Population ecology

- **Population ecology**: is the study of individuals of the same species where the processes as aggregation, interdependencies between individuals etc and various factors governing such processes are emphasized.

- **Population** : Population is a set of individuals of a particular species, which are found in a particular geographical area. Two types of populations are recognised

- **Monospecific population**: it is the population of individuals of only one species.

- **Mixed or polyspecific population**: it is the population of individuals of more than one species

- The subject of population ecology may be discussed as
- **Describing a population (population characteristic)**
- **Population dynamics**
- **Regulation of population**

Population characteristics(describing a population)

Some of the most important characteristics of population are as follows:

- Population size and density
- Dispersion
- Natality
- Mortality
- Age distribution of population
- Life tables.

Population size and density:

- Population density refers to the size of any population in relation to some unit of space. It is expressed in terms of the number of individuals or biomass per unit area or volume, as for example, 500 teak trees per hectare; 40 lions per 100 km^2, 5 million diatoms per cubic meter of water. Population density is seldom static and it changes with time and space.

- **Population size can be measured by several methods:**

(i) Abundance:

- Absolute number of individuals in population.

(ii) Numerical Density:

- Number of individuals per unit area or volume. It is expressed when the size of individuals in the population is relatively uniform, as in mammals, insects and birds.

(iii) Biomass Density:

- Biomass density is expressed in terms of wet weight, dry weight, volume, and carbon and nitrogen weight per unit area or volume.

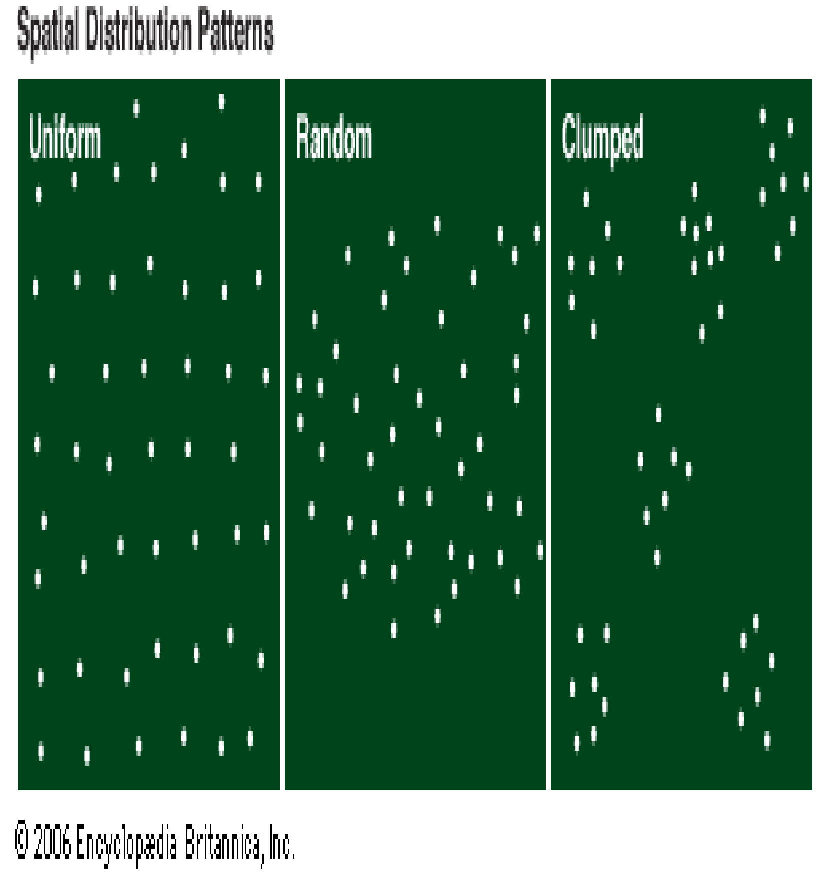
Population density can be expressed in two ways:

- **(i) Crude Population Density :** When the density is expressed with reference to total area at a particular time.

- **(ii) Ecological Density:** When the density is expressed with reference to total area of habitat available to the species. The distribution between crude density and ecological density becomes important because the patterns of distribution of individuals in nature are different and individuals of some species like *Cassia tora*, *Oplismenus burmanni* are found more crowded in shady places than in other parts of the same area. Thus population density calculated in total area would be crude density and the densities for the shade areas and open areas separately would be ecological densities.

Dispersion

- **Dispersion**: is the spatial pattern of individuals in a population relative to one another. Three basic patterns that occur are
- **Regular dispersion**: Here the individuals are more or less spaced at equal distance from one another. This is rare in nature but common in managed systems(cropland) Animals with territorial behavior tend toward this dispersion.
- **Random dispersion**: Here the position of one individual is unrelated to the positions of its neighbors. This is also relatively rare in nature .
- **Clumped dispersion**: Most populations exhibit this dispersion o some extent, with individuals aggregated into patches interspersed with no or few individuals



Natality

- **Natality:**
- Natality refers to the rate of reproduction or birth per unit time. It is an expression of the production of new individuals in the population by birth, hatching, germination or fission.
- **Natality is calculated by the following formula:**

Birth rate or Natality (B) = Number of births per unit time/Average population.

- The maximum number of births produced per individual under ideal conditions of environment is called **potential natality**. It is also called reproductive or biotic potential, absolute natality or maximum natality.
- Natality varies from organism to organism. It depends upon the population density and environmental factors. It is a general rule that if the population density is usually low, the birth rate is also low. This is so because the chances of mating between males and females are low. If population density is unusually high, the birth rate may also be low due to poor nutrition or physiological or psychological problems related to crowding.
- The maximum or absolute natality is observed when the species exists under ideal ecological and genetic conditions. The actual number of births occurring under the existing environmental conditions is much less as compared to absolute natality. It is referred to **as ecological natality** or realized natality. It is not constant for population and may vary with the size of population as well as with the time.

Mortality

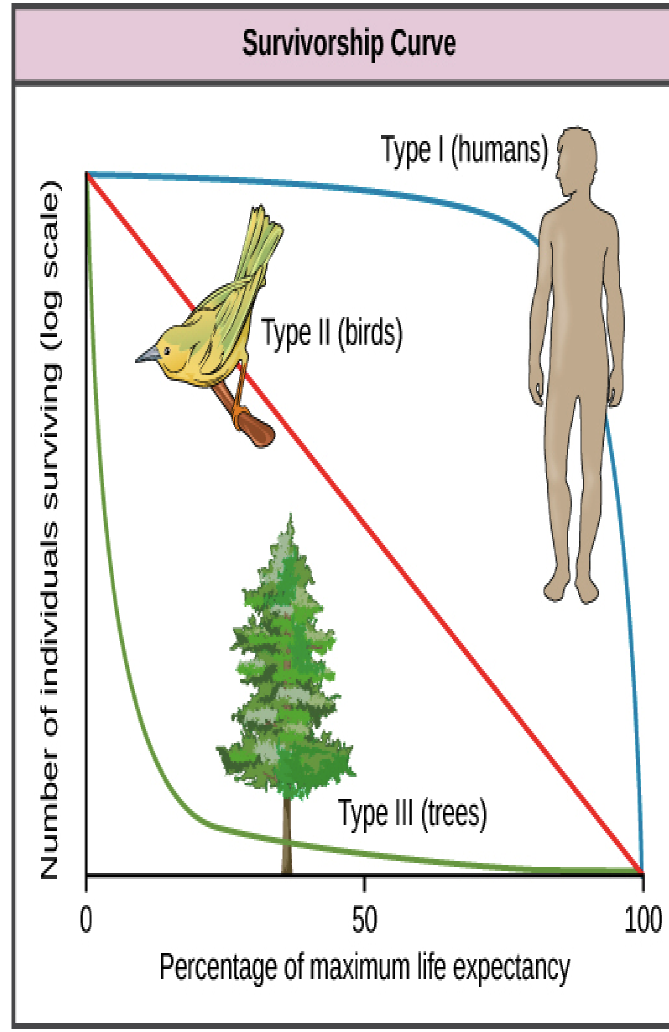
- **Mortality:**
- Mortality refers to the number of deaths in population per unit time.
- Mortality rate = D/t where D is the number of deaths in the time t.

- **Mortality can be expressed in the following two ways:**
- **(i) Minimum or Specific or Potential Mortality:**
- It represents the minimum of theoretical loss of individuals under ideal or non-limiting condition. Thus, even under the best conditions individuals of a population would die of old age determined by their physiological longevity. So it is constant for a population

- (ii) **Ecological or Realized Mortality:**
- It refers to the death of individuals of a population under existing environmental conditions. Since it varies with environmental conditions, it is never constant. The maximum mortality occurs at the egg, larval, seedling and old age. Mortality is affected by a number of factors, such as, **density, competition, disease, predation and environment**. Death rates vary among the species and are correlated with birth rates. When the rate of natality is equal to the rate of mortality the population is stationary.
- A birth death ratio (Births/death x 100) is called **vital index**. For a population, the survival of individuals is more important than the death. The number of births in relation to the carrying capacity of the habitat is a fundamental factor influencing the mortality rate.
- When more young's are born than the habitat can support, the surplus must either die or leave the area. Because the number of survivors is more important than the number of dying individuals, mortality is better expressed as survival or as life expectancy. The **life expectancy** refers to the average number of years the members of a population have left to live.

Survivorship curve

- A **survivorship curve** shows what fraction of a starting group is still alive at each successive age. Different species have differently shaped survivorship curves. In general, we can divide survivorship curves into three types based on their shapes:
- **Type I (highly convex curves)**. Humans and most primates have a Type I survivorship curve. In a Type I curve, organisms tend not to die when they are young or middle-aged but, instead, die when they become elderly. Species with Type I curves usually have small numbers of offspring and provide lots of parental care to make sure those offspring survive.
- **Type II (Diagonal curve).** Many bird species have a Type II survivorship curve. In a Type II curve, organisms die more or less equally at each age interval. Organisms with this type of survivorship curve may also have relatively few offspring and provide significant parental care.
- **Type III(Highly concave curve).** Trees, marine invertebrates, and most fish have a Type III survivorship curve. In a Type III curve, very few organisms survive their younger years. However, the lucky ones that make it through youth are likely to have pretty long lives after that. Species with this type of curve usually have lots of offspring at once—such as a tree releasing thousands of seeds—but don't provide much care for the offspring



Age Distribution

- Age distribution is another important characteristic of population which influences natality and mortality.
- Mortality, usually varies with age, as chances of death are more in early and later periods of life span. Similarly, natality is restricted to certain age groups, as for example, in middle age-groups in higher animals.
- According to Bodenheimer (1958), the individuals of a population can be divided into **pre-reproductive**, r**eproductive** and **post-reproductive** groups. The individuals of pre-reproductive group are young, those of reproductive group are mature and those in post-reproductive group are old.
- The distribution of ages may be constant or variable.
- It is directly related to the growth rate of the population.
- Depending upon the proportion of the three age-groups, populations can be said to be **growing, mature or stable, and diminishing**
- In other words, the ratio of various age groups in a population determines the **reproductive status** of the population.
- Rapidly increasing population contains a large proportion of young individuals,
- a stable population shows even distribution of individuals in reproductive age-group and
- a declining population contains a large proportion of old individuals.

Age Pyramids

- Age pyramid is a model in which the numbers or proportions of individuals in various age groups at any given time are geometrically presented.
- In an age pyramid, the number of **pre-reproductive individuals** is shown at the **base** that of **reproductive age group** in the **middle** and the number of **post-reproductive individuals** at the **top.**
- The shape of age-pyramid changes with the change in the population age distribution over a period of time .The age pyramid indicates whether a population is expanding or stable or diminishing and accordingly three hypothetical age pyramids have been suggested.
- **These are as follows:**

(i) Pyramid with broad base:

- This pyramid shows a high percentage of young individuals and an exponential growth of population due to high birth rate, as for example in yeast, housefly, Paramecium .

(ii) Bell-shaped pyramid:

- This type of age pyramid shows a stationary or stable population having, more or less equal number of young and middle-aged individuals and post-reproductive individuals being the smallest in number.

(iii) Pyramid with narrow base:

- This is an um-shaped pyramid which shows increased numbers of middle aged and old organisms as compared to young ones in the population. It is indicative of contracting or diminishing population.

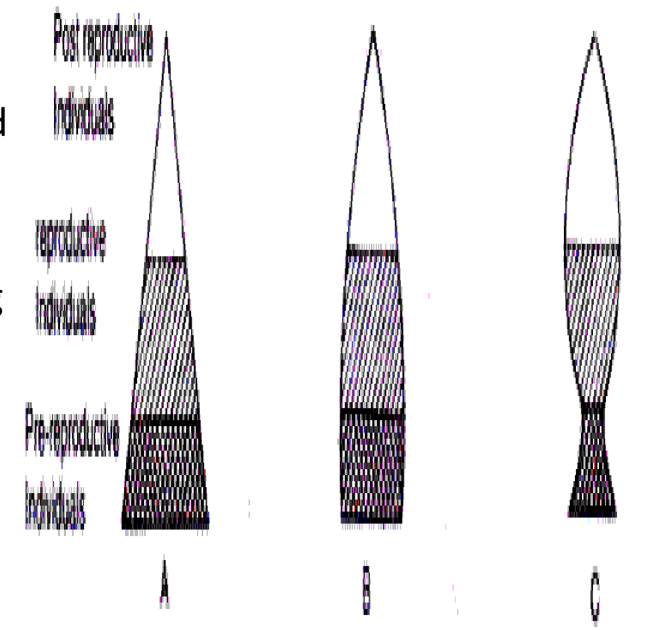


Fig. 4.4. A. Pyramid with broad base. B. Bell shaped pyramid. C. Urn-shaped or pyramid with narrow base.

Life tables

- Information on natality and mortality in different ages and sexes can be combined in the form of life tables.
- From these it is possible to estimate the growth or decline of a population.
- In each table there are columns for age of individuals, number surviving to each age, the number dying in each age group, the proportion dying from the previous age category, fertility rate and the number of young born by each age group
- The information obtained from these figures provides the net reproductive rate of the population i.e. offspring left by each individual
- Similarly from life tables, mortality in a logarithmic form is also obtained.
- These are then used to calculate the rate of population growth.

Types of life tables

- Two types of life table
- **Cohort (or dynamic) life table**: follow all offspring born at a given time (the cohort) from birth until the death of the last individual.
- This is the preferred way to generate a life table
- It works best for organisms that live for a relatively short time period
- **Static (or time-specific) life table**: count all individuals alive at a given time and record the age of each
- This method is less preferred (we'll see why later…)
- However, it is simpler to use for longer-lived organisms that the researcher may not be able to follow across the organism's entire lifetime

Importance of life tables:

- Life tables describes for the successive age intervals the deaths, remaining survivor, rate of mortality and expectation of further life.
- Life table provides an important tool in understanding their life cycles.
- By this technique we can determine the mechanical relationship of various environmental factors and find out the key factor that accounts for large part of the change in population size.

Population dynamics

- Population have characteristics pattern of increase which are called **population growth forms**. Such growth forms represents the interaction of biotic potential and environmental resistance.
- The growth is one of the dynamic features of species population. Population size increases in a characteristic way. When the number of individuals of population is plotted on the y-axis and the times on the x-axis, a curve is obtained that indicates the trend in the growth of population size in a given time. This curve is **called population growth curve**.
- **There are two types of growth curves:**
- **(i) Sigmoid Curve:**
- When a few organisms are introduced in an area, the population increase is very slow in the beginning (positive acceleration phase or lag phase), in the middle phase, the population increase becomes very rapid (logarithmic phase) and finally in the last phase population increase is slowed down (negative acceleration phase) until an equilibrium is attained Lund which the population size fluctuates according to variability of environment.
- The level beyond which no major increase can occur is referred to as saturation level or carrying capacity. In the last phase the new organisms are almost equal to the number of dying individuals and thus there is no increase in population size. In this way, one gets sigmoid or S-shaped growth curve
- **ii) J-Shaped Curve:**
- The second type of growth curve is J-shaped. Here in the first phase there is no increase in population size because it needs some time for adjustment in the new environment. Soon after the population is established in the new environment, it starts multiplying rapidly. This increase in population is continued till large amount of food materials exist in the habitat. After some time, due to increase in population size, food supply in the habitat becomes limited which ultimately results in decrease in population size. This will result in J-shaped growth curve rather than S-shaped
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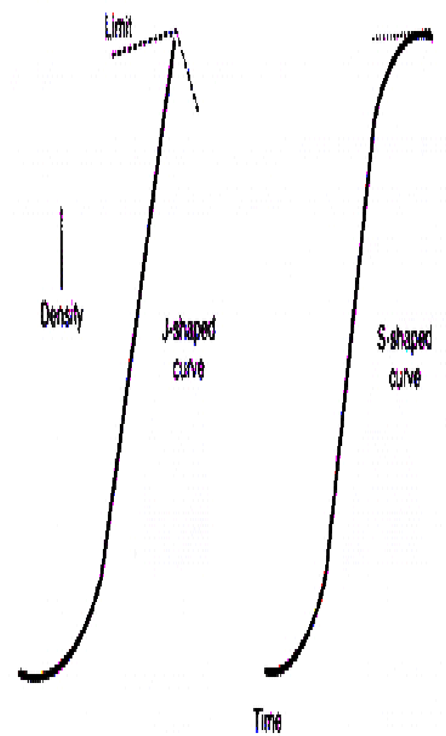

Fig. 4.2. J-Shaped and S-shaped population growth curves.

Population Dynamics and Carrying Capacity

- Four variables that govern population size :
- **births ,deaths ,immigration ,emigration**
- **Population change** = [births + immigrations] - [deaths + emigration]
- or Population change = [births - deaths] + [immigrations - emigration]
- **ZPG** = zero population growth: when number of individuals added to a population from births and immigrations equals the number of individuals lost due to deaths and emigration.
- **Population size** is determined by the interplay between it biotic potential and environmental resistance.
- **Biotic Potential** - capacity of a population for growth
- **Intrinsic rate of growth (r)** - the rate at which a population could grow .It had unlimited resources
- **High r** - reproduce early in life, have short generation times, can reproduce many times and produce many offspring each time the reproduce
- **critical size** - a minimum size a population should have to support a breeding population There are always limits to population growth in nature.
- **Environmental Resistance** - all the factors acting jointly to limit the growth of a population.
- **Carrying Capacity (K)** - the number of individuals of a given species that can be sustained indefinitely in a given space; determined by biotic potential and environmental resistance

- **Exponential Growth and Logistic Growth**
- **Exponential Growth** - a population that does not have resource limitations;
- J-shaped exponential growth curve
- **Logistic Growth** - involves exponential growth when a population is small and a steady decrease in growth in time as the population approaches the carrying capacity
- S-shaped growth curve

- **When a population exceeds the Carrying Capacity**. Overshoot the carrying capacity due to a reproductive time lag - the time it takes for the birth rate to fall and the death rate to rise in response to resource overconsumption)
- the population will dieback or crash (deer on the Aleutian Island, Alaska)

Factors Affecting the Carrying Capacity

Food Availability

- Food availability in any habitat is paramount to survival of a species. Predators, carnivores, must have prey availability.
- As long as their prey is available, they usually do not suffer from food stress.
- Herbivores, plant eaters, have a more complicated diet, and can become stressed from a shortage of food, or a shortage of nutritious food.
- They will feed first on their preferred foods, and then the staple food that satisfies their nutritional needs.
- When no other foods are available, herbivores will feed on emergency foods that will fill them up, but not maintain their body weight.

Water

- Animals must have water to help with food digestion, to help control and regulate body temperature, and to help eliminate waste products from the body.
- Usually, the larger the animal, the more water is required to sustain the animal's organ systems.
- Where water becomes scarce, food may also become scarce as plants die, animals leave or die, and the remaining animals fight each other for whatever water is left.
- Their bodies become weaker and are less able to fight off disease or predators.

- **Ecological Conditions**
- Conditions within or adjacent to an environment also affect its carrying capacity.
- For example, if the environment is located close to a human population, this may affect its carrying capacity.
- Pollution may also affect an environment's carrying capacity.
- A natural disaster, such as a hurricane or a flood, also affects the ability of an environment to sustain animal or plant populations.
- The inability of the land to sustain either crops or plants because of erosion, desertification, or degradation also affects its carrying capacity.

- **Space**
- Animals need a place to shelter from poor conditions, and to provide a place for reproduction.
- Sufficient space within a habitat allows the animals that inhabit it better opportunities to find adequate food and water.
- Without space, animals cannot ensure a place to hide and raise their young -- or to nest.
- Animals also need space to rest, even to play.
- The University of Clemson stated that without sufficient space, animals can become stressed, and stressed animals will not eat or drink enough to sustain adequate levels of health. They also will not reproduce.

Regulation of population density

- The logistic model and its derivatives assume that a population will level off at its carrying capacity, that there is an upper limit to population density set by the environment and that the population is regulated at or around that level . Kreb(1985) gave the factors that regulate population density

- **Nature of factors that influence population density**
- Population density can only be increased by natality or immigration and decreased by mortality or emigration. These factors may be density dependent or density independent in their effects.

- **Density-independent factors** do not vary systematically in their effects as density changes. Density independent population controls affect a pop. size regardless of its density. (floods, hurricanes, earthquakes, landslides, drought, fire, habitat destruction, pesticide spraying)

- **Density-dependent factors** increase in their proportional effect as population increases. These factors include competition and predation. e.g. rate of population growth is increasingly depressed by intraspecific competition as density is increased.

- **Key factor analysis**: This is the method to analyze mortality factors, to find out which may be regulatory.
- The k-value for each mortality factors together with total k(sum of all factors) are plotted for several successive generation.
- The k-factor that most closely follows the pattern of k is called the key factor.
- In insect population, loss of adults through migration or death is the key factor.
- **Self regulation of populations**: Intraspecific density dependent interactions regulate many populations in the laboratory, and in that sense these are self regulating.
- Accumulation of waste products may depress population growth, Social behavior may also be self regulatory. Death or failures to mate are3 density dependent and can regulate population density.
- **Immigration, emigration and population dynamics**: Besides nataliy and mortality, immigration and emigration also effect population density. These both are features of disposal. Whereby individuals move from one population and die if no suitable environment is found; establish a new population, or join an existing one at a new locale

Population Fluctuations

- The size and density of natural population show a changing pattern over a period of time. This is called population fluctuation.
- **There are three types of variations in the pattern of population change:**
- **(i) Non-fluctuating:**
- When the population remains static over the years, it is said to be non-fluctuating.
- **(ii) Cyclic:**
- The cyclic variations may be (i) seasonal, and (ii) annual. Sometimes seasonal changes occur in the population and there are additions to the population at the time of maximum reproduction and losses under adverse climatic conditions. Common examples of seasonal variations are met in mosquitoes and houseflies which are abundant in particular season and so also the weeds in the field during the rainy season. When the population of a species shows regular ups and downs over the years, it is called annual cyclic variation. It appears in the form of a sigmoid curve with regular drops in population after peaks.
- **(iii) Irruptive:**
- When the change in population density does not occur at regular intervals or in response to any obvious environmental factor, it is said to be irruptive fluctuation. In this there is a sudden exponential or logarithmic increase in population density in short time followed by equally quick drop in population density due to deaths, and final return to normal level or even below that level.

Population ecology and evolution

- MacArthur and Wilson(1967) reported that populations are outcome of r or k selection. R-selected populations have a high intrinsic rate of growth and tend to boom when environmental conditions are favorable. K-selected populations have relatively constant density at or near the carrying capacity(K) of the environment.

	R-selected	K-selected
Environment	Variable and unpredictable	Constant or predictably variable
Population characteristics	Survivorship curve concave	Survivorship curve convex
	High fecundity	Low fecundity
	Density variable usually well below carrying capacity	Density fairly constant at or near carrying capacity
	Scramble type intraspecific competition	Contest type interspecific competition
Individual characteristic	Small body size	Large body size
	Good dispersal power	Poor dispersal power
	out crossing	Parthenogenetic or vegetative reproduction
	Low level of social organization	High level of social organization