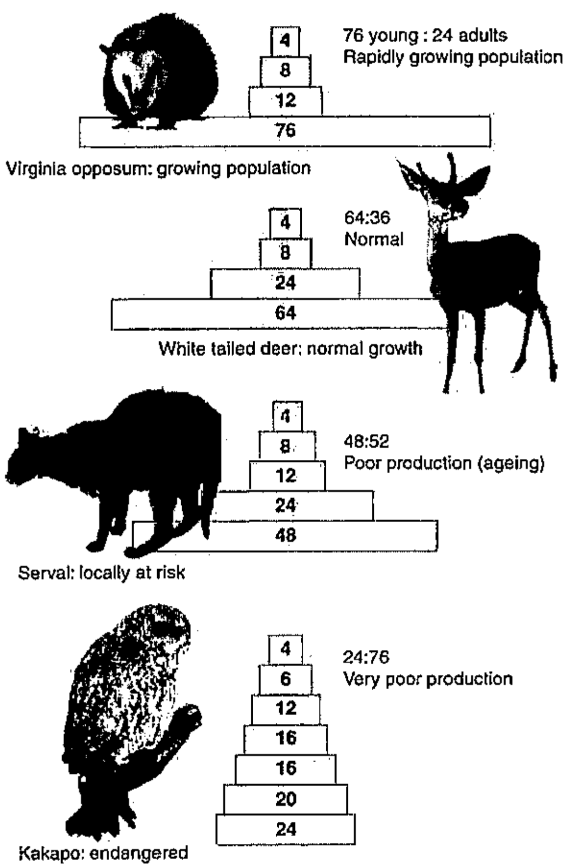
Population Age Structure

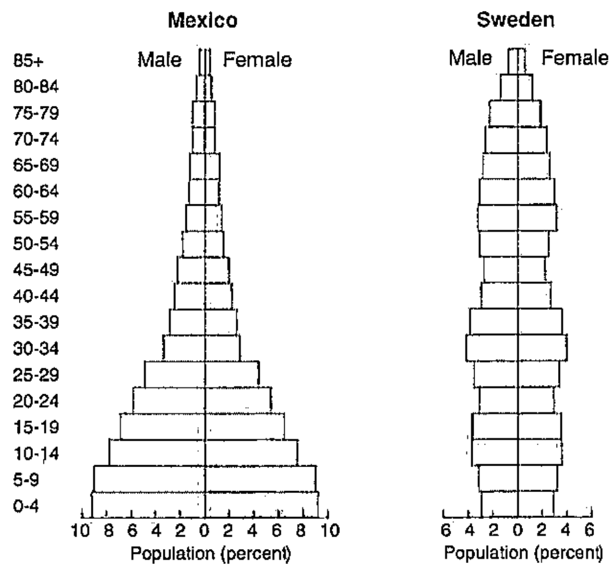
The **age structure** of a population refers to the relative proportion of individuals in each age group in the population. The age structure of populations can be categorized according to specific age categories (such as years or months), but also by other measures such as life stage (egg, larvae, pupae, instars), of size class (height or diameter in plants). Population growth is strongly influenced by age structure; a population with a high proportion of reproductive and prereproductive aged individuals has a much greater potential for population growth than one that is dominated by older individuals. The ratio of young to adults in a relatively stable population of most mammals and birds is approximately 2:1 (below, left). Growing populations in general are characterized by a large and increasing number of young, whereas a population in decline typically has a decreasing number of young. Population age structures are commonly represented as pyramids, in which the proportions of individuals in each age/size class are plotted with the youngest individuals at the pyramid's base. The number of individuals moving from one age class to the next influences the age structure of the population from year to year. The loss of an age class (e.g. through overharvesting) can profoundly influence a population's viability and can even lead to population collapse.

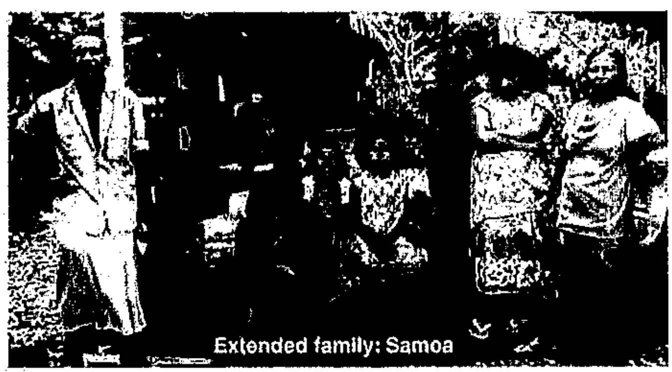
Age Structures in Animal Populations

These theoretical age pyramids, which are especially applicable to birds and mammals, show how growing populations are characterized by a high ratio of young (white bar) to adult age classes (blue bars). Ageing populations with poor production are typically dominated by older individuals.



Age Structures in Human Populations





Most of the growth in human populations in recent years has occurred in the developing countries in Africa, Asia, and Central and South America. This is reflected in their age structure; a large proportion of the population comprises individuals younger than 15 years (age pyramid above, left). Even if each has fewer children, the population will continue to increase for many years. The stable age structure of Sweden is shown for comparison

1. For the theoretical age pyramids above left:

   (a) State the approximate ratio of young to adults in a rapidly increasing population: ____________________

   (b) Suggest why changes in population age structure alone are not necessarily a reliable predictor of population trends:

   ____

   ____

2. Explain why the population of Mexico is likely to continue to increase rapidly even if the rate of population growth slows:

   ____

   ____

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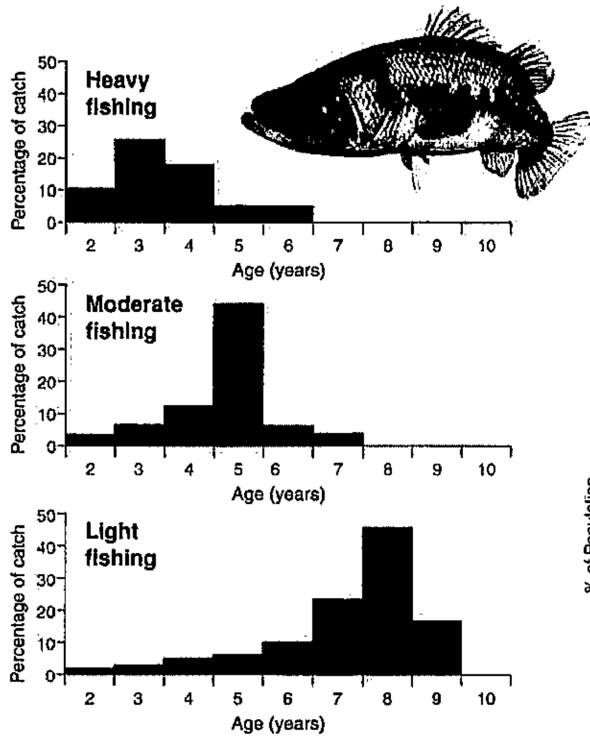
Analysis of the age structure of a population can assist in its management because it can indicate where most of the mortality occurs and whether or not reproductive individuals are being replaced. The age structure of both plant and animal populations can be examined; a common method is through an analysis of size which is often related to age in a predictable way.

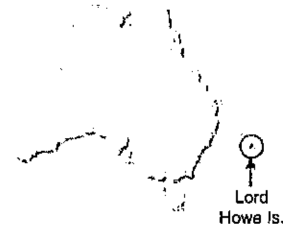
Managed Fisheries

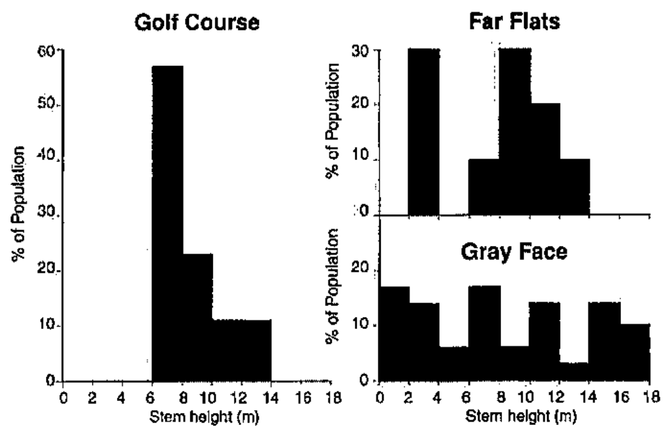
The graphs below show the age structure of a hypothetical fish population under different fishing pressures. The age structure of the population is determined by analyzing the fish catch to determine the frequency of fish in each size (age) class.



Thatch Palm Populations on Lord Howe Island

Lord Howe Island is a narrow sliver of land approximately 770 km northeast of Sydney. The age structure of populations of the thatch palm *Howea forsteriana* was determined at three locations on the island: the golf course, Gray Face and Far Flats. The height of the stem was used as an indication of age. The differences in age structure between the three sites are mainly due to the extent of grazing at each site.





3. For the managed fish population above left:

   (a) Name the general factor that changes the age structure of this fish population: ______________________

   (b) Describe how the age structure changes when the fishing pressure increases from light to heavy levels:

   ____

4. State the most common age class for each of the above fish populations with different fishing pressures:

   (a) Heavy: ______________ (b) Moderate: ______________ (c) Light: ______________

5. Determine which of the three sites sampled on Lord Howe Island (above, right), best reflects the age structure of:

   (a) An ungrazed population: ______________________

   Reason for your answer: ______________________

   (b) A heavily grazed and mown population: ______________________

   Reason for your answer: ______________________

6. Describe the likely long term prospects for the population at the golf course: ______________________

   ____

7. Describe a potential problem with using size to estimate age: ______________________

   ____

8. Explain why a knowledge of age structure could be important in managing a resource: ______________________

   ____

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World Population Growth

For most of human history, humans have not been very numerous compared to other species. It took all of human history to reach a population of 1 billion in 1804, but little more than 150 years to reach 3 billion in 1960. The world's population, now at 7 billion, is growing at the rate of about 80 million per year. This growth is slower than predicted but the world's population is still expected to increase substantially before stabilizing (see Figure 1). World population increase carries important environmental consequences, particularly when it is associated with increasing **urbanization.** Although the world as a whole still has an average fertility rate of 2.8, growth rates are now lower than at any time since World War II. Continued declines may give human populations time to address some to the major problems posed by the increasing the scope and intensity of human activities.

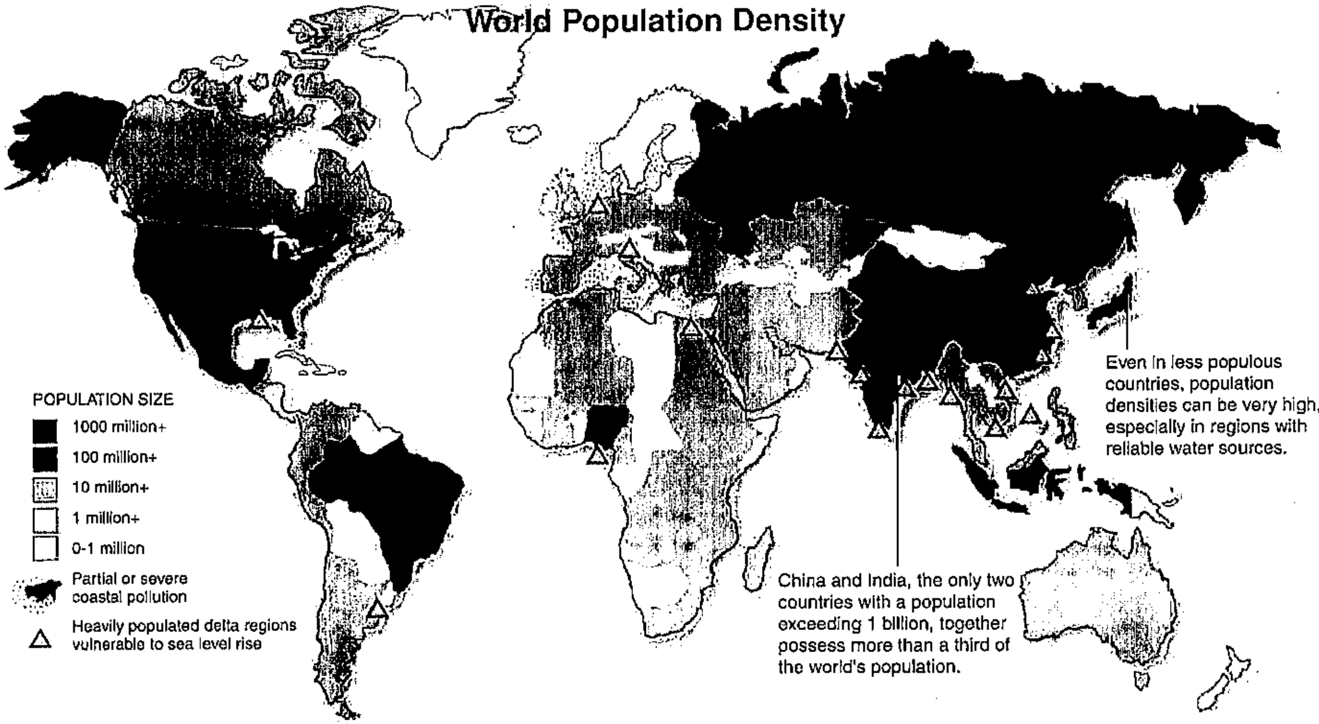


Figure 1: Progress towards population stabilization

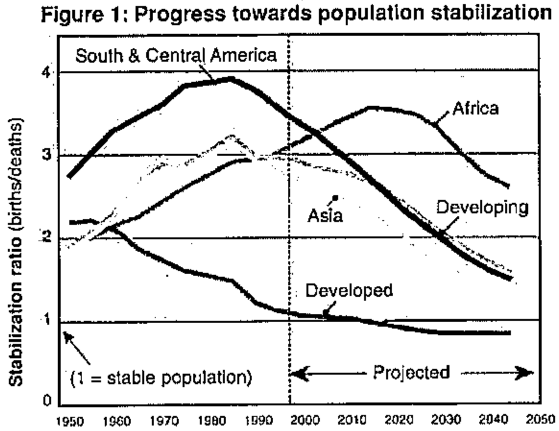


Figure 2: Trends in fertility rates

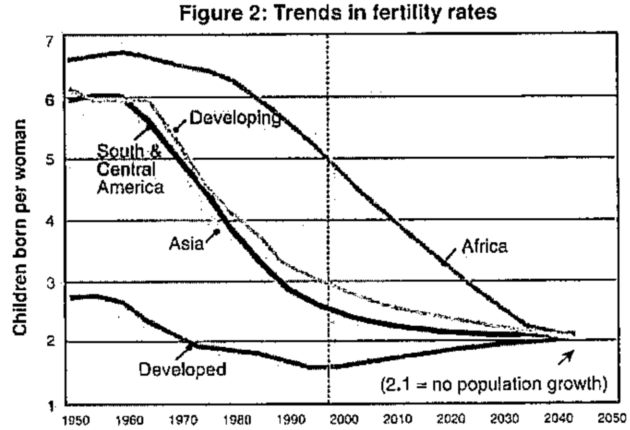
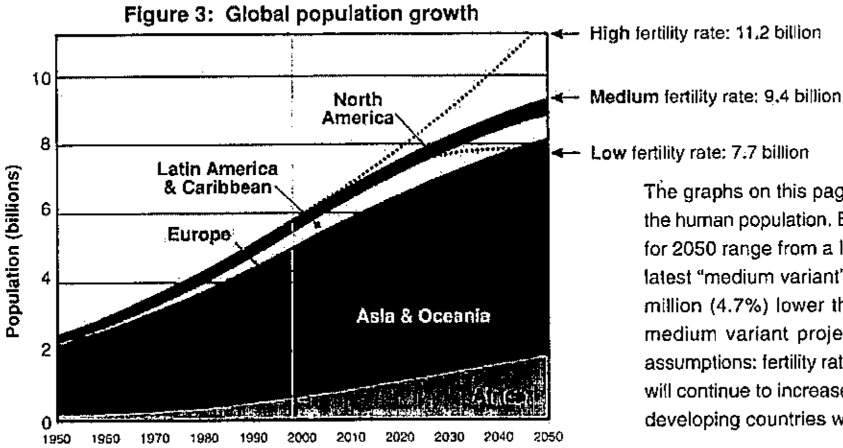


Figure 3: Global population growth



Source for graphs: United Nations Population Division, *World Population Prospects 1950-2050 (The 1996 Revision)*, U.N., New York, 1996.

The graphs on this page attempt to show the likely future growth of the human population. Estimates are highly uncertain and projections for 2050 range from a low of 7.7 billion to a high of 11.2 billion. The latest "medium variant" U.N. projection of 9.37 billion is nearly 500 million (4.7%) lower than the 9.83 billion projected in 1994. The medium variant projection depends on a number of important assumptions: fertility rates will continue to decline and life expectancy will continue to increase (as in the industrialized countries), and that developing countries will broadly follow these demographic trends.

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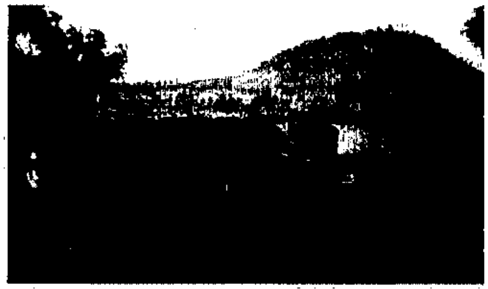


The traditional villages characteristic of the rural populations of less economically developed countries have a close association with the land. The households depend directly on agriculture or harvesting natural resources for their livelihood and are linked through family ties, culture, and economics.

Cities are differentiated communities, where the majority of the population does not depend directly on natural resource-based occupations. While cities are centers of commerce, education, and communication, they are also centers of crowding, pollution, and disease.

Cities, especially those that are growing rapidly, face a range of problems associated with providing residents with adequate water, food, sanitation, housing, jobs, and basic services, such as health care. Slums or squatter settlements are found in most large cities in developing countries as more poor people migrate from rural to urban areas.

The redistribution of people from rural to urban environments, or **urbanization**, has been an important characteristic of human societies. Almost half of the people in the world already live in urban areas and by the end of the 21st century, this figure is predicted to increase to 80-90%. Urban populations can grow through natural increase (i.e. more births than deaths) or by **immigration**. Immigration is driven both by **push factors** that encourage people to leave their rural environment and **pull factors** that draw them to the cities.

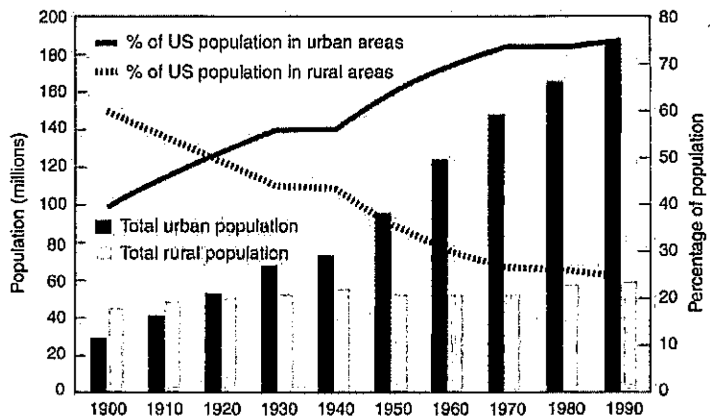
Immigration push factors

- Rural overpopulation
- Lack of work or food
- Changing agricultural practices
- Desire for better education
- Racial or religious conflict
- Political instability

Immigration pull factors

- Opportunity for better jobs
- Chance of better housing
- More reliable food supply
- Opportunity for greater wealth
- Freedom from village traditions
- Government policy

Rural and Urban Populations in the USA



The United States underwent a dramatic rural to urban shift in the 19th and early 20th centuries. Many developing countries are now experiencing similar shifts. Graph compiled from UN data

1. Fertility rates of populations for all geographic regions are predicted to decline over the next 50 years.

   (a) State which continent is predicted to have the highest fertility rate at the beginning of next century: ______________

   (b) Suggest why the population of this region is slower to achieve a low fertility rate than other regions: ______________

   ____

   ____

2. Describe the kinds of changes in agricultural practices that could contribute to urbanization: ______________

   ____

   ____

3. (a) Describe some of the positive effects of urbanization: ______________

   ____

   ____

   (b) Describe some negative effects of urbanization: ______________

   ____

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Human Demography

Human populations through time have undergone demographic shifts related to societal changes and economic development. The demographic transition model (DTM) was developed in 1929 to explain the transformation of countries from high birth rates and high death rates to low birth rates and low death rates as part of their economic development from a pre-industrial to an industrialized economy. The transition involves four stages, or possibly five (with some nations, being recognized as moving beyond stage four). Each stage of the transition reflects the changes in birth and death rates observed in human societies over the last 200 years. Most developed countries are beyond stage three of the model; the majority of developing countries are in stage two or stage three. The model was based on the changes seen in Europe, so these countries follow the DTM relatively well. Many developing countries have moved into stage three. The exceptions include some poor countries, mainly in sub-Saharan Africa and some Middle Eastern countries, which are poor or affected by government policy or civil strife.

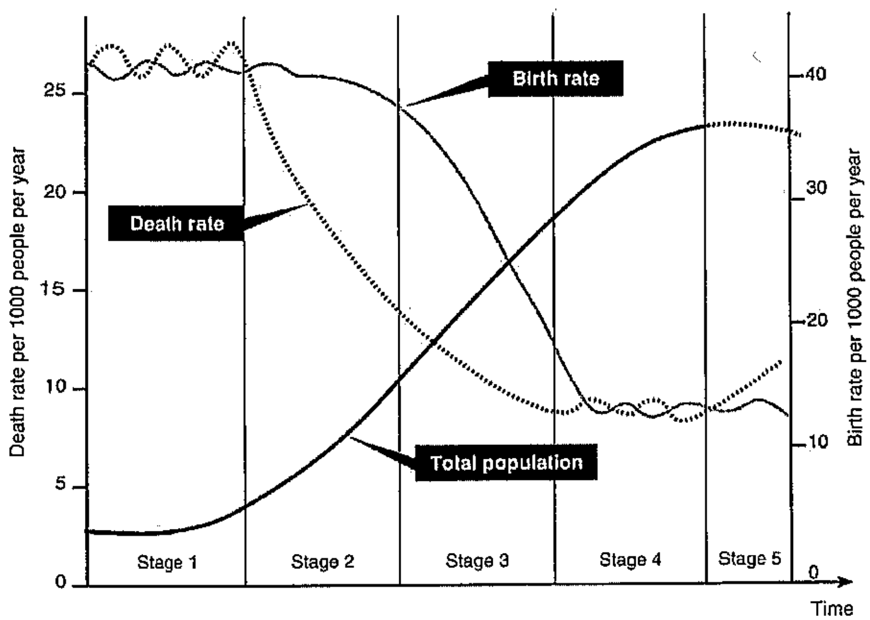
Stage one: Birth and death rates balanced but high as a result of starvation and disease.

Stage two: Improvement in food supplies and public health result in reduced death rates.

Stage three moves the population towards stability through a decline in the birth rate.

Stage four: Birth and death rates are both low and the total population is high and stable.

The Demographic Transition Model



Stage one (pre-modern): A balance between birth and death rates as was true of all populations until the late 18th Century. Children are important contributors to the household economy. Losses as a result of starvation and disease are high. Stage 1 is sometimes called the "High Stationary Stage" of population growth (high birth and death rates and stationary total population numbers).

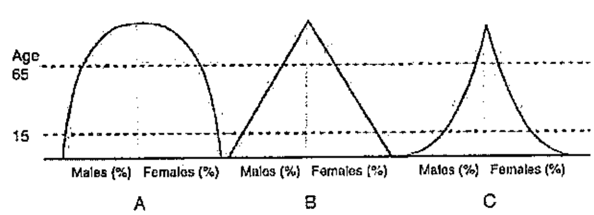
Stage two (early expanding): Rapid population expansion as a result of a decline in death rates. The changes leading to this stage in Europe were initiated in the Agricultural Revolution of the 18th century but have been more rapid in developing countries since then. Stage two is associated with more reliable food supplies and improvements in public health.

Stage three (late expanding): The population moves towards stability through a decline in the birth rate. This stage is associated with increasing urbanization and a decreased reliance on children as a source of family wealth. Family planning in nations such as Malaysia (photo left) has been instrumental in their move to stage three.

Stage four (post-industrial): Birth and death rates are both low and the total population is high and stable. The population ages and in some cases the fertility rate falls below replacement.

Stage five (declining): Proposed by some theorists as representing countries that have undergone the economic transition from manufacturing based industries into service and information based industries and the population reproduces well below replacement levels. Countries in stage five include the United Kingdom (the earliest nation recognized as reaching Stage Five) and Germany.

1. Each of the first four stages of the DTM is associated with a particular age structure. Identify which of the diagrams (right) corresponds to stage one of the DTM and explain your choice:



____

____

2. Suggest why it might become less important to have a large number of children in more economically developed nations:

____

____

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Cemeteries are an excellent place to study changes in human demographics. Data collected from headstones can be used to calculate death rates and produce survivorship curves. It is also possible to compare survivorship curves over different periods and see how certain factors (e.g. war, medical advances) have altered survivorship.

The data (right) represents age of death data for males and females collected over two different time periods; pre-1950 and post 1950. The pre-1950s was characterized by two world wars, and the prevalence of diseases such as polio and tuberculosis. The post 1950s have also seen global conflict, but to a lesser degree than the pre-1950 period. Many advances in medicine (e.g. vaccines) and technology have been made during this time.

The data used in this exercise has been collected from the online records of several cemeteries across five different states in the United States to provide representative data.

Pre-1950				Post 1950			
Males age at death		Females age at death		Males age at death		Females age at death	
81	5	9	4	80	31	92	76
40	0	76	18	81	78	46	92
54	24	0	71	79	56	44	96
70	70	78	2	81	86	70	65
75	39	69	63	8	80	80	54
64	71	6	1	30	64	71	87
45	27	46	84	88	41	88	82
22	64	60	68	90	76	65	80
71	0	84	58	84	17	51	90
62	41	75	19	64	40	80	85
89	77	43	24	60	79	87	63
31	21	64	62	71	74	76	58
10	1	67	52	62	46	63	89
42	75	42	29	63	71	33	56
1	50	39	8	83	90	99	86

Data source: http://www.interment.net/us/index.htm

3. Complete the following table using the cemetery data provided. The males Pre-1950 data have been completed for you.

(a) In the number of deaths column, record the number of deaths for each age category.

(b) **Calculate the survivorship** for each age category. For each column, enter the total number of individuals in the study (30) in the 0-9 age survivorship cell. This is the survivorship for the 0-9 age group. Subtract the number of deaths at age 0-9 from the survivorship value at age 0-9. This is the survivorship at the 10-19 age category. To calculate the survivorship for age 20-29, subtract the number of deaths at the age 10-19 age category from the survivorship value for age 10-19. Continue until you have completed the column.

	Males Pre-1950		Females Pre-1950		Males Post 1950		Females Post 1950	
Age	**No. of deaths**	**Survivorship**	**No. of deaths**	**Survivorship**	**No. of deaths**	**Survivorship**	**No. of deaths**	**Survivorship**
0-9	5	30						
10-19	1	25						
20-29	4	24						
30-39	2	20						
40-49	4	18						
50-59	2	14						
60-69	3	12						
70-79	7	9						
80-89	2	2						
90-99	0	0						
Total	30							

4. (a) On a separate piece of graph paper, construct a graph to compare the survivorship curves for each category. Staple the graph into this workbook once you have completed the activity.

(b) What conclusions can you make about survivorship before 1950 and after 1950? ______________________________

____

____

(c) What factors might cause these differences? ______________________________

____

____

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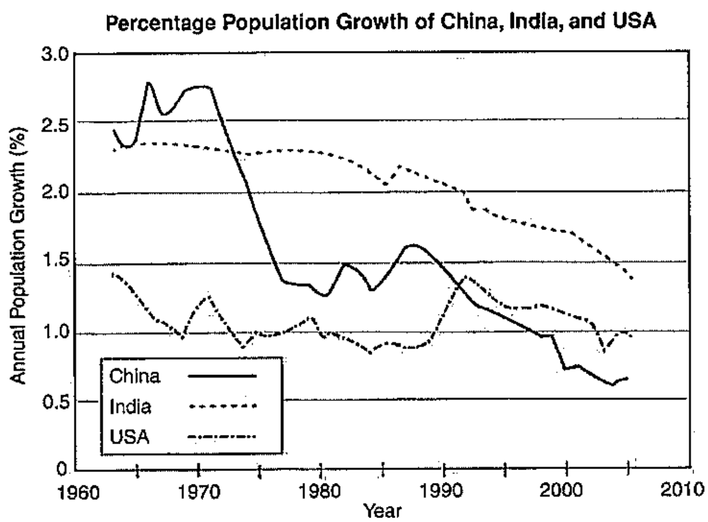
Human Sustainability

The human population has increased from fewer than 3 billion people to over 7 billion in the past 50 years. Since the 1950s, improvements in medicine and access to more food have allowed the world's population to grow at rate of almost 2% each year. Many scientists believe growth of this magnitude is not sustainable and that the human population has already surpassed the planet's carrying capacity. They predict the inevitable collapse of food supplies and populations in the near future. In many countries, initiatives have been taken to lower birth rates in an attempt to relieve pressure on resources.

A major reason for high growth rates in some countries is a societal belief that a large family is needed to help with work. In countries where there is no government support for those unable to work, children often contribute to the family income. Child mortality is high so parents produce a large number of children to ensure some can support the family.

High population growth rates can quickly cause the depletion of a country's resources and increase problems with supply of goods and sanitation, especially if the infrastructure is poor. Often the cost of addressing these issues is beyond the means of the people and the country, leading to permanent poverty and a decline in the population health and wellbeing.

Most developed countries have low population growth rates. These are through easy access to education, contraception, and family planning, gender equality, and a social focus on individual success and self support. Having a large family can cause financial burden and so restrict access to education and commodities and this acts as a disincentive for high birth rates.



China is the world's most populous nation. During the 1960s, officials realized that the country's growth rate could not be sustained and implemented strict regulations for family planning. Couples were encouraged to marry late and have only one child. Contraception and sterilization were made free and those that followed the guidelines were given access to better jobs, food, education for their child, housing, pensions, medical care, and salary bonuses.

India began the world's first national family planning campaign in 1952, when the population was 400 million. Fertility rates have dropped from 5.3 to 3.5 children for women but, unlike the program in China, the campaign suffered from slow uptake by families, poor planning, bureaucratic delays, and a lack of financial support or incentives. As a result, India's population is now more than 1 billion people and India will overtake China as the most populous nation around 2050.

The birth rates in most Westernized nations (e.g. the USA) began to decline during industrialization and dropped even further with the introduction of the contraceptive pill. Developing countries are only now beginning to show a reduction in their population growth rates as they move from industrialized to post-industrialized status.

1. Explain why mainly developing countries have high population growth rates: ______________________

____

____

2. Explain the reasons for the differences in the success of China's and India's family planning campaigns: ______________

____

____

____

3. (a) Describe some benefits of reducing population sizes: ______________________

____

(b) Discuss some negative aspects of a rapidly declining population: ______________________

____

____

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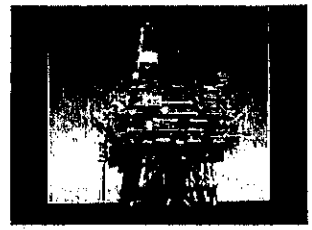
Humans and Resources

The expanding human population puts increasing strain on the world's resources, creates problems of pollution and waste disposal, and often places other species at risk. Even when resources are potentially sufficient to meet demands, problems with distribution and supply create inequalities between regions. This page outlines some of the problems associated with the availability and use of resources. Although the world's situation might seem bleak, progress is being made towards a more sustainable future. Houses and cities are now being designed with greater energy efficiency in mind, steps are being taken to reduce greenhouse gas emissions and other forms of pollution, and sustainable agricultural practices are being increasingly encouraged. Advancements in technology combined with a political commitment to sustainability will add to these gains.

Air pollution contributes to global warming, ozone depletion, and acid rain, and is set to increase markedly in the next 30 years.

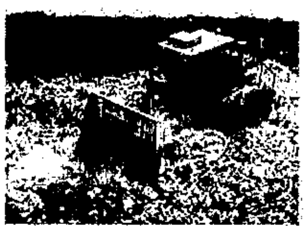
Global water consumption is rising rapidly. The availability of water is likely to become one of the most pressing resource issues of the 21st century.

Combustion engine emissions are increasing rapidly in Asia as their economies develop and their populations become more affluent.



A dwindling supply of fossil fuels provides about 85% of the world's commercial energy. Most of this is consumed by the richest countries.

Global climate change as a result of the greenhouse effect will cause a rise in sea levels and threaten coastal populations such as those in Bangladesh (above).



In industrialized societies, one person consumes many tonnes of raw materials each year, which must be extracted, processed, and then disposed of as waste.

Aquatic environments, such as coral reefs and freshwater habitats in lakes, rivers, and wetlands are at risk from population pressure (58% of the worlds reefs and 34% of all fish species).

Threats to biodiversity from all sources are rapidly reaching a critical level. Current extinction rates have increased 100 to 1000 times due to human impact on natural environments.

Consumption of natural resources, including fuels, water, and minerals, by modern industrial economies remains very high (in the range of 45 to 85 tonnes per person annually).

Forest fires and logging continue to cause shrinkage of the world's tropical and temperate forests. Deforestation in the Amazon doubled from 1994 to 1995 before declining in 1996.

The unsustainable fishing of the world's fish stocks has occurred in many fishing grounds (e.g. cod fishing in the North Atlantic). Many of these fish populations are unlikely to recover.

Although the world's food production is theoretically adequate to meet human needs there are problems with distribution. Some 800 million people remain undernourished.

1. Describe some of the predicted impacts of shortages of fossil fuel and freshwater on world agriculture:

2. Chose two of the following resources and describe its use and the subsequent impact on the environment:

Water Coal Timber Fish

(a) Resource 1:

(b) Resource 2:

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KEY TERMS: Mix and Match

INSTRUCTIONS: Test your vocabulary by matching each term to its definition, as identified by its preceding letter code.

- carrying capacity ....
- community ....
- competition ....
- demographics ....
- density ....
- distribution ....
- emigration ....
- environmental resistance ....
- exponential growth ....
- immigration ....
- K selection ....
- limiting factors ....
- mortality ....
- natality ....
- population size ....
- *r*-selection ....
- sigmoidal growth ....
- survivorship curve ....
- urbanization ....

A The location of individuals in a population within an area.

B A curve showing the age specific mortality of a population.

C Growth that occurs in multiples based on earlier populations. An accelerating growth rate.

D An interaction between organisms exploiting the same resource.

E A naturally occurring group of different species living within the same environment and interacting together.

F The maximum number of a specific organism that the environment can provide for.

G Selection favoring rapid rates of population increase; especially prominent in species that colonize transient environments.

H Selection that occurs in an environment at or near carrying capacity, favoring the production of a few, highly competitive offspring.

I The birth rate of a population, (usually expressed as the number of births per 1000 individuals).

J The act of leaving the area of one's birth or residence to settle in another area.

K The biotic and abiotic factors that prevent a population from continually increasing in size.

L The number of individuals per unit area

M The grouping of populations into particular sets of characteristics, e.g. sex, age etc.

N The act of entering and settling in an area that is different from one's original home.

O A pattern of S-shaped growth, characterized by a lag phase, a phase of rapid growth, and then a stabilizing phase. Also called logistic growth.

P Any factors affecting the maximum number a population can reach.

Q The death rate of a population, (usually expressed as the number of deaths per 1000 individuals).

R The total number of individuals of a species within a set habitat or area.

S The growth of cities as a result of the redistribution of people from rural areas to urban environments.

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