CONCEPTS OF ECOSYSTEM, LEVEL AND SCALE

R. R. Christian
Biology Department, East Carolina University, USA

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Summary

The ecosystem concept has been a major part of ecology for the past two-thirds of a century. This includes the basic science of ecology and the applications of ecology to environmental management and the popular movement of environmentalism. Much has been written about the differences among definitions and the ramifications inferred from these differences. Definitions of ecosystems may have differences among authors but generally all have three common properties that include the presence of (1) biotic and (2) abiotic components and their (3) interactions. This section focuses on the concept of ecosystems, implications of the concept and properties of ecosystems, its relationship to systems ecology, concerns of its veracity, and how it has contributed to ecology and the applications of ecology.

1. Introduction

The term “ecosystem” has great popular currency and is taken to be nearly synonymous with environment by many. It has guided folks to think more comprehensively about complex relationships between living organisms and their environment and the influences of human activities on these relationships. However, the term has evolved from its roots in ecology, to a deeper understanding reflected in the general concept of ecosystem. Today’s view of ecosystems is linked to hierarchy theory and feedback control, but the concept has also been challenged. These issues are addressed, along with the benefits and values perceived from understanding of this construct of nature.

2. Definitions of ecosystem and their history

The ecosystem concept is largely a twentieth century construct, although roots can be traced into the previous century. It has held a central position in modern ecology and environmental science. Currently, a variety of environmental management strategies include recognition of ecosystems as a way of ordering our perception of nature.

Definitions of ecosystems may have differences among authors but generally all have three common properties that include the presence of (1) biotic and (2) abiotic components and their (3) interactions. The biotic component of the ecosystem is generally considered to involve communities of organisms, and the abiotic component includes the organisms' chemical and physical environments. Interactions may be numerous, but the two most frequently identified are those associated with (1) food webs and trophic dynamics and (2) material cycling, particularly of nutrients. More generally, the interactions involve flows of energy, matter and information. However, much has been written about the differences among definitions and the ramifications inferred from these differences.

Although all definitions of ecosystem contain the three aforementioned components, the differences in definitions are telling. It is instructive to consider three definitions of ecosystem that reflect changes in the concept since its first use. A. G. Tansley coined the term "ecosystem" in 1935 as part of a debate over the nature of biological communities. (A.G. Tansley (1935) The use and abuse of vegetational concepts and terms. *Ecology* 16: 284-309).

"Our natural human prejudices force us to consider the organisms (in the sense of the biologist) as the most important parts of these systems, but certainly the inorganic "factors" are also parts—could be no systems without them, and there is a constant interchange of the most various kinds within each system, not only between the organisms but between the organic and the inorganic. These *ecosystems*, as we may call them, are of the most various kinds and sizes."

Tansley identifies the most fundamental and simplistic nature of ecosystems—the combination of living organisms and their environment as a single concept, system, or entity. Interestingly the emphasis or "Our natural human prejudices" focuses on the organisms with the rest as a support system. The nature of the "constant interchange of the most various kinds" is not made explicit. Size and diversity of ecosystems are considered to span wide ranges.

E. P. Odum is perhaps one of the most influential ecologists of the twentieth century in the elaboration and promotion of the ecosystem concept. The definition in his textbook entitled *Fundamentals of Ecology* ((1971) W. B. Saunders Company, Philadelphia) is as follows:

"Any unit that includes all of the organisms (i.e. 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 (i.e. exchange of materials between living and nonliving parts) within the system is an ecological system or

ecosystem."
Thus, Odum defines explicitly the nature of interactions and the characteristics that contribute to and result from the interactions. He gives expectations for an ecosystem. One of the expectations is that energy flow plays a central and controlling role in defining other features of the ecosystem.

Odum also clearly indicates that the ecosystem exists "in a given area" and is thus identifiable geographically. This is a point of departure from the definitions of some other authors who view ecosystems as concepts, not necessarily as specific places. T. F. H. Allen and T. W. Hoekstra provide the alternate, concept-oriented definition in their *Toward a Unified Ecology* ((1992) Columbia University Press, New York).

"The functional ecosystem is the conception where biota are explicitly linked to the abiotic world of their surroundings. Systems boundaries include the physical environment. Size is not the critical characteristic, rather the cycles and pathways of energy and matter in aggregate form the entire ecosystem."

Furthermore, they state,

"Ecosystems may or may not be out there in the real world. What is important is that that they appear to be helpful conceptions that lend predictive power."

Allen and Hoekstra's definition is placed within a larger hierarchical context, which is the subject of their book. Their ecosystems are defined by how they are studied (e.g. study of nutrient cycling or trophic dynamics) as much as what they contain or their size. Note that they have defined a "functional ecosystem" to emphasize process instead of structure. "Population-community" ecosystems more identify with units within a landscape and structural features. Thus, Allen and Hoekstra's definition may consider the biosphere, a lake or a termite's gut as an ecosystem where cycling and energy flow take place.

These three definitions provide both a very brief historical view of how ecologists have addressed the issue and include some of the major features of definitions. Other variations in definition exist. Characteristics of ecosystems that sometimes are included are their self-regulation, stability and sustainability. Another issue in defining the components of ecosystems is whether to include humans and human societal systems. These, however, are more subject to controversy than the features of biotic and abiotic components and their interaction. We address concerns about the ecosystem concept in more depth in the section 6.

Of the definitions given, the one by Allen and Hoekstra provides an opportunity for focusing on a related view of nature. As stated, it is founded within hierarchy theory. Therefore, the following section introduces how this theory contributes to ecosystem ecology.

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Biographical Sketch

Robert R. Christian is a Professor of Biology at East Carolina University. He received his M.S. in 1972 and Ph.D. in 1976 from the University of Georgia in Microbiology. His A.B. was obtained in 1969 from Rutgers University, Camden College of Arts and Sciences in Biology. His research has focused on coastal ecosystems, particularly salt marshes, estuaries and coastal lagoons along the Atlantic and Gulf coasts of the USA and in the Mediterranean. Most recently he has been involved in studies of low order and headwater streams within the coastal plain. In these ecosystems he has studied nutrient cycling, especially the nitrogen and carbon cycles, and energy flow. While initial interests were in the microbial communities and processes, their importance and regulation; his research has often taken broader perspective. Thus he has studied primary production of macrophytes, food webs, and ecosystem state changes. His work has had laboratory, field and modeling components. Recently, much of his efforts have been devoted to network analysis as a mathematical tool for the comparisons among and within ecosystems. He has been active in promoting large-scale studies. These have been associated with the U.S. Long-term Ecological Research (LTER) and International LTER programs and a coastal initiative of the Global Terrestrial

Observing System (GTOS).