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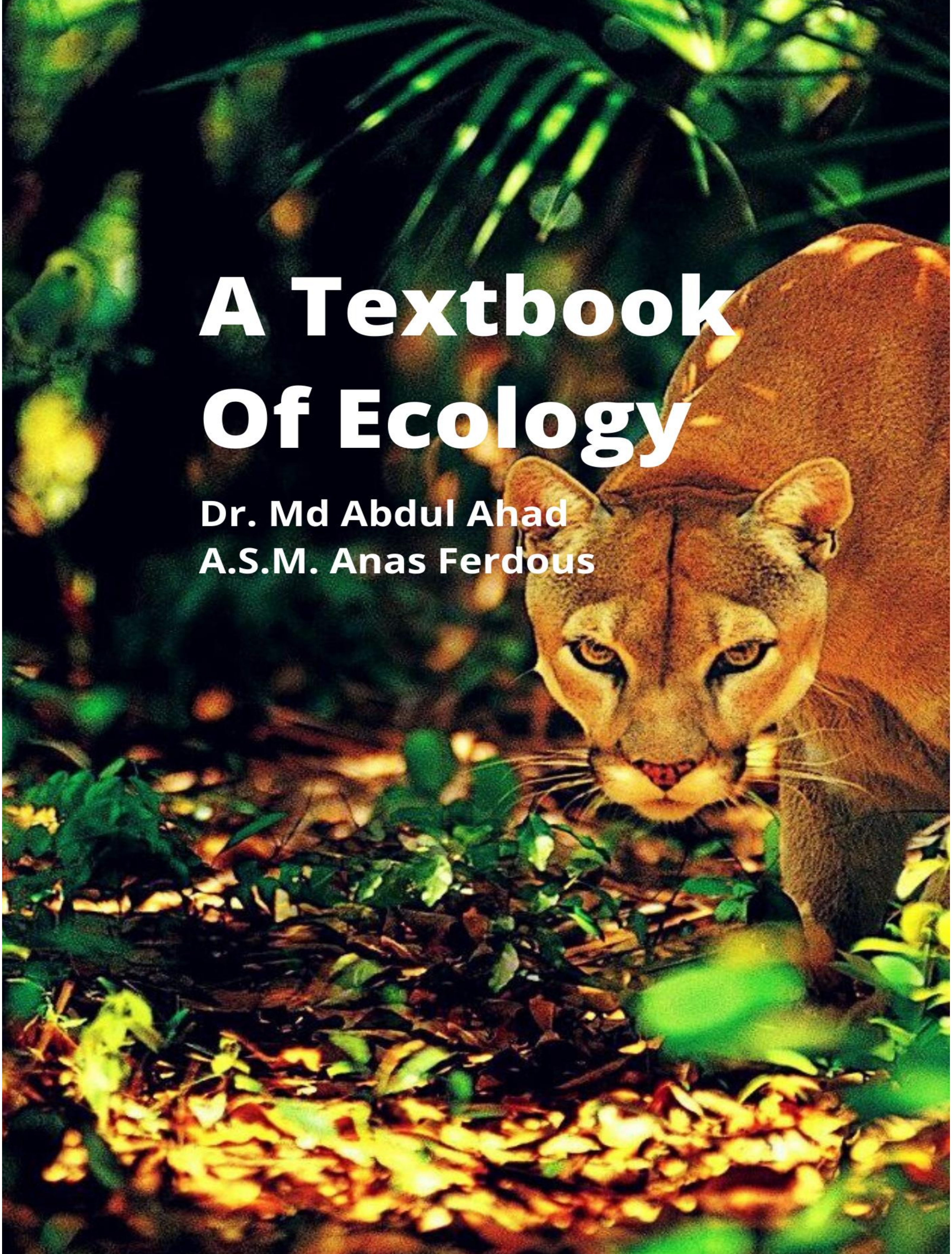

A Textbook Of Ecology

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A Textbook Of Ecology

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Dedicated To
Father Of The Nation
Sheikh Mujibur Rahman

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Introduction To Ecology

Ecology:

The word ecology is derived from the Greek word oikos, meaning “house” or “place to live”. Literally, ecology is the study of organisms “at home.” Usually ecology is defined as the study of the relation of organisms or groups of organisms to their environment, or the science of the interrelations between living organisms and their environment. Insect ecology is the study of relationship of insects with their environment. Specially, it means the study of the interactions of organisms with one another and with the physical and chemical environment.

According to Price (1997) ecology is the science that devoted to the development and study of the theories of natural history of organisms.

Some terms about ecology-

Host: An organism that provides food or other benefit to another organism of a different species usually refers to an organism that can be infected or exploited by a specific parasite.

Habitat: Place where a plant or animal lives (an organism's home), such as in deep woods, running streams, coral reefs, or the human blood stream (for certain life stages of certain species of malaria parasite).

Lotic habitat: Running water-habitat ecosystems, such as a stream or river.

Ethology: Study of animal behavior in natural situations.

Etiology: The cause or developmental history of a condition.

Branch of ecology

Autecology: Autoecology is the branch of ecology, which study of single species of insect in relation to its environment. This ecology deals with the adaptations and behaviour of individual species or populations in relation to their environment; known as autecology e.g. study of effect of temperature on rice weevil Subdivisions of autecology: i) demecology (speciation), ii) population ecology, iii) demography (the regulation of population size), iv) physiological ecology or ecophysiology), and v) genecology (genetics).

Synecology/ community ecology: Synecology also known as community ecology. It is the branch of ecology, which study of different species of insects in a community or habitate e.g study of effect of temperature on stored grain pests. Synecology, and its has many synonyms include community ecology, phytosociology, geobotany, vegetation science and vegetation ecology

Restoration ecology: Study of the use of ecological theory to the ecological restoration of highly disturbed sites of a plant and animal community or ecosystem to states that existed previous to the disturbance; the branch of ecology focusing on the application of ecological theory to restoration theory to return of highly disturbed sites; ecosystems, and landscapes.

Behavioral ecology: Study of the relationships between organisms and environment that focuses on the behavior of organisms in their natural habitat.

Conservation biology: Field of science concerned with the protection (conservation) and management of biodiversity (or biological resources), especially its diversity of species based on the principles of basic and applied ecology

Materials of ecology:

Ecologists may study individual organisms, entire forests or lakes, or even the whole earth. The measurements made by the ecologies include counts of individual organisms, rates of reproduction, or rates of processes such as photosynthesis and decomposition. Ecologists often spend as much time studying nonbiological components of the environments, such as temperature or soil chemistry, as they spend studying organisms. Meanwhile, the "environment" of organisms in some ecological studies may be other species.

Objectives of studying insect ecology:

Through study of insect ecology we are able to apply IPM as it helps to know-

i) It helps to identify and understanding patters of nature.

ii) To know the type of relationship of an organism with the environment.

iii)It also helps why-

a) A certain species of insect is found in a particular area.

b) A particular species of insect is numerous in a particular place and scarce in other places.

c) One species of insect is present in a particular season or a year.

d) A species of insect is more numerous in a year than previous year etc.

So, it helps in pest management.

Ecosystem: Ecosystem is first coin by the phytosociologist A. G. Tansley (1935, 1939). The biological community in an area and all of the abiotic factors influencing that community here a biotic community and its abiotic environment functions as a system. Ecosystem are self-sufficient habitats where living organisms and non-living environment interact together to exchange energy and matter in a continuous cycle. It is an integrating system of all living organisms and non living environment. The ecosystem is the basic functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth. It is the sum of the plant community, animal community, and environment in a particular region, or habitat. The ecosystem: a community and its physical and chemical environment.

An ecosystem has living (biotic) and nonliving (abiotic) components such as Soils, temperatures, rainfall, even organic matter are example of the abiotic component. The classes of organisms detailed above form the biotic component. It is the sum of the plant community, animal community, and environment is a particular region, or habitat. The ecosystem is the basic functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth. From the functional standpoint an ecosystem may be conveniently analyzed in terms of the following: (i) energy circuits, (ii) food chains, (iii) diversity patterns in time and space, (iv) nutrient (biogeochemical) cycles, (v) development and evolution, and (vi) control (cybernetics).

Structure of ecosystem: The structure ecosystem is a guide to who's who in the ecosystem. It is a description of the species of organisms that are present, including information on their life histories, populations and distribution in space.

The structure of an ecosystem basically a description of the species of organisms those are present, including information on their life histories, populations and distribution in space.

From structural point of view all ecosystems consist of following components:

1. **Abiotic Substances-**

These include a) inorganic and organic compounds of the environment or habitat of the organism. The inorganic components of an ecosystem are carbon dioxide, water, nitrogen, calcium, phosphate, all of which are involved in matter cycles (biogeochemical cycles).

b) Organic compounds The organic components of an ecosystem are proteins, carbohydrates, lipids and amino acids, all of which are synthesized by the biota (flora and fauna) of an ecosystem and are reached to ecosystem as their wastes, dead remains, etc. The climate, temperature, light, soil, etc are other abiotic components of the ecosystem.

2. Biotic or Biological Components

a) Producers or Autotrophs:

Producers are autotrophic organisms like chemosynthetic and photosynthetic bacteria, blue green algae, algae and all other green plants. They are called ecosystem producers because they capture energy from non-organic sources, especially light, and store some of the energy in the form of chemical bonds, for the later use. Algae of various types are the most important producers of aquatic ecosystems, although in estuaries and marshes, grasses may be important as producers. Terrestrial ecosystems have trees, shrubs, herbs, grasses, and mosses that contribute with varying importance to the production of the ecosystem.

Since heterotrophic organisms depend on plants and other autotrophic organisms so, when a green plant captures a certain amount of energy from sunlight, it is said to produce the energy for the ecosystem.

b) Consumers or Heterotrophs:

A plant, animal, or microorganism that cannot manufacture its own food from inorganic matter, which therefore uses organic molecules both as a source of carbon and as a source of energy (consumes other organisms for its source of energy). They are also called phagotrophs or macro consumers. Sometimes herbivores are called primary macroconsumers and carnivores are called secondary macroconsumers.

c) Reducers or Decomposers:

An organism that survives by feeding on the carrion or wastes of other organisms, in other words organism that obtains energy from breakdown of dead organic matter to more simple substances. Decomposers play a crucial role in nutrient cycles by breaking down complex organic molecules into simpler constituents; most precisely refers to bacteria and fungi. No ecosystem could function long without decomposers. Dead organisms would pile up without rotting, as would waste products.

Ecotones: Ecotones are transitions from one type of ecosystem to another, for instance the transition from woodland to grassland. Milne models ecotones as a kind of phase transitions. Typical phase transitions involve changes in the state of matter, such as the change of water from a liquid to a solid state as temperature decreases. The change from liquid water to ice involves fundamental changes in the organization of water, including the average distance between water molecules and their distributions. The change along an ecotone involves analogous changes in the structure of vegetation.

It is the zone of transition from one type of community or ecosystem to another (for instance, the transition from a woodland to a grassland). Milne models ecotones as a kind of phase transitions**.** Typical phase transitions involve changes in the state of matter, such as the change of water from a liquid to a solid state as temperature decreases. The change from liquid water to ice involves fundamental changes in the organization of water, including the average distance between water molecules and their distributions. The change along an ecotone involves analogous changes in the structure of vegetation.

Ecotype: Subspecies (or race or local populations) adapted to a particular set of environmental conditions.

Major Pathway of Energy Flow of ecosystems

1. Energy flows into ecosystems from an outside source (the sun, in most cases).
2. Energy flows through ecosystems by way of grazing food webs (based on the consumption of living tissues of photo synthesizers) and detritus food webs (based on the use of organic waste product and remains of photo synthesizers and consumers).
3. Energy leaves ecosystems through heat losses from each organism.

Agroecosystem:

Ecosystem related to agriculture is known as agroecosystem. The agroecosystem will usually include a group of agricultural fields or orchids together with the marginal areas and often certain other intermixed elements such as woods, streams and weedy or uncultivated areas. This implies the limits of movements of biota of a particular locality.

Just as ponds and forests are systems of interacting elements, so are crop areas. Consequently, we can think of the interacting biotic and abiotic elements of an orchard or grain field as an ecosystem. Any ecosystem largely created and maintained to satisfy a human want or need is called an agroecosystem. Just as ecosystems are the basic unit of study for ecology, agroecosystems are the basic unit of study for pest management, a branch of applied ecology. Much typical agroecosystem is composed of the more or less uniform crop-plant population, weed communities, animal communities (including insects), microbiotic communities, and the physical environment in which they interact. Much of land mass in major agricultural areas is occupied by agroecosystems.

The population of plants and animals (including man) and non-living environment together make up an integrated unit the agro-ecosystem.

Man altered landscape or human ecosystem is rapidly coming to cover a large portion of the earth's temperate and tropical land areas. Agro-ecosystems are parts of this man-altered landscape modified and controlled for the production of agricultural and forest crops. Therefore, agro-ecosystems are the evolutionary product of man's attempt to control nature and to meet his needs for food and other products.

It is the complex of plants, associated organisms and environmental features found in an agricultural field, orchard or pasture. It differs from a natural ecosystem in that it is relatively simpler and is artificially maintained. Typically it consists of one (or a few) crop species, weed and any arthropods, a few highly abundant species adapted to the crop involved and many more (usually several hundred) relatively rare species. The most effective systems for controlling pests can be devised only after thorough knowledge has been gained of the principal factors underlying fluctuating of their populations.

The appearance of brown plant hopper (*Nilaparvata lugens*) and increased incidence of Gall midge, Rice leaf roller of paddy in Rice leaf roller (*Cnephalocrocis medinalis*) appearing as a major pest in Bangladesh are spectacular examples of the continuous and rather rapid changes in the agro-ecosystems.

Differences between agroecosystems and natural ecosystems:

Agroecosystems	**Natural ecosystems**
i) Agroecosystems often lack chronological continuity	i) Ecosystems often have chronological continuity
ii)The existence of agroecosystems may be of limited duration.	ii) The existence of ecosystems may be of not limited duration.
iii)It may undergo huge, sudden changes in microclimate because of cutting, plowing, burning, chemical application, and other cultural practices	iii)It may not undergo huge, sudden changes in microclimate because of cutting, plowing, burning, chemical application, and other cultural practices absence here
iii) Agroecosystems are dominated by plants selected by humans.	iii) Ecosystems are not dominated by plants selected by humans.
iv) Most agroecosystems have little species diversity. Usually a single species dominates an agroecosystem	iv) Most ecosystems have large species diversity.
v) The elimination of weed species further simplifies the environment.	v) The weed species are not elimination further not simplifies the environment.
vi)The vegetative structure is uniform, and a given phenological event (for example, flowering or podding),	vi) The vegetative structure is uniform, and a given phenological event (for example, flowering or podding),
vii) Growth occurs in almost all the plants at the same time.	vii) Growth not occurs in almost all the plants at the same time.
viii) Pesticides and nutrients (manures and fertilizers), usually are added to agroecosystems, which results in crop plants with uniformly succulent, nutrient-rich tissues.	viii) Pesticides and nutrients (manures and fertilizers), usually are not added to ecosystems, which results in crop plants with uniformly succulent, nutrient-rich tissues.
ix) Agroecosystems often have frequently occurring insect, weed, and disease out breaks.	ix) Ecosystems often have no frequently occurring insect, weed, and disease out breaks.

x) It is modified ecosystem through human activities.	ix)It is natural ecosystem and not modify through human activities.
xi)In this ecosystem human is benefited naturally	xi)In this ecosystem human is benefited through agricultural production.
xii) Example of such ecosystem is Ocean, River, Saunderbans ecosystem etc.	xii) Example of such ecosystem is Orchard, Pond, crop field ecosystem.

Community: Community is the assembles or collection of different individuals belonging to different species.The populations of all species that occupy a habitat. Ecologists also use the term to refer to certain groups of organisms in a habitat the "bird community or the plat community, for example. Species in a community play different roles.

Causes of success of insect

Insects are the most numerous organisms in the animal kingdom. They often occur in large numbers and are found in almost all conceivable habitats.

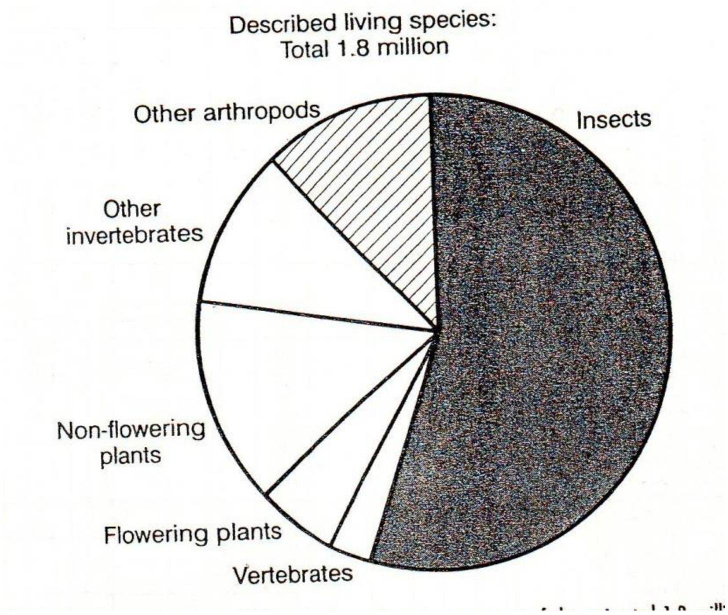


Fig. % Insect and amount of insect in relation to other organism (adapted from Price. W. P.1997)

Some of the most important adaptive unique features that helps of success of insect (according to Coulson and Writter. 1984) are-

(1) Exoskeleton
(2) Complete metamorphosis
(3) Functional wings
(4) Small size
(5)Adaptability of structures such as modification of wing, legs, antennae, respiratory system etc.
(6) Diverse feeding habits
(7) Quiescence and diapause
(8) Dispersal and migration
(9) High reproductive potential and
(10) Defensive mechanisms to avoid natural enemies.

Environmental factors influencing insect population in an agroecosystem:

Environmental factors influencing insect population in agroecosystem are of two types-

1. Abiotic factors (physical factors) :

Abiotic factors include non-living factors which are known as physical factors or weather. Most important components of weather

2.Biotic factors : Biotic factors include all living organisms .

Different between abiotic factors and biotic factors

Abiotic factors	Biotic factors
i) Abiotic factors comprise non living matter or physical factors of the environment such as temperature and moisture soil, air, water, rainfall, temperature, humidity, light etc.	i) Biotic factors comprise living organisms such as predator, parasitoids, procedures, consumer's decomposers and transformers.etc
ii) The consequence of abiotic factors is density-independent.	ii) The Consequence of biotic factors is density-dependent
iii) Its is not controllable i.e. control is difficult as natural.	iii) Its effect is controllable i.e. control is easier.
iv) It does not include i) intraspecific competition ii)interspecific competition	iv) It includes i) intraspecific competition ii)interspecific competition
iv) The abiotic factors can influence insect population alone.	iv) The biotic factors cannot influence insect population alone unless the abiotic factors are favorable
v) The effect of abiotic factors is usually stable /not changeable.	v) The effect of biotic factor is usually not stable /changeable.
vi) They have indirect effect on number of insect population.	vi) They affect directly on number of insects population.
vii). Abiotic components not interact themselves as they are inert matter.	vi) Biotic components react themselves inter-specifically and intra-specifically
vii) It has long-term, permanent and non-changeable effect on ecosystem.	vii) It has short-term, temporary and changeable effect on ecosystem.

Effect of abiotic Factors

Insect is capable of survival only within certain environmental limits, and when possible, individuals actively seek out preferred temperatures, humidities, and light intensities. Within this favorable range, these environmental factors usually influence rate responses of activities such as feeding, dispersal, egg laying, and development.

Effect of Temperature on insect

Temperature probably has the greatest affect on insect developmental rates among the environmental factors. Primarily, this is because insects are **poikilothermic**, or cold blooded that is their body temperature tends to be the same as ambient temperature. However, this does not necessarily mean that an insect's body temperature is always the same as that of the environment.Within certain limits the higher the temperature, the faster the development of the insect. Developmental rate of increases with temperature because chemical reactions occur more frequently and proceed more rapidly at higher temperatures. However the effect of temperature are given below in different headed-

Effect on longevity: Temperature also affects the duration of life by influencing the rate of utilization of food reserves, when the food is present in limited quantities. This is particularly evident in blood-sucking insects such as the tsetse flies, *Glossina* spp. which depend on stored food reserves between meals .Increases in temperature shorten the survival period between meals; If a fly uses its reserve from one meal before it is able to obtain another then it will perish.

Effect on metabolism: Most of metabolic activities of animals and microbes, plants are regulated by varied kinds of enzymes and enzymes turnare influenced by temperature, consequently increase in temperature, up to a certain limit, brings about increased enzymatic activity, resulting in an increased rate of metabolism. For instance, the activity of liver arginase enzyme upon argentine amino acid, is found to increase gradually and gradually, with the simultaneous increase in the temperature from 17^0 C to 48^0C. But an increase in temperature beyond 48^0C is found to have an adverse effect on the metabolic rate of this enzymatic activity which retards rapidly.

Effect on breeding season: The maturation of gonads gametogenesis and liberation of gametes takes place at a specific temperature, which varies from species to species. For example, some species breed uniformly throughout the year, some only in summer or in winter, while some species have to breeding periods, one in spring and other in fall. Thus, temperature determines the breeding seasons of most organisms.

Effects on fecundity: Temperature also affects fecundity of animals. Fecundity of an animal is defined as its reproductive capacity, i.e. the total number of young ones given birth during the life time of the animal, for example, acridid *Chrotogouns trachypterus* highest number of eggs per female was laid at temperatures of 30^{0}C. The number of egg decrease from 243 to 190 when the temperature is raised to 30-35^{0}C the fecundity of certain increase such as cotton stem weevil (Pemphrulus affinis) is found to decline with an increase in temperature beyond 32^{0}C.

Effect on sex: Sometimes environmental temperature determines the sex ratio of the species. For exemple, in plague flea, *Xenopsylla cheopis*, males outnumbered on rats, on days when the mean temperature remains in between 21-25^{0}C, But the position becomes reverse on cooler days.

Effect on development: The insect, chironomid fly *Metriocnemus hirticollis*, requires 26 days at 20^{0}C for the development of a full generation, 94 days 10^{0}C, 153 days at 6. 5^{0}C, and 243 days at 20^{0}C. Some insects will not hatch or develop normally until chilled the rate speed of development is also influenced by narrow range of temperature, the lower and upper limits from the egg to the adult for example in *Sitophilus oryzae* 15° to 34° C, in *Rhizopertha dominica* 18° to 30°C.

Effect on colour: The size and coloration of animals are subject to influence by temperature. In warm humid climates many animals like insects, birds and mammals bear darker pigmentation than the races of some species found in cool and dry climates. This phenomenon is known as “Gloger rule”. The walking stick, *Carouses* has been known to become black at 15^{0}C and brown at 25^{0}C.

Effect on morphology: Temperature also affects the absolute size of an animal and the relative properties of various body parts (Bergman’s rule). Birds and mammals, for example attain a greater body size when they are in cold regions than in warm regions, and colder regions harbour larger species. But poikilotherms tend to smaller in colder regions. Body size has played a significant role in adaptation because it has influenced the rate of heat loss.

Effect on Mortality: The temperature range that insects can with and varies tremendously with the species. The most heat-resistant insects die at temperatures of 47^{0}C to 52°C. Species that live in cool places have correspondingly lower heat tolerances, such as the mountain genus *Grylloblatta* (Grylloblattodea), whose optimum is about 3˚C, and is normally active between -2^{0}C and 16°C. The confused flour beetle, for example, will die in a few weeks at 7°C. Many insects die at temperatures only a few degrees below 0°C (32°F). Hibernating stages of most northern insects are remarkably resistant to cold. The hibernating pupa of the *promethea* moth, for example, can survive continued exposure to -35˚C, and some other insects are known to survive - 50°C.

Effect on oviposition: The optimum temperature for oviposition varies with species and in general, the maximum rate or egg production happens to be almost near the upper limits for reproduction. The aphid *Toxoptera graminum* has a wide temperature range preference for oviposition, between 5° and 35° C. In *Sitophilusorzae* the number of eggs laid reaches a maximum at 26° C for the thinner population and at 29° C for the more dense ones and only very few eggs are produced at temperatures above and below these. *Thrips imagmis* inhabiting roses in Australia lay very few eggs at 8° C, but between 13° to 23° C, many more are laid.

Effect on dispersal: Temperature also affects rate of migration or dispersal. A good example of the influence of temperature on the rate of migration or dispersal is provided by the locusts, in particular *Schistocerca gregaria,* where migration of swarms have been known to occur at temperatures of 17° to 20° C. The presence of upward thermal currents near the ground surface has been known to influence the beginning of migration and in the absence of these currents, migration commences only at relatively high temperatures

of 22° to 23° C.

Effect of Humidity on insect

The water content of insects varies from less than 50% to more than 90% of total body weight. Variation occurs both between different species and between different life stages of the same species. Soft-bodied insects such as caterpillars tend to have comparatively large amounts of water in their tissues, whereas many insects with hard bodies (i.e. relatively thick cuticles) tend to have somewhat lesser amounts. Active stages commonly have higher water content than dormant stages. Effect of Humidity on insect are discussed below-

Mortality of insects: Insects are able to maintain a balance between the water taken in orally or through the integument and the water lost by excretion and transpiration through the integument or through respiration. If an insect loses water faster than it takes it in, it will die, and the rate of transpiration is closely linked to humidity. For this reason, the average humidity for any particular environment can influence the distribution of an insect pest.

The mortality of insect is the lowest in tolerable zone which is greater in both lethal dryness and lethal wetness condition. e.g. mortality of *Drosophila* increases at low moisture condition and hatching or moulting of aphids are inhibited at high relative humidity. The influence of moisture on insects can be graphically shown as follows-

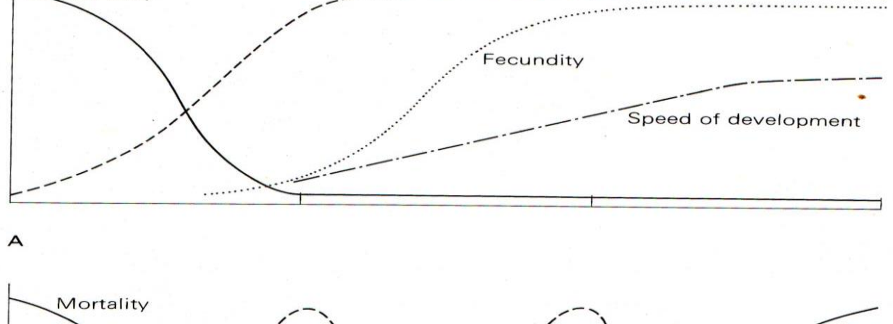


Fig : Hypothetical Curve summarizing the influence of moisture on the mortality, longevity, fecundity and speed of development of insets(According to Romoser and Stoffolan, 1994).

Effect of speed of development on insects:

The speed of development of insects is higher in tolerable zone (40-60/65%RH) and it reduces either in lethal dryness (<40%RH) or in lethal wetness (>60/65%RH). eg. nymph of *Locusta migratoria* develop more rapidly at 70% RH and above or below this range of favorable moisture the development stops.

(d) Fecundity of insects: Moisture greatly influences the fecundity of insects. Fecundity is higher in tolerable zone and above or below this fecundity is greatly reduced e.g. locust lay eggs more at 70% RH.

Effect of behaviour of insects: Moisture plays a great role on the insect behaviour. Insects have tendency to move towards the source of moistures. In case of excessive dryness or wetness, they change the direction and move towards the favorable moisture zone. It they don't, excessive dryness cause desiccation and excessive wetness causes drowning resulting death of insects.

Effect on longivity: The longevity of insects increase up to a certain limit with the increase of moisture but than it decreases. Figure shown that in tolerable zone, the curse becomes slightly downward because in tolerable zone metabolic activity of insect in high and they lay more eggs. eg. Longevity of flies is high in 88% RH but low in 100% RH The fall webworm, *Hyphantria cunea,* the armyorm, *Pseudaletia unipuncta,* and the gypsy moth, *Lymantria dispar,* succumb most readily to viruses when the weather is warm and the humidity is high. Whether high humidity affects the host or the development of the pathogen is not clear. However, many viruses do not develop rapidly unless temperatures of 21 to 29.4° C and relative humilities of 50 to 60%.

Effect on feeding: Spruce budworm larvae stop feeding when the air becomes saturated with water and the tsetse fly, *Glossina tachinoides,* does not feed on its vertebrate hosts when the relative humidity is above 88%.

Effect on oviposition: Newly emerged adult migratory locusts do not produce eggs below about 40% relative humidity. Generally low humidities adversely affect the rates of ovipositon, which increase as humidity increases.

Effect on development: The rate of development may be decreased by extremes of moisture content or development may be halted altogether. Under very moist conditions silkworm larvae fail to pupate. The incubation time for eggs of the spider beetle *Ptinus*, under a constant temperature of 20° C, is 15 days at 30% relative humidity and 10 days at 90%. He further points out those generally higher humidities are more favorable for embryonic stages than low humidities. Two sets of hypothetical curves summarize the point made in this.

Effect of light on insect

Effect on oviposition: Most of the insects are sensitive to light during mating. So they can't mate in light condition. Some insects lay eggs just after mating and due to mating in dark condition or at night insects lay or deposit eggs at night. In many insects oviposition is immobilized by sure to light or darkness. The codling moth, the cotton boll worm *Earias* and *Amsacta* are of interest in view of their ovipositing in darkness, so that they could be induced to lay eggs or stop oviposition by exposing them to darkness and light respectively. On the contrary some fruit flies (*Dacus sp.)* have been known to lay eggs only in light.

Effect on development: *Tenebrio* larvae which live in the dark and when the third instar larvae of the silkworm *Bombyx mori* are kept in the dark, they develop into the fourth instar in five days, while in light, the aye develop in 3.5 days.

Effect of light on fecundity: Light influences insect population indirectly by controlling the quality of food. Plants require light to manufacture their own foods which are consumed by insects. Protein is needed for insect reproduction. Bright light increases protein content of plants e.g. cabbage aphid was raised in both bright and dull light condition whereas they reproduce only 160 youngs in 24 hours under dull light condition. Because cabbage produced under bright light condition are rich in protein than those under dull light.

Effect on type of reproduction: This variation in the light or dark arranged has also effect on sexual and parthenogenetic forms in aphids, where a change form the non-sexual to sexual reproduction has been found to occur as a result of short day length in late summer and early autumn. Reproduction is parthenogenetic and viviparous under long day light, and oviparous and sexual during short day length. Under laboratory conditions it has also been shown that the aphid *Megoura viciae* reproduces sexually under photoperiods of less than 14.5 hr of light per day, while under photoperiods of more than 15 hr, non-sexual forms are produced.

Effect on daily movement: The daily cycle of dark and light with crepuscular (dawn and dusk) periods in between also serves as a clock by which the feeding, mating, etc., are regulated. As with temperature and moisture, the reactions of insects to photoperiod and other light parameters vary both among different species and among different life stages of the same species.

Effect of light on sense organ: light effect of on insect sense organ and on the basis of this

insects can be divided into two groups in relation to the reaction of light or behaviour of insects.

a) Photopositive or Phototrophic insects: The insects which are attracted to light or sensitive to light are known as photopositive insects e.g moth, gall midge, green leaf hopper etc.

b) Photonegative insects: The insects which are insensitive to light are known as photonegative insects. They remain away from light, nocturnal in nature and remain hidden by day time e.g. cut worm, mosqito.

Influence of light on the diapauses of insects: Light is the most important factor controlling the diopause in insects. Light influences inception and termination of diapause which is terminated at long day in summer.

.**Influence of light on wing formation**:Wings of aphid form under light condition. Short day length, low temperature and host quality influences aphid’s wing formation. Generally, an aphid is wingless and reproduces asexually. But under the above mentioned condition they have wing and reproduce sexually i.e. in autumn they become winged.

Influence of light on feeding: Light affects the feeding of insects. Some insects feed in the darkness and some eat by day time. eg. Cockroaches do not take any food during day light but take food in darkness.

Effect of air or wind

Air or wind affect the on mortality and on dispersal, which are given below-

i)Effect on mortality:

Air movement may be directly responsible for the death of insects in two ways. First, severe wind and heavy rain together may cause mortality. Second, movement of air alive surface evaporation is occurring (e.g., insect cuticle increases the gradient of water vapor concentration and hence tends to increase the rate of evaporation. Other factors being constant, the rate of evaporation is proportional to air movement. On the other hand, air movement may be beneficial if humidity is high.Wind probably inhibit the activity of most flying insects. In response to strong air movements, many insects tend to hunker down and hold on. Strong down drafts over marshes and lakes can result in flying insects dropping to the water surface, making them vulnerable to the adhesive forces of water and potential predator by water-dwelling predators.

ii) **Effect on dispersal:** Wind is a very effective agent in the distribution of insects like aphids, leafhoppers, and others being blown for hundreds or even thousands of miles.

For example, many insect pests of crops grown in temperate areas are colonized each year by insects that are blown in from southern states. The corn leaf aphid, *Rhopalosiphum maidi*s (Fitch), after taking to flight is carried north to infest corn as far north as Minnesota, where it' vectors' maize dwarf mosaic virus. The potato' leafhopper, *Empoasea fabae* (Harris), overwinters in Louisiana and is carried by wind to the north central states, and then secondary populations are transported east and infest alfalfa, potato, apples and many other plants.

Often insect pests are carried by wind independent of their natural enemies, and because of this their populations increase rapidly without being kept in check by, their natural enemies

Effect of water on insects

The legs and bodies of these insects are appropriately adapted (e.g., legs capable of clinging and streamlined bodies associated with fast-moving water). Black fly larvae are fasten themselves to 'tones or other stationary material in the water. Several caddis flies (Trichoptera) attach their cases to submerged objects. Many aquatic insects (e.g., mosquito larvae) are unable to survive in moving water. Another important aspect of currents in the aquatic environment involves the circulation of dissolved gases, salts, and nutrients.

Water currents often determine which species of insects will live in a given area. For example, the various genera of mayflies (Ephemeroptera) may be classified into still-water or rapid-water forms.

Effect of air pollutants

Air pollutants such as fluoride, sulfur, ozone, lead, and dust may have significant direct and indirect effects on insect population. Direct effects involve the toxic action of pollutants on insects and the associated decline in insect populations. Indirect effects may cause an increase or a decrease in a given insect population. For example, if parasitoids and predators are more susceptible to a given pollutant than their host/prey insects, the latter may experience an increase in population size. The classic example of natural selection is the industrial melanism in moths, was brought about by the action of soot causing the darkening of light-colored lichens and ultimately a decline in the light-colored moths that rested cryptically upon them.

Biotic factors

A) Influence of biotic factors on living organisms-

Biotic factors include living organisms. They have the marvelous influence on insect population. Insect population will increase if natural enemies are absent in any place. But their population will decrease if they are present there. Biotci factor cannot influence insect population unless abiotic factors are in favourable condition.

The biotic factors can influence insect population in two ways-

Interaction between same species known as intraspecific interaction. The actual rate of increase of insect population can be influenced within the same species under two phenomenon.

Influence of the same species are describe below-

(i)Under population:

In this case number of insect population is less/ few. The reproductive rate will be less in this condition owing to less chance of mating and show less reproduction rate. In red flour beetle (*Tribolium confusum*) the rate of increase is very slow under few beetles in a small colony, but when population reaches to optimum level the rate of reproduction is very high.

Again, if the reproductive rate of increase reduces gradually in under population condition, the rate of increase will become negative and then the population will be extinct i.e. eliminated from the nature e.g. Rich stem borer is always major because they are capable to reproduce rapidly. Minor insects always remain minor as it reproductive rate below the economic threshold.

(ii) Crowding:

Crowding is caused due to over population of insects. There are two types effects of crowding:

(a) Increase of insect population is vast number due to increase of birth rate and will form swarm.

(a) Decrease of insect population due to intra-specific compotation for food and space birth rate becomes maximum when these are neither under population nor crowding (i.e. under normal condition).

Aggregation: Aggregation is one kind intraspecific interaction. The term aggregation or temporary aggregation is usually applied to a group of animals which come together for some external reason. A pattern of distribution in a population in which individuals have a much higher probability of being found in some areas than in others; in other words, individuals are aggregated rather than dispersed. It is a common aggregation of individuals. In this case the individuals remain in grouped in a definite way.

The reasons of aggregation:

i) collection to a food source, ii) for a shelter site, iii) for a site for oviposition, iv) for colonization, v) for recruitment of a sexual partner, vi) and for swarming or dispersal purposes.

Mechanism for aggregation:

The mechanism for aggregation at a chemical source is usually chemotaxis where the insect can detect the gradient of odour molecules, and it often involves orientation by anemotaxis, that is positive orientation to air currents, particularly in the case of flying insects.

According to Hill (1981) example of aggregation are-

i) Leaf Cutting Ant *(Atta spp.)* lay persistent trails to leaf sources up to 100 km in distant, which may last for months. Similar trails are laid by termites when foraging.

ii) Bees and wasps *(Vespa vulgaris)* leave a scent trail from their feet which are important in delimiting the entrance to their nests.

iii) Bark Beetles (Scolytidae) use aggregation pheromones to designate host trees suitable for colonization, as these beetles only flourish when present in quite dense populations. Colonization is usually succeeded by mating which involves the use of sexual pheromones. This type of aggregation can also be seen- in the Japanese Beetle *(Popillia japonica)* and the Cotton Boll Weevil *(Anthonomus grandis).*

iv) Certain mosquitoes release pheromones into the water at oviposition which attracts other females.

v) Sheep Blowfly *(Lucilia cuprina)* females apparently use an aggregation pheromone to form dense populations at sheep carcases for oviposition.

vi) Aggregation at a suitable resting site has been demonstrated for the Bed Bug *(Cimex lectularis)* and someher cryptozoic species.

vi)Many species of embraced insects (Homoptera) exhibit good example of the gregarious habit; sometime on the same host plant (e.g., *Prosopis spicigera)* lodges two different gregarious species (e.g., *Oxyrhachis tarandus and Otinotus oneratus)*.

According to Verma (1981) advantages of aggregation are-

i) A group of insects is more fitting to survive a dry environment than in a single, since, in a limited space, each would lose less water before the relative humidity of the surrounding environment -would be raised to a less dangerous level.

ii) Aggregation may have a protective function against predators. For example- sheep, when threatened, will cluster together, with the rams encircling the young sheep and ewes. A single musk ox or bison may succumb to a pack of wolves. When in a group, the males form a circle facing outward with the females and young inside, whereby they are usually able to ward off the attack.

iii) Aggregation facilitate food gathering. Large numbers of animals seeking food a shorten the time to discovery. Cooperative hunting by whole is a well known example. A single wolf has difficulty in killing a deer; a single coyote in killing pronghorn antelope. But in packs the wolves can overpower a deer and a pack of coyote can chase a pronghorn to exhaustion.

iv) Aggregation of two or more organisms is necessary for sexual reproduction. Sexually gregarious, often bringing together males and females during the reproductive season as in the case of male frogs that sing together in ponds, it increase the likelihood that a female will find the pond and be fertilized. Mayflies, midges, and mosquitoes also swarm for mating purposes.

B) Interspecific interaction-

Interaction between different species known as interspecific interaction. Different species such the natural enemies. e.g. parasites, predators, pathogens etc. as includes interspecific. Major type of interspecific are (according to Odum ,1971)-

- Parasitism (+ -)
- Competition (- -)
- Mutalism (+ +)
- Protocooperation (+ +)
- Commensalism (+ 0)
- Neutralism (0 0)
- Amensalism (- 0)
- Predation (+ -)

Parasitism

a) parasitoid: Insect lava that kills its host, generally another insect, by consuming completely the host soft tissue before metamorphosis into an adult; parasitoids are functionally equivalent to predators. The adult stage of parasitoids is free living but the larval stage is parasitic. The adults lay eggs which hatched into larvae and transformed into adult. The adults come out causing death of the hosts. eg. *Ichneumon* fly. T*richogramma* sp. etc are the examples of parasitoids.

Several special terms are used to describe parasitic insects. A parasitic insect develops in or on a single insect host or on the eggs of one host. The term parasitoid after is used for parasitic insects because they differ sufficiently from true parasites. Six orders of insects including 86 families have listed as parasites and parasitoids

Parasitology: The branch of science that dealing with small organisms (parasites) living on or in other organisms (hosts), in spite of whether the result of the parasite on the host is negative, positive, or neutral.

Characteristics of parasitoids

1. They are free living and smaller than the host
2. They feed on hosts body fluids
3. Life cycles are commonly short, ranging from 10 days to 4 weeks
4. Female lays one or more eggs on or in host and consume the host tissue
5. They must kill the host
6. They are host specific or attacking several related genera.
7. They lays eggs within or upon the host

There two major type parasitoid-

Superparasitism: Superparasitism occurs when an individual host is attacked by more parasitoids of the same species that can develop successfully. If superaprastism occurs, intraspecific competition will produce small adults or result in the death of some or all of the progeny.

Multiple parasitism: Multiple parasitism occurs more than one species of parasitoid attacks the same host.If multiple parasitism occurs, interspecific competition results in the death of some or all of the progeny.

b)Parasites: A parasites is an organism that lives on or within a larger organism, its host and feeds on its host, usually weakening it and sometimes killing it e.g. mites, ticks

Characteristics of parasites

1. They are smaller than the host
2. They are free living

3. They feed on hosts body fluids
4. Life cycles are commonly short, ranging from 10 days to 4 weeks
5. Female lays one or more eggs on or in host
6. It has one or two or more generation (multivoltine) to one of the host.

Some parasitoid insect, their common name, family and order-

Common name	Scientific name	Family	Order
Ichneumon fly	*Xanthopimla predator*	Ichneumonidae	Hymenoptera
Ichneumon fly	*Melcha manculceps*	Ichneumonidae	Hymenptera
Braconid wasp	*Bracon hispae* (Parasitoid of Rice hispa), *B. chinensis* (Parasitoid of pulse beele) *Apanteles obliqua* (Parasitoid of Jute hairy caterpillar)	Braconidae	Hymenoptera
Chalcid wasp	*Brachymeria criculae*	Chalcididae	Hymenoptera
Scelionid wasp	*Telenomus sp.*	Scelionidae	Hymenoptera
Trichogrammatid wasp	*Trichogramma minuta*	Trichogrammatidae	Hymenoptera
Tachinid fly	*Tachinia sp.*	Tachinidae	Diptera

e) Differences between parasites and parasitoids:

Parasitoids	Parasites
i) During development of an individual parasitoid need single host.	i) During development an individual parasite need many host.
ii) The Parasitoids and the host are usually of the same taxonomic class (insects).	ii)The parasite and the host are not the same taxonomic class.
iii)They are parasitic as larvae only and the adults are free – living	iii)They are parasitic on the whole life
iv) They do not exhibit heteroecism (living on first one species of host and then another).	iv)They exhibit heteroecism
v)Their action resembles that of predators more than that of true parasites in the population dynamics of pests	v)Their action is not resembles that of predators more than that of true parasites in the population dynamics of pests.
vi) Generally they live within the living body e.g. *Trichogramma* sp, *Tachinid* fly etc.	vi) Generally they live on the living body surface e.g. Human body lice, bird lice

Generally they are same size *Trichogramma* sp, *Tachinid* fly etc.	Generally they are not same size. host is lager than the parasite e.g. Human body lice, bird lice

Competition:

The competitive interaction often involves space, food or nutrients; light, waste materials and so, become susceptibility to carnivores, disease, and so forth. Interspecific competition takes place among two or more closely related species adapted to the same niche and invariably leads to the elimination of one of the species. It therefore follows that two closely allied fragment cannot survive in the same niche and interspecific competition is a mechanism for separation of closely related species. This has come to be known as "Gauss's principle" or the competition exclusion principle.

A good example of competitive exclusion is the outcome when two species of flour beetles were placed in the same container of flour. If the container is maintained under conditions of high humidity and temperate, *Tribolium. castaneum* invariably wins out. However, maintaining the beetles under conditions of low humidity and temperature results in a "victory" for *T. confusum*. In the absence of the other, either species can be maintained indefinitely under wet and warm or dry and cool conditions.

Competition is found between *Daphnia pulicaria* and *D. magna* in cultures; *Daphnia pulicaria* eliminates the closely related species *D. magna*, but with yeast as food for both, *D. magna* persists for a longer period since this food is less favourable for the dominant species. Competition is less severe between *Daphnia* and *Simocephalus*, which have overlapping niches. In mixed culture both species populations undergo normal growth form and persist together for 40 days, after which *Simocephalus* is gradually eliminated.

It has been shown that in populations of grain beetles *Trogoderma versicolor,* and *Gnathoceros cornutus* reared together to study and found the similar competition mention above.

Mutalism/ Symbiosis: A relationship between two or more species in which the growth and survival of both populations benefit to both partners and cannot live in its absence is known as obligate mutualism.

Mutualism is an obligate interaction; the absence of the interaction depresses both partners. Closely related organisms do not seem to form such an interaction. They are many examples of mutualistic associations between insect. Symbiosis is an exceedingly widespread phenomenon; there is no major group of animals that does not include symbiotic species, and there is probably no individual animal that does not play host to at least one symbiotic process. Practically every animal with an alimentary canal houses billions of intestinal bacteria, chiefly in the lower gut. These bacteria draw freely materials not digested by the host, and as a result of their activities fecal matter decays. The host usually gets benefits from the supplementary digestion carried out by the bacteria and is often dependent on certain of the bacterial by-products

Likewise, in the gut of wood-eating termites, live flagellates- an obligate anaerobic protozoon (*Trichonympha* sp.) secretes an enzyme capable of digesting the cellulose of wood. Termites chew and swallow wood, the intestinal flagellates then digest it. Both organisms share the

Fig. Pogonophorans warms and bacteria symbiosis (adapted from Star and Taggart, 1989)

resulting carbohydrates. Thus termites can exploit unlimited food opportunities; which are not open to other animals. The protozoa get protection and ensure of a stable food supply.

Pogonophoran worms (Fig.), closely related to the annelids (Phylum: Pogonophora) live near a hydrothermal vent in a deep ocean trench near the Galapagos island. They look like white tubes with red marks. Although may reach up to 9 meters, have no digestive system. Their nutrition comes in part from bacteria living symbiotically with the cells of the worms. In the total absence of sunlight, bacteria that oxidize hydrogen sulphide (H_2S) are the food bases of the community.

In addition, there are several species of *Yacca* plants; each is pollinated completely by one kind of Yacca moth species. The adult stage of the moth life coincides with the blossoming of *Yacca* flowers. The female moth gathers up the somewhat sticky pollen and rotates it into a ball. Then she flies to another flower and after piercing the ovary wall, lays her eggs among the ovules. She crawls out of the style and pushes the ball of pollens into the opening of the stigma. When the larvae emerge, they eat small portion of *Yacca* seed. Then they chew their way out of the ovary to continue the life cycle. So sophisticated is this mutual dependency that the moth and larva can obtain food from no other plant, and flower can be pollinated by no other agent.

Besides this, common examples of mutualism are lichens (algae + fungi), mycorrhizae (fungi + higher plants), symbiotic nitrogen-fixation (bacteria or blue-green algae + higher plants), pollination (insects, birds, or mammals + flowering plants), zoochory (animal dispersal of plant propagules), and myrmecophytes (ants + woody plants).

Protocooperation: Association between two species in which both populations help from the association, but the association is not obligatory, frequently termed facultative cooperation.

It is an interaction that stimulates both partners, but it is not obligatory because stable growth continues in the absence of the interaction. One example of protocooperation is root grafts between members of the same or different species.

Attractive kind of protocooperation is found between the ants and aphids (plant sucking insect). The ants 'milk' the aphids by stroking aphids with their foreleg and antennae. The aphid responds by secreting droplets of partly digested sugar-based plant sap (or honeydew) that passed through their guts. The ants use the sugar, which is of no use to the aphids because plant sap is high in carbohydrate but low in amino acid. In return, the ants protect the aphids from predatory wasps, beetles and other natural enemies.

Another example of protocooperation the relationship between water moccasins and large birds such as herons and ibises on several islands of the West Coast of Florida. The birds nest in the lower branches of relatively unprotected trees, while the snakes congregate around the bases. This protects the bird from tree climbing predators such as raccoons. In turn, the snake feed, in part, on fish dropped by the birds and the occasional baby birds falling out of the nest.

One of the most widely known protocoperation is the cleaning symbiosis (Fig.) in the oceans on coral reef. The pacific cleaner fish wrasses (*Labroides* spp.: Labridae) do a little dance and advertise that they are in business in cleaning stations. Then diverse large fishes such as butterfly fish (*Chaetodon miliaris)* come to the station and adopt a cleaning service. The cleaning fish remove parasites, loose scale by eating often entering both gills and mouths to clean. Wrasses and gobies (gobies- Gobidae) are obligate while angelfishes (Pomacanthidae) are facultative cleaner and they act as cleaner when they are young.

Fig : Clinning symbiosis
A wrasse picks food particles from the teeth of a squirrefish near a reef off New Caledonia (Keeton, 1980)

Fig . Cleaning symbiosis (adapted from Keeton, 1980)

iii) The relationship between ... ample of protocooperation. The dorsal fin of the remora is ... which the remora can form a temporary attachment to the sand tiger shark. The shark does not feel difficulty by this and makes no attempt to prey upon the remora. When the shark does not feed (i,e at rest), however, the remora is in a position to pick up scraps the shark fails to consume. Again the Nile crocodile opens its mouth after feeding and it permits the Egyptian plover (Fig.) to feed on any leeches attached to its gums.

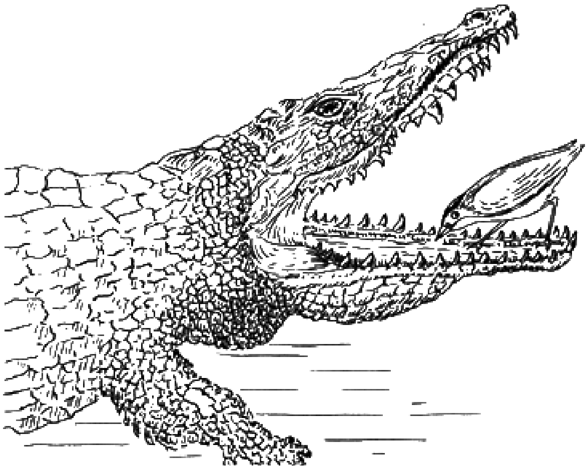


Fig 8. The Nile crocodile and Egyptian plover bird mutualism (adapted from Kimball, 1965)

Commensalism: Commensalisms is the relationship in which one species benefits, but neutral or of no benefit to the other.

It is an interaction that stimulates and benefited one organism but has no effect on the other. One example of commensalism is found between the epiphytes and the trunks of tropical plants. Epiphytes occur in all climatic regions. The trunks and branches of trees provide excellent attachment sites for other plants. This tropical tree supports a heavy load of ferns, orchids, bromelids and mosses.

Predation

Predation is the consumption of one living organism by another, a relationship in which one organism benefits at the other's expense. In its broadest sense predation includes herbivory, parasitism, and cannibalism.

There are many invertebrates predators such as lady bird beetle, tiger beetles, preying mantid, which prey on other small insects particularly soft bodied insects such as aphid, mealybug scale insect, midge, white fly. As a result, insect population is decrease.

There are some vertebrate also predators such as insectivorous bird, fish, toads, snakes, bat, rat, and lizard prey on insects as a result insect population is decrease drastically.

Predator: A heterotrophic organism, usually an animal that actively kills and eats other organisms for food; usually an animal that hunts and kills other animals for food.

.Predators are distributed in about 167 families belonging to 14 orders of class insecta (sathe and Bhosale,2001).Examples-Beetles, true bugs Preying mantid, Lacewing, flies and wasps.

Characteristics of Predator:

1. Generally larger than their prey.

2. Kill or consume many preys than they need to satiate themselves.

3. Males, females and immature may be predatory.

4 Attack both immature and adult insect prey.

5. Need more than one prey to reach maturity.

6. Large predators take large and/or smaller prey, smaller predator take smaller and/or larger prey.

7. May be active during day and night.

8. Having high host searching ability.

Types of predator

Predators are categorized into three types

1. Monophagous
2. Oligophagous
3. Polyphagous

1.**Monophagous**

Monophagous predators feed on one species of prey. e.g. *Cryptolaemus montnouzieri*,Vedalia beetle

2.**Oligophagous**

Oligophagous predators take several prey species e.g. Praying mantids

3**.Polyphagous**

Polyphagous predators take many kinds of preys. Water scorpion

Some predator insect, Spider and their common name, family and order-

Common name	Scientific name	Family	Order
Dragon fly	*Aeshna verticalis*	Aeshnidae	Odonata
Damsel fly	*Argia violacea/ Coenagrion sp*.	Coenagrionidae	Odonata
House Cricket	*-Gryllus sp. / Metioche vittaticollis*	Gryllidae	Orthoptera
Long-horned grasshopper	*Conocephalus longipennis*	Tettigoniidae	Orthoptera
Preying Mantid	*Mantis religiosa*	Mantidae	Dictyoptera
Ear wig	*Forficula auricularia*	Forficulidae	Dermaptera
Assasin or Reduviid bug/ Hunter bug	*Harpector costalis/ Aritus cristatus*	Reduviidae	Hemiptera
Mirid bug	*Cyrtorhinus lividipenis*	Miridae	Hemiptera
Giant water bug bug	*Belostoma indica*	Belostomatidae	Hemiptera
Ladybird beetle	*Coccinella septempunctata Micraspis discolor Menochilus sexmaculatus Harmonia octomaculatus*	Coccinellidae	Coleoptera
Tiger beetle	*Cicindela sexpunctata*	Cicindelidae	Coleoptera
Carabid beetle/Ground beetle	*Anthia segutetta*	Carabidae	Coleoptera
Water scavenger beetle	*Hydrophilus triangularis*	Hydrophilidae	Coleoptera
Red ant	*Solenopsis geminat*	Formicidae	Hymenoptera
Robber fly	*Asilus sp.*	Asilidae	Diptera
Hover/ Syrphid fly	*Syrphis sp*	Syrphidae	Diptera
Lynx spider	*Oxyopes salticus*	-Oxyopidae	Araneae
Wolf spider	*Lycosa sp. / L. pseudoannulata*	Lycosidae	Araneae
Orb spider	*Araneous inastus*	Arancidae	Araneae
Long-jawed spider	*Tetragnatha maxilosa*	Tetragnathidae	Araneae
Dwarf spider	*Atypena formogena*	Linyphiidae	Araneae
Jumping spider	*Phidippus audax*	Salticidae	Araneae

Growth form /Population Dynamics

Population Dynamics (Growth form) or model or law of population increase of a population refers to the particular shape of the density curves during a season or over a longer time period. The particular shape of growth curves determines in part the amount of overlap between numbers of different life stages within a generation and between generations.

1. **S-shaped growth form/ Logistic growth:** S- shaped growth form also known as Sigmoidal growth form (from the Greek word Sigma).The growth is the most fundamental dynamic feature that a species population displays. Populations characteristically increase in size in a sigmoid, S-shaped or logistic fashion. This curvy is commonly; call the logistic model of population growth *and* the changes in' the instantaneous rate of increase When a few organisms are introduced in to an unoccupied area, the growth of the population is at first slow (positive acceleration phase), then becomes very rapid (logarithmic phase) and finally slows down as the environmental resistance increases (the negative acceleration phase) until an equilibrium level is reach; the population size fluctuates more or less irregularly according to the constancy or variability of given environment. The stage of growth of population (after Allee et al., 1955)-

STAGE I		Period of positive, sigmoid growth; population increasing
	A	Establishment of population
	B	Period of rapid growth (exponential growth)
II		Equilibrium position (asymptote); numerical stability
III		Oscillations and fluctuations
	A	Oscillations - symmetrical departures from equilibrium
	B	Fluctuations - asymmetrical departures
IV		Period of population decline (negative growth)
V		Extinction

According to Verhulst-Pearl in differential form the equation may be written as-

$$dN/\ dt = r(K - N/K)N. = dN/\ dt = r(1 - N/K)N.$$

Where,

$$\frac{dN}{dt} = \text{Instantaneous rate of increase}$$

N= Number of insects

r= Intrinsic rate of natural increase

k= Carrying capacity of the environment.

It is evident that as N approaches K, the term *(K - N/K)* approaches zero and hence the instantaneous rate of increase approaches zero, resulting in a leveling off of the population. The population size at which the leveling off occurs is called the carrying capacity (K) of the environment. The level beyond which no major increase can occur represents the saturation level or carrying capacity. The carrying capacity or equilibrium density is represented by the letter K. It is often useful to define the maximum rate of growth of the population. This parameter, generally termed the intrinsic rate of natural increase, is symbolized r and represents the growth rate of a population that is infinitely small.

The carrying capacity (K) of the environment also varies with many factors (e.g, availability of food, extent of predation).

If one desired to represent sigmoid growth of the population graphically, he has to plot the time on the X-axis and the number of organisms on the Y-axis, and consequently, will get a characteristic S-shaped sigmoid curve. Human population and growth of yeast, *Drosophila* or rabbit in laboratory conditions, follow such S-shaped population growth.

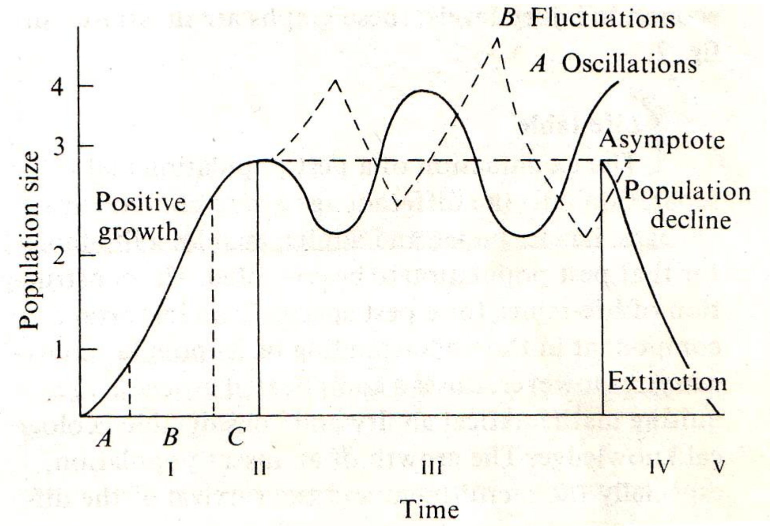
The logistic growth model is only a baseline for studying population growth. Carrying capacities fluctuate with the seasons and from one year to the next. Moreover, the birth and death rates are not necessarily clear cut (even starving animals can continue to consume resources and bear young). For example, in 1910 four male and twenty two female reindeer were introduced on one of the Pribil of Islands of Alaska. Within thirty years, the population increased to 2000 greatly "over shooting" the carrying capacity. The vegetation on which the reindeer grazed almost disappeared, an in 1950 the head size plummeted to eight members.

According to Hill (1981) the growth of a population can be expressed very simply in the equation:

$P_2 \leftrightarrow P_1 + N - M \pm D$

Where P_2=final population, P_1= initial population, N= natality or birth rate, M= mortality, D= dispersal

The objective of pest control is to lowering P_2, which quite clearly can be done by lowering the birth rate of the pest, increasing death rate or inducing the pest to emigrate away from the area concerned.



S- shaped growth form (According to Hill,1981)

Differences between population oscillation and population fluctuations

Population oscillation	Population fluctuation
1. The symmetrical departure of insect population from the equilibrium level, is called population oscillation e.g. Granary beetle and *Trogoderma* sp.	1. The asymmetrical departure of insect population from the equilibrium is called population fluctuation e.g. *collembola*.
2. It is caused/ controlled by the insect population itself or the presence of other species.	2. It is controlled by the physical factors or environmental factors.
3. It is found in interspecies competition condition, where one species is prey and another species is predator.	3. It is not influenced by the interspecies population competition.

2 J-shaped growth form/ Exponential growth-

J-shaped growth form is also known as exponential growth**.** It is the instantaneous rate of population growth expressed as proportional increase per unit of time; a fixed percentage of the size of the population at the beginning of the period. Population growth produces a J-shaped pattern of population increase. In exponential population growth, the change in numbers with time is the product of the per capita rate of increase, *r*, and population size, *N*.

J-shaped growth curve, is obiunded when the density of the organisms increases rapidity or geometrically (2, 4, 8, 1,6 32, 64............) in compound interest fashion, and then stops abruptly as environmental resistance or other limits become effective more or less suddenly. Evaluating the repopulation of an area from which all members of a given species have been previously removed. Because populations under ideal conditions have the capacity for exponential increase, the first step is to consider an equation that describes exponential increase.

In differential form the equation may be written as-

dN/dt = (b - d)N,

where,

dN/dt = instantaneous rate of increase;

= population;

t = time;

b and d = average birth and death rates per individual per unit

The average birth. (natality) and death (mortality) rates, b and d, can be represented as *(b – d)=* r, where r is the *intrinsic* rate *of increase* of a population.

The population equation then becomes *dN/dt = rN.*

If b is greater than *d,* then the population is growing;

if b is equal to d, the population is stable *(r = 0)*; *if b* is less than d, the population is decreasing in size.

Growth curves of many insect populations in temperate climates are J-shaped; the population grows exponentially, and then falls off abruptly with the advent of winter.

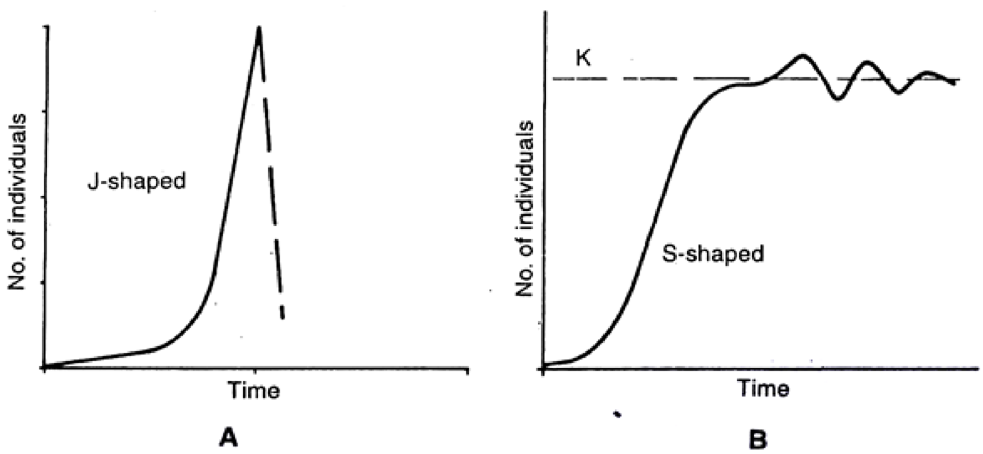


Fig. 11·2. Population growth curves. A. J-shaped; B. S-shaped (sigmoid) curve. K stands for carrying capacity.

J- shaped growth form (According to Romopser,1984)

Birth rate (natality): The number of new individuals produced in a population generally expressed as births per individual or per thousand individuals in the population. Natality is birth rate, often measured as the total number of eggs or eggs per female laid per unit time.

Mortality: Rate number of individuals in a population during a given time interval divided by the number alive at the start of the time interval.

Mortality is the death rate, or numbers dying per unit of time. These processes act in concert, natality adding numbers and mortality subtracting them, in determining population density and dispersion.

Birth rate is a major process for adding new individuals to a population. It is often expressed as numbers born per female or per 1,000 females in the population during a specific t; me period. The major factors determining birth rate are fecundity, fertility, and sex ratio.

i) **Fecundity:** Fecundity is the rate, at which females produce ova. whjere as Gonadosomatic index: Gonadosomatic index, or GSI. GSI was taken as the ovary weight of each species, divided by the species body weight and adjusted for the number of batches of offspring produced by each species per year. For example, because the northern anchovy spawns three times per year, the weight of its ovary was multiplied by 3 for calculating its GSI. Meanwhile, the ovary weight for dogfish sharks, which reproduce only every other year, was divided by 2. However, since most of the species included in the analysis spawn once per year, their ovary weights required no adjustment for GSI calculations.

ii) **Fertility** is the rate at which they produce new individuals, for example, fertilized eggs. With fecundity, the focus is strictly on female capability to produce reproductive units. Fertility focuses on the mating and fertilization process, or the production of zygotes.

ii) **Sex ratios:** in most populations are 1:1, male to female. Exceptions to this ratio are most common in parasitic Hymenoptera and, of course, parthenogenetic species. Overall, changes in birth rate may be caused by changes in the average production of eggs per female, changes in mating success, changes in the proportion of female individuals in the population, or a combination of these.

Both fecundity and fertility may vary greatly for an insect population. Secondary factors like temperature, moisture, and food may strongly influence the number of eggs produced by a female. For instance, in controlled experiments with the European corn borer, *Ostrinia nubilalis,* 708 fertile eggs were produced per female at a temperature of 21°C, but only 533 were produced at 32°C. Likewise, female egg production can be greatly influenced by nutrition.

Differences between J-shaped and S-shaped (sigmoid) growth forms.

J-Shaped growth form	S-Shaped (sigmoid) growth form

i)It is called exponential growth curve.	i)It is also called logistic growth curve or Verhulst-Pearl equiation.
ii) Such type of population growth or increase can be described by the following to exponential equation $\frac{dN}{dt} = (b-d)N$ $= dN/dt = rN.$ Where, $\frac{dN}{dt} =$ Instantaneous rate of increase N= Number of insects b= Average birth rate per individual per unit d= Average death rate per individual per unit.	ii) Such type of population growth or increase can be described by the following logistic equation- $\frac{dN}{dt} = rN(\frac{k-N}{k})$ Where, $\frac{dN}{dt} =$ Instantaneous rate of increase N= Number of insects r= Intrinsic rate of natural increase k= Carrying capacity of the environment.
iii) Population increases in a geometric or arithmetic fashion.	iii) This model not follows geometric or arithmetic fashion of population increase.
iv) Population increases rapidly at first.	iv). Population increases slowly at first.
v)Population declines very sharply	v)Population declines not so sharply
vi)Population reaches to N-limit then decreases suddenly.	vi) Population reaches to an equilibrium level then decreases slowly.
vii) Increases of population do not continue for a long time	vii) Both increases and decreases of population continue in asymmetrical or symmetrical way for a long time
viii) No equilibrium level is maintained.	viii) An equilibrium level is maintained.
ix) Found in fast breeding organism such as rose thrips, cockroach.	ix) Found in slow breeding organism such as human population, reindeer, growth of yeast, *Drosophila* under laboratory condition..

Factor affecting on fluctuations in populations of insects /Limits on Population Growth -

When any essential resource is in short supply, it becomes a limiting factor for population growth.

The occurrence and abundance of insects are dependent on the complex interaction of ecological factors. These factors are not merely additive but each factor potentates another in an endless chain. Among the factors that caused the reduction in the population the following are more important:

i) adverse weather conditions, ii) temperature extremes in particular; iii) predators, iv) parasites, v) pathogens, vi) accidents vii) food shortage; and viii) lack of adequate shelter. For example-

Factors affecting on fluctuations in populations of European corn borer are given below-

i) Strong winds and heavy rainfall destroy the adult moths, prevent oviposition.

ii) Extreme drought prevents hatching of larvae, unstable temperature causes laying of fewer eggs than normal.

iii) Winter caused mortality, and also reduces or cut off altogether the food supply.

iv) Predators and parasitoid killed egg, larvae pupae and adult.

v) Control methods like burning off stubs containing larvae, ploughing-under infected stubble's in autumn.

vi) Variations in the occurrence of the preferred food-plants.

Variable affecting Population Size:

To understand how population changes in size, we will begin with a simple concept. The size of any population increase or decrease with change in one or more of the following variables:

i) Natality: births

ii) Mortality: deaths

iii) Immigration: individuals from other population of the same species join the population

iv) Emigration: individuals leave the population

Together, these for variables dictate the rate of change in the number of individuals in the population over a given period of time:

(population growth rate) = (births + immigration) – deaths + emigration)

(population growth rate) = births + immigration) – (deaths + emigration) x number of individuals)

Suppose, for the sake of argument, that the birth and death rates remain constant, regardless of how much or how little the population grows. Then we can lump them together as a single variable, called $_r$, the net reproduction per individual. (In the mouse example, this would be 0.5-0.4 = 0.1, the birth minus the death rate).

The population dynamics of Predation

(i) There are certainly cases where predation has a profoundly harmful effect on the prey. For example, the 'Vedalia' ladybird beetle *(Rodolia cardinalis)* is famous for having virtually eradicated the cottony-cushion scale insect, a pest that threatened the California citrus industry in the late 1880s.

(ii) On the other hand, there are many cases where predations and herbivores have no apparent effect on their prey's abundance. The weevil *Apion ulicis,* for example, was introduced into New Zealand in an attempt to control the abundance of gorse bushes *(Ulex europaeus),* and it has become one of the most abundant insects in New Zealand. Yet despite eating up to 95 % of the gorse seeds every year, it has had no appreciable impact on the numbers of the plant.

(iii) There are also many examples in which a predator retains a fairly constant density in spite of fluctuation in the abundance of its prey (tawny owls and small mammals there are cases in which a predator or herbivore population tracks the abundance of its prey, although the prey itself varies in density as a result of some other factor (cinnabar moth larvae and ragwort plants).

(iv)There are studies, too, that appear to show predator and prey population linked together by coupled oscillations in abundance and finally, of course.

(v)There are many examples in which predator and prey populations fluctuate in abundance apparently independently of one another.

Forecasting of insect population

i) Observations on the field population:

a) Forecast on initiation of infestation- This type of forecasting is of significance for those pests and for such areas where a pest is of ordinary occurrence and causes serious damage to crop as is the case with yellow stem borer of paddy and aphid on bean among many pasts in West use of light traps, phasing provide such data.

b) Forecasting by field observations- Observations on the population of pest of diverse developmental stages by sampling on the crop or the substitute host plants afford idea of the probable level of population development on crop plants during resulting season. Sampling of young stages of pests is useful.

   The observation on the first laying of egg by lepidopteron pests like *Heliothis* makes it possible to determine the time of adoption of chemical control measures on cotton against this pest.

c) Forecasting by calculation- calculations are sometimes done even with out instant observation as in the abovementioned two methods. But these are also based on observations which have been taken for quite some time during successive seasons earlier and the biological activities of the species reared with some broad abiotic factors that play primary role on the activities of the insect. It is well known that temperature alone plays essential role on the activity of some insects. This knowledge has been profitably unused for prediction of rice stem borer, *Chilo suppresalis* in Japan. The simple method to forecast this insect involves temperature records during the preceding two months ie. April and May.

Surveillance

Surveillance is an action where examine and count the number of pests and their natural enemies in the field and finally to assess this information for taking operative control measures.

Objectives of Surveillance:

(1) To examine what insect species is present in the field.
(2) To count the number, population density and existing weather.
(3) To take appropriate control measures.

Surveillance is usually carried out at certain days interval (7 or 15days) from sowing to harvesting of the crop. Surveillance from is used to record the data. Surveillance is usually carried out through the following steps-

Step 1:

A suitable farm site/field is selected to conduct surveillance activities. The field should belong to a contact grower. For rice, 2 plots each of 33 decimals are selected of which 60% of the plots should be occupied with rice plants.

Step 2:

A sign board should be hung near the field to indicate that the field crop is under surveillance.

Step 3:

i)Surveying is usually started at 7 days after transplanting from one corner of the field.

ii)20 hills are examined diagonally.

iii)Number of insect pests and their natural enemies are counted and these information are recorded to the surveillance form.

iv)% of damage is calculated by using these data and appropriate control measures are taken.

Economic Threshold (ET):

Economic Threshold Level (ETL): Economic threshold level may be defined as the pest density at which control measures should be done / applied to prevent an increasing pest population from reaching Economic Injury Level (EIL). ETL always represent a pest density lower than that of EIL to allow the initiation of control measures so that they /crop grower can take measures before the pest density exceeds the EIL.

Economic Injury Level (EIL): EIL is the lowest pest population density that will cause economic damage (stern *et al.*, 1959). The level of pest population at which damage can no longer be tolerated and at this level or before which appropriate control measure should be taken.

Economic Threshold Level (ETL)	Economic Injury Level (EIL)
1. Economic threshold level may be defined as the pest density at which control measures should be applied to prevent an increasing pest population from reaching economic injury Level (EIL).	1. The level at which damage can no longer be tolerated and therefore the level at or before which appropriate control measure should be taken.
2. The ETL always represents a pest density lower than that of the EIL.	2. The EIL always represents a pest density higher than that of the ETL.
3. In this level damage is tolerable.	3. In this level damage is not tolerable.
4. It indicates the population density that will not cause economic damage.	4. It indicates the lowest pest population density that will cause economic damage.
5. Control measures are economically profitable.	6. Control measures are not economically profitable in this stage.
6. It not depend on season, area, crop	It depend on season, area, crop

ET is the pest population density at which control measures should be taken. Generally, chemical measures are taken at

Threshold levels of cotton pests: The critical threshold levels of cotton pests were determined by CDB are as follows:

Insects	ET
(a) Jassid	(a) 2.0 nymphs/plant
(b) Aphid	(b) 1.50 grade /plant
(c) White fly -	(c)5-6 adults /plant
(d) American bollworm	(d) 0.25 larva/plant
(e)Spotted bollworm	(e) Spotted bollworm

Aphid grade-

0→	Absent infestation
1→	more than 10 but less than20
2→	an observable colony
3→	more observable colony
4→	heavy infestation found on all plant

Threshold levels of for rice pests:

Insects	ET
Rice stem borer	3 moths/egg masses/m^2 10% Dead Heart at mid tillering stage at 40 Days After Transplanting on 5% white head
Rice hispa	2-3 adults/hill or 2-3 grub/ leaf
Green Leaf hopper	1 hopper/sweep
Brown plant hopper	
Rice bug	2-3 bugs/hill
Rice are cutting caterpillar	2-3 caterpillars/10m^2
Caseworm, leaf roller, army worm	25 % leaf damage

If we get above data from surveillance we should take control measures by using insecticides.

Form-1

Page 1

To

DDAE

……………………….. Upazilla

Weekly Surveillance From for Rice at Upazilla Level

District SB Var Space Gs WM W Weed Pesticide

Time Day Month Year

Number of pests and defenders

No. of Hill Pests & Defenders	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total	Av.	%*
Brown Plant Hopper																							
White-Backed Plant Hopper																							
Adult hispa																							
Grub/Pupa of hispa																							
Stem Borer Moth																							
Dead heart/White head																							
Case worm moth/Infested leaf																							
Leaf folder moth/Infested leaf																							
Rice bug																							
Swarming caterpilenr/Infested leaf																							
Ear cutting caterpilar																							
Gall Midge/Siver Shoot																							

Green Leaf Hopper																							
Spider																							
Lady beetle																							
Carabid beetle																							
Staphylinid beetle																							
Damsel fly/Dragon fly																							
Mirid bug																							
Wasps																							
Microvelia and Mesovelia																							
Number of leaves																							
Number of tillers																							

(Please Turn Over)

* % damage as in case of white head, dead heart, leaf folder, etc. In case of disease give% incidence of Blast, Sheath blight etc.

Form-1

Pest Situation at the block Level

Area Cultivated (ha)	Name of Pests	Infested/ Infected Area (ha)	Intensity of Infestation (Area in ha)			Controlled (ha) without Pesticide	Controlled (ha) with Pesticide
			Low	Medium	High		

Remarks :

1. Record the surveillance information provided by the five farmers from the surveillance Unit area.
2. Also provide information on overall pest situations of the block (the area affected and area controlled and any other information on the pest situation).

Signature : …………………………………….…… Name :……………………………………………………..

(Block Supervisor)

Block Name and No. :………………………………………. Date :………../………./…………..

Form-2

To

DDAE

………………………..District

Weekly Surveillance From for Rice at Upazilla Level

Upazilla	1 2 3	1 2 3	Water Management	Weather

Day	Month	Year	Variety	Growth stage	Weeds	Pesticides Use

Pests & Defenders	Av. No. of pests and defenders in the Surveillance Blocks					Total	Av.	%*	Av.S SB/ 10 Sweeps
	1	2	3	4	5				
Brown Plant Hopper									
White-Backed Plant Hopper									
Adult hispa									
Grub/Pupa of hispa									
Stem Borer Moth									
Dead heart/White head									
Case worm moth/Infested leaf									
Leaf folder moth/Infested leaf									
Rice bug									
Swarming caterpilenr/Infested leaf									
Ear cutting caterpilar									
Gall Midge/Siver Shoot									
Green Leaf Hopper									

Spider									
Lady beetle									
Carabid beetle									
Staphylinid beetle									
Damsel fly/Dragon fly									
Mirid bug									
Wasps									
Microvelia and Mesovelia									

(Please Turn Over)

* % damage as in case of white head, dead heart, leaf folder, etc. In case of disease give % incidence of Blast, Sheath blight etc.

Form-2

Pest Situation at the Upazilla Level

Name of Surveillance Blocks	Area Cultivated (ha)	Name*of pests	Infested/Infected Area (ha)	Intensity of infestation (area in ha)			Controlled (ha) without Pesticide	Controlled (ha)with Pesticide
				Low	Medium	High		
Pestwise Consolidated Information from other Blocks of the Upazilla								

*Please use additional sheet of paper if needed.

Remarks : Please provide information on overall pest situation of the Upazilla (the area affected and controlled).

Signature :…………….........… Signature :…........…......……… Signature :………..................

Name :……………………........... Name :……………….............….. Name :……………...............…..

(Plant Protection inspector) (Agriculture Extn. Officer) (Upazilla Agriculture Officer)

Date :....................................... Date :... Date :.......................................

Polymorphism

The term polymorphism means literally "many forms (poly= many, morphe=form)" . Many insects occur in two or more morphologically distinctypes of individuals. The caste polymorphism of the social insets is a striking example of this occurrence. Further examples of polymorphism may be found in Embioptera, Psocoptera, Cicada, Lepidoptera, Hymenoptera and Diptera.. The more restricted definition according to Richards (1961) is as follows:

Polymorphism exists when one or both sexes of a species occur in two or more forms which are sufficiently sharply distinct to be recognizable without a morphometric analysis; the occurrence is regular or recurrent; the rarer of the two forms makes up a reasonable proportion of the population (say, at least 5 per cent) or, as in some social species, the rarest type is at any rate essential to the survival of the species. Polymorphism is defined as "the occurrence together in one habitat of two or more discontinuous forms of a species in such proportions that rarest of them cannot be maintained merely by recurrent mutation". There are many striking examples of polymorphism in Lepidoptera, psocids, cicada and Diptera, besides the caste polymorphism of social insects. The most numerous and remarkable of the polymorphic forms occur in tropic and that in many instances the polymorphism is restricted to one sex. Polymorphism both in genetic make up and chromosomal structure has been observed.

Polymorphism of aphid

The phenomenon of polymorphism of aphid related to i) Parthenogenesis, ii) oviparous iii) viviparous iv) sexual reproduction v) apterous vi) winged form. The life-history is somewhat on the following lines: i) The eggs are laid on the winter food plant during autumn and the winter is passed in the egg stage. With the advent of spring, from these over wintered eggs hatch apterous, parathenogenetic virgin females. These females reproduce parthenogeneticaliy and give birth to nymphs, which in turn produce another similar viviparous, apterous of females are thus produced on the winter food plant during spring and the whole of summer.

ii)Winged, viviparous, parthenogenctic females appear mow and then and late in summer the number of such winged females increases and migration takes place to a new food plant. On the summer food plant the winged females continue a parallel series of parthenogenetic viviparous generations.

iii) Towards early autumn the progeny of the apterous females on the original food plant and of the a late females on the second food plant give rise to a generation of sexual oviparous females and males.

iv) Mating now takes place and the mated females lay eggs once more on the winter food plant. Some species are non-migratory and spend the whole life-cycle on the same food plant. During the life-cycle of a typical migratory aphid the following sequence of polymorphism is met with.

According to Imms(1984) the following types of individuals, arranged in sequence, are present in the life-cycle of migratory aphids:

(1) The Fundatrices: usually apterous, viviparous, parthenogenetic females which emerge in spring from the overwintered eggs. The sense organs, legs and antennae are not so well developed as in succeeding apterous generations, the antennae, for example, being shorter and may comprise a smaller number of segments. The reduction of the parts is apparently correlated with increased reproductive capacity. The eyes are often smaller, or consist of fewer facets than in the succeeding generations, and there may be differences in the cornicles.

(2) Fundatrigeniae: apterous, parthenogenetic, viviparous females which are the progeny of the fundatrices and live on the primary host.

(3 Migrantes: These usually develop in the second, third or later generations of fundatrigeniae and consist of winged parthenogenetic viviparous females. They develop on the primary host and subsequently fly- to :he secondary host.

(4) Alienicolae: Parthenogenetic, viviparous females developing for the most part on the secondary host. They often differ markedly from the fundatrices and migrates; many generations may be produced comprising both apterous and winged forms.

(5) Sexuparae: Parthenogenetic viviparous females which usually develop on the secondary host, the alate forms migrating to the primary host at the end of the summer. The sexuparae terminate the generations of alienicolae by giving rise to the sexualize.

(6) Sexuales: These usually appear only once in the life cycle and consist of sexually reproducing males and females, the latter being oviparous. The females with rare exceptions *(Neophyllaphis, Tamalia)* are apterous, and distinguishable from the apterous viviparous generations of the same sex by the thickened. The hind legs, and the rater body length. The males are either winged or winged less.

Factors affecting of polymorphism of aphid

According to Romosor (1984)

i) Photoperiod, ii) temperature, iii) changes in host plant (e.g. wilting and nutritive changes), and iv) crowding.

Polymorphism of honey bee:

The bee colony is polymorphic, comprising three castes:

The queen i)The queen (fertile female) is unable to produce wax or to gather pollen or nectar ii) Her sole duty is to lay eggs .iv) She has a very large body but less powerful wings than workers. v) She has immensely developed ovaries which allow her to lay one to two thousand eggs a day and as many as a million eggs in her life-time.

The workers i) (imperfectly developed females) are most numerous and undertake all the work of the colony. ii) They are small bees but have very well-developed and powerful wings. iii) A worker has wax glands on the ventral side of the abdomen iv) a pollen basket on her hind legs v) mandibles well-developed for work in the hive and a full-fledged sting. Normally, the worker and non-functional and the little sac in which. the worker have the following work according to the age According to ----- (19----)

-

0-3	***Duty***
	Cleaning brood-cells and keeping brood warm
3-6	Feeding older grubs
6-14	Feeding younger grubs and the queen
14-18	Secreting wax, comb-building, cleansing hive
18-20	Guarding entrance of hive
20-40	Orientation

The drone i) They are larger and stouter than the worker ii) They have greatly enlarged eyes which cover most of the surface the head iii) the tongue is not well developed iv) They have no wax producing gland

Factors affecting of polymorphism of honey bee:

Caste determination in honey bees is dependent on i) fertilization or otherwise of the egg (hence Chromosome number) ii) the diet which the grub receives. Nutrition, both in terms of quantity and dietary balance, plays a significant role in polymorphism in honey bees. Female larvae (from fertilized eggs) all have the potential to develop into either workers or queens, depending on the period of time they are fed royal jelly. If larvae are fed royal jelly for only two or three days, they develop into worker, but if they are fed royal jelly throughout the larval stadia, they develop into queens.

Royal jelly, a highly nutritious substance produced by the salivary glands of workers It is reputedly rich in vitamin B and proteins and leads to queen development, while worker larvae are fed primary on food rich in carbohydrates.

Polymiorphism of Termite:

According to Comostock (1984) the following castes have been found among these insects-

A. Sexually Active Forms-

1. First reproductive caste: i) These are sexually perfect males and females and constitute what is known as the first reproductive caste.

ii) In these the cuticula is black or dark chestnut in color,

iii) the eyes are functional,

iv) the wings project more than half their length beyond the end of the body. A little later, these winged individuals leave the nest in a body, sometimes clouds of them appear. After flying a greater or less distance they alight on the ground, and then shed their wings.

v)The greater number of individuals comprising one of these swarms seen perish; they fall victims to birds and other insectivorous animals.

vi) Each of the more fortunate couples that have escaped their enemies, find a suitable place for the beginning of a nest and become the founders of a new colony.

vii)Such a pair are commonly known as the king and the queen of the colony they are also known as the primary royal pair can be recognized by the presence on the thorax of the stumps of the wings that they have shed.

Viii)After the nest has been begun, the growth of the reproductive organs and their products.

2.The second reproductive caste:

i)There are frequently found in the nests of termites neoteinic sexual forms; that is, individuals which are sexually mature

ii) but which retain the nymphal form of the body, having short wing-buds which do not develop further. These individuals constitute the *second reproductive caste,* which is represented by both males and females.

iii) The members of this Caste are pale in color; their compound eyes are only slightly pigmented; and they never leave the nest unless by subterranean tunnels. If a primary king or queen dies, its place is taken by individuals of the second reproductive caste.

iv) For this reason, the members of this caste are commonly known as substitute kings and queens or as complemental kings and queens. The substitute queens produce comparatively few eggs, and consequently it requires several of them to replace a primary queen.

v) Many pairs of substitute kings and queens are commonly found in orphaned nests.

3. The third reproductive caste.—In some cases there have found adult neoteinic sexual forms which resemble workers in lacking wing-buds. These are known as ergatoid kings and queens the third reproductive caste.—In some cases they have found adult neoteinic sexual forms which resemble workers in lacking wing-buds. These are known as ergatoid kings and queens.

B. Sterile, Aborted, or Sexually Arrested Forms-

4.Workers:

i) a large number of wingless individuals of a dirty white color, usually blind, and of the form represented by worker.

iii)Soft, pale-colored, wholly apterous individuals, usually without eyes

iii) The mouth parts are adapted to reduction of various types of hard and soft vegetable materials. They show little specific differentiation and are difficult to classify.

Duties: These are named the workers, for upon them devolve nearly all of the labors of the colony the reproductve organs are, however, only little developed as a rule; but occasionally workers capable of laying eggs are found. They construct the termitaria, galleries, covered passageways, and fungus gardens, collect and provide the food, feed the queen, soldiers, and young, care for the eggs, and, in species without soldiers, they also defend the colonies against marauders.

5. Soldiers: Associated with the workers. and resembling them in color. and in being wingless, there occur numerous representatives of another caste, which can be recognized by the enormous size of their heads and mandibles; these are the soldiers. They are so named because it is believed that their chief function is the protection of the colony; but they do not seem to be very effective in this. Among the soldiers, as among the workers, both sexes are represented; but as a rule the reproductive organs are not functional.

The members of this caste are of either sex or may or may not have compound eyes and the antennae have fewer segments than in the reproductive castes. There may be large, intermediate, and small individuals. The soldiers are highly specialized in development of the head and the mandibles and accordingly may be divided into two types:

(i) *Afandibulate* — in which the head is very greatly enlarged and heavily chitinized, and the mandibles greatly developed into variously shaped effective or, in some cases, seemingly useless weapons of defense. They are the protectors of the colony who either plug up the burrows or runways with their enlarged heads or guard the entrances with snapping mandibles.

(ii) *The nasuti.—In* certain species of termites there art found individuals in which the head is prolonged into a snout (a nose-like process), from the tip of which a sticky fluid is secrete, which is used as a means of defense their enemies in warfare. Such individuals are known as *nasuti.*

In this caste the mandibles are small, differing greatly, from those of soldiers.

The nasuti are usually smaller than the workers and are pigmented. and have vestigial mandibles and well-developed palpi.

Factors affecting of polymorphism of termite

According to Comostock (1984) the physiology in many termite species supplementary reproductive caste does not appear as long as the original king and queen are present. The king and/or queen produce a substance that circulates throughout the colony and inhibits the formation of supplementary reproductive. Death of the royal pair would then result in the loss of this inhibitory substance, and hence the supplementary reproductive would appear, assuring the continued survival of the colony. Soldiers may also produce a substance that passes from individual to individual throughout the colony and inhibits development of more soldiers.

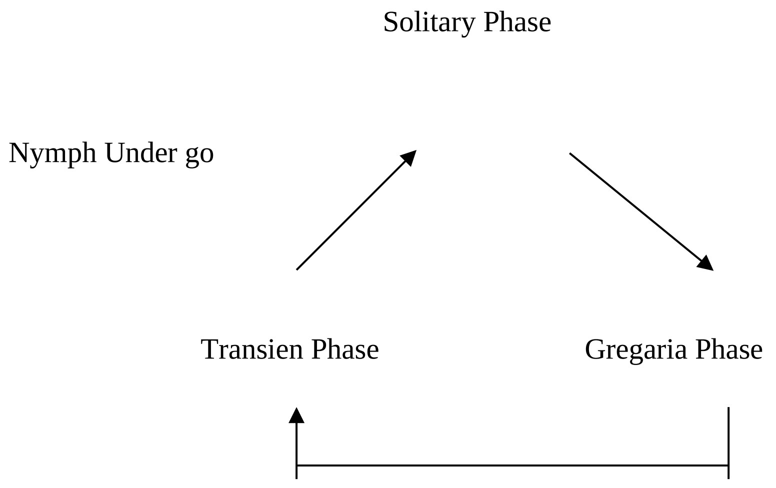
The endocrine system (especially juvenile hormone and ecdysone) is brought to be involved in the expression of polymorphism of termite. The substances that inhibit development in larvae and nymphs apparently exert their effect on the endocrine system; in particular on the balance between juvenile hormone and ecdysone. It is seen that the implantation of additional corpora allata can induce development of larva or nymph into a soldier. With the termites the number of castes is greater than with the social bees, social wasps, and ants; and each caste includes both male and female individuals. The termites differ also from other social whose function is reproduction.

Differences between clonal polymorphism and phase polymorphism

Clonal Polymorphism	Phase Polymorphism
2. It does not depend upon population density.	It is depend upon population density.
3. It is influineed by genetic or phenolypic effect.	It is not influenced by genetic or phenolypic effect.
4. It is live in colony.	It is not live formed colony
5. In clonal polyman 5-6 forms are found namely i) Fundatrices, ii) Fundatrigeniae, iii)Alienicolae, iv) Migrantes, v) Sexuparae, vi) Sexuales	In phase polymorphism 3 forms are found namely i) Solitary phase ii)Gregaria phase iii) Transien phase
Found in aphid only	Found in locust, armyworm, jute hairy caterpillar

Phase Polymorphism/ Polymiorphism of locust

Locust polymorphism is distinct and based on population density. Russian scientist Uvarov (1921, 1927) gave the theory which is known as "Phase theory of locust". According to this theory "Each species of locust exist in two main forms or gregarious phase (phasis gregaria) and the solitary phase (phasis solitaria). Intermediates (phasis transien) also occur during the transition of a population one extreme to the other. These two phases (the solitary phase and the gregarious phase) are often so distinct as to have been regarded by earlier taxonomists as separate species. These two phases, however, are interchangeable. The crowded rearing of solitarian hoppers either by hatching in very large numbers or by the contraction grounds because of climatic conditions form them into gregarious phase and if gregarious hoppers are reared singly they revert back to solitary phase.



Factors effect on formation of swarms:

The formation of swarms depend on

i) The existence of large numbers of adults

ii) Sufficient rainfall for egg laying and their development. Large numbers of eggs then lead to overcrowded nymphs and swarms are formed.

iii) Topography,

iv) Migration behavior and

v) Vegetation of the breeding areas.

vi) Presence of bird predators and other factors may concentrate hopper unto swarms.

Differences between solitary phase and gregarious phase-

The solitary phase	The gregarious phase
i)The solitary phase is characterized in its nymphal instars by the being green, grey or brown and similar to the colour of its normal environment in the adult stage	i)In *gregaria* forms the nymphal coloration is a bold pattern mainly of black and orange
iii)The pronotum is longer and crested	iii)The adult has a shorter saddle shaped pronotum
v)The hind femur is relatively long	v)The hind femur a relatively shorter
vi)Biologically, the most important difference between the phases is the lower activity and solitary tendencies of the solitary phase	vi) Biologically, the most important difference between the phases is the higher activity and gregarious tendencies of the gregaria phase.
vii)Remain scattered and not form swarm	vii)Remain in group and form swarm
viii)Movement of hopper is slow	viii)Movement of hopper is fast
ix) No. of compound eye is 5-8	ix)No. of compound eye is 6
x)Antenna is long and many segmented	x)Antenna is short and no. of segmented is less
xi)Prothorax and mesothorax are small	xi)Prothorax and mesothorax are large
xii) Stage of hopper are juvenile	xii) Stage of hopper are more adult
xiv)This stage is less harmful to crop	xiv)This stage is very harmful to crop
xv)Tegmina is small	xv)Tegmina is large
xvi)Protoracic gland and corpora allata are large	xvi)Protoracic gland and corpora allata are small
xvii)Moulting no. is 4-7	xvii)Moulting no. 5
xviii)Body pigment insectoverdin	xviii)Body pigment is insectorubin I
xix)Respiratory rate is low	xix)Respiratory rate (0_2 uptatke) high

xx)Sexual maturation is slow	xx)Sexual maturation is quick
xxi)Fecundity is high	xxi) Fecundity is less
xxii) Ovariole is large in no.	xxii) Ovariole is few in no
xxiii)Post embryonic development is delayed	xxiii)Post embryonic development is early
xxiv) Females are bigger in size.	xxiv) Females are smaller in size.
xxv)Hatching wt. is light	xxv)Hatching wt. is heavy
xxvi)Feeding behaviors not voracious	xxvii)Feeding behaviors is voracious
xxvii)Longevity of adult is long	xxvii)Longevity of adult is short

Differences between Phase Polymorphism and Social polymorphism

Phase Polymorphism	Social polymorphism
1. Phase polymorphism refers to the presence of two or more forms of an organism in the range of adult form.	When parents and offspring live together in a colony in cluster form and are divided into different caste, then it is called social polymorphism.
2. Two main form with an intermediate are found such as-Solitary phase, Gregaria phase Transien phase	No such forms are present here. Here queen, king, worker and soldier are found.
3. No caste is present here.	3. Insects are divided into 3-4 caste. Among them two are reproductive caste and ½ are sterile caste.
4. Division of labour within the insect species is absent.	4. Division of labour within the insect species is present.
5. Found in locust, armyworm, Jute hairy caterpillar etc.	5. Found in ant, bee, termite etc.

Genetic polymorphism: Genetic polymorphism is of two types, viz, stable, or balanced and transient. Balanced polymorphism is maintained by contending selective forces so that the frequency of each morph reflects the relative strength of these forces. According to Mayr (1963) "it is the genetic polymorphism in which there is a balance of opposed advantage and disadvantage where the beterozygote is favoured compared with both homozygotes”. According to Ford (1964).Transient polymorphism, on the other hand, is a temporary state in a population in which a rare gene with an unopposed advantage spreads until its former normal allele is reduced to a status of a mutant

Differences between Balanced polymorphism and Transient polymorphism:

Balanced polymorphism	**Transient polymorphism**
1) Balanced polymorphism is maintained by opposing selective forces so that the frequency of each morph reflects the relative strength of these forces.	1) It is a temporary state in a population in which rare gene with an opposed advantages spreads until its former normal alleles is reduced to a status of a mutant.
2) It is maintained by super genes.	2) It is maintained by same rare genes.
3) Heterozygote is favored compared with both homozygotes.	3) Heterozygote state is not favored.
4) In this polymorphism there is a balance of opposed advantage and disadvantages.	4) Here remains unopposed advantage with a rare gene.
5) It is always carried to completion.	5) Transient polymorphism may not always be carried to completion.

Difference between Polymorphism and Genetic polymorphism:

Polymorphism	**Genetic polymorphism**
1) Occurrence of more than one distinct form of individuals in a population.	1) Genetic polymorphism is the occurrence of together in the same locality of two or more in such population that two types.
2) It is four types- a) Chonal polymorphism b) Phase polymorphism c) Social polymorphism and d) Genetic polymorphism.	2) It is also four types- a) Balanced polymorphism and b) Transient polymorphism. c) Gene polymorphism d) Chromosomal polymorphism
3) Differences are caused by environmental factors.	3) Differences are the result of inherited characteristics.
4) Example: Sexual dimorphism in insect.	4) Example: Blood group of human being.

Estimation of Population Density

Pest surveillance is the watch kept on a pest for the purpose of decision making. Depending on the kind of pest (native, newly introduced, potential invader), surveillance programs attempt to determine if a pest species is present, to estimate the numbers in a population and their distribution, and to assess how these factors change over time. Long-range migration, local movement, feeding and reproduction are detected and documented through pest surveillance.

An insect pest survey is a detailed collection of insect population information at a particular time in a given area. The survey program may be carried on for an entire growing season or at certain critical periods in the insect life cycle.

Populations: A group of individuals of the same species occupying a given area. The place where a population (or an individual) lives are called its habitat: tree squirrels live in a "forest habitat", muskrats in a "stream bank habitat", and damping in "distributed habitats".

Populations density: Populations density (the number of individuals per unit area) generally varies widely among species living in the same locality. Ecological relationships influence the density of a population. To study these influences, we must determine any changes in space or over time. Density and dispersion are balancing attributes. Density is number of individuals per some unit of measure for example, number of grasshoppers per square meter.

Sampling unit: The sampling unit concept is most easily explained when total counts are taken from a unit area of land surface. For example, direct counts of all the caterpillars in 1 m^2 of alfalfa could be considered a sampling unit. If the caterpillar population occupies 100 m^2, the habitable space is composed of 100 sampling units.

Choice of method of population estimation: Entomologists like to have absolute estimates of pest densties for making management decisions; however, it is generally too costly an investment to obtain these estimates on a routine basis. Once absolute estimates have been established and correlated with pest damage, it is possible to then relate relative estimates to absolute estimates using regression analysis. Then the relative estimates can be used for making management decisions.

Type of estimation-

Surveys may be classified as qualitative or quantitative-

A) Qualitative (observation during quarantine): Surveys are the least complex and are generally aimed at pest detection. Usually, qualitative surveys yield lists of pest species discovered, along with a subjective reference to density; for example, abundant, common, or rare. Such surveys are typical at international ports of entry, states.

B) Quantitative: surveys are the most common type employed in insect pest management. The quantitative survey attempts to define numerically the abundance of an insect population in time and space. Such information is used to predict future population trends and to assess damage potentials.

Population size or abundance is generally expressed in terms of density, which is defined as the number of individuals per unit area or volume. It is seldom possible to observe the total number of insects occupying an area or volume of habitat or we may be more interested in insect activity rather than the actual numbers of insects. There fore, various types of samples are used to estimate population size.

According to South (1978) population estimates can be classed into three general groups 1) absolute estimates 2) relative estimates and 3) population indices .

1)The Absolute Method;

The absolute estimate is the number of insects per unit area or volume such as number of larvae per $m^{2,}$ the number of southern pine beetles per square decimeter of bark area or cubic decimeter of bark volume. Evaluation of the various factors that an influence population of a particular species generally requires that population size is expressed in absolute figures. It is rarely possible to obtain an absolute estimate directly and population size is expressed as intensity. Population intensity is the number of insects per unit area of habitat. The absolute estimate is done in the following way-

a) **In Situ Counts (visual counting method)**

In situ (Latin for "in place") counts, also known as direct counts and direct observation, often require no special equipment but rely on a good eye. With this method, large and mostly conspicuous insects are viewed in the habitat, and counts are recorded. Usually the habitat viewed with this method is the plant canopy, a specific plant part, or a certain region on an animal (for example, the face of a cow). If numbers of insects are relatively low and the plant is small and isolated from adjacent plants (as with seedlings), all insects on the plant may be counted. In this method 30 plants are selected at random from on the diagonal line of the plot and three leaves are selected at random from the selected plant one each from top, middle and bottom parts of the plant.

b)Scoring intensity of infestation- This is usually done in insects with gregarious habits which are small and numerous as in aphids. The terminal part or any part of the plant that harbours aphid colony is scored for intensity of infestation; the score is usually given a numerical value. These score values may be converted in to population by working out standard population for each score value.

c) Knockdown (Shaking/jarring)

Knockdown is closely related to in situ counting, but in this instance, the insects are removed from the habitat by jarring, chemicals, or heating, and then counted. Jarring is probably the most common method of knockdown from plants. It has been used particularly when sampling insects on the lower branches of trees and shrubs. Here a cloth, tray, or other receptacle is placed on the ground, a branch is pulled down over the receptacle and the branch is struck a prescribed number of times with a stick.

2. Relative method : A relative estimate is a population measurement based on units other than area or volume and is usually expressed as catch per unit of effort, for example a number of weevils per 20 sweeps, or number of moths caught per pheromone trap or "sticky trap" in a 2-hour period. Relative estimate are often used in studies of insect dispersal. The relative estimate is done in the following way-

This method includes capture and counting the proportion of insects per some unit of land or area. It is an elaborate method.

a) Sweep net method- This method is commonly followed for highly mobile insect like, jassids, grasshoppers, bugs, etc. The standard sweep net is 42 cm in diameter and its use is determined with reference to the nature of plant. For plant with a close planting, viz paddy, legumes etc, a sweep with an 180^0 is over the crop is used. For row crops, such as cotton a sweep with a pass of the net across the plants on a single row is used

b)Quadrate method: A Quadrat is the basic sampling unit, typically 1 m^2 used to sample grassland and old-field plant communities.

In this method a small area or quadrates are selected at random from a big area which contains the population. A large number of quadrates are necessary for over – dispersed population than that in the randomly spread population. From a quadrate, the insects may be counted or collected directly as in the case of fairly motionless but comparatively large insects such as cutworms, caterpillars and grasshoppers. In case of tissue borers such as sugarcane borers, etc, the estimation is done by first removing the infested plants from the quadrates and then counting them after splitting open the plant parts

c) **Line transects method:** If one walks in a directly line at a frequent speed from first to last a habitat, the number of individuals can be counted. This method is used for quantitative comparisons both between different species, and between different occupiers of habitats. The data based on number of encounters have been used for estimating the absolute population of locusts and grasshoppers.

d) Use of trap-The following trap may be use for population estimation-

i)Sticky trap
ii)Light trap
iii)Windowpane trap
iv)Pit fall trap
v)Trap with attractant
vi)Vacuum trap
vii)Malaise trap

3) Population Indices Method

In all sampling techniques discussed previously, data for estimating population size were expressed as numbers of insects. Estimates can also be made from data on insect effects or products. Such estimates are often called population indices.

A population indices (or index method) the insect population is not count at all, but an estimate based on products of insect activity, such as webs, dead trees, frass and exuviae. An example of population index often used in surveying bark beetle activity is the number of “red tap” (tree with discoloured crown) pine trees observed per 1000 acres of host type. The Population indices estimate is done in the following way-

Damage count- This method is most often followed for borers or other infernal feeders. In this method the number of fruits damaged or shoots showing damage symptoms are counted in the sample and expressed in terms of percentage of infestation or number of fruits. shoots damaged in unit area when the stand of the crop is uniform. The damage is also sometimes related to the population of insects.

Numerical calculation population estimation: Measuring the effects in probably the most common method of indexing an insect population. Root rating schemes indicating the feeding of corn rootworms, percentage defoliation of soybeans, numbers of plants cut by cutworms, and number of plants with tillers or "dead heart" caused by borers are all examples of index data. Such data, of course, are paramount in determining the economic impact of insects on the crop.

For this estimate, we must consider the number of sampling units taken. This estimate is called the standard error of the mean or simply standard error. It is calculated as:

$S_{\bar{x}} = \frac{s}{\sqrt{N}}$ where, $S_{\bar{x}}$ = standard error, sometimes designated SE, S = standard deviation of the sample numbers, N = number of sampling units taken

An important characteristic of the standard error is that its magnitude decreases as the number of sampling units increases. This statistic is particularly important in insect sampling programs.

Reproduction strategies

South wood 1961 classify insect pest as k-pest, r-pest and r-k pest. The two parameters of the logistic equation (the intrinsic rate of increase, and the carrying capacity, K) are also used to characterize development strategies for animal and plant populations. There are a number of different attributes associated with insect (and other animal) species designated as r or k strategists. r-pest also known as r-selection pest and k- pest also known as k-selection or k-strategists pest. Differences between r--pest and k- pest are given in a table-

r-selection/r-pest	**k-selection/k-pest/k-strategists**
i) Rapid development and growth rate	i)Slow development and growth rate
ii) Rapid rate of increase	ii)Low rate of increase
iii)Early maturity and reproduction	iii)Late maturity and reproduction
iv)Take maximum food in short time	iv) Take minimum food in short time
v)Living in a temporary habitats (ephemeral)	v)Live in a stable habitat
vi) Iteoroparity (repeated reproduction)	vi) Semiparty (single reproduction)
vii)Generally mobile and migratory	vii)Generally less migratory
viii) Short life cycle (a few weeks), and many offspring.	viii)Long life cycle (usually several months, few and larger offspring)
ix) Small body size	ix)Large body size

x) Competition usually high	x) Competition in variables, commonly low
xi) Population variable in size, non- equilibrium, usually below the carrying capacity	xi) Population size fairly constant, equilibrium, at or near the carrying capacity.
xii) Periodic recolonization.	xii) No reclonization.
xiii) Mortality catastrophic, usually density independent.	xii) Mortality more evenly density dependent.
xiv) Niche generalists.	xiv) Niche specialists.
xv) Low trophic level	xv) High trophic level
xvi) Adapted to unstable environment	xvi) Adapted to stable environment
xvii) Little parental care and protection	xvii) High parental care and protection
xviii) Have more natural enemies	xviii) Have fewer natural enemies
Example-Ant, house fly, antelope etc.	Example-Bald eagle, elephant, cheetah, shark etc.

Dispersion

Dispersion also known as /distribution in space/ spatial dispersion (distribution)/ spread/ distribution. The term dispersion refers to the internal distribution or pattern of occurrence of individuals in a population over an area. It is a local movement within a favorable area. It is the spatial (in space) pattern of distribution of individuals in a population. When the density of a species in a particular habitat is known; it don't know how the individuals are distributed (arranged) in space. They might be clumped together in certain parts of the habitat, distributed randomly throughout, or spread out rather uniformly.

Example of dispersion according to Hill (1989)

i) Tribolium confusum females release a pheromone in the foodstuff they infest which repels other females and ensures a uniform population distribution throughout the available space.

ii) It is thought that the female apple fruit fly leaves a pheromone trace on the apple surface after oviposition for she can be seen to drag her ovipositor over the surface and generally

iii) It seems that some dispersal secretions are the same as the defence secretions; for instance, nymphs of *Dysdercus* produce stinking coxal gland secretions when disturbed (thought to be a defence against predators) which causes the gregarious bug nymphs to

scatter.

iv) Certain species of ants have alarm pheromones which in some circumstances (in the nest) induce aggregation but under other conditions (away from the nest) result in dispersal.

Causes of dispersion: Most types of population dispersion occur due to a number of reasons such as-

a) For obtaining food,

b) Avoiding predators,

c) Preventing overcrowding,

d) Result of action of wind and water (environmental reasons)

f) Secretion of some hormone of for interchange of genetic material between population.

Individuals in a population any be distributed or dispersed according to three basic patterns such as- 1.Uniform distribution

2.Random

3.Clumped

1.Uniform or regular distribution:

i)A regular distribution is one in which individuals are uniformly spaced.

ii) competition among individuals for a limited resource seems to be the cause.

iii) Nearly uniform distribution (even spacing), as typified by orchards, is exceedingly rare in nature.

iii) In this ease-the occurrence of individuals is regular which is more regular than random distribution. iv) the population is distributed one after another in this way.

v) Here the mean of aggregation is more than the variance.

Here x^2 = mean and

b^2 = variance

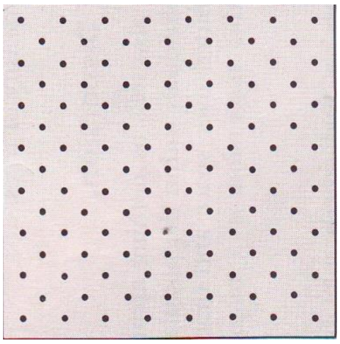


Fig : Uniform aggregation

vi) An example- For the few cases in which uniformity is approached, An example is the nearly uniform spacing of creosote bushes (*Larrea*) in dry scrub deserts of the sort occurring in the American Southwest. Large, mature plants deplete the soil around them of available water, and seed-eating ants and rodents concentrate their activities near the plants. As a result, seeds and seedling are unable to survive near mature plants, so clumps do not form.

ii) **Random aggregation/ distribution**:

Randomness that an insect is as likely to be found in one place as another.

i)A random distribution is one in which individuals within a population have an equal chance of living anywhere within an area.

ii) When the environment is too more uniform then this type of aggregation is seen.

iii) the occurrence of individuals happened on the whole area.

iv) occurrence of insects is randomly.

v) In this condition the tendency of aggregation of insects is low.

vi) Spiders on a forest floor may be an example of random spacing among individuals.

vii) the mean of aggregation is equal to the variance. i. e.

$X^2 = b^2$ where x^2 = mean and

B^2 = variance

Some invertebrates of the forest floor, particularly spiders, the clam *Muhnia lateralis* of the intertidal mud flats of the northeastern coast of North America, and certain forest trees (Pielou 1974) appear to be randomly distributed.

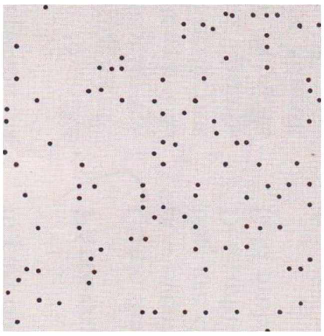


Fig : Random aggregation

3) **Clumped distribution/ Aggregations:**
The term aggregation or temporary aggregation is usually applied to a group of animals which come together for some external reason.

i)A pattern of distribution in a population in which individuals have a much higher probability of being found in some areas than in others; in other words, individuals are aggregated rather than dispersed.
ii) It is a common aggregation of individuals.

iii) In this case the individuals remain in grouped in a definite way.

iv) Most insect populations are said to have clumped of aggregated dispersions. For example, the offspring of an organism settle near their parents and one another; for example the offspring of gypsy moths and other insect pests often spread slowly from the original point of infestation.
v) Here the mean of aggregation less than variance. i. e. $X^2 = b^2$ where

x^2 = mean x` B^2 = variance

When the variance is higher than the mean then the individual are highly aggregated. This type of aggregation is found in aphid.

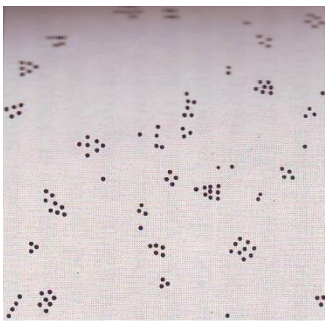


Fig : Clumped aggregation

Dispersal

Dispersal is movement away from the place of birth or origin to another area, movement of individuals or their disseminules (seed, larvae, spores) into or out of a population or of an area. It is the movement from one favorable area to another favorable area. Movement is regular and adaptive part of the biology of most individuals within an individual species. All insects move by spread and dispersal sometime during their life cycle but

The major adaptive feature of insect dispersal and migration are:

ii) Mechanism for escape from environments that become unfavorable

iii) Dispersal into other habitats, and

iii) Colonization of favorable habitats

Advantage of dispersal:

Dispersal has several important functional roles in population dynamics:

i) It permits colonization of new habitats
ii) It allows for exploitation on new food resources and

iii) It may constitute to livable of mate finding

Disadvantage of dispersal

Dispersal hinders population persistence and help mortality; mortality can occur:

i) As a result of depression of the insect or unsuitable hosts or sites

ii) By expenses of the insect to natural enemies iii) By exposures to unfavorable weather condition.

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Factors effecting on dispersal: The means of dispersal of insects differ according to species and environmental conditions and are both active and passive.

i)Active factor: Active of dispersal are common in insects with well developed power of locomotion. The legs of most insects are, however, adapted for the special media, such as soil or water, in which the insect habitually lives. Dispersal by active locomotion is thus generally limited in most species. Active dispersal caterpillars of certain moths move in huge swarms over great on wings in limited generally by the velocity and duration of flight of a species. (Mani-19)

ii)Passive factor: The passive means of dispersal is of considerable importance in the distribution of nearly all insects and has probably played a significant role in the origin of many characteristic patterns of distribution. A large number of insects are dispersed by wind, running water, etc. Even light wind is and important factor in wide dispersal of delicate insects, but heavy bodied insects like grasshoppers, locusts, beetles, etc. are also carried over great distances, across continents and oceans by strong winds.

Barriers of dispersal/ limiting factors:

The principal limiting factors in the distribution of most insects are historical, climatic and geographical. Most insects are specifically adapted for definite climatic conditions and vegetation types, so that they are unable to get across any large unfavorable climatic barriers or absence of suitable vegetation. Most insects are, for example, unable to overcome the climatic barriers from the tropical to arctic zones.

Most phytophagous insects are bound to specific groups of plants, son that their distribution is severely limited by the distribution of the food-plant. Petrophile insects are, for example, unable to overcome the barrier due to absence of rocks. (Mani-19)

Oceans seem to be effctive barriers to the distribution of insects. Narrow arms of sea are naturally effective barriers for the distribution of wingless insects. Even for many winged species, narrow strais are effective barriers. In the case of other species large oceans, which separate continents, may be considered as barriers (Mani-19)

Type of dispersal

a) Migration
b) Emigration
c) Immigration

Migration:

Migration is a peculiar kind of population dispersion which involves the mass movement of entire population. Migration like dispersal involves movements and the invasion of new areas. However, migration differs from dispersal in that it is periodic and mass movement back and forth between two areas (dispersal being one-way outward movement). **Migrations also classified as-**

a)Emigration(movement out of an area)**:**Emigration under natural conditions occurs when there is overcrowding in the migratory locust.

b)**Immigration** (movement into an area)**:** Immigration leads to a rise in population level, causing an overpopulation which may lead to an increase beyond the carrying capacity. These immigrations result in increased mortality among the immigrants or decreased reproductive capacity of the individuals. Both emigration and immigration are initiated by weather and other biotic and biotic environmental factors.

Measurement of migration

According to Pedigo (2002) change in numbers from one time to the next and from one place to the next is one of the most prevalent properties of any population. A widely used expression with the primary factors of this change is:

$$Nt=N_0e(b\text{-}d)t\text{-}E_t+I_t$$

Where,

N_t = number at the end of a short time period

N_0 — number at the beginning of the time period

e = base of natural logarithms = 2.7183

b = birthrate

d = death rate

t = time period

E = emigration = movement out of an area

I = immigration — movement into an area

The expression is a general model of change in any population and shows the mathematical relationship among the primary factors of this change: births, deaths, and movements.

In attempting to explain population numbers, we must account quantitatively for these primary factors. *To* attempt prediction of change, however, we must understand how environment modifies these primary factors.

The effective environment of a population can be thought of as having an array of secondary factors that determine the magnitude, duration, and frequency of the primary factors. Some secondary factors are weather, natural enemies, breeding habitat, and overwintering space. These affect the primary factors by altering the supply of necessary resources or directly affecting the existence of individuals.

Difference between immigration and emmigration

	Immigration	**Emmigration**
i)	Coming of insect/ animal within a population	i) Go out of insect/ animal within a population
ii)	The process occurs when foods and habitats are favorable	ii)The process occurs when foods and habitats are unfavorable
iii)	Population density increase	iii)Population density decrease
iv)	Many immigrated population die and reproduction decrease	iv)Death rate decrease and birth rate increase
v)	Here competition increase for food and habitat	v) Here competition decreases for food and habitat
vi)	Incase of insect it has a bad effect on the crop. So, application of insecticides is needed	vi) Due to enmigration insect population is decrease. So no need for application of insecticides.

Migrations also classified as-

Migrations may be annual or daily or may be in the from of changes of habitat at different stages in a life cycle,

i) daily migrations r is called metamorphic migration and occurs in dragonflies,

ii) Annual migration is best developed in birds but also occurs in mammals, fish and insects.

iii) Anadromous Animals that migrate from sea to fresh water are called anadromous. For e xample, some marine fishes migrate from sea to river for spawning, such as-Ilish. anadromous may be latitudinal, latitudinal or local.

Migration can occur only in mobile organisms and best developed in insects like-

i) the migratory dragonflies *Libellula quadrimaculata* and *Pantala flavescens*;

ii) Desert locusts,

iii) Female mosquito,

iv) Hairy caterpillars,

v) Aphids

viii) Scales insect.

vi) The butterfly monarch-*Danaus plexippus*, travel very long distances and their same conventional routes and their migratory movements are initiated by the oncoming winter and thew return trip being influenced by spring viii)in fishes like eels,

vii) Convergent lady beetle, *Hippodamia converges*.the convergent lady beetle. During May and June the young adults of the convergent lady beetle migrate from their feeding sites in the Central Vaelly of Califronia to overwintering sites in the Sierra Navada mountains. The beetles return the following February and March to reproduction and feeding sites in the Central Valley

Difference between population dispersion and population dispersal

Population dispersion	**Population dispersal**
i) Movement of insect by a medium ii)Scattering in different direction iii)Take place accidentally or certainly	i) Movement of animal by a medium or by locomotion such as swimming or walking or flying ii)Direct toward a place iii)Take place for feeding, breeding or other requirements iv)It is a regular sequence v)Take place with long distance

iv)It is not a regular sequence v)Take place with a short distance vi)All portion do not move vii)It has different pattern	vi)All visible portion move vii) Normally no pattern.

Difference between population migration and population dispersion

Population migration	**Population dispersion**
i) Migration is the movement of whole population ii) May not back to the original place iii)Survival rate is higher iv)migration population live for a long time v) Take place for breeding vi) It is regular way.	i) Dispersion is the movement of certain population (not whole) ii) May back to the original place iii)Survival rate is lower than migration iv) Migration population live for a short time v) Take place for breeding, feeding and other purpose. vi) No regular way.

Density independent and density independent factors

Besides the division of environmental factors into physical and biological groups, such factors may also be classified as to whether they operate in a density dependent or density independent fashion.

a) Density-dependent factor Biotic factors in the environment, such as disease and competition, are often called density-dependent factors because their effects on populations may be related to, or depend upon, local population density. It implies the presence of some type of control mechanisms what is from negative feedbacks. It is known delayed density dependent factors or increase density dependent factors. Predators and parasites, Disease, Quantity of food, Living space. Most ecologist agree that density dependent regulators are essential in conferring stability on biological system since they exert correspondingly greater effect as an organism's numbers increase and thus tend to return the population to a lower level. To use a modern expression, they operate on a negative feedback basis.

b) Density-independent factor: If a factor exerts a similar influence regardless of the density of the population concerned it is said to be density independent. Thus temperature has a similar effect whether there is one insect involved or a thousand abiotic factors in the environment, such as floods and extreme temperature, arc often called density-independent factors because their effects on populations may be independent of population density. Quality of food, Climate, especially temperature, Soil type (for soil inhabiting insects).

Difference between Density-Independent factors and Density-dependent factors

Density-Independent factors	**Density-dependent factors**
ii)It is known as population modifying factors or density legislative factors ii)It is most references to the factors on mortality (death rate) iiii) Catastrophic weather (which affect on mortality), harvesting of crop or a forest fire, pesticide application are the examples of density independent factors those suppress populations numbers. iv) It is a quick control method	i)It is known as population regulating factors or density-governing factors. ii)The term indicate that the direct effect of a factors the birth rate (natality) or death rate (mortality) iii) Use of biological agent (artificial or natural), mechanical, physical method to reduced pest population reduce pest is known as density dependent factors. iv) Delay or slow control method

Trophic structure:

The organization of a community in trophic levels based on the number of feeding or energy shift levels is called trophic structure. The structure of food chain phenomena (energy loss at each transfer) and the size-metabolism relationship results in communities having a definite trophic structure. Trophic structure may be measured and described in terms of standing crop per unit area or in terms of energy fixed per unit area per unit time at successive trophic levels. Trophic structure and function may be shown graphically by means of ecological pyramids in wh[i]ch the producer level forms the base and successive trophic levels the tiers which make up the apex.

Trophic level: Feeding level; working categorization of organisms in an ecosystem according to feeding relationships; for instance primary producer, primary consumer, secondary consumer, tertiary consumer, and so forth.

i) Green plants (the producer level) occupy the first trophic level.

ii) Plant eaters the second level (the primary consumer level).

iii) Carnivores which eat the herbivores, the third level (secondary consumer level)

iv) Secondary carnivores the fourth level (the tertiary consumer level).

Some terms about Trophic.

Trophic (feeding) biology: The study of the feeding biology of organisms.

Trophic dynamics: Transfer of energy from one trophic level (or part of an ecosystem) to another (for example, primary producer to secondary consumer); functional classification of organisms in an ecosystem according to feeding relationships.

Trophic niche: Working rank of a species based on trophic level or energy association.

Food chain

Movement of energy (energy pathway) and nutrients from one feeding group of organisms to another (proceeding from producer to consumer) in a series in ecosystems.; a feeding sequence such as grass zebra lion used to describe the flow of energy and materials in an ecosystem. It begins with plants and ends with carnivores, detritus feeders, and decomposes.

It is the transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain. At each transfer a large proportion, 80 to 90 percent of the potential energy is lost as heat. Therefore the number of steps or "links" in a sequence is limited, usually to four or five. The shorter the food chain, the nearer the organism to the beginning of the chain, the greater the available energy.

Food cycle: Old concept now replaced with concepts of nutrient cycles (nutrients being the food) and energy flow.

Food chains are of two basic types:

i) **Grazing food chain**: Grazing food chain which, starting from a green plant base, goes to grazing herbivores (i.e., organisms eating living plants) and on to carnivores (i.e., animal eaters).

Autotroph (Green plant)→Primary consumers (Cow, Goat, Deer etc.) → Secondary consumers (Toad, Birds) → Tertiary consumers (Snakes) → Final/Last consumers (Eagle)

ii) **Detritus food chain**: Dead or partially decomposed plant and animal matter; nonliving organic matter is known as **detritus** and the organisms that feed on nonliving organic matter (dead or decaying organic matter), usually on the remains of plants (such as earthworms) is known as detritivores**.**

Detritus food chain is the food chain in which the primary producers are not consumed by grazing herbivores, but where dead and decaying plant parts from litter on which decomposer (bacteria and fungi) and detritivores feed, with subsequent transfer of energy thought the detritus food chain.

Detritus food chain, which goes from dead organic matter into microorganisms and then to detritus-feeding organisms (detritivores) and their predators.

Detritus (Dead organism)→Microorganisms (Bacteria, Fungi) →Microorganisms feeders such as Earth worm, Mollucks.

iii) Nectar food chain: Food chain originating from the nectar of flowering plants, commonly dependent on insects and other animals for pollination.

Types of food chain: Generally there are three basic types food chain:

iv) Predator food chain: which, starting from u green plant base, goes to grazing herbivores (i.e., organisms eating living plants) and on to carnivores (i.e., animals eaters). As the chain larger the size of the organism also becomes larger.

E.g. Algae → Puti or mola → Boal→ Men

v) Parasitic food chain:

Which, starting from plant or animal. Here the chain start from larger organism and end to smaller organism.

E.g., Men→ Worm, Cow →*Argulous*

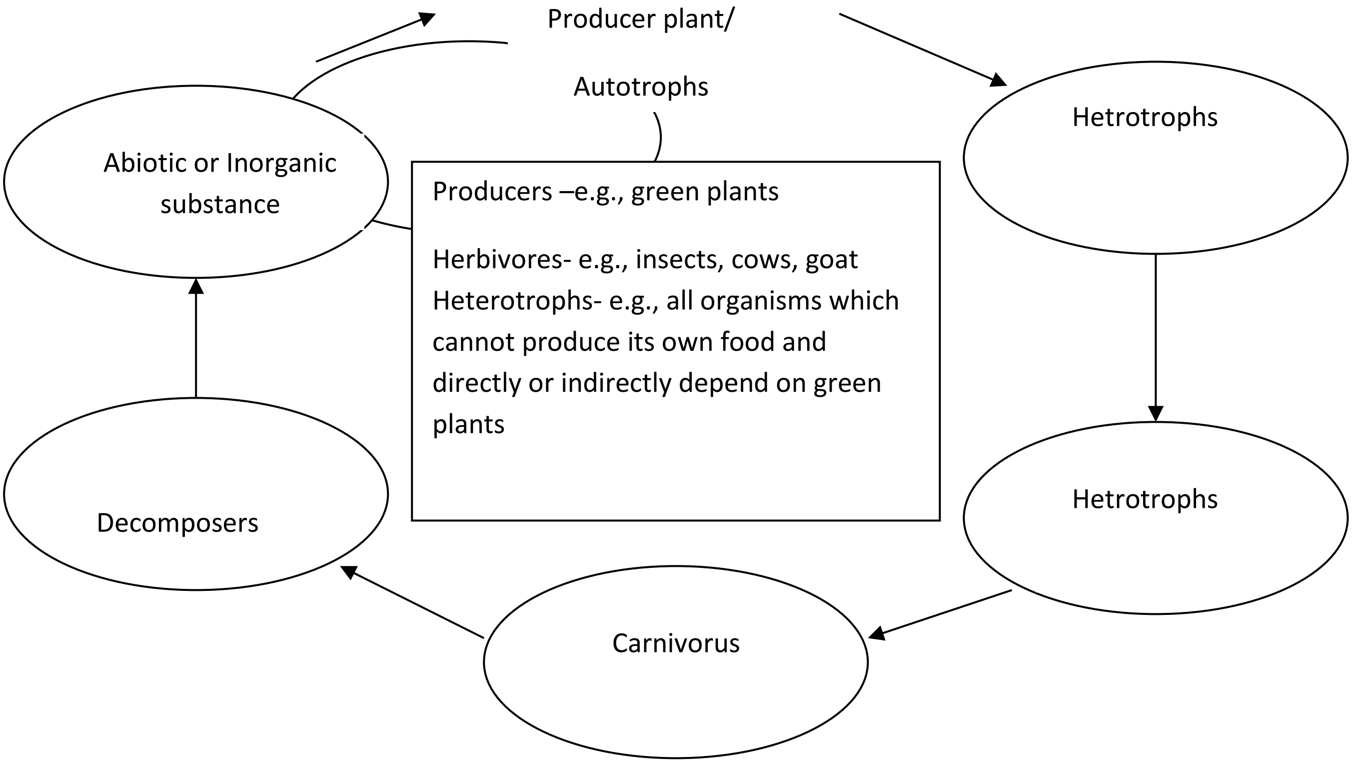

Fig. Schematic representation of food chain

Food web:

None organism lives wholly on another; the resources are shared, especially at the beginning of the chain. The marsh plants are eaten by a variety of invertebrates, birds, mammals, and fish; and some of the animals are consumed by several predators. Thus food chains become interlinked to form a food web, the complexity of which varies within and between ecosystems. Food chains are not isolated sequences but are interconnected with one another.

So, interlocking pattern formed by a series of interconnecting food chains (intertwined food chains). It is a summary (or model) of the feeding relationship within an ecological community.

Pine tree→Catrpillar→Ichneumonid wasp→Spiders→ Spider wasp; Pine tree→Aphid→Lady beetle→Spiders→ Spider wasp (Elton,1977)

Niche

Niche: Also called an ecological niche. An organism's place in the ecosystem: where it lives, what it consumes, what consumes it and how it interacts with all biotic and abiotic factors. It is the way in which an organism obtains its resources; the 'occupation' of an organism as contrasted with its 'address' or 'habitat'.

Closely another with the concept interspecific competition is the concept of niche. Functional role of a species in the community including activities and relationship (Smith, 1990).The way in which an organism obtains it resources; the occupation of an organism as contrasted with its address or habitat is called niche of a species(Ehrlich and Roughgandon, 1987). It is the is the subdivision of the environment occupied by a species (Smith, 1990)

These three aspects of the ecological niche can be conveniently designated as the spatial or habitat niche, the trophic niche and the multidimensional or hyper volume niche. Consequently, the ecological niche of an organism depends not only on where it lives but also on what it does. By analogy, it may be said that the habitat is the organism's "address," and the niche is its "profession," biologically speaking. There three types of niche are described bellow-

Habitat or Spatial Niche: functional status of a species in its habitat expressed as a spatial dimension. It represent the ultimate distributional or spatial unit occupied by a species, each of the species may be combined to its own microhabitat. Because no two species in the same general teritory can occupy for long identically the same ecological niche. For example, three species of scotylid beetles attack the while pine, *Pinus strobus* in the N. E. United States *Dendroctonus valeus* is restricted in its attack to the base of the tree, the smaller Ips pini to the upper trunk and large branches, while the smallest species, *Paityogenes hopkinsi*, only enters to the bark of the smaller branches (Davies, 1988).

Trophic Niche (different food): In this case two species live in the same habitat but they occupy different trophic niches (different food), because of differences in food habits. For example, two aquatic bug, *Notonecta* and *Corixa* live in the same pond, but occupy different trophic (food) niches. The former is an active predator that swims about grasping and eating others animals but latter feeds mainly on decaying vegetation.

Multidimensional or hyper volume niche: In 1975a, G. E. Hutchinson suggested that the niche could be visualized as a multidimensional space or hypervolume within which the environment permits an individual or species to survive can designate as the multidimensional or hyper volume niche, is amenable to measurement and mathematical manipulation. For example, the two dimensional climographs "climatic niche" of a species of bird and a fruit fly, could be expanded as a series of coordinates to include other environmental dimensions. He (Hutchinson) has also made a distinction between the fundamental niche-the maximum "abstractly inhabited hypervolume" when the species is not constrained by competition with other and the realized niche a smaller hypervolume occupied under biotic constraints.

Fundamental niche: Fundamental niche is the Niche in the absence of interspecific competition; a niche that determined in the absence of competitors or other biotic interactions such as predation; total range of environmental conditions under which a species could survive.

Fundamental niche determined in the absence of competitors or other biotic interactions such as predation; total range of environmental conditions under which a species could survive.

Realized niche: Realized niche portion of fundamental niche space occupied by a population; this niche determined in the presence of competitions and other biotic interactions, such as predation. It is a actual niche of a species. This Hutchinson termed the multidimensional space or hyper volume. He also recognized the following two niches: the fundamental niche which is the maximum abstractly inhabited hypervolume when the species is not constrained by competition with others.

Niche overlap: When two different organism use a portion of the same resource, such as food, these niches are said to overlap. Overlap may or may not indicate competitive interaction.

Niche width: The range of resources used by an organism suggests its. Species with broad niches are considered generalist species, whereas those with narrow niches are considered specialists.

Niche assembly theory: Hypothesis that ecological communities are equilibrium groupings of competing species, coexisting as each species is the mainly effective competitor in its own niche.

Ecological pyramids

Ecological pyramids may be of three types:

i) The pyramid of numbers : (or diagram) that act for the number of organisms present at each trophic level of an ecosystem, frequently termed the Eltonian pyramid, attributed to Charles Elton a British ecologist. Observation that food chains run in parallel with animals at any level having comparable size and relative abundance the animals high on the food chains being both large and rare. The number of organisms are depicted. In a predator food chain numbers of individuals are greatest at the producer level, less at the herbivore level, and smallest at the carnivore level. Both the numerical and size relationship is inverted in food chains. Model Observation that food chains run in parallel with animals at any level having comparable size and relative abundance the animals high on the food chains being both large and rare. It is a graphical representation of the number of organisms of different species at each trophic level in an ecosystem.

ii) **The pyramid of biomass**: Model (or diagram) that represents the quantities of standing crop biomass at different trophic levels of an ecosystem. The weight of living substances (protoplasm) in an organism, a population or a community is the biomass. There is a progressive reduction in total biomass for each successive level.

The number and biomass pyramids may be inverted (or partly so), that is, the base

may be smaller than one or more of the upper tiers if producer organisms average smaller than consumers in individual size. It is a graphical representation of the amount of biomass (organic matter) at each trophic level in an ecosystem.

Inverted pyramid of number is the Situation in which more individuals at one trophic level exist than at the trophic level beneath.

iii) **The pyramid of energy**: It is the representation the of energy flow through the different trophic level of an ecosystem. In the pyramid of energy, the rate of energy flow or "productivity" at successive levels is shown. The energy pyramid must always take a true upright pyramid shape, provided all sources of food energy in the system are considered.

iv) Gashed pyramid: Population pyramid in which certain cohorts are missing or rare.

Life table

Life table**:** The examination of a pest population and it is separation into the different age group components, i.e. egg, larvae, pupae and adult and calculation of mortality for that pest population is known as Life table. A group born at the same time is called a cohort. A life table made from data collected in this way is called a cohort life table.

On the other hand life history consists of the adoptions of an organism that influence aspects of its biology such as the number of offspring it produces, its survival, and its size and age at reproductive maturity.

Static life table: A life table constructed by recording the age at death of a large number of individuals; the table is called static because the method involves a snapshot of survival within a population during a short interval of time. Static life table a second way to estimate patterns of survival in wild populations is to record the age at death of a large number of individuals. This method differs from the cohort approach because the individuals in your sample are born at different times. This method produces a static life table.

Age distribution: The age distribution of a population reflects its history of survival, reproduction, and potential for future growth. Population ecologists can tell a great deal about a population just by studying its age distribution. Age distribution indicates periods of successful reproduction, periods of high and low survival, and whether the older individuals in a population are replacing themselves or if the population is declining. Age distribution is the particular proportions of individuals in different age groups at a given time. For instance, in early season the age distribution of an insect population may be adults, 75 percent; eggs, 20 percent; and first-stage larvae, 5 percent. This distribution would change to mostly eggs and larvae as time progressed, and so on.

The probability of death usually changes with age. Moreover, the reproductive rate and the probability of migration to another population of the same species vary with age in different ways from one species to the next. The study of such age specific patterns is the subject of demography.

Life tables are created to summarize the age-specific patterns of birth and death for a particular population in a particular environment. Typically ecologists follow the fate of a group of newborn individuals until the last one dies. A life table combined wit a fecundity schedule can be used to estimate net reproductive rate (R0), geometric rate of increase (λ), generation time (T), and per capita rate of increase (r).

Survivorship curves: Based on studies of survival by wide variety of organisms, population ecologists have proposed survivorship curves. Life table can be used to draw survivorship curves (a survivorship curve summarizes the pattern of survival in a population), which generally fall into one of three categories (i) type I survivorship, in which there is low mortality among the young but high mortality among older individuals. This is the pattern of survival we saw in populations of Dall sheep, *P. drummondii*, and rotifers (ii) type II survivorship, in which there is a fairly constant probability of mortality throughout life, American robins, white-crowned sparrows, and common mud turtles show this pattern of survival and (iii) type III survivorship, in which there is high mortality among the young and low mortality among older individuals. The desert plant *Cleome* provides an excellent example of a type III survivorship curve.

A second way to estimate patterns of survival in wild populations is to record the age at death of a large number of individuals. This method differs from the cohort approach because the individuals in your sample are born at different times. This method produces a static life table.

Important of life table:

i) The construction of life tables for a pest species is an important component in the understanding of its population dynamics

ii) The essential information needed to understand and interpreted the factors affecting population density may be summarized in a life table

iii) A clean systematic picture of mortality and survival is best provided by a life table (Smith, 1990).

From the table given below it may be seen that of the initial populations of 200 eggs per 10 m2, fewer than six (6) adults finally escaped all the succession deaths that are tabulated for each of the immature stage, table such as this may be contracted for each of several successive generations. In this way it may be seen whether a particular stage of life cycle is always accompanied by a high mortality or whether the different causes of mortality exert effect which vary in relative importance from season to season.

Stage	Number of per 10m2	Percentage mortality	Survival ratio	K
Egg	200.75	-	-	-
Instar I	15.86	92.1	0.079	1.102
Instar II	11.42	28.0	0.72	0.145
Instar III	8.68	24.0	0.76	0.119

Instar IV	6.60	24.0	0.76	0.119
Adult	5.80	12.10	0.879	0.056

Table- a life table for the Acridid grass hopper *Chorthippus branneus* in southern England for a single season (1947-8).

K (Key factors that change population density) = $k_1 + k_2 + k_3$ ------------- + k_n

The Degree-Day Method of Pest Management

According to Pedigo (2002) degree days represent the accumulation of heat units above some temperature for a 24-hour period. Below this minimum, no development takes place, but above it, heat units, are accumulated toward development. For degree-day accumulation, if the developmental minimum, or threshold, of an insect is 15^0C and the average temperature for the day is 27^0C, then (27^0C- 15^0C) 12 degree days, would have accumulated on that day. It is symbolized as DD of ^{0}D.

Thermal constant: Thermal constant is the number of degree days required for an event to occur. To predict the stage of development from degree days, the thermal constant for an event must have been established. For instance, the thermal constant for egg to adult development f the painted lady butterfly, *Vanessa cardui*, is 440 Celsius degree days, but for the seed corn maggot, it is 376 Celsius degree days. Developmental threshold for these insects are 12^0C and 4^0C, respectively.

The main difference among workers in making degree day calculation is in computing average daily temperature. The following formula has been devised to calculate degree days for a specific date:

$$DD = \frac{MaximumTemp. + MinimumTemp.}{2} - DevelopmentalThreshold$$

i.e. DD = Average Daily Temperature – Developmental Threshold.

Limitations of the degree-day method:

According to Pedigo (2002) limitations of the degree-day method are given below-

i) Although the degree-day method has been useful in the management of many insect pests, it is not always applicable. For such pests as corn rootworms, *Diabrotica* species, developmental time can be predicted best by date, without considering temperature.

ii) Research information on degree-day requirements is not yet available for many insect species.

ii) Other limitations of the degree-day method relate to accuracy. Accuracy of degree-day accumulations depends on the temperature measurements used in the calculations. Consequently, degree-days should be calculated with temperatures that represent environments where the species is present.

Table 1: Degree Day Requirements (thermal Constants) for Certain Activities of the European Corn borer.

Stage	Activity	Degree Days
First Generation		
Egg	Peak egg hatch	100
1st-2nd instars	Leaf feeding	200 +
3rd instar	Stalk boring	350 +
4th instar	Stalk boring	400 +
5th instar	Stalk boring	550 +
Pupa	Peak pupation	900 +
Adult	Egg laying	1150-1700

(Source:Pedigo, 2002)).

Diapause

Diapause is arrested development induced by certain factors in advance of adverse conditions; the arrested development persists for some time after the adverse conditions pass. It is a resting state (period of dormancy) of an insect usually seasonal, in which development is cease and little energy is used and metabolism is greatly decreased. Insects often enter diapauses prior to a period of unfavorable environmental conditions.

Hibernation: Animal can go into a state of reduced metabolism that may last several months. If this state occurs mainly in winter, it is called hibernation**.** if it occurs in summer, it is called estivation**.**

Torpor: Torpor is a state of low metabolic rate and lowered body temperature. During torpor, a hummingbird's body temperature is about120 to 170C, quite a reduction from 390C. Because this lower body temperature is a direct consequence of a lower metabolic rate, hummingbirds in torpor save a great deal of energy.

Types of diapause

There are two types of diapause:

i) Obligatory : Obligatory diapause is genetically controlled and affects every individual of every generation within a species regardless of environmental conditions. Insects with one generation per year and most insects living in temperate regions have developed obligatory diapause.

ii) Facultative diapause: Facultative diapause may or may not occur within a given individual or population of a species and depends entirely on the environmental conditions prevailing during critical stages of development. For example, many aphids have cycles with several continuous parthenogenetic generations, followed by a sexual generation, and an overwintering diapausing egg stage induced by temperature and photoperiod conditions

Factors effect on diapause-

Diapause has allowed insects to live in areas that are unsuitable for them during certain periods of the year. The most common factors are i) photoperiod, ii) temperature, ii) maternal physiology, and iv) the quality of host food.

Characterization of Diapause:

Characterization of Diapause are- i) low metabolism, ii) little or no development, iii) increased resistance to environmental extremes, and iv) altered (often greatly reduced) behavioral activity.

Mechanism of diapause:

Visually diapause occurs at a specific, genetically fixed stage of the insect's life cycle. All life stages have been known to diapause, depending on the insect species.

The mechanism found to underlie and arrange diapause is hormone activity, with some of the following involved:

(i) larval and pupal diapause, lack of brain hormone, and consequently, ecdysone; For example European corn borers and many bark beetles (Coleoptera: Scolytidae) diapause as larvae; and cecropia moths, *Hyalophora cecropia*, diapause as pupae;

(ii) adult diapause, lack of brain hormone and juvenile hormone; For example boll weevils, *Anthonomus grandis,* diapause as adults.

and (iii) egg diapause, release of a neurosecretory hormone from the subesophageal ganglia of the parent. For example, most grasshoppers and corn rootworms diapause as eggs.

Dormancy and Quiescence

Dormancy is termed aestivation, autumnal dormancy, hibernation, and vernal dormancy, respectively. Some insects may be dormant through more than one season. For those insects, dormancy terms are combined; for example, aestivo-hibernation refers to larvae of the seedcorn maggot, *Delia platura,* which aestivate most of summer and go directly into winter hibernation.

Quiescence: Many insects survive adverse conditions, such as periods of low or high temperature and water or food shortages, by entering dormancy. Quiescence is the simplest type of dormancy. It is simply a temporary response to immediate adverse conditions (i.e., low temperatures).

Dormancy differs from quiescence in that, during dormancy, growth and reproduction may be suppressed even during periods when conditions are temporarily favorable for these functions. But during quiescence, growth and reproduction start again immediately upon the return of favorable conditions.

Supercooling and freezing tolerance-

In temperate climates, hibernation is one of the most common characteristics of the insect seasonal cycle, and cold hardiness usually accompanies it. Cold hardiness is achieved in insects through the physiological processes of supercooling and freezing tolerance. Supercooling is a resistance to freezing by lowering the temperature at which freezing of body fluids begins. Whereas freezing tolerance is survival despite freezing of body fluid.

Life history **and Seasonal cycle:**

Life history: The adaptations of an organism that influence aspects of its biology such as the number of offspring it produces, its survival, and its size and age at reproductive maturity.

Seasonal cycle: The series of one or more life cycles of an insect occurring during a 1-year period (for example, winter to winter) is termed the seasonal cycle**.**

Important Seasonal cycles: Seasonal cycles are very important to the survival of insects to take advantage of environmental resources and avoid unfavorable extremes.

Types of insect seasonal cycle: Seasonal cycles can be grouped according to the number of generations that occur in a year; this number is referred to as a population's Voltinity. Voltinity types are univoltine, multivoltine, and delayed voltine.

Univoltine cycle: The univoltine cycle refers to a single generation each year. This type is common among most grasshoppers, corn rootworms *(Diabrotica* species), and many other insects.

Multivoltine Cycle: Multivoltine cycle have more than one generation per year. Numbers of generations per year may range from two to four or more, depending on developmental time requirements and environmental conditions. Examples of multivoltine insects include house flies *(Mina domestics),* thrips (Thysanoptera), aphids, and the European corn borer.

Delayed Voltine Cycles: Delayed voltine cycles is found in a few insect species, the life cycle requires more than 1 year for completion. Examples of delayed voltinism can be found in wire-worms (Coleoptera: Elateridae) and many June beetles (Coleoptera: Scarabaeidae), with larvae requiring 2 to 3 years to mature. An extreme instance is the 17-year cicada (Homoptera: Cicadidae), which requires 17 years, longer than any other insect, to develop.

Biological clock

Biological clock or Photoperiod (Day length period) is the response of plants and animals to day-length period (in relative duration of light and dark) or signal by which organism times their seasonal activities (e.g., a chrysanthemum blooming under short days and long nights).

Biological clock is also known as Circadian rhythm. Organisms possess a physiological mechanism for measuring time, which is known as the biological clock. The most common and perhaps basic manifestation is the circadian rhythm (circa = about; dies = day), or the ability to time and repeat functions at about 24 hour intervals even in the absence of the conspicuous diurnal clues such as light.

Biological clock or photoperiod effect on-

i) growth ii) molting, iii) fat deposition, iv) migration v) breeding in birds and mammals, v) and the onset of diapause (resting stage) in insects. vi) Among the higher plants some species bloom on increasing day length and are called long-day plants, while others that bloom on short day plants. In flowering of many plants.

Photoperiodism in certain insects is noteworthy because it provides a sort of "birth control." Long days of late spring and early summer stimulate the "brain" (actually a nerve cord ganglion) to produce a neurohormone that brings on the production of a diapause or resting egg that will not hatch until next spring no matter how favorable are temperatures, food and other conditions. Thus population growth is halted before, rather than after, the food supply becomes critical.

Photoperiodicity is coupled with, what is now widely known as the organism's biological clock to create a timing mechanism of great versatility. Animals likewise may respond to either long or short days. In many, but by no means all, photoperiod sensitive organisms the timing can be altered by experimental or artificial manipulation of the photoperiod.

In its natural habitat a nocturnal animal such as the flying squirrel (*Glaucomys)* or the white-footed mouse (*Peromyscus)* remains in its nest during the daylight hours and is active at night. Whatever the mechanism, the innate (i.e., inherited, not learned from experience) biological clock not only couples internal and external rhythms, it also enables the individual to anticipate changes. Thus, when the nocturnal mouse leaves its nest, it is fully alert to the vibrations of the environment because its physiological systems have already been programmed to "go".

Crop loss assessment

It is very difficult to assess crop loss due to pest infestation. The influencing factors are so numerous and uncontrollable that open field assessment can hardly provide an estimate of the exact situation. The loss caused is a function of insect population density.

In assessing crop loss due to pest infestation these are a few of the difficulties as other insets too may cause damage to the crop but not to any appreciable extent.

Inspite of all these and other constraints, the loss assessment of crop due to pest has acquired new dimension for decision making in the pest control operations according to modern concepts. Crop loss depends on –

i) Types of pests.
ii) How many pf them present in the field.
iii) Their nature of damage and symptoms.
iv) locality
v) Environmental factors.
vi) Biotic factors.
vii) Species or varieties of crops.
viii) stage of the plant
association with other organisms particularly the antagonistic ones

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Crop loss may be estimated -

i) Plot methods

The assessment of damage by this method includes comparison of yields of two plots, one receiving well proved insecticide control to exclude pest damage and the other left to natural infestation of pest. It is better that such experiments are repeated under different conditions to obtain better results. The supporting data on the pest incidence and other organisms would provide comparable conditions of different types to make out the relationship between pest level and yield.

ii) Pot method: In these experiments potted plants or small plots are used. The pots or plots are protected from natural infestation of the crops by multiple pests and occurrence of any other associated organisms is excluded. Such plants are artificially inoculated with varying levels of pest population at different stages of the growth of the plant. Comparison of yield between the pest free plants and the plants experiencing the damage of pest of different levels and varying duration provide accurate data about the influence of pest on yield and correlation between pest. level, duration of infestation, and stage of the plants infested may be established. Though the results are experimentally more sound.

iii) By estimation of different level of incidence: In very rare situations all the plants in the field are infested with pests. Rather plants with various levels of population of pest for variable duration's are of usual occurrence. Well planned field surveys on incidence of pests on labeled plants of any crop would provide data that can he grouped into various classes and yield from such plants when statistically analyzed may provide useful information's on the influence, of pest incidence thereon on yield.

Modern concepts or systems of crop loss assessment:

Example: Estimation of loss by analytical method on a crop infested by aphids.

Problem – 1:

Parameters measured	Value
Total number of plants (T)	1200
Number of attacked / infested plants (NAT)	300
Actual yield per unit area (ACT)	2100 kg
Mean yield per non attacked plant (a)	2 kg
Mean yield per attacked plant (b)	1 kg

Solution:

Actual loss = (a-b) X NAT
= (2-1) X 300
= 1 X 300
= 300 kg

Expected yield = Actual yield + Actual loss
= (2100 + 300) kg
= 2400 kg

$$\text{Loss (\%)} = \frac{\text{Actual loss}}{\text{Expected yield}} \times 100$$

$$= \frac{300}{2400} \times 100$$

= 12.5

Loss = 12.5 %

Problem – 2: Estimate the crop loss on bean plant by aphids. A total number of bean plants are exposed to aphid attack 2000. Total number of attacked plants are 650. Average yield per unattacked bean plant is about 2 kg. Average yield per attacked bean plant is about 1.2 kg.

Actual loss	=	(a-b) X NAT
	=	(2-1.2) X 650
	=	0.8 X 650
	=	520 kg

Expected yield = Total no. of plant X average yield per un-infested plant

=200X2kg

=4000 kg

$$\text{Loss (\%)} = \frac{\text{Actual loss}}{\text{Expected yield}} \times 100$$

$$= \frac{520}{4000} \times 100$$

= 12.5

Loss = 13 %

Result: Therefore, Bean crop loss = 13 %

Model of pest management

A model is a formulation that mimics (copies) a real-world phenomenon, and by means of which predictions can be made. In simplest from, models may be verbal or graphic (i.e., informal). Ultimately, however, models must be statistical and mathematical (i.e., formal), if quantitative predictions are to be reasonably good. The failure of a model to predict change is in itself useful, because it may point out flows in the conceptual framework from which the model was developed (Odum1980).

Computer operations of models make it possible to predict probable outcomes as parameters in the model are changed, new parameters added or old ones removed.

Mathematical symbols provide useful shorthand for describing complex ecological systems, and equations permit formal statements of how ecosystem components are likely to interact.

The mathematical system is called a model and is an imperfect and abstract representation of the real world (Odum1980).

Type of model

Model may be either stochastic or deterministic. Stochastic models attempt to include the effects of random variability in forcing functions and parameters. Deterministic models ignore this chance variation. Stochastic models are mathematically difficult to deal with, so it will use mostly deterministic models as examples (Odum1980).

Use of model: Model may be constructed for a variety of reasons. i) by providing an abstract and simplified description of some system, ii) they may be used simply to guide research efforts or outline a problem for more detailed study. iii) more often, mathematical models are developed for prediction of dynamic change over time.

Models of Predation

There are fours types of model about predation such as-

i) Lotka-Volterra model

ii) Nicholson-Bailey model

iii) Leslie-Gower model

iv) Hassell-varley model

Lotka -Volterra models

Model developed in the 1920s by Alfred Lotka, an American mathematician and Vito Volterra, an Italian mathematician based on the logistic equation, preciseing interspecific competition such as predator prey relationships.

It is the simplest differential equation model is known by the name of its origination. The independently proposed mathematical equations to express the relationship between predator and prey population. They attempted to show that as the predator population increase, the prey decreases to a point where the trend is reversed and oscillations are produced. The Lotka- Volterra model involves one equation for the prey population and one for the predator population. The prey growth equation involves two components, the maximum rate of increase per individual and the removal of prey from the population by the predator.

Interactions between predator and prey have been described by the mathematical models of Lotka and Volterra and by subsequent modification of their model by others. Essentially all of these models predict oscillations of predator and prey populations. The oscillations may be stable, damped, or unstable. Relationships between predator and prey populations result in two distinct responses. As density of prey increases, predators may take more of the prey, is known as a functional response, or-predators may become more numerous, is known as a numerical response.

Lotka and Volterra separately developed mathematical equations based on the logistic curve to describe the relationship between two species utilizing the same resource. They added to the logistic equation for the population of each species a constant to account for the interference of one species on the population growth of another. This constant, in effect, converts the number of members of one species population into the units of the other:

In differential form the Lotka -Volterra equation may be written as-

Species 1(prey): $\frac{dN1}{dt} = r1N1(\frac{K1-N1-\alpha N2}{K1})$

Species 2(predator): $\frac{dN2}{dt} = r2N2(\frac{K2-N2-\beta N1}{K2})$

where r_1, and r_2= the rates of increase for species 1 and 2, respectively; K, and K_2 = equilibrium population size for each species in the absence of the other; α = a constant, characteristic of species 2, a measure of the inhibitory effect of one N_2 individual on the population growth of species 1; and β = a constant, characteristic of species 1, a measure of the inhibitory effect of one N, individual on the population growth of species 2.

Assumptions of Lotka-Volterra: The Lotka- Volterra model is based on a number of simplifying assumptions:

(i) Predators move at random among a prey population is distributed at randomly;

(ii) The environment is homogeneous and stable, without any fluctuations;

(iii) In absence of predation the prey shows exponential growth;

(iv) All reaction are immediate with no time pause for handling prey;

(v) The model makes no allowance for age structure, for interaction of the preys with their own food supply, and for density-dependent mortality of the predator.

(vi) Every meet of a predator with prey results in arrest and use;

(vii) Migration is unimportant;

(viii) Coexistence requires a stable equilibrium point;

and (ix) Competition is the only important biological interaction.

Mathematical deduction of Lotka - Volterra models

The effect of competition on interacting organisms can be modeled mathematically with the Lotka-Volterra equations. The model has two components: C, the numbers present in a consumer (predator) population, and N, the numbers or biomass present in a prey population.It can be assumed firstly that in the absence of consumers the prey population increases exponentially.

The properties of the model are revealed by zero isoclines-

Lotka -Volterra Prey eqation-

$$\frac{dN}{dt} = rN.$$

$$\frac{dN}{dt} = rN - a'CN. \text{ -------------(i)}$$

In the absence of of food, individua predators lose weight and starve to death. Thus, in the model predator numbers are assumed to decline exponentially through starvation in the absence of prey-

$$\frac{dC}{dt} = -qC,$$

Where q is their mortality rate. This is counteracted by predator, birth, the rate of which is assumed to depend on only two things: (i) the rate at which food is consumed, a′CN; and (ii) the predator’s efficiency, f, at turning this food into predator offspring. Predator birth rate is therefore fa′CN, and overall-

Lotka -Volterra Predator eqation

$$\frac{dC}{dt} = fa'CN - qC \text{ ------------(ii)}$$

Equation : (i) & (ii) constitute the Lotka –Volterra model

The properties of the model are revealed by zero isoclines-

In the case of the prey (equation), when:

$$\frac{dN}{dt} = O, rN = a'CN$$

or

C=r/a'

Thus, since r and a′ are constants, the prey zero isocline is a line for which C itself is a constant.

Likewise, for the consumers (equation), when

$$\frac{dC}{dt} = O,\ fa'CN = qC$$

Or

$$N = \frac{q}{fa'}$$

The predator zero isocline is therefore a line along which N is constant.

Nicholson and Bailey model of predation

There have been two main series of models developed as attempts to understand predator- prey dynamics. One, based originally on the work of Nicholson and Bailey (1935), uses difference equations to model host-parasitoid interactions with discrete generation. These models have been subjected to a relatively.

The second series, which will be examined here, is based on differential equations and relies heavily on simple graphical models.

An ecologist, A. J. Nicholson, and a mathematician and engineer, V. A. Bailey, developed a mathematical model for a host parasitoid relationship in 1935. It has also involves two equation.

In differential form the Nicholson-Bailey equation may be written as-

Which are-

For prey-

$$N_{t+1} = LN_t e^{-ap}t$$

For predator-

$$P_{t+1} = N_t(1 - e^{-ap}t)$$

N_t = Number of prey at time t

$P_t =$ Number of predator at time t

$a =$ Area of discovery

L = Host reproductive rate

e = Exponential constant

This feature of this model allows and estimates of prey in the next generation-

i) If the number of hosts that the parasitoid removes within its sampling area is equal to a fraction of prey that represents recruitment, then the base parental stock remains.

ii) If the parental stock remaining is sufficient to replace the individual prey taken and if it is sufficient to maintain the density of parasitoids, then the two populations remains stable indefinitely.

iii) But if the parasitoid removes part of the parental stock along with recruitment, the prey ultimately the predator population decline.

iv) If much of the recruitment is left untouched, prey increase and predators may not be up to the task of removing increasing recruitment. Ink either of these two cases the two interacting populations will undergo oscillation with increasing amplitude.

Weaknesses of the Nicholson- Bailey model: The Nicholson- Bailey model has following weaknesses such as-

i) It assumes random searches by the predator for static prey homogeneously dispersed over a homogeneous landscape.

ii) The predators have a constant area of discovery and prey has synchronized generations (same time span and same length) and

iii) Predator mortality is independent of density and of course, on such predator exists.

Difference between Lotka-Voltera model and Nicholson-Bailey model

Lotka-Voltera model	**Nicholson-Bailey model**
i) It assumes predators move random among the prey population that is randomly distributed	i) It assumes predator move randomly to the prey population that is distributed uniformly.
ii) Predators and prey has not synchronized generations	ii) Predators and prey has synchronized generations.
iiii) Predator mortality dependent on the density.	iii) Predator mortality independent of density.
iv) Prey density is affected by predator death rate.	iv) Prey density is unaffected by predator death rate.
v) It also assumes that predators are satiable regardless of prey density.	v) It also assumes that predators are insatiable regardless of prey density.
vi)This model involves two equations Which are- **Species 1:** $\frac{dN1}{dt} = r1N1(\frac{K1-N1-aN2}{K1})$ **Species 2.** $\frac{dN2}{dt} = r2N2(\frac{K2-N2-\beta N1}{K2})$ where r1, and r2= the rates of increase for species 1 and 2, respectively; K, and K_2 = equilibrium population	vi)It has also involves two equation. Which are- For prey- $N_{t+1} = LN_t e^{-ap} t$ For predator- $P_{t+1} = N_t (1 - e^{-ap} t)$

size for each species in the absence of the other; α = a constant, characteristic of species 2, a measure of the inhibitory effect of one N2 individual on the population growth of species 1; and β = a constant, characteristic of species 1, a measure of the inhibitory effect of one N, individual on the population growth of species 2.	N_t = Number of prey at time t P_t = Number of predator at time t a = Area of discovery. L = Host reproductive rate. e = Exponential constant.

Some terms about predation

Functional responses: Change (or increase) in rate of exploitation of a prey species by a predator in relation to changing prey density. It occurs in response to an increase in food (prey) availability.

Functional response views predation in terms of the relation of predator attack rates to prey density. Here are three types of functional responses-

i) In Type- I, the number of prey had eaten per predator increases linearly to a maximum as prey density increases.

ii) In Type- II, the number of prey taken rises at a decreasing rate toward a maximum. Type- II occurs in situations of varying densities of one species of prey. Both invertebrate and vertebrate predation may exhibit Type- II

iii) In Type- III, the number of prey taken increases in a sigmoidal fashion. Type III involves two or more species of prey. Inherent in Type- III responses are a search image, in which the predator develop a facility for finding a particular prey item, and switching, in which the predator turns to an alternate, more abundant prey species for more profitable hunting. It takes that prey in a disproportionate amount relative to other prey species.

Numerical response: Numerical response refers to the increase of predators resulting from an increased food supply. Numerical response may involve an aggregative response, the influx of predators to a food-rich area, or more importantly, a change in the rate of growth of the predator population through changes in developmental time, survival rates, and fecundity. Such changes produce a delayed numerical response, for a time lag necessarily exists between birth of young and maturation of reproducing individuals.

Search image: Mental image formed in predators, enabling them to find more quickly and to concentrate on a common type of prey.

The image presumed to be formed in the minds of predators, in response to which they tend to concentrate on a common type of prey. People searching for a cryptic animal often quickly find additional individuals after the first is spotted, presumably because they form search images also.

Optimal foraging theory:

Tendency of animals to harvest food efficiently; to select food sizes or food patches that will result in maximum food intake for energy expended is called optimal foraging.

According to Smith (1990)-Optimal foraging theory attempts to model how organisms feed as an optimizing process. Evolutionary ecologies predict that if organisms have limited access to energy, then natural selection is likely to favor individuals within a population that are more effective at acquiring energy. This prediction spawned an area of ecological inquiry called optimal foraging theory. Optimal foraging theory attempts to model how organisms feed as an optimizing process. Because prey occurs in patches, the predator finds it more efficient to spend time in areas not necessarily where prey is most abundant, but where hunting is most profitable in time allocated relative to net energy gained. Study of such behavior has given rise to the concept of optimal foraging, a strategy that obtains for the predator a maximum rate of net energy gain. There is a break-even point above which foraging in a particular patch is profitable and below which it is not. Optimal foraging involves an optimal diet, one that includes the most efficient size of prey for both handling and net energy return. Optimal foraging efficiency involves the concentration of activity in the most profitable patches of prey and the abandonment of those patches when they are reduced to the average of profitability of the area as a whole.

Optimal foraging theory assumes that of energy supplies are limited, organisms cannot simultaneously maximize all of life's functions; for examples, allocation of energy to one function, such as growth or reproduction, reduces the amount of energy available to other functions, such as defense.

Foraging strategy: Manner in which individual animal seeks food and allocate their time and effort in obtaining it; ways in which animals choose their diets and allocate their time when seeking, catching, and eating food.

Principle of allocation: The Principle of allocation underscores the fact that if an organism uses energy for one function such as growth, it reduces the amounts of energy available for others functions such as reproduction. This tension between competing demands for resources leads inevitably to trade-offs between functions. One of those is the trade-off between number and size of offspring. Organisms that produce many offspring are constrained, because of energy limitation, to produce smaller offspring (seeds, eggs, or live young).Grasses and grass-like plants, such as sedges and ruches, were classified as graminoids. Herbaceous plants other than graminoids were assigned to a forb category. Species with woody thickening of their tissues were considered as woody plants. Finally, climbing plants and vines were classified as climbers.

Mimicry

Mimicry is a special form of protective resemblance, in which two or more species of insects (often not closely related) has evolved very similar colour patterns and behaviour.

Though several complicated classifications of mimicry have been proposed, however the following types are best known-

i) Batesian mimicry

ii) Mullerian mimicry

iii)Protective Mimicry

iv)Warning Mimicry

v) Aggressive Mimicry

Smith (1990) described the following type mimicry-

i) **Batesian mimicry:** In Batesian mimicry (named after the naturalist H. W. Bates who first described it among other examples) one species, the model, is unpalatable or injurious in some way and advertises this fact by a distinctive colour pattern so that predatory birds or mammals learn to avoid it. Another species, the mimic, is palatable but is protected because it has evolved a colour pattern very similar to the unpalatable model and is therefore mistaken for it by predators that have learned to associate the pattern with distastefulness.

Mimicry of a dangerous (noxious) or distasteful species by a harmless or tasty one.

A good example is the Monarch *(Danaus plexippus)* subfamily Danaine whose larva feeds on milkweeds (Asclepiadaceae) and sequesters a cardiac glycoside which makes the adult unpalatable. It is mimicked by the Viceroy *(Limenites archippus,)* which is a palatable-species from a different subfamily (Nymphalinae).

ii) Mullerian mimicry: The mutual resemblance of distasteful organisms that presumably makes it easier for unintelligent predators to learn what patterns to avoid. In Mullarian mimicry complexes, all members are both models and mimics. Mullerian mimicry occurs when two or more unpalatable species have evolved the same appearance. So that losses due to the attacks of inexperienced predators, which have not yet learned to associate the pattern with distastefulness are shared between the two species.

Remarkable mimetic resemblances are shown by the various colour forms of the female swallowtail *Papilio dardanus,* each mimicking species of *Danaus* and *Amauris*.

The model, the distasteful swallowtail, has as its mimics the black swallowtail and the spicebush swallowtail. The black female tiger swallowtail is a third mimic all these butterflies are founds in the same habitat.

Lull (19760) described the following type mimicry-

iii)Protective Mimicry:

Many butterflies are also leaf-like in appearance, simulating not only the general hue of a dead or with red leaf but its petiole. The geometrid moths *Sclenia tetralunaria*, whose caterpillars are the familiar measuring worms, are often not only protectively colored but may mimic the twigs and smaller branches of various plants such as the birch tree, the pear tree, and many others.

iv)Aggressive mimicry: Resemblance of a predator or parasite to a harmless species to in order not to alert potential prey or hosts.

Aggressive mimicry is that shown by certain carnivorous forms such as the spiders found on golden-rod and other flowers, whose yellow bodies so harmonize with the flowers upon which they rest as to render them invisible to the visiting insects which form the spider's prey (Lull, 1976). The robber fly, a mimic of the bumblebee, the drone fly is a mimic of the honeybee, illustrates aggressive mimicry.

v) **Warning Mimicry-** Some of the most remarkable mimicry of all is included under the slogan of warning mimicry- mimicry of advertising colored forms which are distasteful or even poisonous either when eat greedily or through the possession of poisonous teeth. The most familiar instance is that of the immune monarch butterfly, *Anosia plexippus*, which is inedible, and its imitator, the viceroy, *Basilarchia crchippus*, which would otherwise be destroyed, as it is palatable from the point of view of insectivorous birds (Lull, 1976).

Different between Mullerian mimicry and Batesian mimicry

Mullerian mimicry	**Batesian mimicry**
i) Mullerian mimics include members of the same genus and family.	i) Batesian mimics and models belong to different phylogenetic line.
ii)It is rare or less common type mimicry	ii) It is common type mimicry
iii) It involves resemblance of both palatable and model unpalatable	iii) It involves resemblance of only unpalatable model
iv) It is advantageous to both organism	iv) It is not advantageous to both organism
The number of mimic and object almost same.	The number of mimic is fewer than model.
The feedback from handling the mimic is negative.	The feedback from handling the mimic is positive.

Difference between Aggressive and Protective mimicry:

Aggressive mimicry	**Protective mimicry**
i) Resemblance of predator or parasite to a harmless species to mislead potential prey.	ii) Resemblance of predator or parasite beneficial to species to mislead potential prey.
ii) Aggressive mimicry comprises concealing and attractive.	ii) Protective mimicry includes concealing and warning.

iii) Model and mimic may or may not be occupied in the same area.	iii) Model and mimic must occur in the same area occupy the same habitat.
iv) Imitators are always more defensive than model.	iv) Imitators are always more defenseless.
1) Example: Spider found on golden rod and other flower, whose yellow bodies so harmonize with the flowers upon they rest as to render them invisible to the visiting insects, which form the spiders prey.	1) Example: Many butterflies are also leaf-like in appearance, simulating not only the general hue of a dead or with red leaf but its petiole.

Structure of Ocean:

The oceans can be divided into following vertical and horizontal zones which are given below:

a) Littoral, or interdial zone:The shallow shoreline under the influence of the rise and fall of the tides is called the littoral, or interdial zone.

b) Neritic zone**:** The neritic zone extends from the coast to the margin of the continental shelf, where the ocean is about 200m deep.

c) Oceanic zone: Beyond the continental shelf lies the oceanic zone.

The ocean is also generally divided vertically into several depth zones-

i) Epipelagic zone: The epipelagic zone is the surface layer of the ocean that extends to a depth of 200m.

ii)mesopelagic zone: The mesopelagic zone extends from 200 to 1000 m,

iii) Bathepalagic zone: the bathepalagic zone extends from 1000 to 4000 m.

iv) Abyssal zone: The layer from 4000 to 6000m is called the abyssal zone, and

v) Hadal zone: Finally the deepest parts of the oceans belong to the hadal zone.

vi) Benthic: Habitats on the bottom of the ocean, and other aquatic environment, are referred to, as benthic,

vii) Pelagic while those off the bottom, regardless of depth, are called. Each of these zones supports a distinctive assemblage of marine organisms.

Structure of Lake: Lake structure parallels that of the oceans but on a much smaller scale.

i) Littoral zone: The shallowest waters along the lakeshore, where rooted aquatic plants may grow, is called the littoral zone.

ii) Limnetic zone Beyond the littoral zone in the open lake is the limnetic zone.

Lakes are generally divided vertically into three main depth zonessuch as-

iii) Epilimnion: The epilimnion is the warm surface layer of lakes.

iv) Thermocline: Below the epilimnion is the thermocline, or metalimnion. The thermocline is a zone through which temperature changes substantially with depth, generally about 1^0C per meter of depth.

vi) Hypolimnion: Below the thermocline are the cold dark waters of the hypolimnion.

Each of these zones supports a distinctive assemblage of lake organism

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