UNIT 1 CONCEPT OF BIODIVERSITY

Structure

1.0 INTRODUCTION

Biodiversity affects us in almost every walk of life. Biodiversity provides us with food in the form of cereals, grains, fruits, vegetables, meat, milk and eggs. Apart from the edible things, we get an assortment of materials like gum, resin, rubber, fibres, blubber, colours and dyes, hide, perfumes, pesticides, wax, lubricants, timber, paper which make our lives easier. Many medicines and drugs are either direct plant products, derived from plant products or synthetically produced compounds which mimic the actions of plant produced/derived chemicals. Coal, petroleum and natural gas, all are products of biodiversity. Biodiversity not only provides us with such materials (provisioning services), it also serves a lot of other regulatory functions like regulation of natural cycles (carbon cycle, water cycle, nitrogen cycle etc.), water purification, disease regulation. It also has protective functions such as protection of soil from erosion, protection against floods and tsunamis by reducing their impact. Biodiversity also has an aesthetic as well as social and cultural value to us. In this unit, you will be

1.1 OBJECTIVES

After studying this unit, you will be able to:

- Understand the Meaning and concept of biodiversity
- Identify the scope and constraints of Biodiversity Science
- Describe the Composition and Types of Biodiversity
- Describe measures of biodiversity

1.2 BIODIVERSITY - CONCEPT AND DEFINITION

Biodiversity is an umbrella term to refer to all the living organisms present in an area. The terms biological diversity and biodiversity are used synonymously, with their roots in 1980s. Biological diversity was used by Thomas E. Lovejoy to refer to the number of species, whereas Norse and McManus utilized it to refer to genetic and ecological diversity. The term Biodiversity has some ambiguous origins. The credit is however shared among W.G Rosen (In person, 1985), L. Tangley (in a table in a scientific paper, 1985) and E.O Wilson (In a book title, 1986).

United nation's Convention on biological diversity (CBD) a milestone conference that took place in 1992 defines biodiversity as "the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD, 1992).

1.3 SCOPE AND CONSTRAINTS OF BIODIVERSITY SCIENCE

Biodiversity science is much more than just identification and classification of species. As a science it is an amalgamation of various branches of science like Microbiology, Biotechnology, Bioinformatics, Biochemistry, Taxonomy, Physiology, Biophysics etc. Biodiversity science is indispensable if we want to conserve the present flora and fauna of the world. Many direct and indirect benefits arise from biodiversity and to use those resources sustainably we need to preserve the current life forms as best as we can.

Various limitations in this field are as follows:

- Vastness of the biodiversity and Area to be explored: The number of species that are still left to be discovered as well as the area, both terrestrial as well as marine is gargantuan.
- Lack of taxonomists/ specialists: The world faces a shortage of experts

that can find and identify new species as well as update the taxonomic status of different species. The lack of awareness about the importance of biodiversity among the masses and government is also one of the reasons for the poor condition of Biodiversity and conservation studies and research.

- Disturbance and extinction: The accelerated rate of biodiversity extinction due to anthropogenic reasons like industrialisation, habitat loss, biological invasion etc. have made it almost impossible to keep up with the current rate of extinction.
- Lack of resources in terms of manpower, fundings etc.

1.4 COMPOSITION AND TYPES OF BIODIVERSITY

There are three hierarchical levels of biodiversity in which it can be studied: Genetic diversity, Species diversity and Ecosystem or Community diversity.

1.4.1 Genetic diversity:

The genetic information of all the living species is contained in their genetic material either in the form of DNA or RNA. This genetic variability contained in the genetic material facilitates adaptations in an organism and constitutes the genetic diversity of a species. The more the genetic variability, the more a species is likely to adapt and survive natural selection and other environmental pressures. Lesser the genetic variability, more are the chances of a species to be vulnerable to threats like fungal, parasitic and insect infestations and diseases. Example of the threats arising due to reduced genetic variability includes the case of Gros Michel Banana which was one of the prime varieties grown in commercial plantations till 1960s, and was attacked by a fungal disease called as Panama disease caused by the Fusarium oxysporum which nearly wiped out the variety. As these plantations were essentially propagated by using cuttings and suckers, there was minimal genetic variability among them which led to the devastation of huge number of plantations of Gros Michel. Cavendish bananas (Musa acuminate) which are attacked by a disease called Black Sigatoka caused by the fungus Pseudocercospora fijiensis face the same fate as Gros Michel presently.

The number of genes identified in the living organisms varies a lot from 182 in Carsonella ruddii (a bacterium), 4000 in E. coli, 31,000 in freshwater crustacean Daphnia pulex, 25000 in domestic dog (Canis familiaris) to 32,000- 50,000 in Oryza sativa. Humans have around 20,000 to 25,000 genes although a recent study speculates the figure to be 46,831. The variations in the genetic makeup of species result in different phenotypes or morphological forms found in a species. Different breeds of domestic dogs result due to these variations even though they all belong to the same species.

Many molecular techniques are available to identify and manipulate genetic diversity. PCR (Polymeric Chain Reaction) is one such tool that allows us to make multiple copies of the desired segment of DNA, which can be further be used in other techniques. BLAST (basic local alignment search tool) is a tool that uses amplified DNA from PCR and compares primary biological sequences such

as amino acids of proteins or nucleotides of DNA/RNA. Other techniques like RFLP (restriction fragment length polymorphism), AFLP (amplified fragment length polymorphism), RAPD (randomly amplified polymorphic DNA) are also effective for studying and estimating genetic diversity. These tools and techniques can be used to trace back the evolutionary history (Phylogeny) of a species and its relatedness to other groups of organisms.

1.4.2 Species Diversity:

What is a species? Many researchers have tried to explain this basic term of biology using different concepts. Over 20 different concepts are available that try to define the term, such as morphological species concept, ecological species concept, phylogenetic species concept etc. However, currently the most accepted concept is the biological species concept (Mayr, 1942). According to the biological species concept ‘‘groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups”.

Estimation of number of species on earth has been taken up by many scientists, who have tried to come up with a number as close to the actual figure. But there is little consensus among them. One of the classical study taken up by Robert M. May in 1988 mentioned about the global number of species to be around 5 to 50 million. The major hindrance arising in the estimation of species present on earth is due to the number of unknown species whose prediction becomes excessively difficult. It is impossible to reach every nook and corner of the world and inventorying every single species, so certain patterns are extrapolated to estimate the number of species that inhabit the earth. An example of this is that the general assumption is that the ratio of fungi to vascular plants is of 6:1. And if there are ~270,000 species of vascular plants the number of species of fungi would be around 1.6 million. Similarly, there are roughly 50,000 species of tropical trees. Assuming a ratio of 5:1 of host beetles to trees, beetles represent 40% canopy arthropods and that the canopy has twice the number of species on ground, a figure of 30 million species of arthropods in the tropics was reached (Mora et al, 2011). Such ratio estimates have been criticised heavily but they do give a vague idea of the biological diversity. Other methods include extrapolation of discovery records using computer modelling.

Other studies have given numbers up to 100 million for the upper limit. The latest estimates of the number of species present on earth by Mora et al. in 2011 (both documented and undocumented) predicted that approximately 8.7 million (± 1.3 Million) species of eukaryotes reside on earth including ~2.2 million marine organisms (±0.18 million). The number of recorded species till now also varies from study to study, the general consensus is of ~1.7 million species (Table: 1). Insects form the majority of this figure, with a little over a million species described so far. Insects also outweigh other taxa in terms of the number of individuals. The variety of species living in an area constitute the species diversity of that region. Species diversity has different geographical distribution patterns. Ecosystems like tropical rainforests and corals are considered to be one of the most species diverse ecosystems. Whereas ecosystems like alpine tundra and boreal forests are comparatively less diverse. The general distribution patterns that are observed for species diversity predicts an increase in species diversity from poles towards equator. Also, a spatial movement from sea-level

to higher altitudes results in a decrease of species diversity.

1.4.3 Ecosystem Diversity: The number of ecosystems present in a region constitutes its ecosystem diversity. Earth harbours a wide variety of ecosystems which can be divided into terrestrial and aquatic. Aquatic ecosystems can be further be categorised into marine, freshwater and wetlands. Various types of terrestrial ecosystems are forest, grassland, desert, wetland, and tundra. Larger ecological systems are composed of biomes, which are fundamental units categorised on the base of vegetation and climatic parameters. Ecosystems like grasslands, rainforests, deserts and other ecosystems including aquatic ecosystems can be found a region, and make it ecosystem diverse.

The more ecosystem diverse a region is, the more species diversity can be expected to be found there.

Biomes are large geographical area categorised mainly on the base of vegetation and climatic conditions. The various biomes harbour different kinds of diversity. The major terrestrial biomes are as follows:

Tropical rainforests: These forests are located on or near the equator, where the atmosphere remains humid with small or no dry season. They receive high rainfall and generally have acidic, nutrient poor soil. The decomposition rate is rapid, the nutrients released are also swiftly taken up by vegetation. Vegetation stratification is common and the canopy can be so dense that almost no direct sunlight reaches the ground. The biodiversity and productivity of these areas are very high. South America, Central America, Africa, South East Asia are the major parts of the world that harbour this kind of vegetation.

Tropical seasonal forests: These comprise of monsoon forests and many other forest communities with semi evergreen or deciduous leaf habit. In comparison to Tropical rainforests have a pronounced dry phase during which the most of the trees partially or wholly shed their leaves. These forests are majorly found in India, South America, Central America South East Asia, Africa, Northern Australia and West Indies. These areas receive a large amount of rain although most this precipitation occurs in short periods.

Tropical thornlands and broadleaf woodlands: These occur in tropics as well. Broadleaf woodlands occur towards drier climatic conditions. Cerrado of Brazil is a representative forest of the tropical broadleaf woodland where the canopy varies from closed to open, with or without scattered trees. Leaves on trees and scrub are large in size, branches are markedly twisted and the barks are thick and fire resistant. Cerrado occurs in the transition zone of Tropical seasonal and tropical thornwoods.

Tropical Savannas and grasslands: Savannas are tropical grasslands with scattered shrubs or trees. The most dominant vegetation is of grasses like *Panicum, Andropogon, Pennisetum* and *Imperata.* Trees (mostly *Acacia* spp.) are scattered sparsely in the landscape. Savannas are most dominantly found in Africa, which has given rise to the most prolific diversity of grazers and browsers. Apart from Africa, tropical grasslands are found in Australia, South America and Southern Asia. Species richness is far lower in savannas as

compared to tropical rainforests. Loamy sand and summer rains less than 50 cm favours the sustenance of savanna. Frequent fires are common feature of tropical grasslands.

Temperate rainforests: These are forests found at higher latitudes than the tropics, with winter rainfall and develop in colder climatic conditions. Species richness is low as compared to tropical rainforests. *Sequoia, Pinus, Abies, Larix* and *Calocedrus* are some of the tree species found here. Trees easily acquire longevity of 500 years. A belt of mixed coniferous rainforests along the pacific coast of North America is a typical example.

Temperate Forests: Temperate forests are divided into temperate evergreen forests and temperate deciduous forests**.** Temperate evergreen forest have trees with relatively small and broad leaves are found in the less humid, maritime climates in California, the Mediterranean region and southern Australia, whereas needle shaped evergreen forests (Conifers) are found in large areas of continental climates. The mixed forests of Sierra Nevada with Pine, Fir, Incense Cedar, and Sierra Redwood are also representative of temperate evergreen forests. In India, high altitude areas in Himalaya have abundant temperate evergreen forests. Temperate deciduous forests are mostly confined to northern hemisphere. The temperature may vary from -30° C to 38° C, without clear-cut wet and dry seasons. Annual precipitation is between 600-2000 mm with moderately humid continental temperate climate with a prominent winter (Although not prolonged). Tree height is usually around 35 meters. Canopy is relatively open as compared to temperate coniferous forests. Growth period is 4 to 6 months which starts with snow melt in March-April and ends in autumn. Acorns and beech nuts are common. Bears, gray fox, gray squirrels are some of the animals found in these forests.

Temperate grassland: These occur in areas receiving intermediate rainfall between deserts and forests. Long cold winters and hot summers is characteristic of these areas. The prairies of North America and steppes of Eurasia are the typical examples of this biome. They are also found in Africa (Velds) and Argentina (Pampas). Mammals of these regions are either large running types like, Zebra, Bisons, Wild Horse, and Pronghorns or small burrowing type such as Prairie dogs and Ground squirrel. Big Bluestem (*Andropogon gerardii*), Wheat grass (*Agropyron smithii*) and Buffalo grass (*Buchloe dactyloides*) are some of the grasses found in this biome.

Desert: Deserts are mainly located in the subtropics, and receive very less annual precipitation. The amount of precipitation received can be used to classify deserts into different categories like hyper arid, arid and semi-arid. These areas can get extremely hot, especially during summers. Biodiversity is poor and vegetation is sparse with distinctive low shrubs and xerophytic adaptations. Soil type is mostly sandy with or without salt crust. Sahara, Arabian peninsula, west coast of South America, parts of Australia are typical examples of desert. Thar in the western region of India is the only desert in India.

Taiga (Boreal forest): Extensive cover of coniferous trees is found in these areas. Trees like evergreen spruce, firs and pines dominate the landscape. These are found in areas unfavourable for the growth of broadleaf deciduous or

evergreen temperate forests. Summers are too short and winters, too long here. Species richness is generally low. Shrubs and under canopy trees are scarce. However, mosses and lichens may cover the entire ground surface. Taiga covers Eurasia to the northern parts of North America.

Tundra: Tundra does not have climatic conditions that favour tree growth. The vegetation is mainly of lichens, mosses, grasses and dwarf shrubs that grow mostly during the summers when the permafrost thaws. Plants generally do not exceed the height of 10 cm because of low temperature, low sunlight, permafrost, strong wings, and low evaporation rate. Reindeer, Muskox, Caribou, Polar bears and Lemmings are prominent mammals

1.4.4 Landscape Diversity: Landscape, in ecology, is a unit with geographical limits and having climatic and geo-morphological characteristics. A landscape may cover one or more than one community and ecosystem. Diversity of biotic and abiotic system, each characterized by a specific geo-diversity and biodiversity and incorporates anthropogenic interactions as important structural and functional component.

Global patterns of biodiversity distribution:

Biodiversity is unevenly distributed across the different biogeographic regions with certain places being more biodiversity rich. Tropical forests stretching on or near the equator account for only about 7 percent of earth's geographical area but contain around 70 percent of species documented till now. These biodiversity rich areas are called as biodiversity hotspots. These hotspots have a high rate of endemism and are under a high degree of threat of habitat destruction. Two gradients of biodiversity distribution are observed: Latitudinal and Altitudinal. As we move from equator towards poles, biodiversity decreases. This pattern is seen not only in terrestrial ecosystems but freshwater and marine ecosystems as well (Figure: 5). Northern hemisphere generally shows a steeper gradient than southern hemisphere. The amount and duration of sunlight, temperature, precipitation, humidity, seasonal variability and other environmental factors are the reasons for this kind of distribution. Altitudinal gradient is also affected by these factors and results in decreased biodiversity as we move towards higher elevations.

The above mentioned patterns and gradients of biodiversity at the global level can be explained based on a number of hypotheses. Evolutionary time hypothesis states that as more time was available for diversification of older communities, they show higher degree of species diversity as compared to newer communities. Another proposition according to Climate stability hypothesis is that more diverse niches are created and sustained in stable climatic condition zones and hence lead to more species diversity. Spatial heterogeneity hypothesis explains these patterns on the basis that availability of more diverse and complex environment on a spatial scale favours and supports a wider range of species diversity due to less competition and greater availability of resources. The amount of energy flowing through the food web determines the diversity in a community is yet another explanation provided by the Productivity hypothesis.

1.5 MEASURES OF BIODIVERSITY

Conservation and management of biodiversity first requires to have an accurate estimate of the total abundance and distribution of species in an ecosystem. There are multiple methods of estimating biodiversity of a region, more important of which are briefly mentioned below.

Genetic diversity is measured basically from the gene pool of a particular species. To estimate the genetic diversity of an organism (Whole Genome Sequencing) is carried out. This includes mapping of chromosomal as well as mitochondrial DNA sequencing for animals and DNA from chloroplast in case of plants. Genbank is a repository which maintains a database of nucleotide sequences and their protein translations. Human genome project was one such ambitious project which was initiated in 1990 and aimed at sequencing the entire euchromatic human genome. The project was declared to be complete in 2003.

Species diversity can be estimated on count of two main parameters i.e. species richness and relative abundance. Species richness is a simple count of different species occupying a particular area. Relative abundance of a particular species is the proportion of the total number of species found in an area. Relative abundance gives an estimate of evenness or dominance of a species. An increased evenness gives more stability to an ecosystem and makes it more species diverse. On the contrary increased dominance of one or a few species makes the ecosystem fragile and prone to collapse. Many research studies have established that more species rich systems exhibit an increase in productivity, nutrient cycling, and resistance towards disturbance or invasion as compared to systems with lesser species richness (Hughes and Stachowicz, 2004).

A Rank abundance curve (Whittaker plot) is a graph depicting the relative abundance of species in an area. Species are plotted on x axis arranged from most to least abundant and on y axis their relative abundance is plotted (generally in a $\log_{10}$ format). It can also be used to show species diversity and abundance. Species richness and evenness can be easily visualized in a Whittaker plot. A steeper slope on a Whittaker plot shows high dominance, whereas a shallower slope depicts high evenness. Preston Plot is a histogram that depicts logarithm bins of abundance on x axis and numbers of species in each abundance bin.

1.5.1 Biodiversity Indices

For better understanding of the distribution of species, ecosystem health and other such phenomenon we need to estimate the diversity of the area and to estimate it we use different indices. A biodiversity index is a quantitative tool which helps us measure the distribution of various species present in a community and their richness, evenness and dominance. Many such indices have been devised so far, some of which are as follows:

1. **Shannon index** relies on the assumption that the individuals are sampled randomly from an infinitely large community and that all the species are represented in the sample. The equation for calculating Shannon index is as follows:

$$H' = - \sum p_i \ln p_i$$

Where p_i is the proportion of individuals found in the *i*th species.

The value of H' generally ranges between 1.5 and 3.5 and rarely goes over 4. Only when the number of species in the sample are huge, high values of H' are obtained.

2. **Simpson's index** gives us the probability of drawing any two individuals at random from an infinitely large community belonging to the same species. The formula for Simpson's index is as follows

$$D = \sum p_i^2$$

Where p_i= proportion of individual in *i*th species.

As the value of D increases, diversity decreases therefore Simpson's index can be simplified by expressing it as 1-D or 1/D. Simpson's index is more sensitive towards finding out the most abundant species rather than to species richness.

3. **Simpson's measure of evenness:** A simple derivation of the Simpson's diversity index can provide the value of evenness by simply dividing the value of Simpson's index by the total number of species in the sample, given by the formula:

$$E_{1/D} = \frac{(1/D)}{S}$$

S= Total number of species in the sample.

The value of Simpson's measure of evenness ranges from 0-1.

4. **Berger Parker Index (d):** It is a simple dominance measure which expresses the proportional abundance of the most dominant (Abundant) species. It is calculated by the following equation:

$$d = N_{max}/N$$

where, N_{max} is the number of individuals of the most abundant species.

One major flaw that estimates of species diversity have is that they considers all taxa to be theoretically of equal significance, which is not always the case. Organisms have different ecological roles, some may have more ecological importance than compared to others.

1.5.2 Alpha, Beta and Gamma Diversities:

Ecosystem diversity can be observed at three different levels: Alpha (α) diversity, beta (β) diversity and gamma (γ) diversity. Alpha diversity is the diversity of a particular site and includes all the species of organisms in that area. Beta diversity is a comparison of two ecosystems and gives the number of species unique to the ecosystems being compared. Alpha diversity includes the diversity **within** the ecosystem and beta diversity includes the diversity **between** ecosystems. Gamma diversity gives the **overall** diversity of a large

area which may include many ecosystems. Beta diversity can be calculated as $\beta = \gamma/\alpha$. Although Beta diversity can also be calculated as absolute species turnover (where presence absence data is used for two subunits) which is given by the following formula:

$$\beta_A = (S_1 - c) + (S_2 - c)$$

Where, S_1 is number of species in community 1, S_2 is the number of species in community 2 and c stands for the number of species common to both communities.

Consider the following example: In a comparison of two ecosystems of Grassland and Wetland, five species are found (A, B, C, D and E). The presence of the species is shown with a + sign, whereas the absence is shown with a – sign.

Species	Grassland Ecosystem	Wetland Ecosystem	Pond ecosystem
A	+	-	-
B	+	-	-
C	+	+	-
D	+	+	+
E	-	+	+

Here the alpha diversity of grassland ecosystem is given by counting the number of species in each ecosystem (4 in grassland, 3 in wetland and 2 in case of pond ecosystem) whereas Beta diversity is the number of uncommon species between any two ecosystems (For example, in a comparison between grassland and wetland ecosystem, the number of species which are not common to both the ecosystems = 3). Gamma diversity is the total number of species in an area which may include all these three ecosystems (=5)

Check Your Progress 1

Note: a) Use the space given below for your answers.

b) Check your answers with those given at the end of unit

1. What is biodiversity and what are the different levels of biodiversity?

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2. What are the measures of biodiversity ?

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1.6 LET US SUM UP

Biodiversity is the variability of all the living organisms inhabiting an area, and it includes the genetic, species and ecosystem variability. Genetic diversity includes the variability of genetic information carried by an individual or a species from a given area. Species diversity includes the number of species residing in an area at a particular time. Ecosystem diversity is the diversity of different ecosystems present in an area and can be measured as alpha, beta or gamma diversity. Various measures of diversity have been devised of which the most important ones are the biodiversity indices like Shannon index and Simpson index.

1.7 KEYWORDS

- **Biodiversity**: The variety and variability among the life forms including plants, animals, and microorganisms.
- **Species:** According to the biological species concept ‘‘groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups”.
- **Alpha (α) diversity**: Alpha diversity is the diversity of a particular site and includes all the species of organisms in that area.
- **Beta (β) diversity**: Beta diversity is a comparison of two ecosystems and gives the number of species unique to the ecosystems being compared.
- **Gamma diversity**: Gamma diversity gives the **overall** diversity of a large area which may include many ecosystems

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Table 1: Number of documented species in various taxa. (Retrieved July 03, 2019, from https://nc.iucnredlist.org/redlist/content/attachment_files/2018_2_RL_Stats_Table_1_new_errata.pdf)

Organism Group	Estimated Number of described species
VERTEBRATES	
Mammals	5,677
Birds	11,122
Reptiles	10,711
Amphibians	7,866
Fishes	33,900
Subtotal	69,276
INVERTEBRATES	
Insects	1,000,000
Molluscs	85,000
Crustaceans	47,000
Corals	2,175
Arachnids	102,248
Velvet Worms	165

Horseshoe Crabs	4
Others	68,658
Subtotal	1,305,250
PLANTS	
Mosses	16,236
Ferns and Allies	12,000
Gymnosperms	1,052
Flowering Plants	268,000
Green Algae	6,050
Red Algae	7,104
Subtotal	310,442
FUNGI & PROTISTS	
Lichens	17,000
Mushrooms	31,496
Brown Algae	3,784
Subtotal	52,280
TOTAL	1,737,248

1.9 TERMINAL QUESTIONS

- Define biodiversity and its significance?
- What is genetic diversity and elaborate its importance?
- What is the difference between alpha, beta and gamma diversity?
- Briefly explain the different biomes found on earth.
- How can diversity of an area be calculated?

1.10 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Your answer must include the following points
    - definition and concept of biodiversity (Refer section 1.4)

2. Your answer must include the following points
    - Different levels of biodiversity (Refer section 1.5)