PART 1

Entities and Process in Ecology

When ecologists enter a natural setting and begin their observations, they recognize a variety of entities and patterns. "Natural setting," used in this sense, consists of entities, objects, or things that appear to be distinct and bounded against a background matrix. "Boundedness" involves a recognizable difference between the properties of an entity and those of the matrix in which it is located. The observer perceives the difference and distinguishes the entity as separable from its background. For example, we encounter trees in the forest and we begin to give them technical names and note their size and condition. A bird flies in front of us and we do the same, except the bird's mobility leaves us uncertain if we saw a flash of white on the tail feathers as it flew away.

Entities are never static; they come into being and are destroyed. Some move quickly, like the bird, and others move slowly, like continental plates. So ecology is not simply concerned with discerning entities against an environmental backdrop, but also with discerning patterns of change. Nature's intrinsic dynamism makes the work of the ecologist all the more complicated and challenging.

Part 1 examines the metaphysical character of ecological entities and processes. Surprisingly little work has been done on this basic but complex topic in the philosophy of ecology.

Entities: Preliminary Metaphysical Considerations

An entity is something that exists as a discrete unit—that is, something that is distinct and bounded. The conditions that make the entity a discrete unit, discernible from its environment, differ: both the marmot and the granite boulder it sits upon we recognize as entities, but radically different types of entities. The *way* the entity is bounded—its internal structure—makes a difference.

The intentionality of the observer also makes a difference. When we recognize things in the world, we always do so from a temporal, or subjective, perspective. A tree may be seen as an excellent center beam for a house or a source of shade in the hot summer. As Kant (1965) points out, all knowledge arises from experience, but knowledge is not comprised only of experience: subjects experience the world in physiologically similar ways (Kant refers to these as "categories of the mind").

Moreover, subjectivity involves more than physiological features of the perceiving being. Subjectivity also involves socially inculcated interests and purposes. Philosopher Frederick Ferré (1996) remarks: "What is 'essential' or 'accidental' for entities is a matter of interests and purposes interwoven with the facts. The actual attributes, relations and functions of something are not irrelevant to the decisions we make. They provide the basis for our decisions. Entities 'are' the joint product of what we find and what we make" (325). The role of intentions in defining entities means that the scientific enterprise always involves an element of subjectivity. In terms of the long-running debate about objectivity in science (Harré 1967), the hope for pure objectivity is unrealizable. This suggests an epistemology of *mitigated* scientific realism as an alternative to a thoroughgoing scientific realism. Some part of knowledge is contingent upon the intentionality of the knower—that is, the subjectivity of the observer influences the observation.

Keeping in mind the role of the value judgments we make in analyzing the world, Ferré identifies six types of entities: (1) aggregate entities, (2) systematic entities, (3) organic entities, (4) formal entities, (5) compound entities, and (6) fundamental entities.

Aggregate entities, such as granite boulders, mountains, lakes, and glaciers, are characterized by external relations among the parts. Even a huge disturbance, such as the explosion of Mount Saint Helens in the Cascade Range of the northwestern United States (which blew away the top of the mountain), is insufficient for us to alter our recognition of the entity. Mount Saint Helens is radically changed, but it remains Mount Saint Helens. Aggregate entities provide a background for ecology, serving as the stage upon which the ecologic play is acted.

Systematic entities include ecosystems, which are characterized by feedback loops. Ecosystems retain coherence even under intense stress until the pressure overwhelms them and they collapse. The term *systematic* refers to this capacity to maintain structure and function under continually changing conditions.

Living organisms are examples of *organic entities.* Living organisms are made up of parts that are internally related. The whole organism is governed by this internal system of relationships that maintain homeostasis. Further, organic processes are creative in generating unique, new forms of life.

Formal entities are based on the subjective intentionality of the observer, for example, definitions. In biology, a "species" is a formal entity. A species is real as a group of related biota capable of interbreeding, but what makes a species "real" is that it was invented as a way of classifying organisms.

Ferré completes his taxonomy of entities with two final categories: *compound* and *fundamental entities.* Compound entities have strong internal relations but are without an apparent internal system dynamics, for example, inorganic molecules. Finally, fundamental entities constitute the deep structure beneath entities in general—that is to say, they are the basic ontological units of nature.

All entities relevant to ecology are the joint product of what we observe and the context in which we understand our observation. It is the knowledge added by the knower that creates both a richness in the diversity of ecological entities and the endless quarrels among ecologists about the validity of entities and relationships.

Ecological Entities

Systematic entities, organic entities, and formal entities are closest to the immediate concerns of scientific ecologists. Formal entities are conceptual constructions, and systemic and organic entities are the direct objects of ecological investigation. Systemic and organic entities have noticeable boundaries, are identifiable against a matrix of space/time flux, and have some kind of internal structure.

Even so, given ontological interconnectedness, the boundaries of ecological entities are imprecise, in part because of the entities' *openness* (porousness or permeability). A closed entity would be isolated from its environment; no closed entities exist in nature. An organism continually exchanges matter and energy with its environment, and an ecosystem exchanges matter and energy with the larger system of which it is a part. These flows couple the system to the physical environment (we return to this point in the discussion of Tansley below). Linkages tend to blur the distinctness of ecological objects. The selection of a boundary is always arbitrary because boundaries vary over space and time.

Ecological boundaries also vary spatially. For example, in the center of the United States a great grassland borders an eastern deciduous forest. The boundary between these two regions of the country is made up of a mixture of trees and grasslands in a patchy, savanna-like system. If we examined a satellite photograph we would observe that the two broad regions of the country are distinct and easily recognized. At this scale there is a boundary, and we treat each region as separate and distinct.

Boundaries also may vary over time, as a stream margin varies between flood and drought. In this case the boundary of the stream, based on the presence or absence of water, may move upward and downward and laterally in or out of the floodplain. The boundary of the stream becomes an important environmental factor to organisms living in the wetlands bordering the stream.

The stream margin is similar to the "fuzzy boundaries" Zadeh (1965) uses to represent the imprecision of language. Fuzzy boundaries are more common than distinct ones in nature.

Despite the indeterminacy of boundaries, an ecological entity can be distinguished from its environmental matrix in terms of internal versus external processes: an entity is characterized by internal processes of connection that are stronger than the external linkages of the entity to other entities and the matrix. It is these strong internal connections that create the difference between "inside" and "outside" and permit us to distinguish entities from the broader environment.

Ecological Entities: Three Ontologies

The focus of ecology is the interaction of organisms with each other and with the inorganic environment. The constellation of these interactions forms the basic unit of ecological inquiry. Interestingly—but not surprisingly—ecologists have not agreed on the metaphysical status of the primary ecological entity. We will consider three prominent ontologies recognized by twentieth-century English-speaking ecologists: (1) the biotic community, (2) the individual organism, and (3) the ecosystem.

The Biotic Community

Occidental philosophers, scientists, and theologians have long seen grand design in nature. Along these lines, the American ecologist Frederic Clements speculated that an entire community of organisms—or "biotic community"—has a specific structure of internally related parts, like an organism itself. For this reason, Clements referred to a biotic community as a "superorganism."

In his preface to *Plant Succession: An Analysis of the Development of Vegetation* (1916), reprinted here as chapter 1, Clements asserts that the "developmental study of vegetation necessarily rests upon the assumption that the unit or climax formation [i.e., biotic community] is an organic entity." Through a process of development (succession), each plant association matures predictably according to a final, ultimate identity. Treating the plant community "as a complex organism with a characteristic development and structure in harmony with a particular habitat . . . represents the only complete and adequate view of vegetation[;] in short, . . . every climax formation has its phylogeny as well as its ontogeny."

Clements began forming his theory of the community as a University of Nebraska student at the end of the nineteenth century. He and fellow student Roscoe Pound (who would later become a famous jurist) built square quadrats in order to sample the prairie vegetation. They found that repeated observation

of the prairie plants within the square yielded data on the species of plants present, the numbers of individuals of each species, and the patchiness or sociability of the individuals within species (Pound and Clements 1897). The patterns produced by repeated samples from quadrats gave quite different conclusions from those obtained by the traditional botanical observer who walked over the prairie listing species and their abundance.

By applying this methodology to observations across the western United States over a lifetime of study, Clements was able to form a synoptic geographical view of the vegetation. Flora form a community that will appear repeatedly across its ecological range of environments. By correlating climate (mainly temperature and precipitation), plant species distribution, and abundance, Clements and other ecologists working with similar methods created a regional plant community geography.

Clements also had before him abundant evidence of disturbance to vegetation. Fire, plowed land, grazed land, and abandoned agricultural land were commonplace. Clements noted that over time plants invaded the disturbed area and then replaced themselves in patterns of development that led ultimately to the vegetation that was present under similar conditions in different locations. Clements named this endpoint the "climatic climax" of the process of plant succession.

Combining the spatial and temporal descriptions of vegetation, Clements then made his creative leap. He postulated that the plant community was, by analogy, an individual superorganism. The superorganism was born on an abandoned field with the plant invaders present on the site; development took place, and eventually maturity was achieved. Because the mature state was set by the regional climate, all the sites undergoing succession eventually converged to a single state. Clements and Victor Shelford teamed up in the late 1930s and added animals to Clements's conception of vegetation.

The Individual Organism

Perhaps, contrary to the mainstream current of Western thought, grand design in nature is an illusion. Perhaps what appears to the human observer to be teleologically ordered is really the accidental association of various parts.

This is the essence of Henry Gleason's "individualistic hypothesis" of plant association. In "The Individualistic Concept of the Plant Association" (1939), reprinted here as chapter 2, Gleason argues that plant communities are not organized associations; rather, they are random assemblages of individual organisms. Gleason came to this conclusion when he applied the quadrat method to savanna prairie vegetation in Illinois and reached diametrically different conclusions from Clements. Gleason, like Clements, found that a few species were abundant in the squares and most species were uncommon or rare. The specific species patterns were best treated probabilistically. The conditions of the environment for plant growth differ on a microscale; in one place individuals of a species will be common and in another place individuals of the same species will be rare. Not all species had equal chance of appearing in every quadrat. Thus the species actually present were there due to the chance of dispersal and their ability to invade and colonize and then compete for resources, grow, and reproduce.

Gleason concluded that the species composition of a site is indeterministic. Plant associations are accidental assemblages: "Are we not justified in coming to the general conclusion, far removed from the prevailing opinion, that an association is not an organism, scarcely even a vegetation unit, but merely a *coincidence*?" (1926: 16; emphasis in original).

The Ecosystem

A third ontology is the *ecosystem*. Precipitated by South African ecologist John Phillips's defense of Clements (Phillips 1931, 1934, 1935a, 1935b), English botanist Arthur Tansley (1935 [reproduced in this volume]) argued that the organismic analogy between plant development and ecological succession is a poor one. Biotic communities, he said, are more like machines—ecosystems.

"The Use and Abuse of Vegetational Concepts and Terms" (1935), reprinted here as chapter 3, is Tansley's refutation of Clementsian ontology, published in honor of a major explorer of plant succession, the Chicago ecologist Henry Cowles. In this paper, Tansley defines the ecosystem as "the whole *system* (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense. . . . It is the systems so formed which, from the point of view of the ecologists, are the basic units of nature on the face of the earth." In this definition Tansley distances ecology from biology and its embarrassing arguments about vitalism and entelechies and identifies ecology with physics. In doing so, Tansley follows the tradition of mechanistic materialism. Physics was considered the most fundamental science because it was believed that ultimately all knowledge would be explained by physical principles. Physics had made brilliant progress in the Cavendish Laboratory at Cambridge University, where Tansley was a lecturer in botany. Tansley also connects the ecosystem concept with the definition of ecology by Ernst Haeckel (1879), emphasizing the interactions of organisms and environment. The ecosystem, Tansley claims, is the basic unit of ecological entity.

Tansley's concept of the ecosystem is a totally different ecological entity from those made up exclusively of biological entities. The ecosystem involves the physical, chemical, and informational features of the environment characteristic of a space/time continuum, which are closely and reciprocally interacting with the biotic community. The ecosystem of interest is a subsystem nested in another more extensive ecosystem, which serves as the environment of the system of interest. Thus, from this perspective there are two kinds of environments: those of a particular habitat that react with the biotic community to form a whole system, and the environment outside the system that affects it, provides it with resources, and receives its outputs.

Tansley's contentions are problematic from our perspective. His choice of physics in his claim that ecosystems are one level of a hierarchy of physical systems that range from the planet Earth to the atom conflicts with ecologists' view of systems. The physical concept of an entity is of an isolated, material object, which is explained through the structural interaction of its parts. Ecological systems are different: their processes are stochastic and interconnected with processes outside the system. They are not closed and their essence derives as much from their connections to the environment of the system as from the interactions among the parts of the system. These problems do not invalidate the ecosystem concept, but they change the emphasis in a fundamental way. Biology has developed in such a way that there is no need for identification with physics. Indeed, contemporary ecology is closely allied to biology in many of its subfields. Instead, the modern emphasis of the ecosystem concept is on a complex of stochastic interactions that make up the actual systems we encounter in the field.

Ecologists critical of the ecosystem claim that it is idealistic and subjective because it erects a concept that is rooted neither in natural history nor in evolutionary theory, the two other primary sources of inspiration for ecological science. Because ecosystem boundaries are fuzzy, critics call the existence of the entity into question. Because the dynamic behavior of ecosystems is usually described in terms of the flows of matter, energy, and information, and not in terms of evolution and natural selection, or behavior, competition, and cooperation, evolutionary ecologists disparage it as physical, chemical, and mechanistic. Other authors have even claimed that it is "fascistic" because it is holistic (Chase 1995) and undervalues the individual vis-à-vis the organic whole.[1]

While all of these claims can be shown to be incorrect, it is interesting how negatively ecologists have reacted to the ecosystem concept. Apparently, it represents a serious alternative entity to those of the biological persuasion, and is thus threatening. It is doubtful if any other recent ecological concept has attracted such widespread and vituperative comment.

Paradigm Shifts

Clements's theory of vegetation dominated ecological thought in the United States for almost fifty years, notwithstanding the efforts of Gleason, Tansley, and others. Echoes of Clements still reverberate in ecological research projects. The Gaia hypothesis (e.g., Lovelock and Margulis 1974) is basically the concept of the Clementsian superorganism applied to the entire biosphere.

This elegantly teleological ontology was convincing to most ecologists. The theory corroborated the observations of ecologists, it provided a simple and deterministic scheme of organizing the observations, and it was predictive. The Clementsian paradigm was so dominant that Gleason's observations were discounted even though they were published three times (1917, 1926, 1939) during his lifetime.

It was only after the middle of the century that support for Clements's paradigm diminished when it was observed that the prairie did not respond to the drought of the 1930s as the biotic community model predicted. After seven years of drought (1933–1940), thousands of acres of mixed prairie had been destroyed and replaced by short-grass prairie, 20 percent of the soil was covered by cactus, and the recovery capacity of the grassland was compromised. As Ronald Tobey points out, "The grassland formation that Clements and [John] Weaver had once described as the terminal climatic climax, in perfect harmony with the environment, was destroyed and replaced by a different set of dominants" (1981: 201).

Ecologists such as Robert Whittaker (1953) and John Curtis (1959) showed how individual plant species responded to environmental factors. These new viewpoints led to a shift in the perspective of ecologists, a decrease in interest in Clements's paradigm, and growing recognition of the validity of Gleason's observations (McIntosh 1975). Today the term *association* refers to a collection of plant species at a site that is part of a set of sites all with roughly the same species composition and the same environmental conditions. Usually, these associations are named after the dominant species. Clearly, the shift from Clements's to Gleason's ontology was a scientific revolution in the sense of Thomas Kuhn's (1970) theory of scientific progress.

In "A Succession of Paradigms in Ecology: Essentialism to Materialism and Probabilism" (1980), reprinted here as chapter 4, Daniel Simberloff interprets this paradigm shift in ecology as part of a broad revolution in science, namely, the rejection of "essentialism" in favor of materialism and probabilism. What Simberloff means by "essentialism" and "idealism" is the belief that nature has an elegantly teleological structure, and natural things have set, unchanging essences typified by Plato's metaphysics. Simberloff argues that geneticists and physicists rejected the deterministic, teleological model of nature in the early twentieth century; they were followed by ecologists in the 1940s and 1950s with the rethinking of the superorganism model.

Simberloff's paper has value to us as a historical comment on the philosophical development of ecological thought in general, as well as for the discussion it generated. In the 1980 volume of *Synthese* titled "Conceptual Issues

in Ecology," where the paper first appeared, Marjorie Grene excoriates Simberloff for abandoning the "standards of accuracy that, at least in the layman's view, ought to govern their discourse as scientists" (1980: 41)—for example, by equating idealism with the ancient Greeks (omitting Fichte, Hegel, and Berkeley), Greek thought with idealism (omitting Democritus), and idealism with determinism (as Hobbes was a materialist determinist). Richard Levins and Richard Lewontin's "Dialectics and Reductionism in Ecology" (1980 [reproduced in this volume]) proposes "dialectal materialism" to resolve the "confusions" of Simberloff's interpretation by focusing on the resolution of unity with discord rather than their separation. In spite of equivocations and ambiguities, Simberloff's point is clear: the Western intellectual tradition, as a whole, has been characterized by a pervasive belief in order, design, and balance in nature.

Ecological Hierarchies

The entities recognized by ecologists are multifarious, depending on the intentionality of the ecologist. They include individual organisms, species, ecosystems, populations, metapopulations, guilds, breeding and feeding groups, ecotopes, landscapes, and biomes.

In order to represent the variety of ecological entities and relations, philosophers of ecology have created the concept of the *nested hierarchy* (vide chapter 17), a taxonomy of entities based on scale. Smaller entities are nested inside larger ones, somewhat like a Russian matryska doll, which opens to reveal another smaller doll. Accordingly, larger-scale ecological entities, such as a landscape, contain smaller-scale entities, such as ecotopes (figure 2). Biomes, landscapes, and ecotopes are all ecosystems of different sizes. Biomes are larger than landscapes and provide a matrix for landscape systems. Biotic communities, populations, and individual organisms represent another kind of hierarchy of scale, with the community being largest and the individual being the smallest.

Because smaller entities combine to form larger ones, larger entities are in-

Biosphere
Biome or Ecoregion
Landscape
Ecotope

Community
Population
Organism

Figure 2. Two nested ecological hierarchies

clusive of smaller ones. Think of a watershed as an ecosystem. The watershed of the Escalante River in southern Utah is made up of many smaller watersheds, such as Calf Creek, Boulder Creek, Harris Wash, Coyote Gulch, and so forth. The smaller riparian ecosystems are present in the larger Escalante ecosystem. (For heuristic purposes, we could classify the Escalante ecosystem as a landscape, and Calf Creek, Boulder Creek, Harris Wash, and Coyote Gulch as ecotopes. The entire Colorado Plateau could be classified as an ecoregion.)

The nested hierarchy differs from a control hierarchy, such as an army, in which members of one level, such as privates, do not appear at another level, such as generals. Following anthropologist Carole Crumley (1987), we could use the word *heterarchy* as a synonym for the nested hierarchy in order to distinguish ecological hierarchies from control hierarchies.

A nested hierarchy is constructed on the principle of similarity (O'Neill et al. 1986). Similar criteria should be used to classify the nested entities. In the Escalante River example, we organized watersheds across different scales. Using a geographical criterion on one level and a biological criterion on another is illegitimate. If one is concerned about the flow of water across the land surface, then the nested hierarchy is a hydrological order of watersheds, ranging from headwater streams to the river basin as a whole.

Obviously scale is central to ecological hierarchies. If we stay within one level of a hierarchy, we can observe many entities that associate and interact with each other. For instance, we may encounter many different patches of forest in a landscape. These patches will differ from one another in the landform, the species and age of trees, and the type of the undergrowth. However, in an aerial photograph, all patches will be characterized as forest. If we shift to an even larger scale by looking at a photograph covering more area, we will observe new entities interacting on a new matrix. In our example the images of forest patches will be much smaller and may even disappear as entities converge. The forested land unit becomes a new kind of entity at this higher level of scale.

Is the background matrix an entity too? Yes. But the matrix is an entity at a different level of scale than the entity of interest. The matrix contains the entity. If we shift scale again, the matrix itself may be observed as an entity within a yet larger matrix. Ecologically, this dimensional property of nature extends from the whole planet to the smallest organism; cosmologically, it extends from the universe to subatomic particles.

Ecological Processes

Philosophers are accustomed to speaking of metaphysics in terms of *being* or *becoming*. For some metaphysicians the essence of reality is motionless (perfect Being, in the verbal sense), while for others the essence of reality

is change (in other words, continuous Becoming). In the Western tradition, the emphasis on stasis runs from the ancient Eleatic philosopher Parmenides through Plato, Augustine, Descartes, Newton, and others. The emphasis on flux runs from the ancient Milesian philosopher Heraclitus through Spinoza, Hegel, Alexander, Bergson, Nietzsche, Whitehead, and others.

Nature is so complex that both approaches seem relevant. Entities both persist and perish. However, as Robert Ulanowicz (1986) and other philosophers of ecology point out, ecology has been dominated by the entity (Being) approach at the expense of the process (Becoming) approach. As we have seen, Simberloff traces the dominance of the entity approach to the Platonic and Aristotelian metaphysics of essence. And on a practical level, it is easier to catalog persistence than to map patterns of change. Whatever the reasons, the hegemony of the entity approach is unfortunate because it is impossible to talk about nature without talking about process.

From the process perspective, entities are processes rapidly replicating form, creating the possibility that our sense organs can apprehend structure (Ferré, personal communication, May 1999). Energy and matter flow through networks at different rates within the system; objects are nodes in the network where flows of energy and matter are consumed, stored, and/or transformed. Sometimes we can physically observe the nodes qua entities. Less often can we observe the interactions, although the predator consuming the prey or the movement of the pollinating insect above the flower, its legs covered by yellow pollen, are vivid examples. Usually the interaction is interpreted as a consequence of a process.

In ecology, these processes are not just biological; they are also physical. For example, gravity causes a sediment-laden stream to deposit the heavier sand particles on the levee bordering the water and the lighter silt particles on the floodplain behind the levee. The process can be as clear to us as the flying insect. In this complex of interaction we often use the metaphor of a network, derived from systems science, to describe pathways of interactions and flows in space/time.

Thus ecological study is greatly complicated by the fact that entities are not static; they change, and they change at varying rates. The life cycle of some insects or microorganisms may be only days long. In contrast, some processes are so slow in terms of human life that we do not readily discern them. The uplifting and wearing down of mountain ranges goes on continually but takes millions of years to accomplish. From our perspective mountains are virtually eternal. The field ecologist must carefully observe organisms over long periods—as Frank Frasier Darling (1937), who stalked red deer in northern Scotland for more than two years—in order to see interactions that can be interpreted as a process. But there are relatively few such collections of intense, long-term observations, and generalizations made from natural history or experiments usually are inadequate to describe the connecting processes of the hundreds or thousands of kinds of organisms that occur in a typical community.

As we noted above in the discussion of the ecosystem ontology, the stochasticity of ecological process makes the deterministic model of mechanism inadequate. To convey the indeterminism of ecological process, Claudia Pahl-Wostl (1995) proposes a "macroscopic uncertainty principle"[2] roughly analogous to the "microscopic uncertainty principle" of quantum mechanics (Heisenberg 1927): "I conjecture that an uncertainty principle at the macroscopic level of living systems can be postulated especially when the global system as a whole is considered" (1995: 224). As Robert Ulanowicz (1999) in chapter 5, the science of ecology is in need of a new, post-Newtonian, postmechanistic, postmodern metaphysics.

The necessity of paying attention to process is illustrated by the challenges faced by evolutionary ecologists (see part 5). Evolution involves the selection of a genome containing a unique set of genetic characteristics by the environment. The complex processes associated with genetics and reproduction produce individual organisms or groups of siblings with unique genetic properties. These organisms interact with an environment that is made up of other organisms at the same scale, and with the matrix in which the organisms occur. Organisms that survive may reproduce and continue the genetic line. Organisms that do not survive mark the end of a genetic line.

Evolution is a process. The interaction of genome and environment Darwin called "natural selection." Using the criterion of natural selection that acts upon most, if not all, organisms, some ecologists focus on the individual organism as the fundamental entity in ecology. Other ecologists and geneticists argue that selection does not always operate at the scale of the organism. They claim that a group of organisms, such as a beehive, may also be selected as a unit because the group has a better chance of survival than does the individual. In their opinion, populations, communities, and even ecosystems might be the primary evolutionary entities. This is decidedly the less popular opinion, but it has adherents such as David Wilson (1980).

Conclusion

Entities may be considered in several different ways. The naturalist observes entities in the field that take a particular form, behave in repeatable patterns, and have a history. These entities are individuals in some cases. In other cases they represent collections of organisms combined physically, chemically, or biologically. Coral is an example in which individualism makes little sense. Lichen, made up of an alga and a fungus, is another. Field biologists group like-appearing and like-acting individuals into categories for the sake of speaking about them and recording observations. The genus/species taxonomic system, invented by Carolus Linnaeus, serves the field ecologist as a generally satisfactory system of organizing ecological information.

As the essence of nature is flux, it appears that there are no absolute criteria by which we can distinguish one entity from another in space/time continuums. The answer to the question, What is an entity? is "it depends." It depends upon how the properties are arranged according to the goals and purposes of the ecologist; how energy, matter, and information are received and exchanged; and so on.

The most important point in this discussion is that the ecologist is allowing natural organization and process to become visible through close, long-term observation and manipulation, taking advantage of natural experiments when the system of interest is stressed or affected by unusual events. The ecologist is not forcing ecological entities into a mechanical model of nature in which parts clunk across the stage of nature. The dynamism and stochasticity of ecological processes and the subjective intuition and creativity of the individual are reasons why Ferré (1996) claims that ecological studies are models for postmodern science.

Notes

1. This same argument has been made in the context of animal rights versus land ethics debates in environmental philosophy. For example, Tom Regan writes: "Like political fascism, where the individual is made to serve the interests of the larger political community, an unbridled ecological holism, where it is permissible to force the individual to serve the interests of the larger life community, is fascistic too" (1992: 138).

2. As Ulanowicz (personal communication, 1998) points out, *uncertainty* is epistemic, and the issue of determinism is metaphysical, so in this context *indeterminism* is a better word than *uncertainty*.