Chaudhary Mahadeo Prasad Degree College
(A Constituent Postgraduate College of Central University of Allahabad

e-learning module

Ecology & phytogeography

M.Sc.Botany

Course code 507

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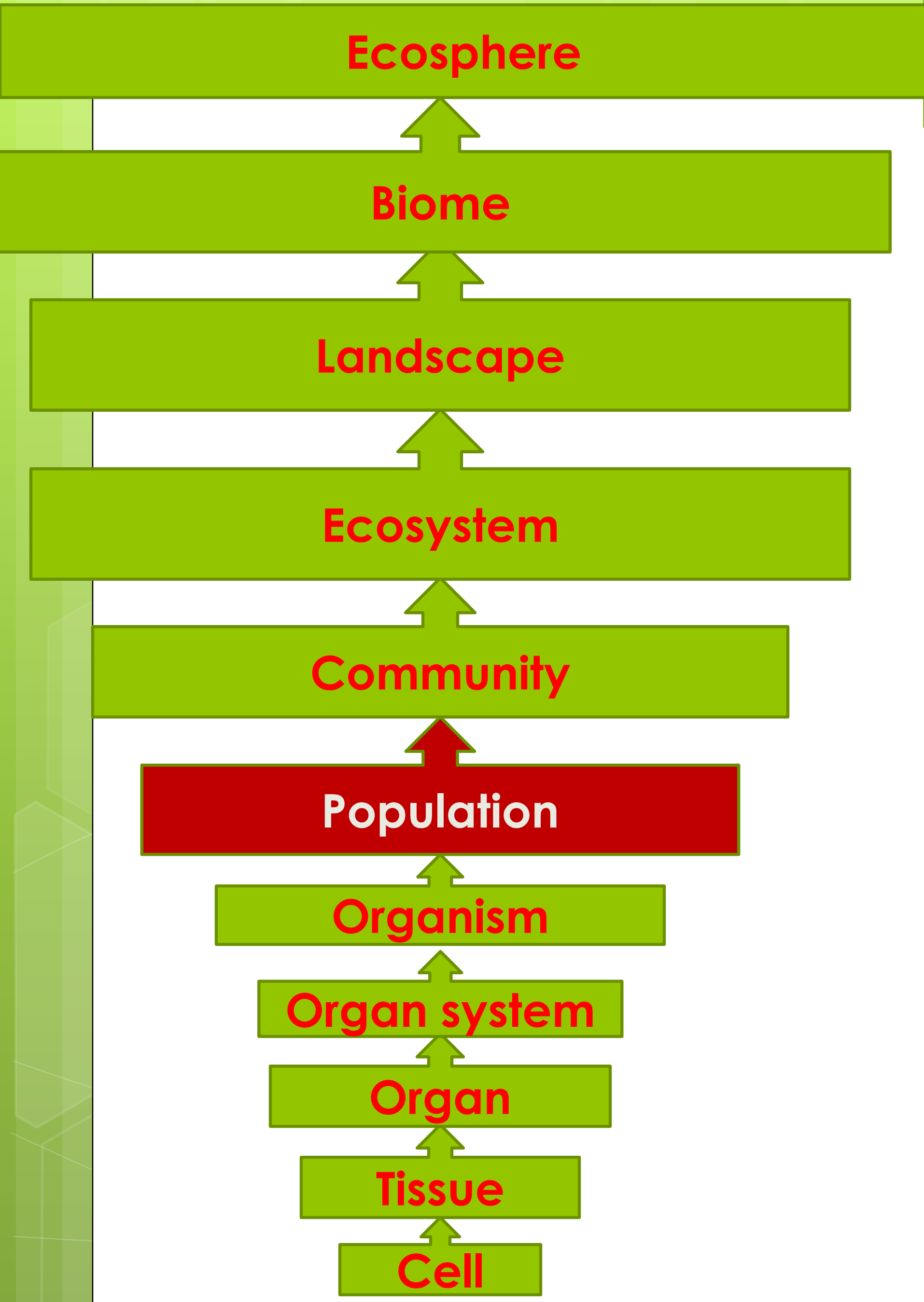
Population Ecology



What is population?

Population is a group of organisms of same species/ one species occupying an area and are able to exchange genetic information.

Metapopulation

concept given by Husband and Barrett 1996

- Metapopulation is a network of populations with occasional movement between them
- It is advantageous because if a species exists as a metapopulation it can be colonized and reestablished even if it is extinct in a particular area

Population Ecology

- Populations are always changing therefore they are **dynamic**
- Seasonal fluctuations in the population is very important aspect of population study

Population are open systems

Population dynamics

- **Population is stable. Equilibrium state**
- when gains due to birth and immigrations are equal to the losses due to Deaths and emigrations.
- i.e. B+I=D+E;
- **Population will increase**
- when gains are greater than losses
- i.e. B+I > D+E
- **Population will decrease** when
- Losses are greater than gains
- i.e. B+I< D+E

Population Ecology

- Organisms inhabiting an area at a given time constitutes a **Population.**
- When all the organisms belong to same species it is **single species population.**
- If the species belong to different groups then it is **mixed population**

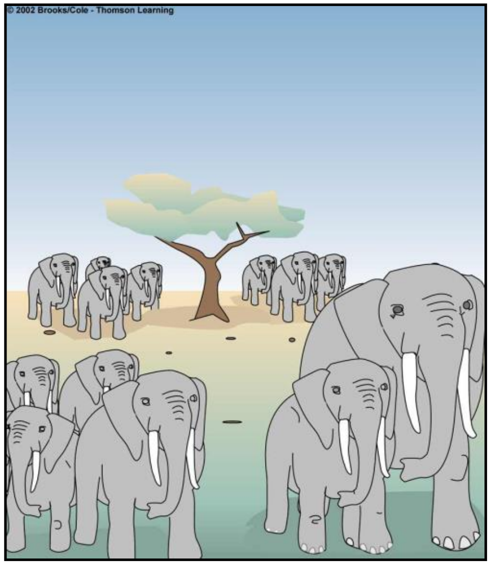
Population is studied under following headings

- Density
- Natality
- Mortality
- Lifetables
- Fecundity schedules

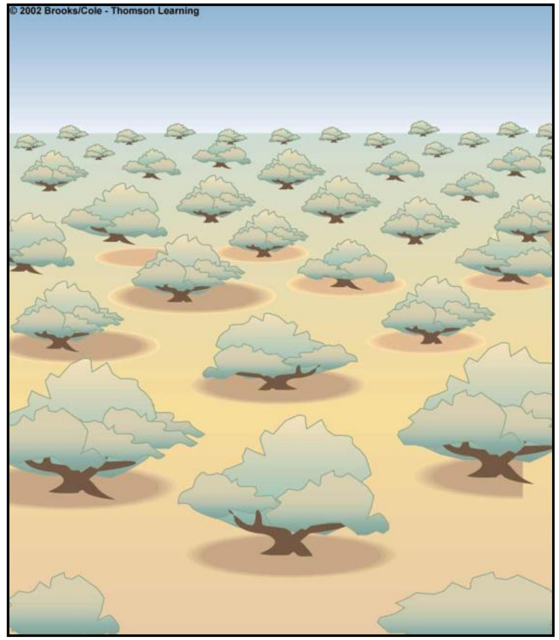
2. Distribution of a population

- There are 3 types of distribution patterns in populations
- Uniform/regular distribution
- Random
- Clustered or aggregated

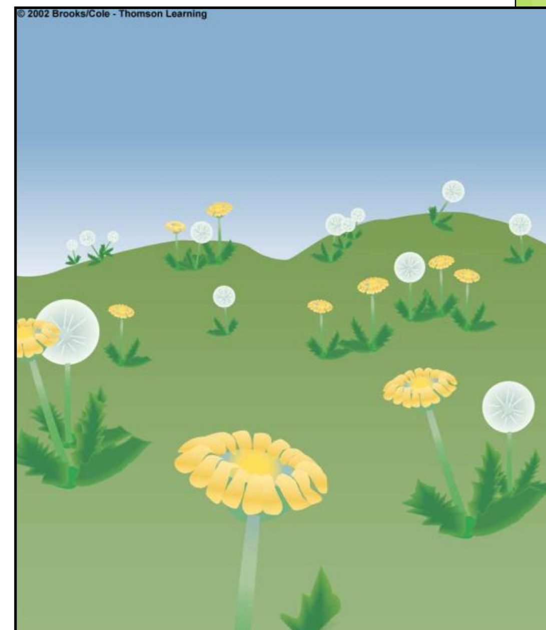
Common Dispersion Patterns



Clumped (elephants)



Uniform (creosote bush)



Random (dandelions)

Clumped is most common because resources have a patchy distribution.

UNIFORM DISTRIBUTION

- The distance between individuals is uniform over a large area
- This is common in artificial ecosystem.
- This is not possible in case of animals
- Among plants is holds true for the Tree which provide shade
- In case of smaller plants it is true where they secrete chemicals which diffuse.
- Distribution is uniform when the Mean is greater than variance

Random distribution

- In this the distance between the organisms is random.
- This type of distribution is most common in plants and animals.
- There is equal probability of occupying any plant in area or
- When the presence of one organism doesn't affect the presence of other organism
- Here the Mean~Variance

Clustered Distribution

- There is higher density of individuals at a particular area and in other area it is absent or minimum.
- It is more common in animals than plants
- This is so because the individuals may be attracted to a particular point or
- Presence of one individual may attract other individual
- Here **variance is greater than mean**
- **Territorial behavior** is seen in case of Clustered distribution.

Methods of sampling a population

- **The Lincoln index** is a common mark recapture method to estimate the total population density in a defined area
- This methods captures and marks some fraction of total population and use this fraction to estimate the total population density
- **Minimum known alive** is a mark recapture method to estimate population density over an extended period of time

Lincoln index

$$\frac{\text{Population estimate x}}{\text{No of individuals captured in sample } S_1 \text{ at time } t_1} = \frac{\text{No of individuals captured in sample } S_2 \text{ at time } t_2}{\text{No of marked individuals found in sample } S_2 \text{ at time } t_2}$$

- **Total count method**: count each and every individual
- **Marker of Transmitter:** marks or signals are received due to movement of population
- **Plotless method**: without making plots we count the population
- **Removal method:** we remove some plants from the samples
- **Quadrat Method: we take samples of the population by quadrants and we draw inference about pupulation**

Important % value for a species = A+B+C

- **Relative density A** =

$$A = \frac{\text{density of a species}}{\text{total density for all the species}} \times 100$$

- **Relative dominance B**=

$$B = \frac{\text{basal area for a species}}{\text{total basal area for all the species}} \times 100$$

- **Relative Frequency C**=

$$C = \frac{\text{freq. of occurrence of a species in a plot}}{\text{total frequency for all the species}} \times 100$$

- **Important % value for a species gives a better index of importance or function of a species in its habitat. A table of importance of each tree species gives the rank of a particular tree species in a forest community**

Growth of a population

- Regulated by two factors
- Natality: abiltiy to reproduce at a given time
- Mortality: inherent capacity for death or physiological longevity
- **1928: ROYAL CHAPMAN** referred these forces a **biotic potential** & **environmental resistance**

Natality

- It is the ability of a population to increase by reproduction
- Equivalent to BIRTH RATE of human population
- **Definition**: Natality is a broader term covering production of new organisms whether such organisms are born, hatched, germinate or arise by division.

Types of Natality

- **ABSOLUTE OR CRUDE BIRTH RATE**:
- Crude birth rate(B)= $\Delta N_n / \Delta t$
- N_n= number of individuals produced in time Δt;
- Where Δ= change $(N_0 - N_t)$, N_0= initial population; N_t= no of individuals at time t
- **Specific birth rate (b)=**
- specific Natality= $\Delta N_n / N_0 \Delta t$
- Where N_0=initial population
- Dividing the number of new individuals produced per unit time by a unit of population

Types of Natality

- **Maximum natality:** also called absolute or physiological natality
- if everything is ideal then the maximum no of individuals added to a population .
- It is constant for a given population

- **Ecological or realized natality**: Population increase under the given set of environmental conditions
- It is not constant for a population

*PN is always greater than EN
*If PN-En is minimum then conditions are favourable for the growth of a population

Mortaltiy Death Rate

- It is the death of the individuals in a population.
- Mortality is equivalent to demographic death rate
- Definition: Number of individuals dying in a given period of time
- **CRUDE Mortality DEATH RATE (**M)= $\Delta D / \Delta t$
- **SPECIFIC MORTALITY (**m)= m= $\Delta D / N\Delta t$
- N= size of the population
- Death rate is studied to see the survival rate
- Survival rate= 1-M
- Survivorship curves show how individuals are surviving in a given population

Two types of Mortality

- **Physiological mortality (PM)**
- It is also termed as theoretical or minimum mortality
- It is constant for a population
- Represents the minimum loss under ideal conditions or non-limiting conditions
- When conditions are favorable Individuals die on their own or physiological disturbances i.e old age
- It is always minimum

- **Ecological Mortality (EM)**
- also called realized mortality
- Loss of individuals under a given environmental conditions
- It is not a constant but varies with the population and environmental conditions
- This is always maximum

1. EM = PM means conditions are favorable or less harsh or each individual is living its physiological age
2. EM-PM is less means favorable conditions
3. EM-PM is high means the conditions are not favorable for survival of individuals

Life expectancy is the life span

- Life expectancy is the average time for which they can live
- Net reproductive rate: number of offspring produced per individual
- Survivorship patterns: patterns of survival.
- Life expectancy can be calculated by life tables
- Vital index= is ratio of birth and death for a population (birth/death x 100)
- It is the survivorship that is important index therefore survivorship curves are significant

Life table

Introduced by Raymond Pearl

- Life table is systematic representation of mortality in a population
- Life table gives a complete picture of mortality in a population.
- It is a statistical representation of mortality.
- It represents the number of survivors and death in a particular age class

How to construct a life table

- Life table is a statistical representation of some variables in a systematic form
- to predict the pattern of mortality in a population

- Variables:
- x=age class/ age intervals
- lx= no of survivors at the beginning of an age class
- dx = no of organisms dying in an age class during an age interval x and x+1
- x=age class & x+1=next age class
- qx= death rate or age specific death = dx/l_x
- Lx= theoretical value, average time lived by organism of an class Lx= **$(l_x)-(dx/2)$**
- T_x= theoretical value. Total time lived by individual of an age class. T_x= summation of L_x values from bottom to top
- $T_{x1}=T_{x1}-L_{x1}=l_{x5}+l_{x4}+l_{x3}+L_{x2}$
- ex=life expectancy=T_x/l_x

Life table of a grass species

X age class	lx	dx (x-x+1)	qx= (dx/lx)	Lx= $(l_x)_-(dx/2)$	Tx	ex= T_x/l_x x age interval
00-30	1000	92	0.092	954	3248	3248/1000 x 30 =97.44
30-60	908	100	100/908	858	2294	75.78
60-90	808	120	120/808	748	1436	53.31
90-120	688	400	400/688	488	688	30.00
120-150	288	232	232/288	172	200	20.82
150-180	56	56	56/56	28	28	15.00

On the basis of mortality rate the plants are classified as

- **Annuals**: only one reproductive event eg. Grass, insect.
- Annuals have discrete generations
- where one generation is clear-cut different from other **no overlapping of generations**
- **Perennials**: where there is more than one reproductive event in the life.
- The off springs as well as parents can survive at the same time, i.e. **continuous generations**
- Overlapping of generations is seen
- **Cohort:** in annuals we see cohorts a group of individuals of same species of same age group at a place.

Types of life tables: two types

- **Horizontal/dynamic or cohort type**: it is applicable to the individuals which have no overlapping in their generation.
- **Vertical/ static/ time specific**: in case of long lived populations. Here the values of lx and dx is calculated from the age structure of the population at a single sampling rate

Fecundity schedules:

- These are made on the basis of patterns of birth among the individuals of different age class.
- It is done to find out the net reproductive rate R_0

In animals following variables are used

- x= age class
- l_x= age specific survival rate or portion of the original cohort surviving at the beginning of the age class
- m_x= age specific birth rate- number of offspring's produced per individuals or
- Number of female individual produced per female individuals of and age class
- net reproductive rate $R_0 = \sum lx.mx$

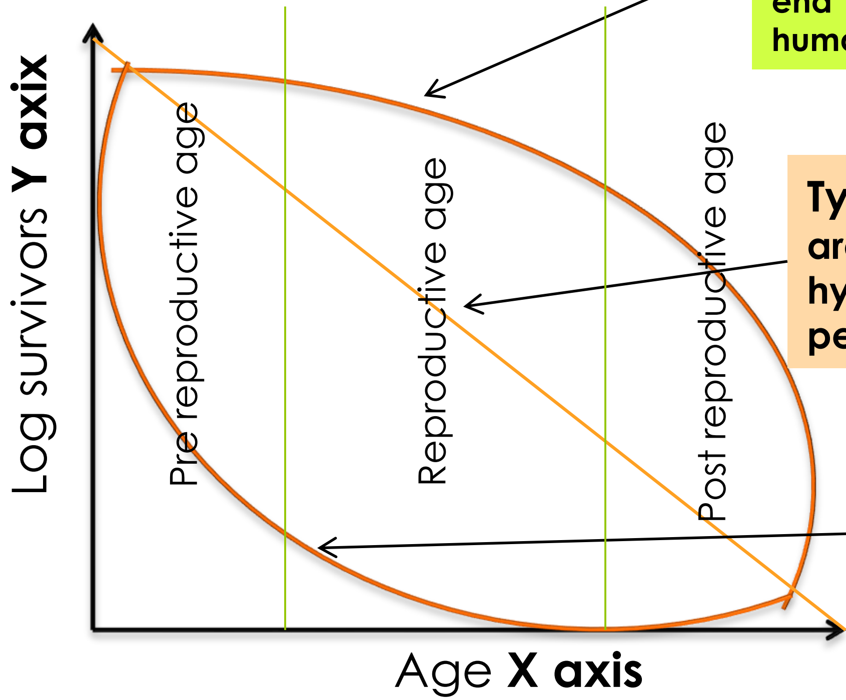
In plants following variables are used

- X= age class
- Bx ^{seed}= seed production by plants in unit time
- Nx= number of individuals in the beginning of an age class
- bx^{seed} = average no of seed produced per individuals belonging to an average age class
- Bx^{seed}=Bx ^{seed}/Nx
- Lx= survival rate
- lx.bx= product of survival rate and seed produced per female individual
- $\sum$ lx.bx= Net reproductive rate R_0
- Net reproductive rate- R_0 is the average number of seeds produced by an individual in its life time

Survivorship curves

- Showing the **pattern of survival**
- These curves were given by **Pearson in 1929 and Deevy 1947.**
- therefore also called as **Deevy's curve**
- These curves are plotted with log number of survivors against their age
- Survivorship curves are affected by
  - life history of survivors and
  - by the environmental conditions

Survivorship curve



Ist type convex : when individuals live their full life and there is high rate of mortality at the end of the life span eg: perennial plants, shrubs, humans

Type II STRAIGHT LINE: if mortlity rates are constant throughout the life span eg: hydra, birds, rodents, monocarpic perennials-Ranunculus

Type III CONCAVE CURVE
when mortality rates are high at the early stages of life span and decreases during the remaining parts of life span. Eg: oyester, invertibrates, fish, annuals

Population Age distributions

- Age distribution is an important attribute of population.
- It influences both natality and mortality
- The ratio of various age groups in a population represents the **current reproductive status** of the population
- and also predicts the **future rate of growth**
- **Ratio of Pre Reproductive: Reproductive: Post Reproductive**

Types of Age distribution

- There are three types of Age distribution:
- Stable population
- Rapidly growing population
- Stabilized or declined population

Population Ecology

A. Stable population

1. Here specific birth rates are equal to specific death rates
2. Where the ratio of each age class is same
3. Here every young individual is able to live upto the post reproductive age
4. Ratio is 1:1:1
5. age pyramid is bell shaped
6. Here r=0 and net reproductive rate is =1

B. Rapidly growing

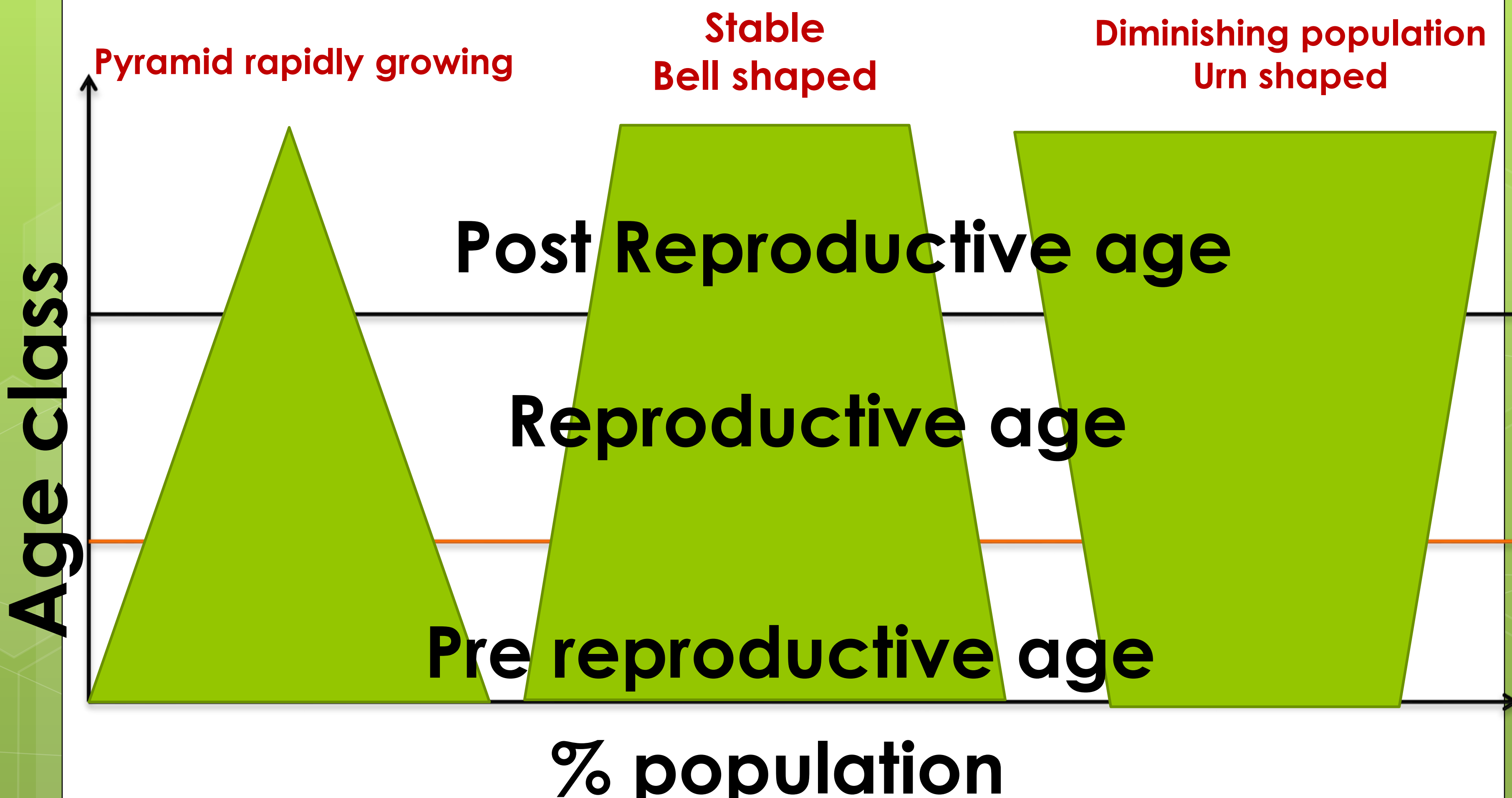
1. When age specific birth rate is higher than the age specific death rates
2. When the maximum population belongs to the pre reproductive age
3. And minimum % of population belongs to post reproductive age
4. Ratio is 3:2:1 pre reproductive: reproductive: post reproductive
5. Age structure is pyramid shaped

C. Stabilized / declined population

1. The age specific birth rates are less than the specific death rates
2. Maximum % of population belongs to the post reproductive age class
3. Here the competetion for the resources is minimum and therefore the life span is extended
4. Ratio is 1:2:3
5. Urn shaped age structure

Age pyramids

- Graphical representation of the age distribution



Biotic potential: Chapman 1928

- Intrinsic rate of population growth or inherent capacity of the population to grow. Under unlimited conditions the specific growth rate
- $rN=dN/dT$
- where r= average rate of increase per unit time per individual when competition is absent.
- dN=instantaneous change in size of the population with respect to the instantaneous change in time i.e. dt
- r= b-d i.e. r= the difference between the instantaneous birthrate and death rate
- under **unlimited environment** ; $r=r_{max}$
- R_{max} is the **BIOTIC POTENTIAL or maximum potential of the population under natural conditions.**
- $r_{max} - r=0$
- Unlimited competition most limiting condt

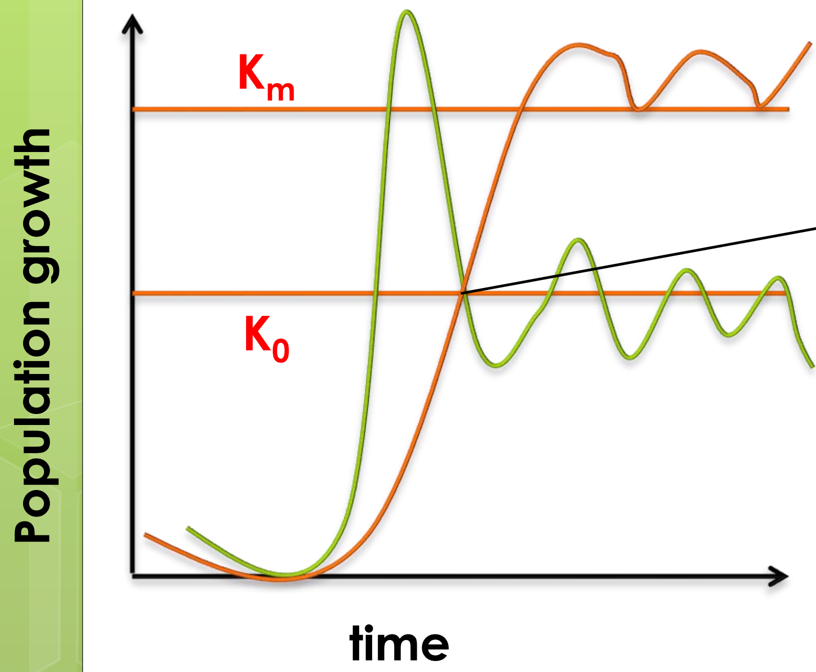
  Competition=0 → competition maximum=1

Carrying capacity (K)

- It is the maximum capacity of an ecosystem to support a maximum size of population within it.
- Relation between the size of population N & K is :
  - N<K means no or minimum competition b>d &r>1
  - N=K high competition b=d & r~1
  - N>K intense competition b<d & r<1
- This shows that as the population increases ‘r’ starts decreasing

Population Ecology

- Carrying capacity is two types
- Maximum carrying capacity
- Optimum carrying capacity



K_m or maximum carrying is the maximum density that the resource in a particular area can support

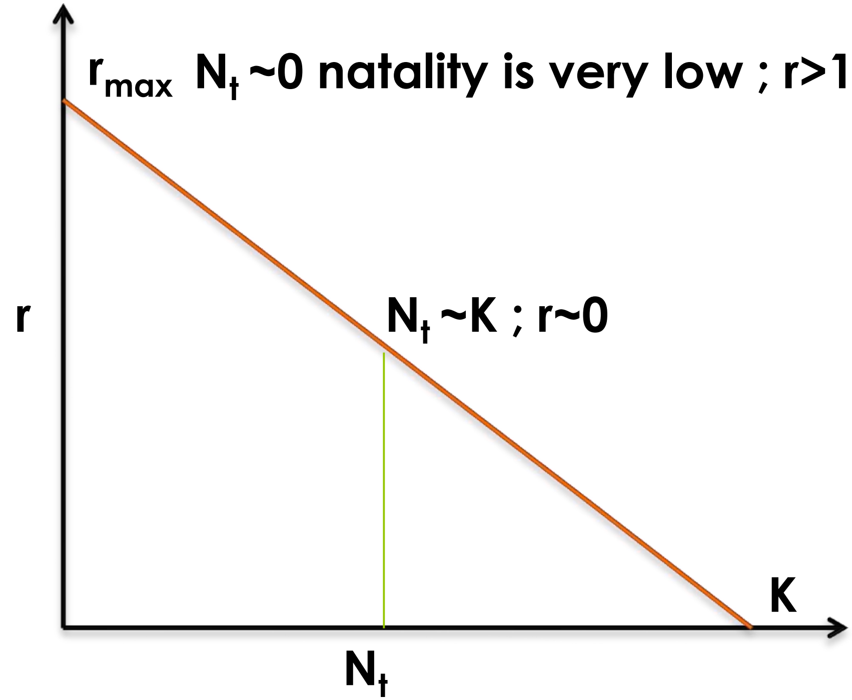
Point of inflection is the point showing maximum rate of increase

Optimum carrying capacity: Ko is a lower level density that can be sustained in a particular habitat without living on the edge regarding resources such as food or space(a quality over quantity parameter)

Carrying capacity (K)

maximum capacity of an ecosystem to support a maximum size of population within it

whenever the size of the population is minimum the amount of competition is minimum so the population can exercise maximum growth i.e. $r = r_{max}$



- Unlimited environment

  $r = dN/NdT$

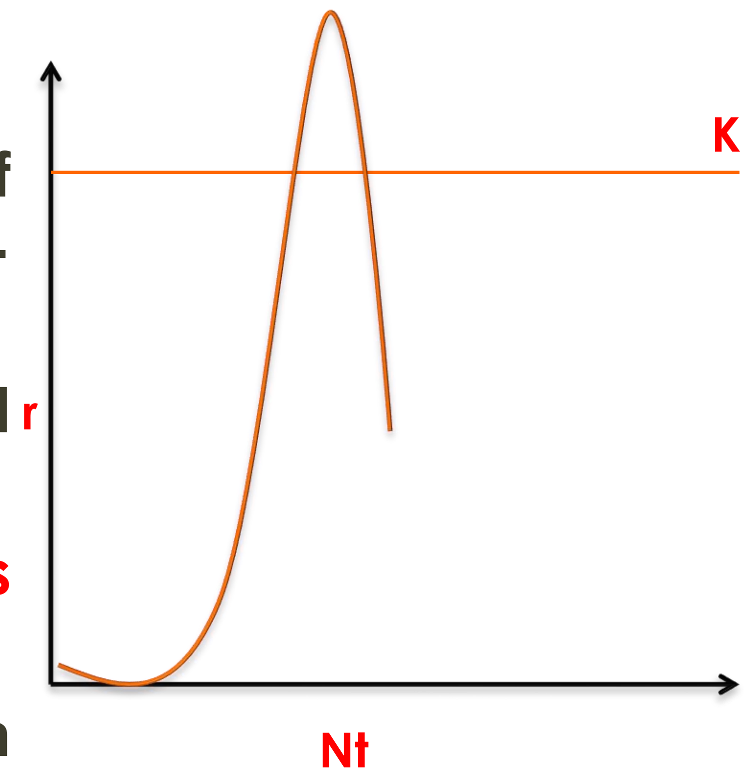
- **in limited environment**
- **$(K-N/K)r = dN/NdT$**

Population growth forms

- Each population shows characteristic increase patterns these are population growth forms
- J-shaped growth forms
- S-shaped growth forms

Population under unlimited environmental conditions

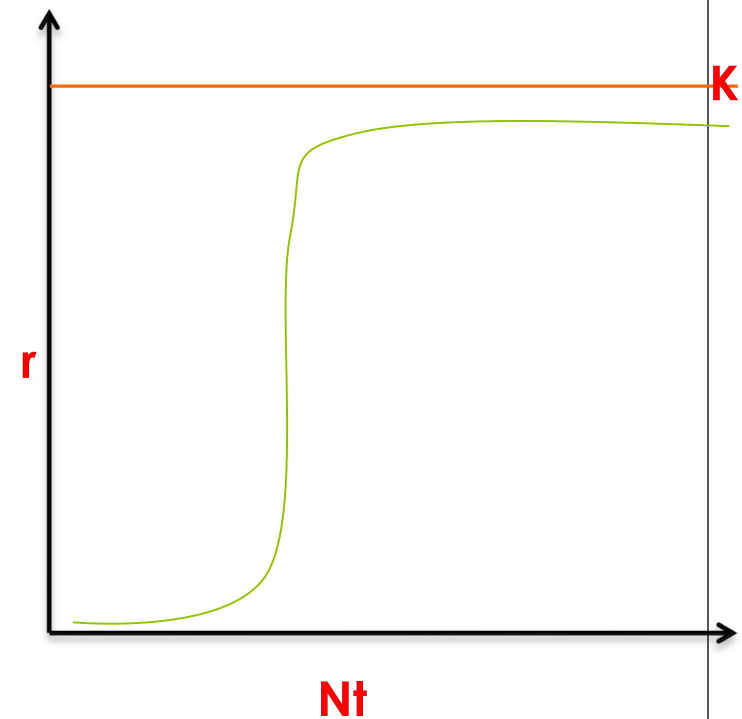
- r=dN/Ndt
- Growth Curve is J shaped
- It is **density triggerred** curve
- Organisms following this type of curves are known as r-strategists
- These are **ruderal species** and soon perish
- They are **pioneering species** and are **opportunist**
- This type of curve is seen when there is **minute competition**
- and if the competition increases then their number also decreases



J shaped growth curve

Population in limited condition

- in limited environment
- (K-N/K)r=dN/NdT
- S shaped growth curve
- Also called density conditioned growth curve
- Means the growth rate is being brought down as the density increases
- Also called as logistic growth curve
- The organisms under this conditions are called K-stratigists and there is competition between them
- These are also called persistent species
- These maintain their population below the carrying capacity
- These are the climax species



r & K strategists

- Whenever a species is growing in an ecosystem it can select 2 types of growth curves.
- **Ruderal species**: ***'r'-selection***, following J-shaped growth curve and called **r-startegists**
- **Persistent species: 'K' selection,** following S shaped growth curve.
- r- strategists may change into k-strategists but *vice-versa* is not possible

r-strategists

- These are defined as organisms adapted for colonization and reproduction in expanding population with means of wide dispersal.
- These are considered as exploiters, opportunists
- Adapted to grow in absence of competition
- These ruderal species are the early colonizers or pioneering species

K-strategists

- These are organisms adapted for persistence and reproduction in stable population
- They lack means of wide dispersal
- They are competitive species
- They are late colonizers
- During the course of succession the ruderal species are followed by the persistent ones
- R-strategists may change into k-strategists but not vice versa

Population Ecology

By Stern & Tigerstedt in 1974

parameters	r-strategists	k-strategists
Habitat	Variable/unpredictable environment , uncertainty	Fairly constant & predictable or more certain
Mortality	catastrophic (high rate), uncertain, random, density independent	More selective and certain, density dependent
Population size	Variable with time	Fairly constant with time
Density	No equilibrium, normally far below the carrying capacity of the environment	In equilibrium with the habitat and is near the carrying capacity i.e K-line
Size	Population size is governed by annual colonization. Colonize the fresh area	No recolonization

parameters	r-strategists	k-strategists
Intra and interspecific competition	variable, Lax (subdueded)	Vigorous
Selection favors	• Rapid development of organisms • High value of rmax • Early reproduction • Small body weight • One time reproduction and after that they die	• Slow development • Low value of r max • Delayed reproduction • Greater body weight • Many reproductive events in life cycle
Life span	Short life span, usually less than one year	Long life span >1year
Example	Microbes, annuals, insects	Perennial plants, mammals