Discipline Courses-I
Semester-I
Paper: Perspectives in Ecology
Lesson: Introduction to Ecology
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Introduction

Ecology is the study of organisms in relation to the surroundings in which they live. These surroundings are called the environment of the organism. Ecology can also be defined as the scientific study of the interactions that determine the distribution and abundance of organisms. Each organism has requirements for life, which interlock with those of the many other abiotic and biotic components of the environment. For e.g. Fig. 1 illustrates how an organism fits in with other physical and biological components of environment just like interlocking pieces of jigsaw puzzle. In this case an animal is represented which eats other plants or animals as its food (as a predator) and which in turn may become prey for other predator. It may face competition from members of its own species for food or shelter or mating. Its life is also affected by weather condition and its ability to withstand disease. Also during its lifetime it needs to produce offspring for continuation of its race.

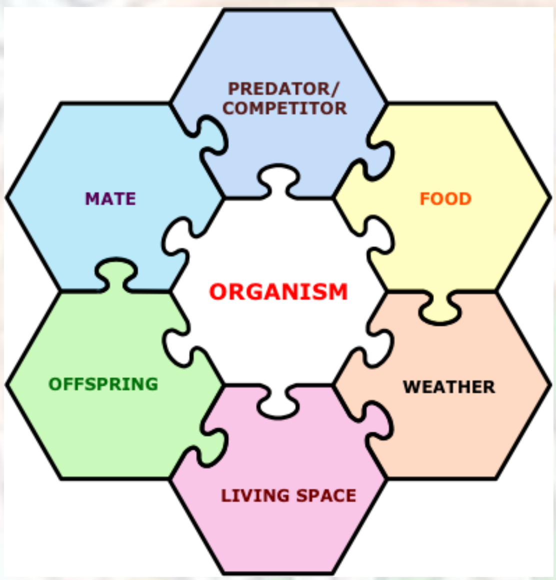

Fig. 1. Diagram showing relationship of an organism with abiotic and biotic factors of environment.
Source: ILLL in house

Relevance of studying Ecology

The word ecology is derived from Greek "oikos" meaning "household", and "logos", meaning "study". Literally then, ecology is the study of "life at home" with emphasis on the totality or pattern of relations between organisms and their environment.

The word economics is also derived from Greek root "oikos". As "nomics" means "management" so it states the "management of household" and accordingly ecology and economics are sister disciplines. With the rapid development there is a new interface discipline, "ecological economics" that will bridge the gap between Ecology and Economics. (*eg. Agricultural economics*) (Costanza, Cumberland *et al*, 1997; Barrett and Farina 2000).

History of Ecology

History of ecology is as old as the human civilization. In primitive society, all individual needed to know their environment that is to understand the forces of nature and the plants and animals around them to survive. The beginning of civilization coincided with the use of fire and other tools to modify the environment. Even with the latest technological achievements, the humans are directly and indirectly dependent on the natural environment for their survival such as the food and water we consume and the air we breathe. And not to mention waste assimilation, recreation, and many other services supplied by nature. We assume they are unlimited or somehow replaceable by technological innovation, even though we know that life necessities such as oxygen and water may be recyclable but not replaceable.

The science of Ecology has had gradual if spasmodic development during recorded history. The writings of Hippocrates, Aristotle clearly contain references to ecological topics. The word Ecology is of recent origin having been proposed by the German Biologist **Ernst Haeckel** in **1869**. Haeckel defined *ecology as the study of natural environment including the relation of organisms to one another and to their surroundings*. Before this the word ecology was not in use. For example in early 1700s, Antonie von Leeuwenhoek, best microscopist, also pioneered the study of food chains and population regulation and writings of English Botanists Richard Bradley revealed his understanding of biological productivity. All of these three areas are important in modern ecology.

As a recognized field of science, ecology dates back from about 1900. At first the field was divided into plant ecology and animal ecology but the biotic community concept of Fredrick E. Clements and Victor E. Shelford, the food chain and material cycling concepts of Raymond Linderman and G. Evelyn Hutchinson, and the whole lake studies of Edward A. Birge and Chauncey Juday helped establish basic theory of general ecology.

The worldwide environmental awareness movement burst upon during 1968 to 1970. When astronauts took the first picture of earth as seen from outer space during 1970, everyone became concerned about pollution, natural areas, population growth, food and energy consumption and biotic diversity. Even the "**Earth Day**" was initiated on **April 22, 1970**. Then in 1980 and 1990's environmental issues were pushed into political background by concerns for human relations. And now during early stages of twenty-first century environmental issues are again coming to the forefront of human abuse of Earth continues to escalate. While the scope of ecology is expanding the study of how individual organisms and species interface and use resource intensifies.

Value Addition: Do you know

Heading Text: Timeline of ecologists

S.No.	Name	Life span	Contribution
1.	Antoni van Leeuwenhoeke	1632–1723	Concept of food chains
2.	Carl Linnaeus	1707–1778	Naturalist, inventor of science on the economy of nature
3.	Alexander Humboldt	1769–1859	First to describe ecological gradient of latitudinal biodiversity increase toward the tropics
4.	Charles Darwin	1809–1882	Theory of natural selection, Founder of ecological studies of soils
5.	Herbert Spencer	1820–1903	Early founder of social ecology, coined the phrase 'survival of the fittest
6.	Karl Möbius	1825–1908	First to develop concept of ecological community, biocenosis, or living community
7.	Ernst Haeckel	1834–1919	Coined the term Ecology, popularized research links between ecology and evolution
8.	Victor Hensen	1835–1924	Invented term plankton, developed quantitative and statistical measures of productivity in the seas
9.	Eugenius Warming	1841–1924	Early founder of Ecological Plant Geography
10.	Stephen Forbes	1844–1930	Early founder of Entomology
11.	Vito Volterra	1860–1940	Mathematical populations models
12.	Alfred J. Lotka	1880–1949	First to pioneer mathematical populations models explaining trophic (predator-prey) interactions using logistic equation.
13.	Vladimir Vernadsky	1869–1939	Concept of Biosphere
14.	Henry C. Cowles	1869–1939	Pioneering studies of ecological succession
15.	Arthur G. Tansley	1871–1955	Coined the term Ecosystem in 1936.
16.	Charles Christopher Adams	1873–1955	Animal ecologist, biogeographer, founded ecological energetics.
17.	Friedrich Ratzel	1844–1904	Coined the term biogeography in 1891.
18.	Victor Ernest Shelford	1877–1968	Founded physiological ecology, pioneered food web and biome concepts, founded

			The Nature Conservancy.
19.	Charles S. Elton	1900–1991	'Father' of animal ecology, pioneered food web & niche concepts.
20.	G. Evelyn Hutchinson	1903–1991	Limnologist and conceptually advanced the niche concept

Source: Author, ILLL in house.

Value Addition: Do you know

Heading Text: Ecology is an interdisciplinary science

Body Text: The complex interactions in ecology involve both physical and biological processes. This dependency makes it an interdisciplinary science.

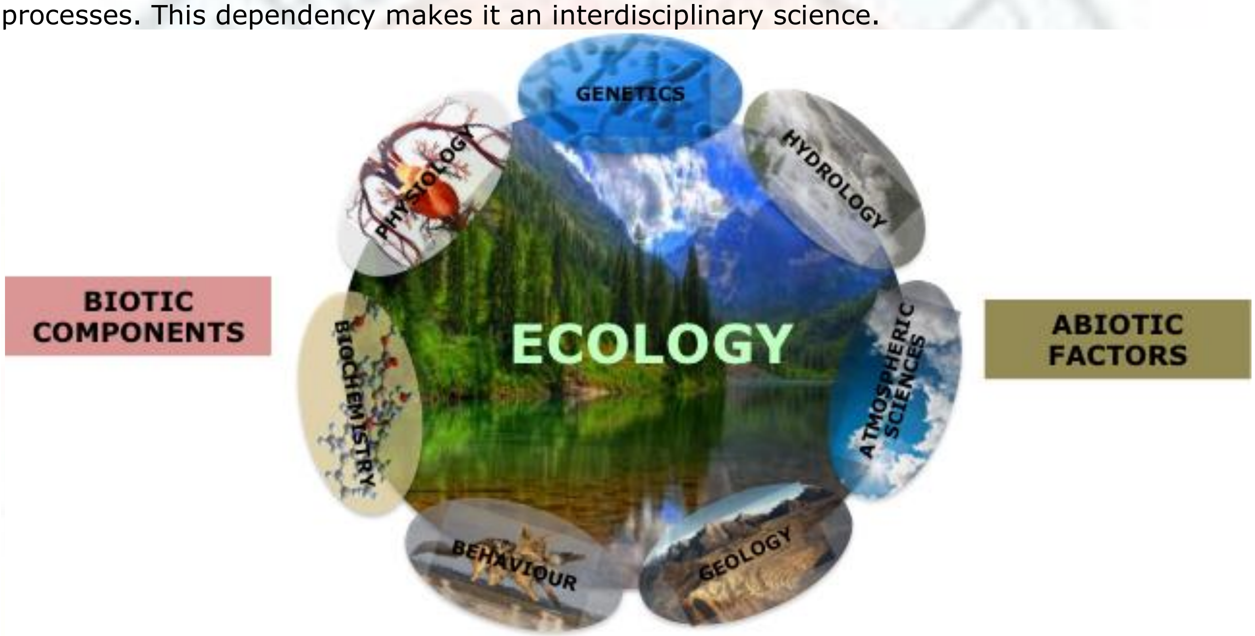

Fig. Diagram showing relationship of Ecology with other sciences.

For e.g. Study of how human body responds to low availability of oxygen at higher altitude is an example of Physiology. Ecology studies its response to the environment. Availability of oxygen is part of atmospheric science whereas the altitude talks about the topography of the area (geology). So in this case, other sciences are critical to understand how individuals respond to their environment.

Source: Author, ILLL in house.

Subdivision of Ecology

Ecology is divided into two categories:

1. Autoecology

2. Synecology

Autecology

It deals with the study of individual organism or an individual species. It is organism-based study or it can be population of a species (natality, mortality, survival, growth pattern, population dynamics etc.), which is generally called as Population ecology. For example, if a study is made of the relation of a deer or herd of deer to the environment, then the study would be autecological in nature. Here the focus is mainly on relationship of an individual or population to its environment i.e. how a particular organism fits into the particular ecological frame.

For e.g. In order to understand the whole life cycle of a species, many autecological studies are conducted and ultimately their results are combined to give the complete picture. These studies may include appearance and distribution, feeding habits, reproduction and their importance in an ecological system.

Synecology

It deals with the study of groups of organisms, which are associated together as a unit (i.e. community). If the study were concerned with the forest where the deer or herd of deers live, then this type of study would be synecological study. Here the focus is on the components of the ecological set up where the organism lives.

Synecology can be further subdivided into:

- **Terrestrial Ecology**: It includes Forest, Grasslands, Desert and Tundra etc.
- **Aquatic Ecology**: It includes Marine, Estuarine, Freshwater ecology.

Recently two more division of ecology have emerged:

- **Palaeoecology**: It deals with organism and their environment in geological past.
- **Conservation ecology**: It deals with the applications of ecological principles to the proper management of resources leading to sustained yields of useful resources for human welfare.

Laws of Limiting factor

In order to grow and multiply, every individual organism of a species population, need certain elements or abiotic factors. Out of these naturally occurring elements, some are very essential and needed in a large amount whereas others are needed in very small amounts.

The major elements are called as macronutrients and these are used widely and other elements, which are needed in a small amount, are called as micronutrients. The table below describes the list of macro- and micronutrients:

Table 1. List of macro- and micronutrients

Macro nutrient	Micronutrient	
Carbon	Iron	Iodine
Hydrogen	Manganese	Selenium
Oxygen	Boron	Silicon
Nitrogen	Molybdenum	Fluorine
Phosphorus	Copper	Barium
Calcium	Zinc	Cobalt
Magnesium	Sodium	Vandanium
Sulphur		

Law of Minimum

An organism is exposed solely to the single environmental factor but is subjected to simultaneous action of all the factors in its environment. However some factors exert more influence than other and attempt to evaluate their relative role for the survival of organism. Later on it was stated by German Biochemist, Justus Liebig in 1840 that growth of organism is dependent on the amount of foodstuff that is present in "minimum quantity". This comes to be known as **Law of Minimum or Liebig's Law of minimum**. Liebig was the pioneer in the study of the effect of various factors on the growth of plants.

Law of Minimum or Liebig's Law of minimum states that "*To occur and thrive in a given situation an organism must have essential materials which are necessary for growth and reproduction. These basic requirements vary with the species and with the situation. Under* ***steady state*** *conditions the essential material available in amounts most closely approaching the critical minimum needed will tend to be the limiting one. This* ***law of the minimum*** *is less applicable under* ***transient state*** *conditions when the amounts and hence the effects, of many constituents are rapidly changing.*" (Odum, 1971)

It is also incorporated with the Laws of limiting factors developed by British physiologist F. F. Blackman (1905). He investigated the factors, which affect the rate of photosynthesis. He listed five factors involved controlling the rate of photosynthesis:

- Amount of CO_2 available
- Amount of H_2O available

- Intensity of solar radiation
- Amount of Chlorophyll
- Temperature of the chloroplast

Blackman discovered that rate of photosynthesis is governed by the level of factor that is operating at its limiting intensity. The same principle of limiting factors applies to animal functions also.

So the law of minimum stated as "The functioning of an organism is controlled or limited by that essential environmental factor or combination of factors present in least favorable amount. The factor may not be continuously effective but only at some critical period during a year or perhaps only during some critical year in a climatic cycle". (Taylor, 1934)

There are two subsidiary principles are added to the concept of Law of Minimum:

1. Liebig's Law is strictly applicable only under steady-state conditions, that is, when the inflows balance outflows of energy and materials.
2. Factor interaction. High concentration or availability of some substance or action of some factor other than the minimum one may modify the rate of utilization of the latter.

Shelford's Law of Tolerance

Every environmental factor varies through a wider range of intensity, which any organism can tolerate characteristically. Each individual has a lower and an upper limit in the range of environmental factor between which it functions efficiently. For any one factor, different organism finds optimal conditions for existence. So the minimum quantity / condition for any factor in the list of an organisms requirement is called its threshold level. It may be any chemical or physical factor such as light, temperature, moisture or phosphate etc. Above threshold the rate of function increases more or less rapidly until a maximum is reached beyond which there is usually a decline in the rate of process either because of deleterious effect produced, or interference of some other factor.

So **V.E. Shelford** in **1913** incorporated the idea that factors could be limiting at the maximum as well as minimum quantity as the **Law of Tolerance**. Each ecological factor to which an organism responds has maximum and minimum limiting effect between which lies a range of gradient that is known as limits of tolerance. Moderate rise or decrease can lead a condition of physiological stress for that organism and further rise or decline can cause death of the organism as it reaches the zone of intolerance or zone of coma (**Fig. 2**).

Shelford's Law of Tolerance states that "*the presence and success of an organism depend upon the completeness of a complex of conditions. Absence or failure of an organism can be controlled by qualitative or quantitative deficiency or excess with respect to any one of the several factors, which may approach the limits of tolerance for that organism*". (Odum, 1971)

Between the lower and upper limit of tolerance lies a broad sector of a gradient, which is called, as **zone of compatibility** or **zone of tolerance** or **zone of biokinetic** or **zone of capacity adaptation**. The region at either end of zone of compatibility is called the **lethal zone or zone of resistance or zone of intolerance**. The zone of compatibility too includes broad range of optimum and narrow zone of physiological stress in between the range of optimum and lethal zones.

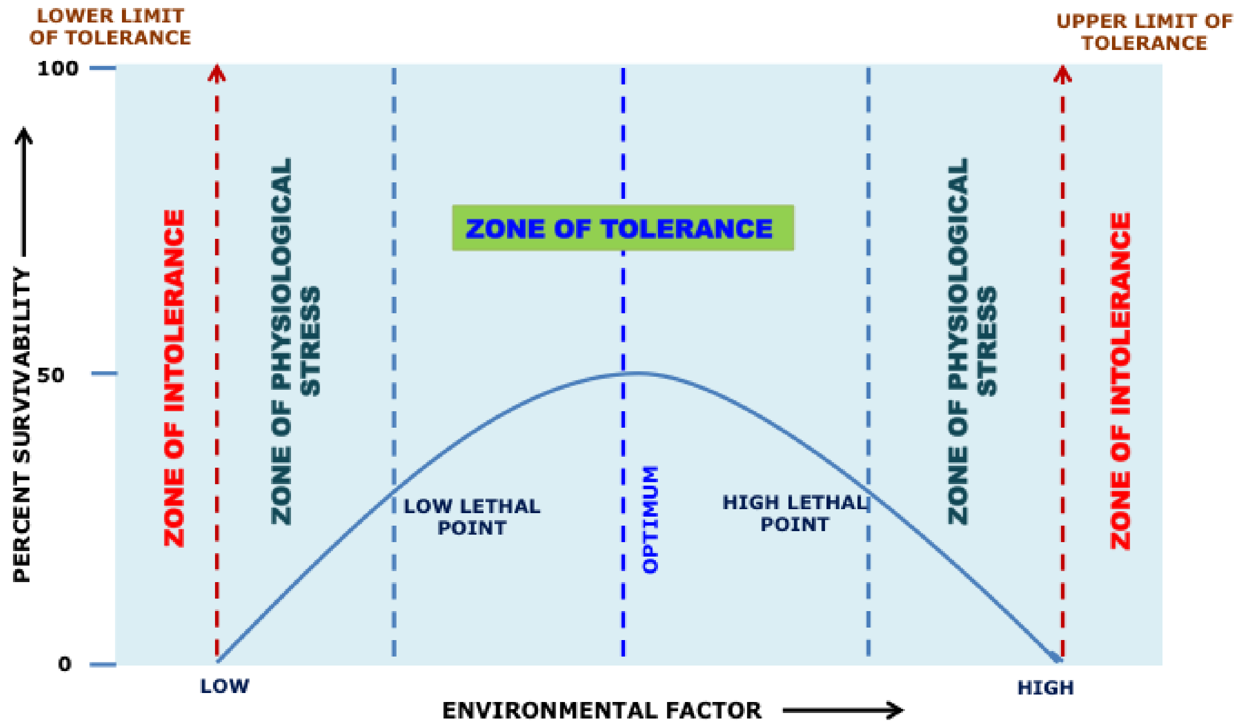

Fig. 2. Zone of tolerance and resistance for an organism with regard to environmental factor.

Source: ILLL in house

This can be generalized for any environmental factor. This transition point varies from species to species and even within individual of the same species. One can get to know the physiological diversity of a species by studying a number of members belonging to it.

For e.g. Carbon dioxide is necessary for plant growth. Small increase in concentration enhances the plant growth rate but if the concentration becomes higher than the optimum range then it becomes toxic for the plant.

Value Addition: Do you know

Heading Text: Animal Responses to the Extreme Temperature Condition

Body Text:

All organisms live in and exchange energy with a thermodynamic environment-heat and cold. **Maximum effective temperature** is the greatest heat intensity the species can tolerate and live indefinitely. Temperature higher to leads to heat coma but animal can recover from it if it is not too long exposure. Exposure time at high and low temperature is plays an important role in determining whether the animal would recover from the coma or not.

For e.g. the life cycle of house fly is temperature dependent requiring roughly 10 days at 29°C, 21 days at 21°C and 45 days at 15.6°C. No flies are generally produced at temperatures less than 10-11.6°C. In areas with cold winters, house flies survive as immature stage or survive as adults out of doors. There is no diapause or suspended development stage in lifecycle of the housefly. However, house flies survive inside buildings (if suitable conditions are available) with only a reduction in breeding activity. While adult fly activity may begin around an average temperature of 6.7°C, but the flies are still relatively inactive or crawl only slightly from 7.2-8.9°C and can fly at 11.6°C (Table). This suggests a threshold of around 10°C or a little less for outdoor fly activity. Adult house flies appear to seek temperatures above 15.6°C when possible. However, lower temperatures are associated with longer survival. Death occurs within a few minutes exposure to high temperature (46.5 °C) and at low temperature(-5.0 °C , -8.0 °C, -12 °C).

Table: Temperature relations of the house fly *Musca domestica* indicating the range of tolerance, zone of stress and zone of coma.

S.No.	ZONE	TEMPERATURE RANGE	EXPOSURE TIME	SURVIVAL OF POPULATION
1.	Death	46.5°C	In few minutes	**$T_{maximum}$ (Maximum survival temperature)**
2.	Heat coma	44.6 °C	------------	Lethal effect begins
3.	Excessive activity	40.1 °C	------------	Preferred resting temperature
4.	Rapid movement	27.9 °C	------------	Maximum effective temperature
5.	Normal activity (Flight, mating, oviposition begin)	11.6-23 °C	------------	Effective temperature range
6.	Feeble movements	7.2-8.9°C	------------	Minimum effective temperature

7.	Crawling activity begins	6.7 °C	------------	Threshold
8.	Chill coma	6.0 °C	------------	Lethal effect begins
9.	Death	-5.0 °C -8.0 °C -12 °C	40 minutes 20 minutes 5 minutes	**$T_{minimum}$ (Minimum survival temperature)**

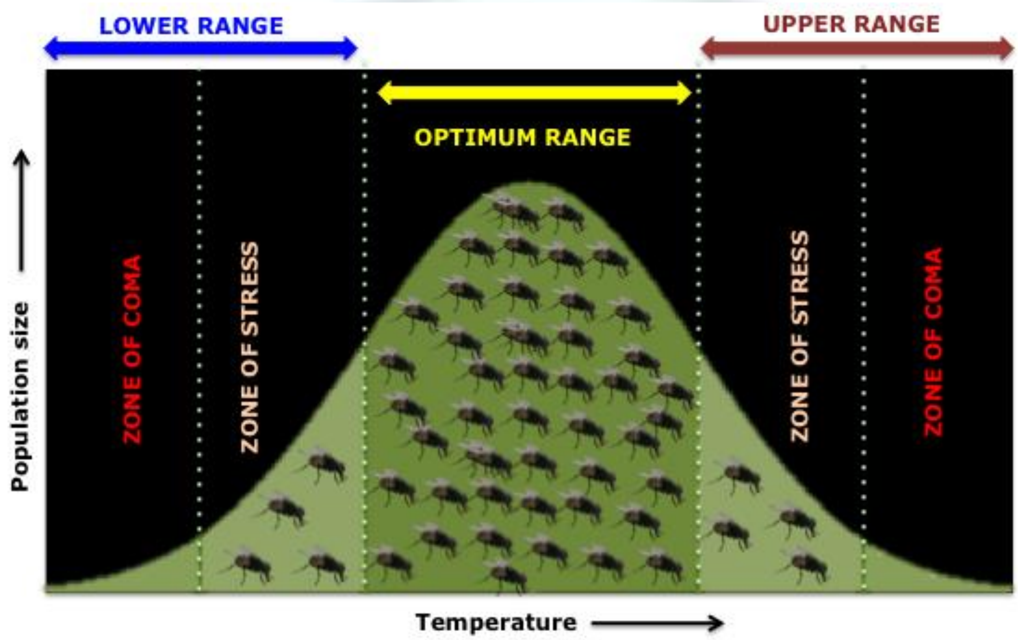

Fig. **Temperature relations of the house fly *Musca domestica*.**

Source: Author, ILLL in house.

Subsidiary principles to the law of tolerance are:

1. Organisms may have a wide range of tolerance for one factor and a narrow range for another. The organisms that have a wide range of tolerance for any factor can be stated with a prefix " eury" and those with a narrow range as *"steno" For example Eutythermic* animals have a wide range of tolerance for temperature and stenothermic animals have a narrow range of tolerance for temperature.

2. Organisms with wide ranges of tolerance for all factors are likely to be most widely distributed.

3. When conditions are not optimum for a species with respect to one ecological factor, the limits of tolerance may be reduced with respect to other ecological factors. For e.g. when soil nitrogen is limiting the resistance of grass to drought is reduced.

4. Organisms are not actually living at the optimum range (as determined experimentally) with regard to a particular physical factor. In such cases some other

factor or factors are found to have greater importance. For e.g. In nature orchids grow only in shade though they can grow better in full sunlight (provided they are kept cool) because they cannot tolerate the heating effect of direct sunlight.

5. The period of reproduction is usually a critical period when environmental factors are most likely to be limiting. The limits of tolerance for individuals in reproductive state (seeds, eggs, embryos, seedlings and larvae) are narrower than individuals in non-reproducing state. For e.g. anadromous fishes, which spend most of their lives in the sea and migrate to fresh water to breed whereas catadromous fishes, which spend most of their lives in fresh, water and migrate to the sea to breed.

To express the relative degree of tolerance, prefixes "steno-," meaning narrow and "eury-," meaning wide are used. Example, the Antarctic fish and desert pupfish provide an extreme contrast in limits of tolerance related to the difference in environmental condition of their habitat. Antarctic fish has a limit of temperature tolerance of less than 4°C in the range of -2°C to +2°C so it is extremely stenothermally (can tolerate narrow temperature range) cold adapted. As the temperature rises to 0°C, the metabolic rate increases but if goes beyond 1.9°C then the fish becomes immobile. In contrast, the desert fish is eurythermal (can tolerate wide temperature range) and also euryhaline (can tolerate wide salinity range), tolerating temperatures between 10°C and 40°C and salinities ranging from freshwater to that greater than seawater. (Odum, 1971)

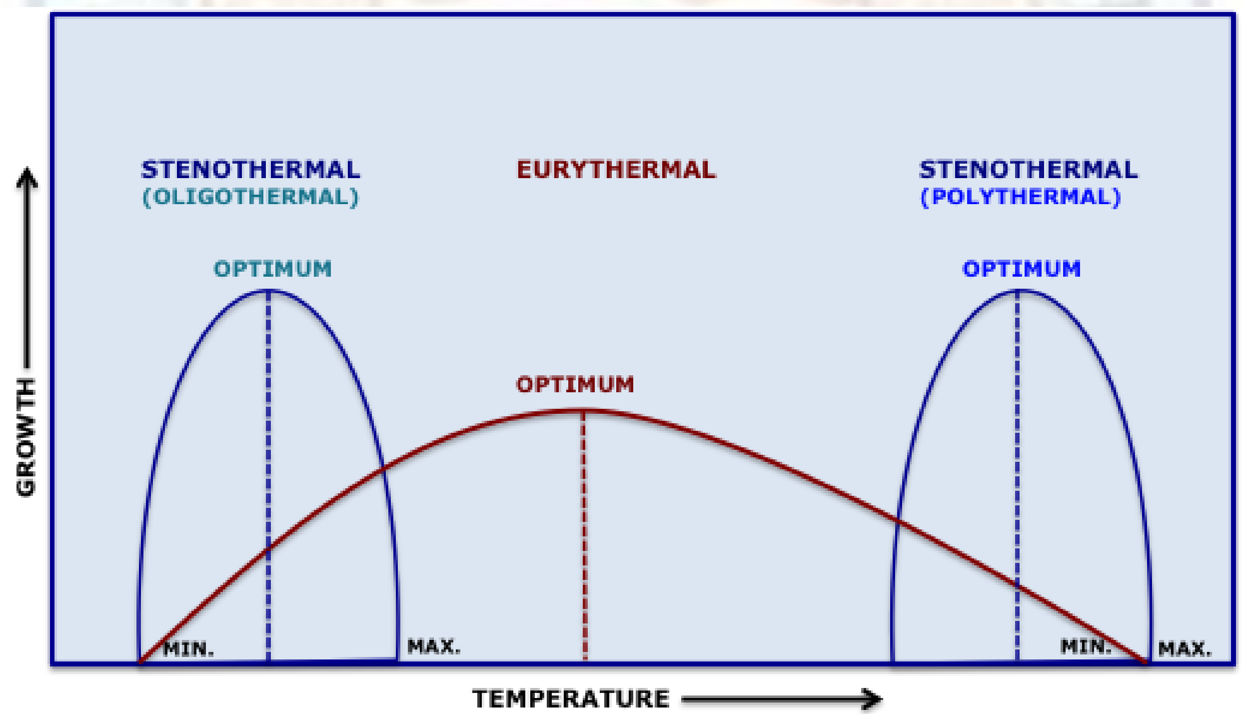

Fig. 3. Comparison of the relative limits of tolerance of stenothermal and eurythermal organism. For stenothermal organism, maximum, minimum and optimum lie close to each other so they have narrow range of tolerance whereas maximum, minimum and optimum lie far apart in case of eurythermal organism giving them wide range of tolerance. Stenothermal organism can either be ***oligothermal*** (low-temperature tolerant) or ***polythermal*** (high-temperature tolerant).

Source: Author, ILLL in house

Combined concepts of Limiting factors

"*The presence and success of an organism or a group of organisms depends upon a complex of conditions. Any condition, which approaches or exceeds the limits of tolerance is said to be a limiting condition or a limiting factor*". (Odum, 1971)

Organisms are controlled in nature by:

- The quantity and variability of materials for which there is a minimum requirement and physical factors, which are critical.
- The limits of tolerance of the organisms themselves to these factors and other components of the environment.

For e.g. Oxygen is so abundant, constant and readily available to terrestrial organisms whereas it relatively scarce in aquatic environment hence a limiting factor for aquatic organism.

Level of Organization Hierarchy

In modern ecology, the concept of level of organization, visualized as an ecological spectrum (Fig.3) and as an extended ecological hierarchy.

Hierarchy means an arrangement into a graded series (Webster Collegiate Dictionary).

Interaction with the physical environment (energy and matter) at each level produces characteristic functional system. A system consists of "regularly interacting and interdependent components forming a unified whole" (Webster Collegiate Dictionary).

System containing biotic (living) and abiotic (nonliving) components constitutes biosystem ranging from genetic system to ecological systems. This spectrum may be conceived of or studied at any level as in Fig. or at any intermediate position convenient for analysis. For example, host-parasite relationship or system or two-species system of mutually linked organism (such as the fungi-algae partnership that constitutes the Lichen) is intermediate levels between population and community.

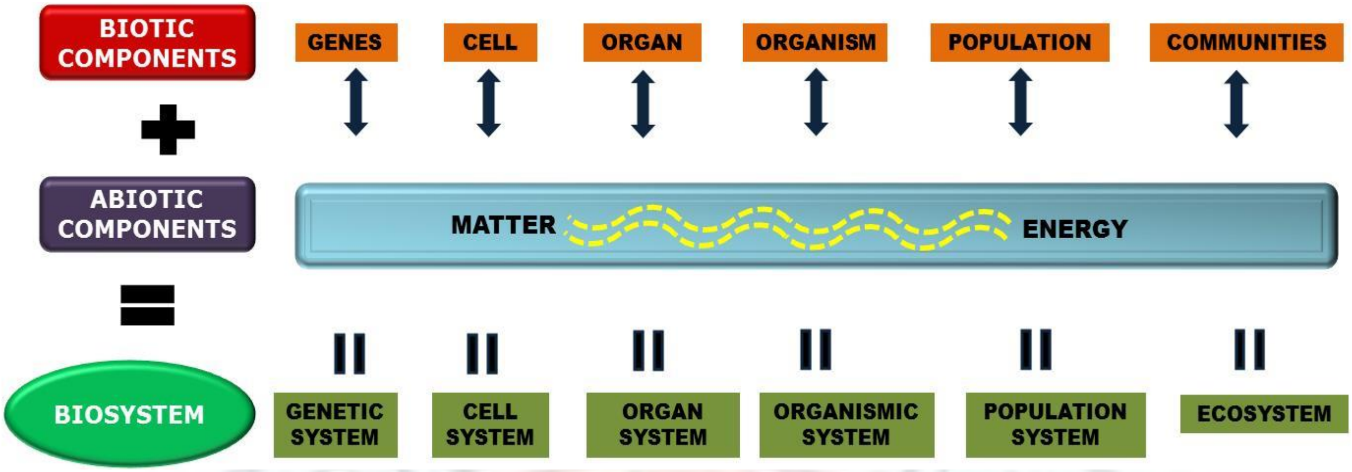

Fig. 4. Ecological level of organization spectrum emphasizing the interaction of Living (biotic) and nonliving (abiotic) components.
Source: ILLL in house

Ecology is largely, but not entirely concerned with the system levels beyond that of organism (Fig 4.). In ecology, the term population denotes a group of people is broadened to include groups of individuals of any one kind of organism.

Community, in ecological sense (sometimes designated as "biotic community") includes all the populations occupying a given area. The community and the nonliving environment function together as ecological system or **Ecosystem**.

Biocoenosis and **Biogeocoenosis** (literally, "Life and earth functioning together") terms frequently used in European and Russian literature are used equivalent to community and ecosystem respectively.

After ecosystem, is the landscape, which refers to scenery or painting. It is defined as a heterogeneous area composed of a cluster of interacting ecosystem that is repeated in a similar manner throughout. Large regional or subcontinental system characterized by a particular major vegetation type (such as temperate deciduous forest) is called biome. After landscape the largest and most nearly self-sufficient system is Ecosphere, which includes all the living organism of Earth interacting with the physical environment as a whole to maintain a self-adjusting loosely controlled pulsating state.

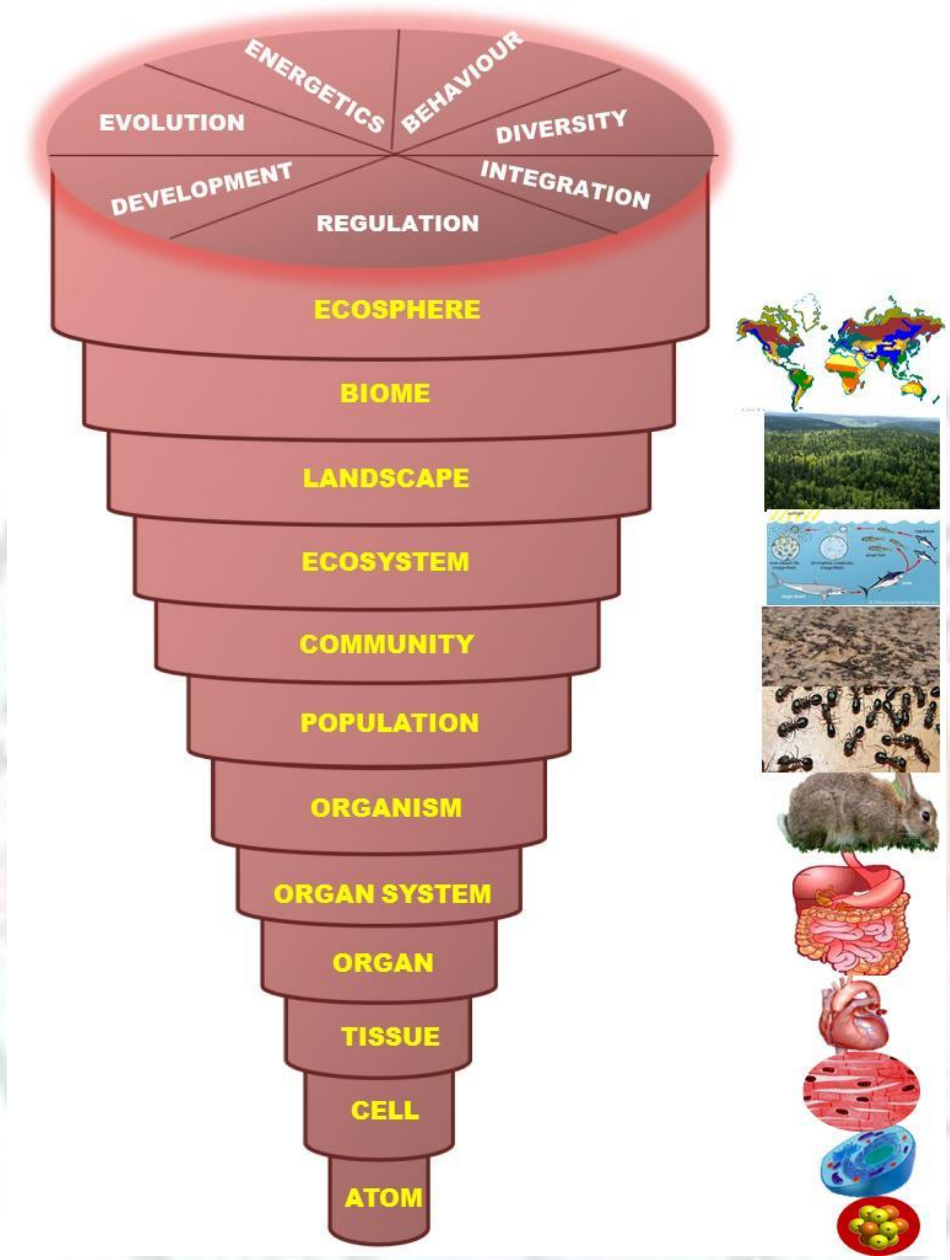

Fig. 5. Ecological level of organization hierarchy; seven transcending processes or functions are depicted as vertical components of eleven integrative level of organization. (After Barett et al, 1997)
Source: ILLL in house

Value Addition: Do you know

Heading Text: Levels of organization for living things

LEVEL	CHARACTERISTIC	EXAMPLE/APPLICATION
Biosphere	Worldwide ecosystem	Earth
Ecosystem	Interaction of biotic component with abiotic component in a particular space.	Aquatic ecosystem is made up of various flora and fauna, which live together and interact among themselves and also with the environment.
Community	Populations of several species, which interact with each other in a particular place.	Various forms of microbes living in gut of human.
Population	Group of individuals of a particular kind	Human population
Organism	Independent living unit	Bacteria, Amoeba, Rose plant
Organ system	Group of organs of body which coordinate to perform a physiological process	Circulatory system comprising of heart, arteries, veins, capillaries mainly works for blood circulation in body.
Organ	Group of various tissues which perform a particular function	Heart, Kidney, brain
Tissue	Group of cells which work together in coordination to perform a particular function	Blood is a connective tissue made up various components
Cell	Structural and functional unit of life.	Red blood cell
Molecules	Group of atom in specific arrangement	Carbohydrate, protein, DNA
Atoms	Smallest unit of matter	Carbon, Hydrogen, Nitrogen, Oxygen

Source: Author, ILLL in house.

Summary

- The term Ecology is the study of interrelationship of organisms with their total environment, physical and biological.
- Its origin is diverse but the main root goes back to early Natural History and plant Geography.
- It has evolved into the study of plant communities, ecosystems, trophic levels and energy flow.
- It also goes back to the study of natural selection and evolution, beginning with contribution of Darwin and Wallace. It is divided into population ecology, evolutionary ecology and theoretical ecology.
- Main subdivisions of ecology are autecology and synecology.
- Applied ecology is concerned with the application of ecological principles to major environmental and resource management problems.
- Various abiotic factors acts as limiting factor for the growth of any species or organism. And it has given rise to law of minimum and law of tolerance for their sustainable growth on earth.
- Modern ecology deals with the level of organization. Hierarchy means an arrangement into a graded series. It starts from cell level and goes to ecosphere level through graded series.

Exercises

1. Define the following:
    a. Ecology
    b. Population
    c. Ecosystem
2. Fill in the blanks

    a. …………………… factor of ecosystem includes plants, animals and microorganisms.

    b. An association of individuals of different species living in the same habitat and having functional interactions is called ……………………..

    c. The organisms that have a wide range of tolerance for any factor can be stated with a prefix …………………

    d. ……………………. deals with organism and their environment in geological past.

    e. Group of individuals of a particular kind are called …………………..
3. What is the difference between autoecology and synecology?
4. What do you mean by Limiting factors?
5. Explain the Liebig's Law of minimum.
6. Describe Law of Tolerance.
7. What do you mean by level-of-organization?

Glossary

Abiotic: Nonliving component of an ecosystem such as water, air, light and nutrients.

Biome: Large regional or subcontinental system characterized by a particular major vegetation type (such as temperate deciduous forest).

Biosphere: It is that part of environment of earth in which living organism are found.

Biotic: It refers to the living component of an ecosystem.

Community: It includes all their population inhabiting a specific area at the same time.

Ecology: It is derived from Greek word 'oiko", household and "logos", study of. It is a branch of science dealing with interactions and relationships between organism and environment.

Ecosphere: All living organisms of Earth interacting with the physical environment as a whole.

Ecosystem: A biotic community and its abiotic functioning as a system (first used by A.G. Tansley, 1935).

Habitat: It is a place where an organism lives.

Landscape: It is a heterogenous area composed od cluster of interacting ecosystem that are repeated in a similar manner throughtout the area.

Liebig's Law of minimum: This concept, first stated by Baron. J. von Liebig in 1840 sates that the essential material or resource most closely approaching the minimum need tends to be the limiting one.

Limiting factor: It is the resource that limits the abundance, growth and distribution of an organism or species.

Niche: Functional role of a species in a biotic community or ecosystem.

Population: A group of individuals of the same species living in a given area or habitat at a **given time.**

Shelford's Law of Tolerance: V.E. Shelford proposed it in 1911, stating that the presence and success of an organism or species depends on both the maximum and minimum resource and set of conditions.

System ecology: It is a branch of ecology focusing on general systems, theory and applications.

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