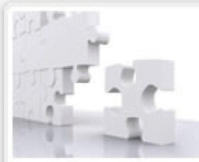

Ecosystem

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This article has been reviewed and approved ***by the following Topic Editor:*** J. Emmett Duffy (other articles)

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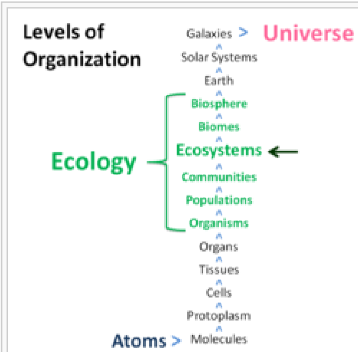
Introduction

Ecosystems are composed of organisms interacting with each other and with their environment such that energy is exchanged and system-level processes, such as the cycling of elements, emerge. The ecosystem is a core concept in Biology and Ecology, serving as the level of biological organization in which organisms interact simultaneously with each other and with their environment. As such, ecosystems are a level above that of the ecological community (organisms of different species interacting with each other) but are at a level below, or equal to, biomes and the biosphere. Essentially, biomes are regional ecosystems, and the biosphere is the largest of all possible ecosystems.

Ecosystems include living organisms, the dead organic matter produced by them, the abiotic environment within which the organisms live and exchange elements (soils, water, atmosphere), and the interactions between these components. Ecosystems embody the concept that living organisms continually interact with each other and with the environment to produce complex systems with emergent properties, such that "the whole is greater than the sum of its parts" and "everything is connected".



Levels of organization of Ecology, highlighting ecosystems. (Credit: Erle Ellis)

The spatial boundaries, component organisms and the matter and energy content and flux within ecosystems may be defined and measured. However, unlike organisms or energy, ecosystems are inherently conceptual, in that different observers may legitimately define their boundaries and components differently. For example, a single patch of trees together with the soil, organisms and atmosphere interacting with them may define a forest ecosystem, yet the entirety of all organisms, their environment, and their interactions across an entire forested region in the Amazon might also be defined as a single forest ecosystem. Some have even called the interacting system of organisms that live within the guts of most animals as an ecosystem, despite their residence within a single organism, which violates the levels of organization definition of ecosystems. Moreover, interactions between ecosystem components are as much a part of the definition of ecosystems as their constituent organisms, matter and energy. Despite the apparent contradictions that result from the flexibility of the ecosystem concept, it is just this flexibility that has made it such a useful and enduring concept.

History of the Ecosystem Concept

The term "ecosystem" was first coined by Roy Clapham in 1930, but it was ecologist Arthur Tansley who fully defined the ecosystem concept. In his classic article of 1935, Tansley defined ecosystems as "The whole system,… including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment". The ecosystem concept marked a critical advance in the science of ecology, as Tansely specifically used the term to replace the "superorganism" concept, which implied that communities of organisms formed something akin to a higher-level, more complex organism—a mistaken conception that formed a theoretical barrier to scientific research in ecology. Though Tansely and other ecologists also used the ecosystem concept in conjunction with the now defunct concept of the ecological "climax" (a "final", or "equilibrium" type of community or ecosystem arising under specific environmental conditions), the concept of ecosystem dynamics has now replaced this. Eugene Odum, a major figure in advancing the science of ecology, deployed the ecosystem concept in a central role in his seminal textbook on ecology, defining ecosystems as: "Any unit that includes all of the organisms (ie: the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (ie: exchange of materials between living and nonliving parts) within the system is an ecosystem."

Ecosystem Structure and Function

Ecosystem components (structure)

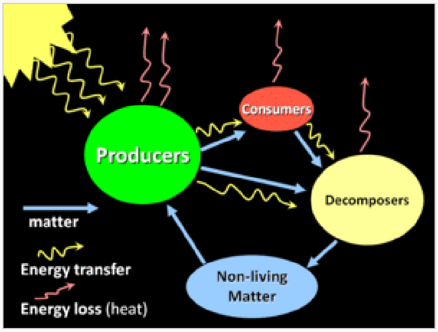


Illustration of the flow of matter and energy in ecosystems. (Credit: Erle Ellis)

Ecosystems may be observed in many possible ways, so there is no one set of components that make up ecosystems. However, all ecosystems must include both biotic and abiotic components, their interactions, and some source of energy. The simplest (and least representative) of ecosystems might therefore contain just a single living plant (biotic component) within a small terrarium exposed to light to which a water solution containing essential nutrients for plant growth has been added (abiotic environment). The other extreme would be the biosphere, which comprises the totality of Earth's organisms and their interactions with each other and the earth systems (abiotic environment). And of course, most ecosystems fall somewhere in between these extremes of complexity.

At a basic functional level, ecosystems generally contain primary producers capable of harvesting energy from the sun by photosynthesis and of using this energy to convert carbon dioxide and other inorganic chemicals into the organic building blocks of life. Consumers feed on this captured energy, and decomposers not only feed on this energy, but also break organic matter back into its inorganic constituents, which can be used again by producers. These interactions among producers and the organisms that consume and decompose them are called trophic interactions, and are composed of trophic levels in an energy pyramid, with most energy and mass in the primary producers at the base, and higher levels of feeding on top of this, starting with primary consumers feeding on primary producers, secondary consumers feeding on these, and so on. Trophic interactions are also described in more detailed form as a food chain, which organizes specific organisms by their trophic distance from primary producers, and by food webs, which detail the feeding interactions among all organisms in an ecosystem. Together, these processes of energy transfer and matter cycling are essential in determining ecosystem structure and function and in defining the types of interactions between organisms and their environment. It must also be noted that most ecosystems contain a wide diversity of species, and that this diversity should be considered part of ecosystem structure.

Ecosystem processes (function)

By definition, ecosystems use energy and cycle matter, and these processes also define the basic ecosystem functions. Energetic processes in ecosystems are usually described in terms of trophic levels, which define the role of organisms based on their level of feeding relative to the original energy captured by primary producers. As always, energy does not cycle, so ecosystems require a continuous flow of high-quality energy to maintain their structure and function. For this reason, all ecosystems are "open systems" requiring a net flow of energy to persist over time—without the sun, the biosphere would soon run out of energy!

Energy input to ecosystems drives the flow of matter between organisms and the environment in a process known as biogeochemical cycling. The biosphere provides a good example of this, as it interacts with and exchanges matter with the lithosphere, hydrosphere and atmosphere, driving the global biogeochemical cycles of carbon, nitrogen, phosphorus, sulfur and other elements. Ecosystem processes are dynamic, undergoing strong seasonal cycles in response to changes in solar irradiation, causing fluctuations in primary productivity and varying the influx of energy from photosynthesis and the fixation of carbon dioxide into organic materials over the year, driving remarkable annual variability in the carbon cycle—the largest of the global biogeochemical cycles. Fixed organic carbon in plants then becomes food for consumers and decomposers, who degrade the carbon to forms with lower energy, and ultimately releasing the carbon fixed by photosynthesis back into carbon dioxide in the atmosphere, producing the global carbon cycle. The biogeochemical cycling of nitrogen also uses energy, as bacteria fix nitrogen gas from the atmosphere into reactive forms useful for living organisms using energy obtained from organic materials and ultimately from plants and the sun. Ecosystems also cycle phosphorus, sulfur and other elements. As biogeochemical cycles are defined by the exchange of matter between organisms and their environment, they are classic examples of ecosystem-level proceses.

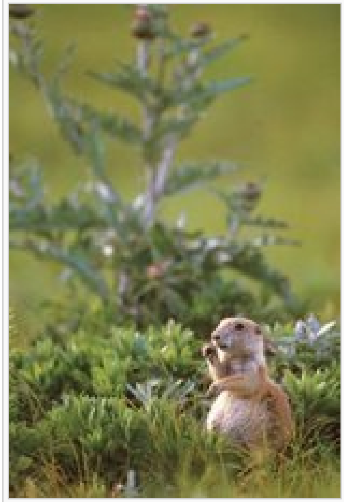
Ecosystem Research

Scientists who study entire ecosystems are generally called systems ecologists. However, most ecologists use the ecosystem concept and make measurements on ecosystem properties even if their work focuses on a single species or population.

Methods

Observing ecosystems

Researchers can make direct observations on ecosystems in the field and indirect observations using remote sensing. Direct measurements include sampling and measurement of soils and vegetation, characterization of community structure and biodiversity, and the use of instruments for observing gas exchange and the fluxes of nutrients and water. As ecosystems can be very challenging to recreate under laboratory conditions, observational studies on existing ecosystems are a core methodology of ecosystem science.


Prairie ecosystem and Prairie dog (*Zapus trinotatus*). (Source: **USDA Forest Service**)

Ecosystem experiments

Though it has historically been difficult, ecosystems are now often studied using the classic experimental methods of science, For example, small- and meso-scale ecosystems containing a significant set of interacting organisms and their environment may be created in the laboratory, or in enclosures in the field. There are also methods for excluding organisms or altering environmental conditions in the field, such as the addition of nutrients and artificially enhancing **carbon dioxide** concentrations, **temperature** or **moisture**.

Modeling

To better understand how ecosystems function and change, modeling is often used to simulate ecosystem dynamics, including the biogeochemical cycles of **carbon** and other **elements**, the role of specific species or functional groups in controlling ecosystem function, and even dynamic changes in ecosystem structure and function across landscapes and the entire **biosphere**.

The Future

Ecosystem science is evolving rapidly in both methodology and focus. Human alteration of ecosystems is now so pervasive globally that **ecologists** are working to integrate humans into ecosystem science at many levels—including the study of urban ecology, agroecology and global ecology. New techniques for ecosystem modelling are being developed all the time, as are new methods for observing ecosystems from space by **remote sensing** and aerial platforms, and even by networks of sensors embedded in **soils** and plants across ecosystems and on towers that can make observations on ecosystem exchanges with the **atmosphere** on a continuous basis. Examples of cutting edge ecosystem research are the **Carnegie Airborne Observatory**—an aerial remote sensing system capably of precisely mapping ecosystem **carbon** and **species diversity**, and the development of the **National Ecological Observatory Network (NEON)**, a continental-scale research platform for discovering and understanding the impacts of climate change, **land-use change**, and **invasive species** on ecosystems.

More About Ecosystems

- **Biosphere**
- **Biome**
- **Ecology**
- Biogeochemical cycles
- **Ecological energetics**
- **Biodiversity**
- **Millennium Ecosystem Assessment**
- **International Geosphere-Biosphere Programme (IGBP)**

Further Reading

- Golley, F. B. 1993. *A History of the Ecosystem Concept in Ecology: More Than the Sum of the Parts*. Yale University Press, New Haven. **ISBN: 0300066422**.
- Odum, E. P. 1971. *Fundamentals of Ecology*. Third edition. W. B. Saunders, Philadelphia.
- Tansley, A. G. 1935. The use and abuse of vegetational concepts and terms. *Ecology* 16:284-307.

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