Ecology and Environment 2

The study of environmental science has assumed great significance, particularly during the second half of the 20th century. Ecology deals with the study of structure and function of nature, whereas environmental science, with somewhat vague and limitless boundaries, is primarily concerned with the interrelationships of humanity among other living organisms and the non-living physical environment. Therefore, environmental science is though strongly biocentric, its holocoenotic nature is emphasized. The holocoenotic approach to environment stresses that any part of the environment responds simultaneously to all environmental factors that impinge upon it. This is a holistic approach to the environment in the sense that it recognizes that the environment as a whole affects the living biota (or now abiotic too). Holocoenotic is derived from *holocoen,* a term coined by the marine ecologist Karl Frederick in the 19th century to emphasize the interdependence and interconnections of organisms with their environment.

Thus environment is the object and ecology is the science that deals with it. Ecology, therefore, must be at the core of any environmental science programme. Ecology provides the most scientific approach and methodology to understand and evaluate the present day environmental crisis, and to find ways and means to resolve the crisis so as to ensure a better tomorrow for the human race. Resolution of burgeoning environmental problems is not possible without a thorough understanding of ecological principles, therefore appropriately trained ecologists (both generalists and specialists) are required with the passage of time for the sustainable environment, and the new generation of ecologists should be capable to predict, plan and manage the environment and resources.

Like morphology, physiology, genetics or embryology, 'ecology' is a basic division of biology. It is also an integral part of any and all taxonomic systems such as Protozoology, Mycology, Entomology, Ornithology, etc.

Ecology is the study of the relationships between living organisms (the biota) and their physical environment (the abiota). In its broadest sense, ecology is the study of organisms as they exist in their natural environment.

According to *Taylor* (1936), "Ecology is the science of all the relations of all living organisms to all their environment."

The origin of the word "ecology" is of interest. It has been traced to the Greek word *oikos*, which means 'household', and thus ecology basically means the management of the household, or the management of the living space. The term ecology was first used by the German ecologist *Haeckel* in 1866, who defined it as follows:

Ecology basically means the management of the household, or the management of the living space.

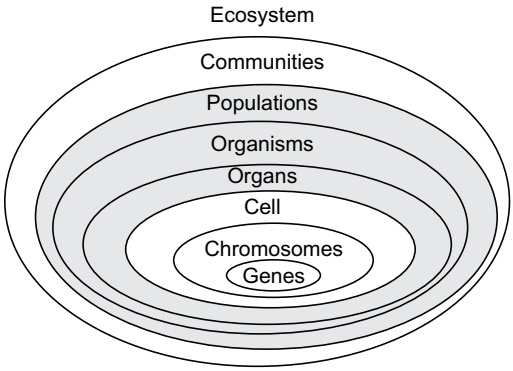
area measured in terms of acres or hundreds of square miles to an exposed surface of rock or the lower surface or a twig, a few square centimeters or a fraction of a square millimeter in area. The latter two examples are called microhabitats by most ecologists; they have been intensively investigated for the past twenty or more years as instruments have become available for measuring the fluctuations in the microenvironment extent in such localities.

The environmental conditions prevalent within any specific habitat will be unique for that area, though similar conditions may prevail in a habitat of the same type a fraction of a kilometer or thousands of kilometers distant. For example, temperature, wind movement, fauna and flora present will be similar in any particular type of deciduous forest for any specific time of year, but all of these conditions will not be exactly the same for any two such habitats. Furthermore, conditions within any habitat will vary from place to place. For example, there would be in a forest environment different temperatures, humidity, and wind movement in the treetop area (forest canopy) than there would be near the forest floor or in the soil. Finally, to compound the situation, seasonal differences will exist in any habitat throughout the year. In a pond habitat, the temperature of the water, oxygen content, amount of plankton (including diatoms, algae, and bacteria as well as small and often immature crustaceans and various aquatic worms) and fish population will be quite different in the vernal (spring) period than they would be in the aestival (summer) aspect of the year.

Ecologist

The ecologist is a chartered libertine. He roams at will over the legitimate preserves of the plant and animal biologist, taxonomist, physiologist, geographer, meteorologist, climatologist, physicist, chemist and even the sociologist. He poaches from all of these and from other established and respected disciplines.

Since Macfadyen wrote that passage (Animal Ecology: Aims and Methods, 1957), many changes have taken place in our attitudes and approaches to the study of the environment. In the mid-1950s, the global population figure was about 2.7 billion. Now, at the turn of the Millenium, it is more twice that at 6.0 billion. Whereas in the mid-1950s, it was the study of ecology that was seen as central to the study of the total environment. Now we recognise that we must deal with not only the natural environment but also the human environment. It is the impact of people upon the planet and, in particular, on its resource base that has now assumed major concern. The central position of the ecologist has been replaced by the 'specialist' trained in the skills of multi-disciplinary approach to problem solving. Geographical knowledge forms an integral part of this new multi-disciplinary approach for solving the environmental and conservation issues.



BIOLOGICAL SPECTRA

Delimitation of the field of ecology can be done on the basis of concept of levels or organization. We can think of the following sequence with respect to levels of organization: Genes → Chromosomes → cells → tissues → organs → organ systems →

organisms → populations → communities → ecosystems, and the biosphere.

According to Odum, ecology is concerned mainly with the latter four levels (populations → communities → ecosystems → biosphere), i.e., beyond that of the individual organism. The term "population" in ecological sense means 'groups of organisms'. Similarly, in ecology, the community (also known as biotic community) includes all the populations of a given area. The ecosystem or ecological system includes both the community and the nonliving environment, each influencing the properties of the other. The biosphere denotes the portion of the earth in which ecosystems can operate, i.e., biologically inhabited soil, air, and water.

An *ecological hierarchy* has been established that becomes more restrictive as we pass downward from one hierarchical level to another. The ecosystem includes all living and nonliving components of the environment, so that the entire world could be considered a giant ecosystem. A pond, a forest, and a desert area are examples of *ecosystems*, each containing living organisms. A pond ecosystem would likely contain algae, insects, crustaceans, bacteria, seed plants, snails and fish as its living component. Then the ecologist must consider all of the abiotic factors of the environment such as sunlight, cosmic radiation, temperature, oxygen concentration of the water, mineral content, type of substrate, and other related factors.

At the community level, as distinguished from the ecosystem, the ecologist is primarily concerned with the plant and animal life in an area.

Going a step further down, the ecological hierarchical ladder, population ecology deals with a species or at times several closely related species and can often provide with essential material. Meteo and rological studies and climatological data for certain geographic localities allow for a more subtle interpretation of results.

Pedology, the study of soils, their acidity, alkalinity, humus content, mineral content, soil type, and so on, is often of importance to the terrestrial ecologist. If an investigator restricts his studies to forest communities, a basic knowledge of forestry can be unvaluable in terms of forest type distribution, floristic composition and prevalent environmental factors.

Statistical data are becoming more important in interpreting the reasons for activity, population increases, migrations, probability of ecological events occurring in a particular area, sampling techniques and reliability of results.

Ecology is also closely allied with a number of biological disciplines; in fact, there are few biological disciplines that cannot be utilized by some ecologists in a phase of laboratory or field work. Some biological studies are of prime importance to the ecological investigator.

Since ecology is related to the study of physical and biological environment, therefore, many branches of science such as *Physics, Chemistry, Geology, Microbiology, Botany* and *Zoology*, are intimately associated with it. In other words, the study of various aspects of ecology is facilitated by the coordinated application of the various branches of science.

Palaeontology provides information about the ancestral organisms and environmental situations prevalent in the past. Without the knowledge of the functional aspect (physiology) of life, the ecologist would generally have a very incomplete idea of the critical environmental factors and their effects on the biota. Systematics provide the means of identifying the organism(s) under investigation as well as information about the effects of isolation and geographic races. Evolution and genetics are utilized to interpret the reason for organic changes when linked with environmental conditions, establishment of new populations and species, environmental effects of genetic populations, and so on.

Ecology may also be subdivided from the view point of taxonomy, e.g., plant ecology, insect ecology, microbial ecology, vertebrate ecology, etc.

Ecology is concerned to a great extent with the habitat and is, consequently, applied habitat biology. The habitat may be defined as an area possessing uniformity of physiography, vegetation, climate, or any other quality investigator assumes is important. The environmental conditions prevalent within any specific habitat will be unique for the area, though similar conditions may prevail in a habitat of the same type a fraction of a mile or thousand of miles distant. For example, temperature, wind movement, fauna and flora present will be similar in any particular type of deciduous forest for any specific time of year, but all of these conditions will not be exactly the same for any two such habitats. Furthermore, conditions within any habitat will vary from place to place. For example, there would be in a forest environment different temperatures, humidity and wind movement in the treetop area than there would be near the forest floor or in the soil. In a pond habitat, the temperature of the water, oxygen content, amount of plankton (including diatoms, algae, and bacteria as well as small crustaceans and various aquatic worms) and fish population will be quite different in the spring period than they would be in the summer of the year.

Other specialized fields of ecology are **zoogeography**, the scientific study of the geographic distribution of animals; **oceanography**, the study of the biotic and physical conditions existing in oceans, bays, and estuaries; and **limnology**, the study of the living and nonliving components of inland waters (fresh water bodies, ponds, lakes and streams). With the establishment of specialized disciplines, the value of applied ecology has become apparent to farmers, agricultural extension workers, and foresters as many of the basic principles of ecology have been applied in solving problems such as dust bowls, soil erosion, wildlife management, and other conservation problems throughout this country and other parts of the world. A few of the relationships that exist between ecology and related fields of study are represented in Fig. 2.1. This graphic presentation is far from exhaustive, but reciprocal exchanges between ecology and a related discipline are represented by double arrows.

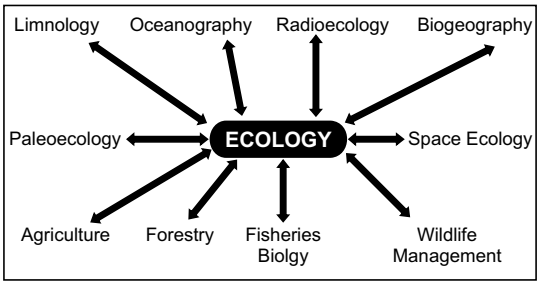


Fig. 2.1 Graphic representation of the interdependence between ecology and other ecologically oriented disciplines.

HISTORY OF ECOLOGY

The beginning of ecology may be traced back to prehistoric man, who utilized environment information to hunt food, trap animals, find edible vegetation, and locate shelter to survive the hardships imposed by nature. Palaeontological evidence gathered in different parts of the world indicates the continual migration of some social groups and tribes to escape unfavourable temperatures or the harsh effects of storms.

Environment in Vedas

Veda is the oldest religious document originally available in the Sanskrit language. Literally, Veda means "knowledge", and Hindus are the followers of the Veda. The Vedic hymns were collected and arranged between 1000 and 500 BC. Vedas are considered to be the eternal truth and are comprised of four types: Rigveda (wisdom of verses), Yajurveda; (wisdom of sacrificial formulas),

Samveda (wisdom of chants) and Atharveda (wisdom of Atharvan priests). Vedas are the absolute religious authority for Hinduism and also contain the social, religious, cultural, spiritual and scientific life of the Aryans in the Vedic period, i.e., second millenium to 7th century BC.

Since Hinduism is polytheistic, many objects, both consumable and non-consumable, are designated as "holy". The Vedas have categorically explained the rule of nature, principle of food, life, intellect and immortality. Earth, space constellations, and their roles are also defined in the Vedas. For instance, sun and moon are celestial Gods; air, water and sky are aerial Gods; and earth, river, sea, and fire are the terrestrial Gods. The universe is composed of five elements: earth, sky, wind, water and fire.

Earth is represented as a Goddess, which feeds everyone. All the forms of the earth and of life on it are the children of the Earth. Rivers, trees, animals are the attendants of the Earth Goddess. The sun, moon, wind, rain, and lighting are the children of the sky. The sun is one of the three main deities of the Vedas, which is at the center of creation and known as the nourisher. The Rig-Veda says that the sun is the soul of the world. Between the earth and the sky, the abode of the sun, is the sphere of sky and air—the cosmic life breath. Fire is another important deity of the Vedas, which serves human from birth to death. Water is not only an element of purification but also the element pervading all life, and thus a symbol of pervasiveness. The Veda speaks a lot about the water or the rivers. The Himalayas and rivers, particularly confluence, are the inhabitants of Gods and Goddesses.

Veda and Biodiversity

The Vedas and the Upanishads mention that the Gods and Goddesses favor different biological resources. Knowledge of biodiversity, interrelation between living species and the environment, the need to maintain natural dynamism, and the right ways of transgressing the ecological principles are mentioned in the Yajurveda. Similarly, Rigveda mentions about the forest goddess and healing properties of plants, tribes of fishes, goats, horses, cow, calves, dogs, owls, frog, etc. Cow is believed as a theriomorphic animal in Atharvaveda. Hence, followers of Veda should avoid eating it. In general practice, there are many flora and fauna that are sacred among the followers of the Vedas, because they are directly or indirectly related with different Gods or Goddesses. Among the faunal diversity, there is no discrepancy between domestic and wild animals as is evident from the following list:

Animals Favored by Gods/Goddesses

Cow: Goddess of wealth (Laxmi)
Bull: Lord of animal (Pashupatinath)
Lion and Tiger: Goddesses of power (Durga, Kali etc.)
Horse: Lord Sun
Serpent: Lord Shiva
Monkey: Lord Hanuman
Dog: Lord Bhairab
Rat: God Ganesh
Swan: Goddess of Knowledge (Saraswati)
Fish: Lord Vishnu

Similarly, there are many sacred plants that Hindus worship regularly. For instance, Tulsi (*Ocimum basilicum*), Rudrakchya (*Elaeocarpus sphaericus*), Bar (*Ficus bengalensis*), Pipal (*Ficus religiosa*), and Sami (*Ficus benjamina*) are the most religious plant species. In the Rigveda, Soma (*Ficus benjamina*) is mentioned as the king of the plants. There are hundreds of medicinal plants, which are in use since the vedic periods till date.

There are some ecological codes of conduct practiced among the followers of the Vedas. For example, defecation in water resources is a sinful act. One should always pray in front of the food before taking the meal. In the same manner, Vedas insist upon not to disturb the habitat of wild animals including birds at night when they stay in

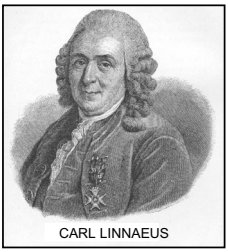
their nests; trees are prohibited not to be cut during night because of the presence of God's soul in tree trunk. Such rules are mentioned in Law of Manu (Manusmriti). These rules were framed to avoid the tragedy of commons in the communities.

Ethics is the other very common factor among the Veda and environmental conservation and sustainable development campaigns. The Vedas accept that the soul is the sum of all the Gods; the soul is the unity that links all individual beings. Since material wealth, family, country, and the world cannot satisfy the human greed, the Vedas encourage spiritual freedom. Since, wealth and happiness is a legitimate human aspiration, Vedas insist that they should be gained in ethical ways if they are to lead to spiritual freedom.

The early Greek philosophers and scientists were aware of the importance of environmental studies. *Aristotle* in his writings on natural history refers to the habits of the animals and environmental conditions prevailing in certain areas. One of Aristotle's students, *Theophrastus*, a botanist, is considered by many as the first true ecologist, for he wrote about plant communities and the types of plants found in different areas. After a gap of many years, natural history studies were resumed by a number of workers. The Frenchman, *Reaumur* (1683-1757), published six Volumes on the natural history of insects, which contained a great deal of ecological information about insects. It was during the nineteenth century that natural history studies became more numerous and knowledge began to accumulate at a rapid pace in tropical and temperate S. America. He collected plant specimens and recorded local environmental conditions including air temperature and type of flora.

Swedish Botanist—Carolus Linnaeus (1707-1778)

One of the most important individuals in the early development of an ecological view of nature was


CARL LINNAEUS

Swedish botanist **Carolus Linnaeus (1707-1778).** Linnaeus was the father of modern taxonomy, the science of identifying and naming species. His great goal was to describe and catalog all known organisms. In 1749, Linnaeus published a book called *The Oeconomy of Nature.* In this book, Linnaeus presented his view that nature, while seemingly chaotic and unpredictable, actually existed in a balanced state of order as designed by the creator. Linnaeus felt that if one looks closely at nature, it is clear that even the simplest organisms have an important role to play in this natural economy; that no living thing is useless.

Rather than the static, harmonious world that Linnaeus envisioned, nature was dynamic and constantly changing. The chief proponent of these views was German explorer and scientist Alexander von Humboldt (1769-1859). Humboldt insisted that the only way to understand nature's complexity was to take accurate measurements in the field and then search for general laws. Influenced by German philosopher, Immanuel Kant (1724-1804), von Humboldt believed that nothing in nature could be studied in isolation. All phenomena were connected.

German Explorer—Scientist Alexander von Humboldt 1769-1859

Alexander von Humboldt was the greatest explorer-scientist of the eighteenth and early nineteenth centuries. Humboldt's contributions to science were remarkably diverse. He was the first person to map areas of equal air temperature and pressure, a technique now used in every

weather forecast around the world. By measuring the magnetism of rocks in the Alps, he found that Earth's magnetic field reverses its polarity. This fundamental discovery allowed geologists in the twentieth century to prove the theory of **continental drift**. Humboldt also developed the idea of seismic waves that travel through Earth's surface after an earthquake. In physics, he conducted more than four thousand experiments on electricity and magnetism. Perhaps his most important research, however, concerned the distribution and environmental relationships of plants.

Humboldt's interest in botany developed early on. While a teenager he spent many hours with Karl Willdenow, one of the leading botanists in Europe, collecting and classifying plants in the woods around Berlin. In 1789, while studying at the University of Gottingen, Humboldt met Johann Forster. Forster had accompanied James Cook on a voyage around the world and was one of the best naturalists of his time. On expeditions with Forster to France, England, and the Netherlands, Humboldt learned the techniques of scientific observation, plant classification, and precise measurement, which he kept on employing throughout his long and incredibly productive career.

In 1790, Humboldt began work in plant geography that had revolutionized botany. Humboldt's botanical work was greatly influenced by German natural philosophers such as Immanuel Kant. Kant believed that there was an underlying causal unity in nature and that Earth should be viewed as a single, interconnected one complex unit. Extending these ideas to the study of plants, Humboldt sought to create a universal, **holistic** science of botany that encompassed both the diversity and interrelationship in the nature. He stated: "*Science can only progress ... by bringing together all of the phenomena and creations that the earth has to offer ... nothing can be considered in isolation. ... Nature, despite her seeming diversity, is always a unity."*

By 1797, Humboldt had become bored with his work in geology at the German Ministry of Mines. "I was spurred by an uncertain longing for the distant and unknown," he wrote. "For … danger at sea … the desire for adventures." On June 5, 1799, accompanied by his colleague, the botanist Aimé Bonpland, Humboldt embarked on an expedition to South America to "find out how the geographic environment influences plant and animal life." Landing in Cumana, Venezuela, Humboldt spent the next five years exploring un-charted regions of the Oronoco River, Colombia, Peru, and Ecuador.

During this journey, Humboldt survived attacks by Native Americans, tropical disease, starvation, near drowning in capsized canoes, and shocks from electric eels. Despite incredible hardships, he carried out meticulous observations on South American plants, geography, geology, climate, Aztec art, and native languages. In Ecuador, he mapped the zonation of vegetation on mountain sides and correlated this zonation with climatic changes. In Venezuela, anticipating the field of conservation biology, he analyzed complex relationships between logging, river ecology, and erosion. These fundamental studies of the relationships between plants and their environment laid the foundation for the emergence of the science of ecology during the nineteenth century.

Humboldt's extensive work stimulated other naturalists to investigate the flora and fauna of S. America. Of the many naturalists, Henry Bates and Richard Spruce explored this portion of the world and collected important data. Other naturalists journeyed to other areas of the world during this period. Eward Forbes, a British naturalist, investigated the flora and fauna of the Mediterranean sea as well as fossil deposits. He believed that plants as well as animals had moved across land bridges between Europe and the British Islets in the geological past. Significant advances were made in the eighteen and nineteenth centuries, when the

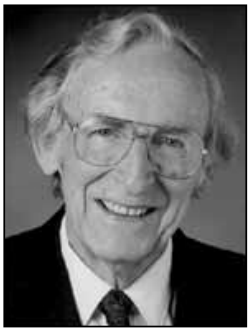
son Botanical Congress adopted the term "ecology" as denoting a new branch of botany distinct from physiology and morphology.

The community concept of study, which materialized toward the latter part of the nineteenth century, heralded the birth of modern ecology as distinct from the important but more generalized, nature studies of preceding eras. A community, in the most limited sense, may be represented by two species living together or in close proximity to one another, though in actuality many species are generally involved. However, as regards community studies, the fact that two or more species are living together in a limited area is not only obvious but superficial. The importance of community work, in the ecological sense, is the study of interaction between species and its effect on longevity and changes in the surrounding environmental conditions. Various aspects of community interactions—parasitism, predation, and other vital heterospecific and reciprocal relationships—are presented in later sections of this text. Botanists of this period realized the importance of plant communities some time before zoologists became aware of the value of aggregate interactions. Le Coq, Sendtner, and Kerner are a few of the botanical investigators involved with community, work in nature. Karl Mobius (1877), while studying oyster bed communities, stated: "Every oyster bed is–a community of living beings, a collection of species, and a massing of individuals, which find everything necessary for their growth and continuance..... Science possesses, as yet, no word by which such a community where the sum of species and individuals, being mutually limited and selected under external conditions of life have.... continued in possession of a certain definite territory. I propose the word Biocoenosis for such a community. Thus, Mobius was one of the first animal ecologists to recognize the significance of communities and propose a synonym for the term community—a biocoenosis.

Shortly after the turn of the century, community studies increased in number. Davenport (1903) published a paper on the animal ecology of Cold Spring Harbor, and S.A. Forbes (1907) wrote about the distribution of Illinois fishes; both men used the community approach. E.Warming (1909), a Danish plant ecologist, recognized the interdependence and close relationships that often exist between plant and animal communities and cautiously recommended dealing with plant and animal communities as entities rather than separately, as had been done in the past, V. E. Shelford (1907, 1908) accepted Warming's cautious proposal and included pertinent data on both botanical and animal components of the environment in his now famous tiger beetle work.

As the years have passed, an immense amount of literature of an ecological nature has been published. During the first third of this century, the total volume of ecological work surpassed by a healthy margin all of the written material on ecology and natural history produced during all of the written preceding centuries of recorded history. A tendency toward increased specialization in ecology has occurred as is evidenced by the establishment of such disciplines as paleoecology, a study of environmental conditions and life as it existed in past ages. Pollen analysis, radioactive dating, and paleontology have aided the paleocologist.

American Ecologist Eugene Odum (1913-2002)



Dr. Odum has been called the **father of modern ecology**, largely because of his work for the government in the early days of Savannah River Site. The year was 1951, Dr. Odum had been a zoology professor at the University of Georgia for

11 years. Under the influence of American ecologist and educator Eugene Odum (1913-2002), a whole new subdiscipline of ecosystem ecology grew to prominence during the latter half of the twentieth century. Ecosystem ecology emphasized both the **biotic** and physical aspects of the environment. In particular, ecosystem ecology was concerned with the large-scale flows of energy and nutrients through ecological communities. Eugene Odum is an American ecologist who has worked to advance ecological awareness and research. Born in 1913 to an academic family, he spent most of the twentieth century promoting the ecosystem concept and warning of the impact humans have on the **ecosystems** in which we live. One of his most important accomplishments was writing *Fundamentals of Ecology* in 1953, which he wrote partly in response to the zoology department at the University of Georgia rejecting ecology as an important area of study. His book was remarkably clear and concise, and it presented the important principles of ecology in a way that helped to define the science.

Fundamentals of Ecology also brought the idea of an ecosystem to a wider audience at a time when the concept was just beginning to gain recognition among ecological specialists and ways to study ecosystems were just being developed. Previously, ecology had focused on natural history and on the variety of species in the environment rather than on the details of physical and metabolic interactions among the species and nonliving material around them, as is done in the study of ecosystems. Odum placed the idea of the ecosystem at the beginning, as a fundamental concept of ecology. He explained that ecosystems are the largest functional unit in ecology, comprising both living and nonliving parts that exchange materials in cycles. These interactions and exchanges of nutrients could allow ecosystems to evolve as units over time. Ecosystems could be seen at many levels, from something as small as a lake to the entire Earth seen as a global ecosystem.

In emphasizing how the study of ecology needs to examine the way humans affect their ecosystems, Odum published ideas that became the focus of the environmental movement. Given the knowledge that humans were influential and often destructive components of ecosystems, it was especially important that Odum's book was clear and understandable by non-ecologists. Being at the time one of the only ecological textbooks, *Fundamentals of Ecology* was enormously important in driving the study of ecosystems.

Odum also wrote several other works while teaching and doing research at the University of Georgia. His work was funded by the Atomic Energy Commission, an institution that funded much early ecological research. He became a leading authority on ecosystem studies, defending the new discipline against its critics, and he also served as chair of a section of the International Biological Program. His leadership in the program helped guide research into landscape ecosystems, studying terrestrial and marine areas and the human influences on them. Remaining active into his late eighties by the turn of the twenty-first century, Eugene Odum still worked to promote the study of ecosystems. He has done much to encourage environmental study around the world, and especially where he worked in Georgia.

Father of Indian Ecology Ramdeo Misra (1908–1998)

Ramdeo Misra laid the foundations of ecology and environmental science in India. He may be called 'Father of Indian Ecology'. Born on 26 August 1908 in a village of District Jaunpur, Misra had his early education at Varanasi, and obtained his B. Sc and M. Sc degrees with honours from the Banaras Hindu University. The