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Fundamentals of

Ecology *and* Environment

Pearson

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Fourth edition

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Chapter 1

The Environment

Organisms and their environments are dynamic and interdependent. The term '**environment**' etymologically means *surroundings*. It includes everything (biotic as well as abiotic) that surrounds an organism. Any factor, abiotic or biotic, that influences living organisms is called **environmental factor** (or *ecological factor* or *ecofactor*). **Abiotic factors** include factors such as temperature, sunlight levels, pH, salinity and soil composition. In contrast, **biotic factors** encompass producers, consumers and decomposers.

1.1 Physical environment

Soil

Soil constitutes the uppermost weathered layer of the Earth's crust. It is a mixture of weathered mineral rock particles, organic matter (i.e. both living and dead), water and air. Soil is a biologically active matrix and home of diverse organisms. The scientific discipline dedicated to the study of soil is known as **pedology**.

Weathering and soil formation

The process of soil formation includes the formation of unconsolidated materials by the weathering process and the soil profile development. Weathering refers to the **physical disintegration** and **chemical decomposition** of the rocks and minerals contained in them. Physical disintegration breaks down rock into smaller fragments and eventually into sand and silt particles that are commonly made up of individual minerals. Simultaneously, the minerals decompose chemically, releasing soluble materials and synthesizing new minerals. New minerals form either by minor chemical alterations or by a complete chemical breakdown of the original mineral and resynthesis of new minerals. Based on the location of soil mineral particles formation and deposition, the soils are classified as *residual soil* and *transported soil*. If the soil mineral particles have been formed in place from the bedrock below, it is called **residual soil**. If the soil mineral particles have been carried from some other location by wind, water, gravity or ice then it is termed as **transported soil**. The transported soil can be classified into **colluvium** (transported by gravity), **alluvium** (transported by the movement of water), **glacial soil** (transported by the movement of glaciers) and **eolian soil** (transported by wind).

Chapter 2

Ecosystem Ecology

An **ecosystem**, also known as an **ecological system**, represents a structural and functional unit of nature that encompasses all organisms within a physically defined space. These organisms interact with each other and their physical environment. Essentially, any system that encompasses interacting **biotic** (living) and **abiotic** (nonliving) components can be classified as an ecosystem.

The concept of an ecosystem was first formally proposed by the English botanist Arthur Tansley in 1935. The term **biogeocoenosis** (proposed in the 1940s by the Soviet ecologist V. N. Sukachev) frequently used in Russian literature is roughly equivalent to the ecosystem. Its literal meaning is '*life and Earth functioning together*.' A key advance in the adoption of the ecosystem concept occurred after the appearance of a popular textbook by Eugene Odum. Odum's textbook was organized around the ecosystem concept. After Odum's textbook, a famous article in Science by Francis Evans (1956) mentioned the ecosystem as '*the basic unit in ecology*.' In the broadest sense, *an ecosystem is the interacting system made up of all the living and non-living objects in a physically defined space.*

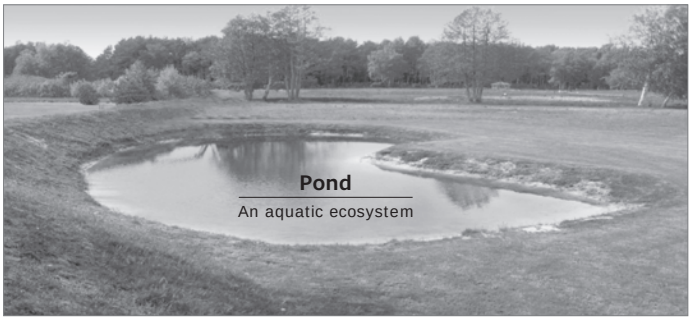

Figure 2.1 An aquatic ecosystem. A physically defined space comprising all the organisms which are interacting with one another and with their physical environment.

According to this simple definition, the size, location and timescale at which ecosystems are defined can therefore precisely match the question that the scientist is trying to answer. An ecosystem could be of any size depending on the communities to be studied and its boundaries can be either real or arbitrary. An ecosystem may be as small as a single tree or as large as the entire Earth and can be studied for time periods as long as millions of years.

An ecosystem can be visualized as a functional unit of nature. It has all components: biological and physical, necessary for survival. Accordingly, it is the basic unit around which theories and experiments of ecology are organized.

Chapter 3

Population Ecology

Each species in an ecosystem exists as a population. A **population** is a group of individuals of the same species that live together in a region. In essence, a population, also referred to as a biological population consists of a group of interbreeding or potentially interbreeding individuals found in the same space or area at the same time. The study of populations (especially population abundance) and how they change over time is called **population ecology**. It studies the spatial and temporal patterns of the abundance and distribution of organisms and mechanisms that produce those patterns. The study of population ecology includes understanding, explanation and prediction of population growth, regulation and dynamics or demography.

Multicellular organisms are of two kinds, unitary organisms and modular organisms. Most animal populations are made up of **unitary organisms**. In unitary organisms, the form is highly determinate consisting usually of a strictly defined number of parts (such as legs or wings) established only during embryogenesis. Their pattern of development and final form are predictable. For example, all dogs have four legs, all squid have two eyes, etc. In **modular organisms**, on the other hand, neither timing nor form is predictable. These organisms grow by the repeated iteration of modules, usually to yield a branching pattern. Examples of modular organisms include plants and many sessile benthic invertebrates. In modular organisms, a single genetic individual (or *genet*) can consist of many modules (or *ramets*) capable of existence as individuals. In plants, a **genet** is an individual that has arisen from a seed. A **ramet** is a new plant which has arisen through vegetative propagation and is now a completely independent plant with its own roots and shoots. For example, a population of grasses may consist of several genets, each of which has several ramets.

3.1 Population characteristics

Scientists study a population by examining how individuals within that population interact with each other and how the population as a whole interacts with its environment. A population has several characteristics or attributes which are a function of the whole group and not of the individual. Different populations can be compared by measuring these attributes. These attributes are *population density, natality, mortality, distributions*, etc. The study of the group characteristics of a population, their changes over time and the prediction of future changes is known as **demography**.

Demography is the study of the vital statistics of populations and how they change over time.

Chapter 4

Community Ecology

An **ecological community** is a group of species that coexist in a space and time and interact with one another directly or indirectly. The term 'community' means different things to different ecologists. Most definitions of ecological communities include the idea of a collection of species found in a particular place. For instance, Whittaker (1975) defined ecological community as,

'…an assemblage of populations of plants, animals, bacteria and fungi that live in an environment and interact with one another, forming together a distinctive living system with its own composition, structure, environmental relations, development and function.'

Simply, an ecological community is a group of interacting species that inhabit a particular location at a particular time. Most communities are extraordinarily complex. However, the main features of ecological communities include the following.

Firstly, a community represents the biotic or a living component of the ecosystem. Organisms within a community include primary producers, consumers and decomposers. In terrestrial communities, the community structure is largely defined by the vegetation.

Secondly, considering the functional aspect, communities are made up of organisms with interlocking food chains and each species depends on many other species in a community which is taxonomically unrelated.

Thirdly, a community may be of any size. It can range from small pond communities to large tropical rainforests.

Community ecology is a field that examines the effects of abiotic and biotic features on community or assemblage structure. Community ecologists study the number of species and their relative abundance in a particular location and ask why the number of species and their abundance changes over time. They also do study communities in different locations and differences in the species diversity with location. In a broad sense, the goal of community ecology is to understand the origin and maintenance of biological diversity within communities.

A **community** is a group of interacting populations of different species present together in space, whereas **assemblage** is a taxonomically related group of species populations that occur together in space.

There are two contrasting concepts of the community – *organismal* and *individualistic concepts*. The **organismal concept** of communities (put forward by Clements, 1916) views the community as a unit, an association of species, in which each species is representing an interacting, integrated component of the whole and development of the community through time (a process termed *succession*) is viewed as the development of the organism. This type of community organization is commonly known as a **closed community**.

Chapter 5

Biodiversity

Biodiversity, short for **biological diversity**, refers to the sum total of all the variety and variability of life in a defined area. In contrast to the more specific term *species diversity*, the term *biodiversity* was coined to emphasize the many complex kinds of variations that exist within and among organisms at different levels of the organization. It refers to the totality of genes, species and ecosystems of a region. United Nations Earth Summit defined biological diversity as:

'*Biological diversity means the variability among living organisms from all sources including, inter alia (among other things), terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems*.'

Convention on Biological Diversity, **1992**

5.1 Levels of biodiversity

Biodiversity includes three hierarchical levels: Genetic, species and ecosystem diversity.

Genetic diversity

Genetic diversity refers to the variation in the genetic composition of individuals within or among species. Genetic diversity enables populations to adapt to their environments and respond to natural selection. The extent of genetic variation serves as the raw material for speciation. Genetic diversity can be observed at multiple levels of biological organization, including kingdoms, phyla, families, as well as among species and within species. The most significant genetic diversity is typically observed between organisms from different kingdoms (e.g., plants versus animals), between phyla (e.g., arthropods versus chordates), between classes (e.g., birds versus reptiles), and so on.

Species diversity

According to the biological species concept, species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups. Hence, species diversity refers to the variety of species within a region, i.e., **species richness**. However, in the broader sense, species diversity includes not only species richness but also **species evenness**.

Chapter 6

Pollution

Pollution is any undesirable change in the physical, chemical, or biological characteristics of the air, water and land that can harmfully affect the living organisms and the ecosystem as a whole. Any substance introduced into the environment that adversely affects the physical, chemical or biological properties of the environment that have a harmful effect on the ecosystem as a whole is termed as **pollutant**. There are three major types of environmental pollution: air pollution, water pollution and soil pollution.

6.1 Air pollution

Air pollution may be defined as any atmospheric condition in which *substances* are present at concentrations above their normal permissible levels to produce a *measurable effect* on man, animals, vegetation or materials. Substances mean any natural or anthropogenic (man-made) chemical compounds capable of being airborne. They may exist in the atmosphere as gases, liquid drops or solid particles.

According to Air (prevention and control) act, 1981, an *air pollutant* is any solid, liquid or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human being or other living creatures or plants or property or environment.

6.1.1 Composition of air

Air is a heterogenous mixture of different gases that makes the atmosphere. *Atmosphere* is the gaseous mass or envelope surrounding the Earth and retained by the Earth's gravitational field. The troposphere is the lowest portion of Earth's atmosphere. It contains approximately 80% of the atmosphere's mass. By volume, standard dry air contains 78.08% nitrogen, 20.9% oxygen, 0.9% argon, 0.040% carbon dioxide, and small amounts of other gases. There are two common ways by which one can represent the composition of air – *percentage of gas by volume* or *percentage of the gas by mass.* It is important to note that, the composition of different gases (in dry air) by mass is a fixed one whereas the percentage composition of the gases by volume or mass in wet air (i.e. air containing moisture) is dependent on humidity or the moisture in the air.

Chapter 7

Climate Change

Climate refers to the long-term patterns of weather conditions in a specific location, region, or across the entire planet. It is typically characterized by analyzing meteorological data over a period of at least 30 years, and this analysis includes variables such as temperature, humidity, atmospheric pressure, wind patterns, precipitation, and other meteorological factors.

'*Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system*.'

IPCC, **2001**

The terms **climate** and **weather** have different meanings. *Weather* represents the short-term state of atmospheric conditions (such as temperature, pressure, humidity, precipitation, wind speed and direction, and more) for a specific place and time. It exhibits both temporal (time-related) and spatial (location-related) variations.

7.1 Climate change

Climate change is a large-scale, long-term shift in weather patterns and atmospheric conditions on a global scale.

According to **IPCC**, 'Climate chang*e refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use*.'

The **UNFCCC** defines climate change as, '*a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods*'.

The UNFCCC, thus, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.