5 Communities and Ecosystems

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Abstract Communities and ecosystems are two related and contested concepts in ecology. Despite their longevity, three unanswered philosophical questions apply to both concepts. First, "what are they?" Both concepts have multiple definitions and little agreement among ecologists about which is correct or which is most useful. Second, "how are they individuated?" Working from any particular definition, how can ecologists delineate the boundaries of the entity described in the definition? And third, "what is their ontological status?" Are the communities and ecosystems that we define and delineate real objects that exist mind-independently, or are they merely "useful fictions?" Despite the fact that these questions are unanswered, ecologists have been able to make a good deal of progress in the study of these concepts. Nevertheless, answers to these questions would be useful for many applied questions in management and conservation.

5.1 Introduction

There is much philosophical work to be done in the subdisciplines of community and ecosystem ecology.[2] It is quite a task to cover both concepts in one chapter. These subdisciplines have unique philosophical problems to consider, but they also share some philosophical problems. To respect my word limit, I am going to address these three perennial questions in both fields:

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[2]I am an ecologist, and for much of my professional life I did not think about philosophical questions in ecology. I feel the need to point this out so the reader has a sense of my perspective on these matters.

1. *What are they*? Without clear definitions, misunderstandings and miscommunications are bound to permeate the professional discourse.

2. *How are they individuated*? How can we pick out a particular community or ecosystem from the otherwise continuous variation that exists in nature? and

3. *What is their ontological status*? Here, we ask whether the entities that we pick out as communities or ecosystems are real things that are found in nature or are they merely useful fictions that help us make progress in the face of enormous complexity?

The reader may well scratch their head and wonder aloud, "surely ecologists have worked out the answers to these questions by now?" Unfortunately not, these questions have been around for many years and are regularly revisited because there are not yet clear answers. Spoiler alert, I am not going to answer these questions either—they are unanswered for a reason! The best I can do here is frame the questions, consider the various views on them, and point out some ways forward that may be profitable for both ecologists and philosophers.

My sense is that most ecologists do not care about the answers to these questions. But should they? The lack of clear answers has not stopped progress in the field. Ecologists have been quite adept at ignoring these questions. For example, in contemporary research papers and grant proposals, ecologists freely use both terms but rarely provide definitions or clearly delineate spatial boundaries. And I think ecologists would proceed exactly as they have whether or not either concept refers to something real. I think that the answers do not matter much for those of us that study theoretical or fundamental ecology, but that they do matter for applied ecology—particularly in the areas of community and ecosystem conservation, as well as ecosystem management. In these areas, we will be confronted by people who disagree with us about policy and practice, and the answers will matter in these disagreements. For example, how would we respond to a court challenge about whether an endangered species was a member of a particular biotic community or not? How would we respond to a developer who argued that her property is *outside* an ecosystem of conservation or management interest? And the answers will most definitely matter if, as many ecologists do, we wish to make claims about our moral responsibilities toward these entities [see e.g. 1]. It is difficult to see why we should take costly action to conserve something that is not real [2].

5.1.1 A note on terminology

Writing "communities and ecosystems" throughout this essay is clumsy and long-winded. As we shall see, the concept of an ecosystem includes the concept of community. In the interest of brevity and readability, I will sometimes use one or the other term, depending on the context, as a stand-in for "communities and ecosystems." Please keep this in mind.

I use the term *useful fiction* in places. Ecologists might be offened at this. The term is commonly used in philosophy, derived from the concept of *fictionalism*. Fictionalism typically denotes a practical, anti-realist stance in discussions about scientific realism [3]. It is not a pejorative term. It simply means, in the context of this chapter, something to effect of: "I am of the opinion that communities and ecosystems do not exist in a tangible sense, yet these concepts serve as valuable tools for advancing our research endeavors."

5.2 What are they?

In this section, I consider the various definitional challenges for both concepts. What, exactly, do we mean when we invoke either concept? I will first consider an historical view of the community concept, then the ecosystem concept, and finally I will round out this section with some thoughts on the philosophical work that is needed to clarify the use of these concepts.

5.2.1 The ecological community concept

In 1887, Stephen Forbes [4] was the first to use the term *community* in the ecological literature:

> " …to study the system of natural interactions by which this mere collocation of plants and animals has been organized as a settled and prosperous community." (p. 80)

And ecologists have been arguing about what that means ever since. Seventy-five years later, Robert MacArthur wrote [5]:

> "Irrespective of how other ecologists use the term *community*—and there are almost as many uses as there are ecologists—I use it here to mean any set of organisms currently living near each other and about which it is interesting to talk." (pp. 189–190)

A century after Forbes, Paul Giller and John Gee [6], concluded the 1986 Symposium of the British Ecological Society on the *Organization of Communities Past and Present*, with this observation:

> "Community ecology may be unique amongst the branches of science in lacking a consensus definition of the entity with which it is principally concerned. A random sample of definitions would be likely to show an inverse relationship between specificity and popularity. Many authors have expressed concern that communities rarely exist as naturally definable units. …The community has been given such a variety of meanings and used to describe so many different levels of species associations, that it borders on being meaningless." (p. 535)

The ways in which ecologists use and define the term *community* have evolved [7]. In the 1980s, when I was in graduate school, one of the leading ecology texts [8] defined the terms simply as:

> "The *community* is an assemblage of species populations which occur together in space and time. …The nature of the community is obviously more than just the sum of its constituent species. It is their sum plus the interactions between them. …the *ecosystem* …comprises the biological community together with its physical environment." (p. 591)[3]

Interaction was what distinguished a *community* from an *aggregation*[4] where species are just drawn together by some resource or environmental condition. By analogy, would travelers on an airplane comprise a *community* in any meaningful sense of the word? Nevertheless, the requirement, or lack thereof, for interactions was as controversial then as it is now [10]. As Stroud et al. [7] showed, the various definitions of *community* have shifted over time toward definitions that do not require species to interact [see also 9, for further discussion].[5] Kurt Jax [11] reviews nine community concepts and concludes that in four, interaction is unimportant, and in two the interaction is of low importance. Table 5.1 shows some of the contemporary definitions of a *community*.

[3]Note the use of the term 'assemblage.' *Species assemblage* is commonly used by ecologists and probably a synonymy for *community*. My sense is that we use species assemblage when we are not interested in being drawn into arguments about the importance of interspecific interaction, although definitions of species assemblages often include the such interactions.

[4]According to Gleeson (1926), communities are just coincidental groupings of populations of various species. He believed that the "structure" of these communities, such as the number and types of species present, was solely the result of each species adapting to the local environmental conditions. Gleason (1939) later somewhat moderated his stance on that somewhat radical position [9].

[5]One way to think about the importance of interaction is to consider a term we sometimes hear in reference to human communities: the *global community*. This term implies that all humans are part of a single community that extends around the world. This only makes sense if interaction is not required. There are more than eight billion people in the world. While not all of them directly engage with one another, they might be loosely or remotely linked through common relationships, and they all have some core interests in common, such as ensuring that the Earth can sustain human life.

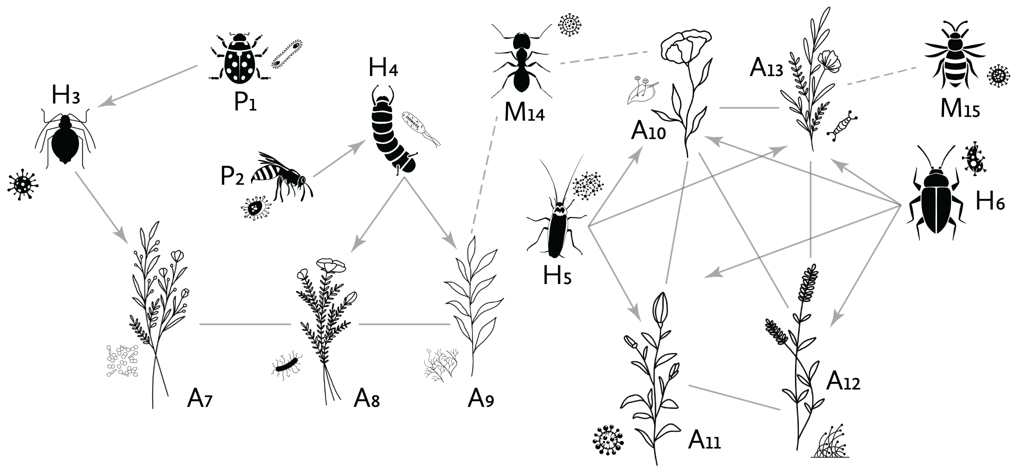

Figure 5.1: A sample of species and their interactions from a field behind the biology building on campus. Arrows denote consumptive relationships and P_x denotes predators, solid lines denote competitive relationships—in this case herbivory—and the H_x denotes herbivores, and dashed lines denote mutualisms and M_x denotes mutualists. Also shown are microbial icons that denote the bacteria and fungi that live on and in each of these macroscopic species. How would we delineate the community(ies)? Icons used with permission (CC BY 3.0) from https://thenounproject.com/browse/icons, artists: Gilad Sotil, my.taa, parkjisun, panji, Léa Lortal, Mahmure Alp, Denicon, Oleksandr Panasovskyi, Olena Panasovska, CombineDesign, Matej Design, mette galaxy, Icon Lauk, Jaime Serra, and riverbrother.

To help motivate the discussion, consider Figure 5.1. Using the definitions in Table 5.1, how would we delineate the community(ies)? C1 requires that the species interact, but it does not say how much interaction is necessary, nor what type of interaction. Do all species have to interact with each other? Does a species have to interact with at least one other species? With more than one other species? How strongly do they have to interact? As ecologist Don Strong wrote [12, p. *vii*] in 1984:

> "The contemporary questions in community ecology concern the existence, importance, looseness, transience and contingency of interaction."

In Figure 5.1, visually, there are two clusters of species connected via a mutualist species, M_{14}. Do these 15 species comprise a single community (C1)? We can speak about a community of only herbivore species (C6) or all invertebrates (C9), etc. A more realistic diagram might have 100s or 1000s of species. The plethora of definitions (Table 5.1) mean that it is entirely possible for two ecologists to look at some group of organisms and divide them into very different communities or ecosystems. The resulting communities may be distinct, interacting, overlapping, or one may be nested in another. The term *ecological community* does not appear to have any unique or meaningful definition absent further context or qualification.

You might have a definition in mind of what *you* mean by the term *community*, but all these definitions are used by at least some ecologists, and the definitions do not all seem to define the same entity, whatever it may be.

5.2.2 Ecosystems

The definition of an *ecosystem* has also changed over time and resulted in multiple definitions. Authur Tansley coined the term *ecosystem* in 1935 [13]:

> "But the more fundamental conception is, as it seems to me, 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. Though the organisms may claim our primary interest, when we are trying to think fundamentally we cannot separate them from their special environment, with which they form one physical system. It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth." (p. 299)

Table 5.1: Some of the many ways that biological communities are defined and used by ecologists. See Strouds et al. [7] for further discussion and a historical perspective; see Box 1 in Looijen and van Ardel [9] for more on the diversity of definitions. They call this *the problem of ambiguity*. Note that at least some of the definitions below are incompatible with each other. For example, a taxonomic community might actually exclude all or most species in an interaction web community, since many biotic interaction occur between species in different taxonomic groups.

Community type	**Definition**
C1. Species Assemblage	A set of species found in a particular area that interact with each other.
C2. Trophic Interactions	The network of feeding (trophic) relationships among species in a particular area.
C3. Guild Structure	The set of species that exploit the same environmental resource(s) in a similar way (e.g., a pollinator community).
C4. Interaction Web	The network of all interspecific interactions among species.
C5. Spatial or Habitat	A set of species defined by their spatial boundaries.
C6. Ecological Niche	A set of species characterized by the ecological niches they occupy.
C7. Successional Stages	A set of species defined by its stage in ecological succession, with characteristic species and interactions.
C8. Functional	A set of species defined by the collective functions performed by its members, such as energy transfer or nutrient cycling.
C9. Taxonomic	A set of species defined by their taxonomic relationships.
C10. Disturbance-mediated	A set of species determined by the types and frequencies of disturbances (e.g., fire, floods, or various human activities) and how these disturbances shape species composition and interactions.
C11. Climate-defined	The set of species determined by the climate conditions of the area, such as an arctic tundra community.
C12. Landscape	A set of species determined by the spatial patterns and processes at the landscape level.

Like the community concept, the debate about the importance of interspecific interaction also permeates the ecosystem concept. In the mid-1990s Michael Palmer and Peter White [14, p. 280] reviewed 26 ecology textbook definitions and found only one that considered communities and ecosystems to be defined as organized wholes.[6] Thirteen definitions encompassed the concept of interaction, without necessitating the inclusion of integration or discreteness. And 12 were purely operational definitions.[7] Some contemporary uses of the term *ecosystem* are shown in Table 5.2.

Table 5.2: Some of the many ways that ecosystems are defined and used by ecologists [16]. See also Jax [17] for further discussion and a historical perspective.

Ecosystem type	**Definition**
E1. Biological and Physical Integration	A community of living organisms in conjunction with the nonliving components of their environment, interacting as a system.
E2. Energy Flow and Nutrient Cycling	Described by the flow of energy through trophic levels and the cycling of nutrients.
E3. Spatial or Habitat-Based	Definitions focused on specific spatial boundaries or habitats. In this view, an ecosystem is confined to a particular physical space.
E4. Functional System	An ecosystem is viewed as a unit of biological organization with inputs, processes, and outputs.
E5. Dynamic & Self-Regulating Systems	A system in which biotic and abiotic components interact to regulate energy flow, biogeochemical cycles, and community structure.
E6. Landscape and Ecotone	Considers ecosystems in the context of landscapes, including the ecotones (transitional areas) between adjacent ecosystems.
E7. Ecological Niche	An ecosystem is viewed in terms of the ecological niches occupied by the species within it.
E8. Human-Integrated	This definition includes the impact of human activities and urban environments as integral components of ecosystems.
E9. Climate-defined	Ecosystems can be classified into different categories according to their climate, such as tropical rainforests, deserts, or tundra.
E10. Conservation and/or Management	An ecosystem is a unit for conservation and/or management practices.
E11. Ecosystem Services	Defined by the services they provide to humans.
E12. Holistic and Integrated Systems	A definition emphasizing the complex and integrated nature of the interactions between organisms and their environment.

Examining Tables 5.1 and 5.2 shows overlap between definitions. Both definitions have changed, multiplied, and at times blended into each other. This is perhaps not surprising; since the ecosystem concept in some sense encompasses the community concept, the two terms are sometimes used interchangeably. These days, the only things that separate community ecology from ecosystem ecology are the questions the research is trying to answer; otherwise, the two terms mean something very similar.

[6]This is an antiquated definition, sometimes called the Clementsian community, or super-organism, after ecologists Frederic Clements [15].

[7]What philosophers sometime call *useful fictions*.

5.2.3 Philosophical work: bringing conceptual clarity

> "For almost as long as ecology has been a discipline, it has struggled to define what constitutes an ecological community." —Velland (2012, [18])

Underwood [19] and Ricklefs [20] have both argued that the arbitrariness of the definitions means that ecological communities are not even valid units of study. A philosopher formally trained in conceptual analysis would find fertile ground to work with these definitional problems. Although I doubt that anyone will be able to give a satisfactory account of the necessary and sufficient conditions for employing either term, striving for conceptual clarity would undoubtedly be beneficial. Philosopher Mark Sagoff [8] tried this a decade ago and came to the conclusion that [22, p. 253]:

> "What are called natural ecosystems or ecological communities are so mixed up, contingent, fractious, intractable, unexpected, protean, erratic, changeable, unpredictable, fickle, variable, and dodgy they repel the mathematical abstractions theorists lay over them."

Community and ecosystem ecologists might resist such an assessment, and perhaps Sagoff was being too harsh, but the need for conceptual clarity should be obvious.

Philosopher Jay Odenbaugh [23] also attempted a conceptual clarification exercise for the community concept. He rejects the notion that one can have an objectively real community (see section 5.4) if the constituent species do not interact. From this starting point, Odenbaugh's analysis proceeds as follows. He takes species interaction to be a community-level property. From this, he gets:

> "For example, if w and x interact as predator and prey and x and y interact as interspecific competitors, and there is no z such that it interacts qua community with either w, x, or y, then x, y, w form a community excluding z. However, given considerations discussed above, this suggests that communities may be much smaller and more ephemeral than ecologists have typically considered." (p. 637) ...By way of summary, first, not every species or every collection of species occurring in a place at a time is a part of a community or forms a community. Even if species or their populations form communities, they may be mereologically smaller and more shortlived than ecologists have appreciated." (p. 638)

My own feeling is that there is still much work to do here, and philosophers have made progress with similar exercises for even less tractable concepts like *justice*, *morality*, and *consciousness*. Surely communities and ecosystems are not beyond our wit! Some paths forward might include the following.

[8] Sagoff sadly died recently [21]. He was a philosopher who deserved a wider audience with ecologists.

Definition and analysis. We need to break down the concepts of community and ecosystem into their fundamental components or aspects to understand their essence. Although the definitions in Tables 5.1 and 5.2 are a good start, more *analysis* is necessary. We seem to have plenty of definitions, but what we lack is a rigorous analysis of each and a comparison between these definitions. For example, consider the *trophic interactions* community concept (C2) and Figure 5.1. These are probably not all of the trophic interactions in an area. Does this concept require us to map *all* trophic interactions, just the *major* interactions, or *any* subset of interactions? Does it require a clear spatial boundary or can it be arbitrary?

Distinctions and categorization. What are the distinctions between the various community or ecosystem concepts? We might make headway clarifying these concepts by explaining how they are different from related concepts. For instance, distinguishing between *communities*, *aggregations*, and *species assemblages* might help to clarify the nature of each. If the community definition does not require interspecific interactions, is it different than an aggregation? Does the distinction matter?

Logical reasoning. Employing logical principles to explore and establish the edges and implications of a concept is crucial. For example, are there a minimum number of species that are required before we can say that the collection qualifies as a community? If there is, by what logic did we arrive at that conclusion? Is it possible to identify members of a community without explicitly identifying its boundaries? If so, how do we do so? By what logic did we come to this conclusion?

Thought experiments. We can use hypothetical scenarios to explore the implications of a concept and test its coherence. As an example, suppose that we are thinking about an *energy flow and nutrient cycling* ecosystem concept (E2) and we begin to get a new flux; are we still talking about the same ecosystem or is this a new ecosystem? Suppose a farmer begins (or stops) farming a field up slope from the putative ecosystem, and nutrient runoff starts (or stops) to enter the ecosystem. Is this now a new ecosystem under the definition? See also section 5.3.3 and Figure 5.6 later in this chapter.

Historical contextualization. Understanding how a concept has been viewed and treated throughout history can provide insight into its current understanding and usage. This work has been done to some extent (see, e.g., [9, 11]). However, this only helps so much, as ecologists generally do not stand on past precedent. We are perfectly willing to change word usage and meaning in the middle of a paper, let alone throughout decades. We are also, as a group, woefully ignorant of our own history, and if colleagues of my generation are correct, this problem is only getting worse.

Dialogue and critique. Engaging in discussions and debates with other ecologists is a key method. By challenging and critiquing each other's views, ecologists can uncover assumptions and biases, leading to a more nuanced understanding. This work is not helped by the fact that many ecologists do not want to engage in this dialogue, arguing that it is *unscientific* and *unhelpful*. See, for example, the exchange between New Zealand ecologist Bastow Wilson [24] and Canadian ecologist Paul Keddy [25].[9]

Defining *communities* and *ecosystems* is a bit like defining human *culture*. Like ecological communities, human cultures comprise distinct elements that interact and influence each other, but defining the boundaries and contents of a culture can be challenging. Culture encompasses beliefs, behaviors, values, practices, institutions, and material objects that characterize a specific group of people or society. It includes language, customs, traditions, art, music, moral norms, and social structures, among other aspects. Culture is transmitted from generation to generation, evolving over time as it interacts with internal and external factors, including other cultures. Like species distributions, these elements of culture also vary across the world. Dividing them into discrete cultures is similar to the problem of dividing species into discrete communities. Perhaps neither are, in fact, discrete. We take up this question in the next section.

5.3 How are communities or ecosystems individuated?

In this section I consider the task of taking a definition of either concept and going out on the landscape and identifying a community or ecosystem that answers to that definition. First, I consider a motivating example. Then I explore some historical views on individuating communities and ecosystems. Next, I consider how one could use the steps in the metaphysics of individuation to make some progress. I motivate this part of the discussion by considering the concept of ecosystem collapse, because this naturally leads us to a consideration of the *essential properties* of communities and ecosystems. Identifying essential properties is a key step in the individuation process.

Before diving into the question, I need to make a distinction between individuating a *type*

[9] Sadly, Wilson died a few years ago [26], and Keddy died more recently [27]. Both were intellectual leaders in the field.

of community or ecosystem and a *token* community or ecosystem. A type of community is a classification. For instance, what does it mean to be a *grassland community*? A token community is an example of a type. We can talk about a particular grassland community in southern Ontario, for example. In this section, I am interested in the latter problem, because individuating types of ecosystems is moot if we cannot individuate token ecosystems.[10]

Figure 5.2: Landscape along the Inuvik-Tuktoyaktuk highway, Northwest Territories, Canada. How would we individuate one or more communities or ecosystems from this landscape? Photo credit: Kristian Binder, eightyoneimages.com. Used with permission.

5.3.1 Motivating example

To motivate the discussion, consider the landscape shown in Figure 5.2. It is a habitat located inside the arctic circle, along the Inuvik-Tuktoyaktuk highway, in Canada's Northwest Territories. Visually, we see an area of deciduous forest in the foreground and coniferous forest in the background, as well as several bodies of water. Although the definitions of communities (Table 5.1) differ, they all agree on one thing: Communities comprise a collection of species. The disagreement comes down to *which* species comprise the community. The landscape shown in Figure 5.2, despite being a low arctic tundra habitat, and therefore likely has fewer

[10]For those interested in the former problem, the IUCN has developed a classification of ecosystem types [28].

species than, say, a tropical rainforest, nevertheless might have hundreds of macroscopic species within it. Some will be very abundant and/or widely distributed, and some will be rare and/or narrowly distributed on the landscape. Using the definitions in Table 5.1, we can pick out the landscape (C12) which presumably includes all species found in the landscape. We can pick out just those species that interact in some way with each other (C1, C4), just the trophic relationships (C2), just the vertebrate animal community or deciduous tree community (C9), just the aquatic insect community (C5, C9), just the herbivores (C3, C6), just the decomposers (C8), the shoreline community (C10), the tundra community (C11, which in this case coincides with C12), the ecotone from deciduous to coniferous trees (C7), and many, many, more. The fact that an individual species might belong to more than one community is not particularly problematic, any more so than the fact than an individual human might simultaneously belong to more than one human community.[11]

With the notable exception of *Spatial or Habitat Communities* (C5), most of the definitions in Tables 5.1 and 5.2 do not have an explicit boundary condition.[12] Even spatial or habitat communities can be ambiguous. In Figure 5.2, where does the deciduous tree community end? Even if we are talking about just one particular type of community, say the insect community, where does that community start and end in that landscape? For descriptive purposes, it may not matter. We could just sample a few places in that landscape and use the sample to make inferences about the whole community, whatever its regional extent—this is the basic task of statistics, sample from an unknown community and use the sample to make inferences about that community. However, for other purposes, it matters very much where the boundaries are located. If the community or ecosystem is of conservation interest, for example, we need to know *what* we are conserving [see e.g., 28]. If the ecosystem is of management interest, we need to know *what* ecosystem we are managing [22, 29].[13]

[11] It is with some trepidation that I make an analogy to human communities, because human communities can be very different form ecological communities and equivocating between them has caused problems in the past [see e.g. 1, 10.4.3.2 The Community Concept in Ecology].

[12] In practice, where there is no obvious boundary—as with lakes or islands—ecologists usually either set an arbitrary boundary for the purpose of the study, or use one of many available statistical techniques to define a boundary.

[13] Ecosystem management often sidesteps this tricky question by managing *watersheds*—which have relatively unambiguous boundaries—rather than ecosystems. And this works for some applications. However, it still does not really answer the question, as watersheds are not ecosystems (except when they are defined as such), and watersheds often overlap, contain other watersheds, and are themselves contained by other watersheds. See Garcia and Newman's [2] Figure 3 for an example.

5.3.2 Historical views

Faced with such challenging questions, many ecologists have given up on the idea that communities are discrete entities. Take Begon et al. [8] in 1986 :

> "The safest statement we can make about community boundaries is probably that they do not exist, but that some communities are much more sharply defined than others. The ecologist is usually better employed looking at the ways in which communities grade into each other than in searching for sharp cartographic boundaries." (p. 597)

Looijen and van Andel [9] in 1999 stated:

> "The second problem concerns the fact that what are usually called communities, i.e. groups of populations of different species which occur together in space and time, rarely if ever form discrete units in a landscape, but gradually blend into one another. Therefore, it is often very difficult or even impossible to draw objective, non-arbitrary boundaries between different communities. This problem is known as the boundary problem. *It is probably the most notorious problem in community ecology and is generally considered irresolvable.* As a result, most, if not all, ecologists today regard communities as more or less arbitrary units of investigation (see, among many others, Cohen 1989; Krebs 1994; Begon et al. 1996)." (emphasis added; see original for references, p. 211)

And this is still a contemporary view, as this quote from Tozer and Keith [30] in 2023 demonstrates:

> "The problem arises because the concept of deviation from type explicitly requires acknowledging the existence of vegetation types (Wiegleb, 1989), and yet most researchers and naturalists accept the continuum theory of vegetation as central to ecology (Austin, 1985, 1986). ... It holds that species are distributed independently on resource and climatic gradients (Austin & Smith, 1989), and recognisable, repeated combinations of species occur due to the coincidence of their resource requirements and physiological tolerances (Moravec, 1989)." (see original for references; p. 2)

In the face of such continua, ecologists use gradient analysis and other statistical techniques to try to pick out a community in some non-arbitrary way, from the vast array of gradients and continuous variation. This is caricatured in Figure 5.3. There is much to say about gradient analysis, but it is beyond the scope of this essay. For now, I simply observe that the process is much more difficult than this simple caricature would imply.

To summarize the thinking of ecologists, although ecological communities can have boundaries, their clarity and definition are influenced by many factors. The idea of boundaries in ecology is more complex than a simple *threshold* condition, reflecting the complexity and variability of natural systems.

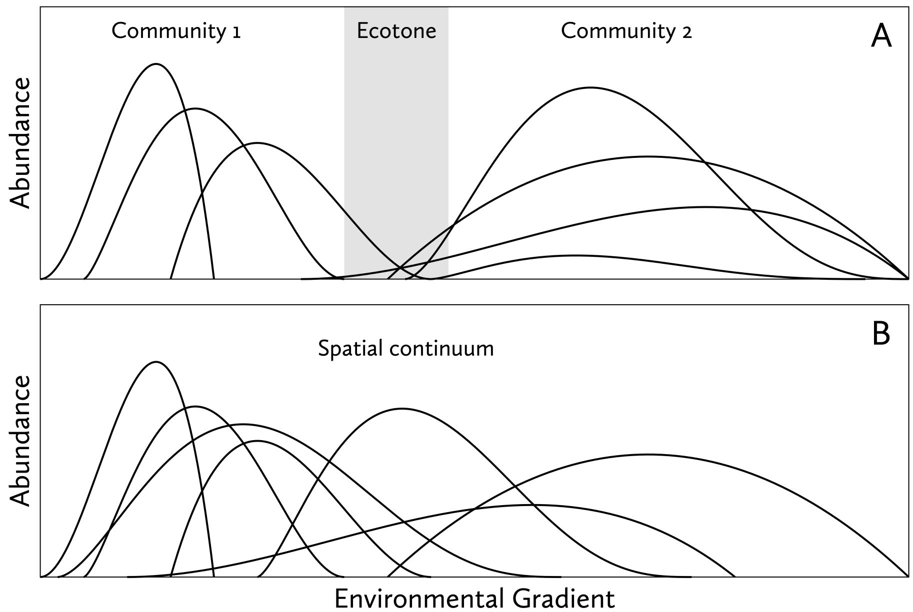

Figure 5.3: A charicature of a gradient analysis. Imagine an environmental gradient like moisture, shade, nutrients, etc. In A, the seven species abundances along the gradient seem to separate into two communities with a transitional area in between, called an ecotone. In B, the seven species overlap so much along the gradient that they cannot be separated into more than one community. Figure adapted from Whittaker [31].

5.3.3 Philosophical work: metaphysical individuation

Philosophically, this is the problem of *individuation*. In metaphysics, individuation refers to the relationship between entities. It refers to the unique characteristics of an object that distinguish it from others and make it the object that it is, as opposed to any other thing. In other words, it is the features that make an object a distinct and singular entity [32]. It seems to me that ecologists can make some progress with the individuation problem, if not solve it, by trying to go through the individuation process. Along the way, we might clarify some of our thinking on these objects (assuming that they exist!).

Some of the steps that could shed light on the problem include the following. Determining the *accidental* and *essential* properties of communities and ecosystems. Accidental properties are those that a community or ecosystem *can* lose without changing its identity. These might include very rare species or very minor nutrient fluxes. Essential properties are those that *cannot* be lost and still remain the same entity. These might include dominant or very abundant species or particular nutrient fluxes. The spatial and temporal contexts are also crucial in individuation. Two identical objects can be differentiated if they exist at different locations or times. Two fish communities that are identical in every way but located in different lakes would be considered different communities.[14] The individuation process is often influenced by the conceptual framework or the philosophical perspective adopted. For instance, in some frameworks, individuation might heavily rely on the observer's perception. It is also important to identify counterfactual scenarios to test the individuation process. By asking what changes *could* occur to the object without it ceasing to be the same object, we can ensure that the object's essential properties are well defined. To the best of my knowledge, no one has formally tried to do such an analysis, but the process of trying to do so would likely illuminate the debate. I do not have space in this chapter to thoroughly treat each of these steps, but I offer a few thoughts for consideration.

Ecosystem collapse: the loss of essential properties

To ground our consideration, it might be useful to think about the concept of *ecosystem collapse*. Like many terms in ecology, the meaning of this one is also somewhat murky. The International Union for Conservation of Nature (IUCN) [28] provides the following definition:

> An ecosystem is collapsed when it is virtually certain that its ***defining biotic or abiotic features*** are lost from all occurrences, and the characteristic native biota are no longer sustained. Collapse may occur when most of the diagnostic components of the characteristic native biota are lost from the system, or when functional components (biota that perform key roles in ecosystem organisation) are greatly reduced in abundance and lose the ability to recruit. (p. 7; emphasis added)

Despite its evocative name, ecosystem collapse is really a process by which one ecosystem becomes a different ecosystem. This transformation may result in the disappearance of characteristic features long before the last characteristic species disappears. The transformed ecosystem may retain some of the characteristic biota of the collapsed system, but their abundances, interactions, or ecological functions are different [28].

The definition is pretty straightforward, but what are the *defining biotic or abiotic features*? How do we know when the ecosystem becomes a different type? If ecosystems can change their identity, they must first have identities. Before I look at two categories of the proposed defining features used by ecosystem ecologists, I need to say a few words about the nature of these defining features. Most of these features are continuous in nature. Loss of defining

[14] Thanks to Pedro Peres-Neto for this example.

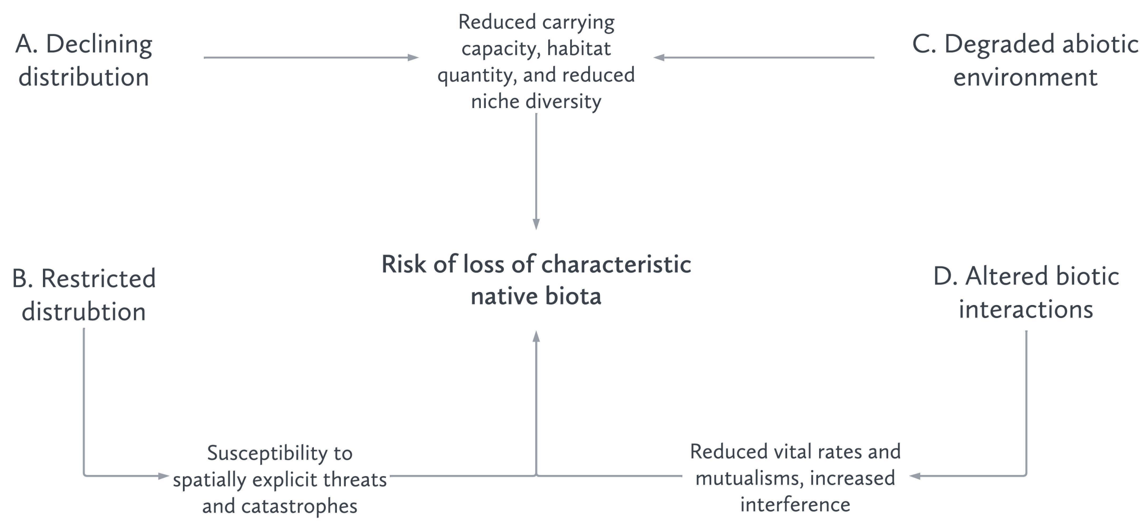

Figure 5.4: Part of the framework used by the International Union for Conservation of Nature (IUCN) to assess the risk of ecosystem collapse. Adapted from Keith et al. [33].

characteristics is, generally speaking, a continuous process.[15] Like losing hair on your head. At one end of the spectrum you have a full head of hair and at the other end of the spectrum you are completely bald. Somewhere in between, there is a transition to baldness, but exactly where that transition occurs is not often clear, even though the two end states are patently different. The situation is similar with ecosystems, except that it involves multiple characteristics rather than just one. Keep this in mind as we consider the defining features that make a particular ecosystem what it is and not another ecosystem.

Loss of essential properties (*i*): characteristic native biota

Figure 5.4 shows much of the IUCN's ecosystem risk assessment process. You can see that "risk of loss of characteristic native[16] biota" is a key characteristic in defining ecosystem collapse. What are these species and how are they identified as *characteristic*?

The presence and abundance of indigenous flora and fauna specific to an environment are a crucial indicator of whether an ecosystem has collapsed (or will so do). This includes genetic material, groups of organisms, individual species, and the interactions among different species

[15]Notwithstanding notable examples like the damming of a river or converting forests into farmlands, where the ecosystem transformation is remarkably abrupt.

[16]The emphasis on *native* suggests a value judgment. There are plenty of highly functioning ecosystems that are dominated by non-native species. Are these ecosystems not of conservation interest? Equating "native" with "good" is to commit the *naturalistic fallacy*. See Newman et al. [1, p. 275].

that distinguish one ecosystem from another and influence its operations and processes. These characteristic and operational elements must exhibit a certain level of distinctiveness and significance. Their disappearance signifies a shift in identity, the breakdown of the ecosystem's structure, and its replacement by a different ecosystem. Examples of such unique native biota might include apex predators, dominant tree species, ecosystem engineers,[17] pollinators, etc. [28]. If they can be identified in some non-arbitrary way, the characteristic native biota would comprise *essential properties*.

The complete species composition is unlikely to be an essential property, but some subset of species might be. We are generally interested in two types of characteristic native biota, the most abundant species and species whose impact on ecosystem functioning is considerably greater than its abundance, called *keystone species*.[18] For example, consider the grassland community rank-abundance curve shown in Figure 5.5. The figure includes 24 grassland species, but probably only the most abundant four or five species are essential to the definition of this community. Two possible exceptions to this are *Lupinus bicolor* and *Lotus humistratus*. Both are legumes that are capable of fixing atmospheric nitrogen and making it available to other plants in the community [see e.g. 35]. Otherwise, the least abundant dozen or so species can change through deletions and additions—as long as the additions remain at relatively low abundances—and we would still consider this the same community.

To see how characteristic biota might be used to individuate communities, consider work by Machtans and Latour [37], who studied songbird communities in the boreal forest of the Liard Valley, Northwest Territories, Canada. They compiled rank-abundance curves for six types of forest communities. These ranks are shown in Table 5.3, where the five most abundant species are highlighted for each community. If we focus on coniferous, mixedwood and deciduous forests, we can see the transition from one bird community to another. Coniferous bird communities transition to mixedwood communities when Western Tanager and Bay-breasted Warbler become much more common, while Swainson's Thrush and Chipping Sparrow become less common. The mixedwood bird community transitions to the decidu-

[17] *Ecosystem engineer* is another murky term used by ecologists. They are commonly described as species that alter their environment significantly, by creating new habitats or adapting existing ones to meet their requirements. The exemplar often used is the beaver (*Castor spp.*) [e.g., 34].

[18] The *keystone species* is yet another fairly nebulous concept in ecology. It is generally defined as a species that has an outsized effect on the community relative to its abundance. Needless to say, no one ever defines "outsized" or the critical ratio of effect to abundance to justify the claim. It is something that is mostly just asserted by authors without proof, or the proof comes only after the species is gone.

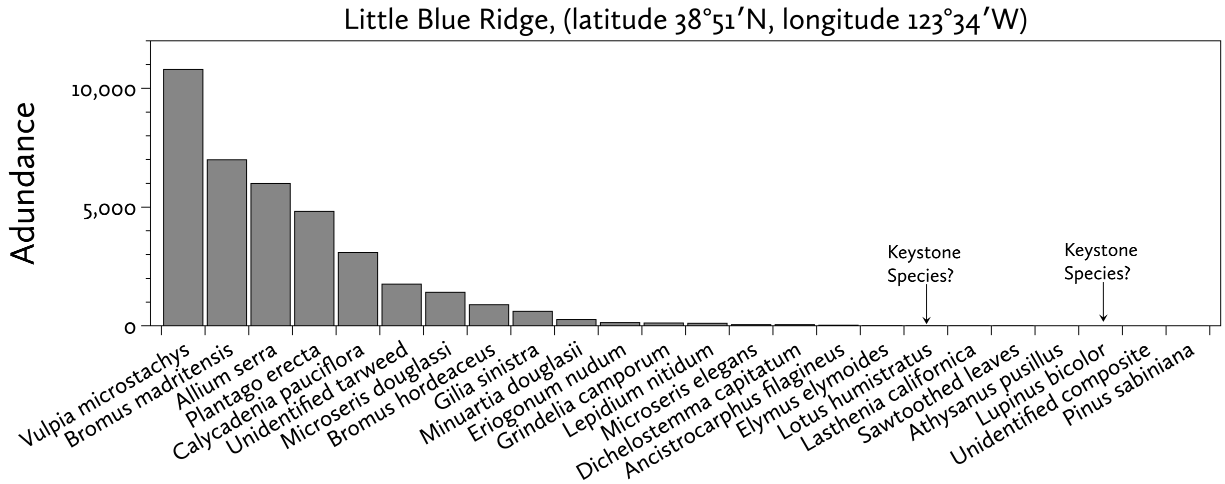

Figure 5.5: The rank–abundance (number of individual plants) relationship for Little Blue Ridge grassland in California. Data from Green et al. [36].

ous community when Ovenbirds and American Redstarts become dominant species, while the Tennessee Warbler, Yellow-rumped Warbler, and Chipping Sparrow become less common. And so on. These six habitat types have different mixtures of characteristic native bird species. Combining similar rank-abundance information for plants and other animal groups would allow us to define the characteristic native biota for these different ecosystems. Looking back at Figure 5.2, it might be possible to separate the deciduous forest from the coniferous forest by the abundance and distribution of these characteristic native biota in the landscape. Of course, I am glossing over the really difficult questions about how much change is necessary, etc., but roughly speaking, this is a method of individuating communities and ecosystems.

Loss of essential properties (*ii*): characteristic nutrient cycling

Like characteristic native biota, another indicator of ecosystem collapse is when we observe large changes in nutrient cycling, energy transport, or hydrology. Consider this example from Mahendrappa et al. [38]. They present a diagram similar to Figure 5.6, which shows the pool and flux sizes for two different forests, one a 30 year old pine forest and the other a 135 year old maple-birch forest. Inspection shows that these two ecosystems have fundamentally different nitrogen pools and fluxes. Similar pool size and flux data are often gathered for carbon, phosporous, potassium, water, and energy. Together, these indicators represent another way to characterize differences between ecosystems. All of these are candidates for essential properties and can be used to individuate ecosystems. Again, looking at Figure 5.2,

Table 5.3: Ranks of abundances of bird species in the boreal forest of the Northwest Territories in Canada. Ranks from Machtans and Latour [37]. The top 5 most abundant species in each community type are shaded gray.

Bird Species	**Coniferous**	**Mixedwood**	**Deciduous**	**Young**	**Wooded Bog**	**Clearcut**
Tennessee Warbler (*Oreothlypis peregrina*)	1	2	6	3	3	4
Magnolia Warbler (*Setophaga magnolia*)	2	1	2	5	9	6
Swainson's Thrush (*Catharus ustulatus*)	3	6	3	2	8	
Yellow-rumped Warbler (*Setophaga coronata*)	4	5	7	11		
Chipping Sparrow (*Spizella passerina*)	5	7	14	12	2	7
Western Tanager (*Piranga ludoviciana*)	6	4				
Bay-breasted Warbler (*Setophaga castanea*)	7	3	13	8		
Red-breasted Nuthatch (*Sitta canadensis*)	8	11				
Gray Jay (*Perisoreus canadensis*)	9			13	6	
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	10	9	11			
White-winged Crossbill (*Loxia leucoptera*)	11					
Cape May Warbler (*Setophaga tigrina*)	12					
Boreal Chickadee (*Poecile hudsonicus*)	13			15		
White-throated Sparrow (*Zonotrichia albicollis*)	14				7	1
Ovenbird (*Seiurus aurocapilla*)	15	8	1	9		
American Redstart (*Setophaga ruticilla*)		10	4	1		
Canada Warbler (*Cardellina canadensis*)		12	8			
American Robin (*Turdus migratorius*)		13			13	10
Red-eyed Vireo (*Vireo olivaceus*)		14	5	6		
Black-and-white Warbler (*Mniotilta varia*)		15	12	4		
Least Flycatcher (*Empidonax minimus*)			9	14		9
Warbling Vireo (*Vireo gilvus*)			10			8
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)			15			
Yellow-bellied Flycatcher (*Empidonax flaviventris*)				7	10	
Fox Sparrow (*Passerella iliaca*)				10	11	
Palm Warbler (*Setophaga palmarum*)					1	
Hermit Thrush (*Catharus guttatus*)					4	
Dark-eyed Junco (*Junco hyemalis*)					5	11
Lincoln's Sparrow (*Melospiza lincolnii*)					12	5
Ruby-crowned Kinglet (*Regulus calendula*)					14	
Alder Flycatcher (*Empidonax alnorum*)					15	2
Mourning Warbler (*Geothlypis philadelphia*)						3

we might be able to tell where the deciduous forest ends and where the coniferous forest starts by looking at differences in the sizes of the characteristic pools and the magnitudes of the fluxes for key nutrients.

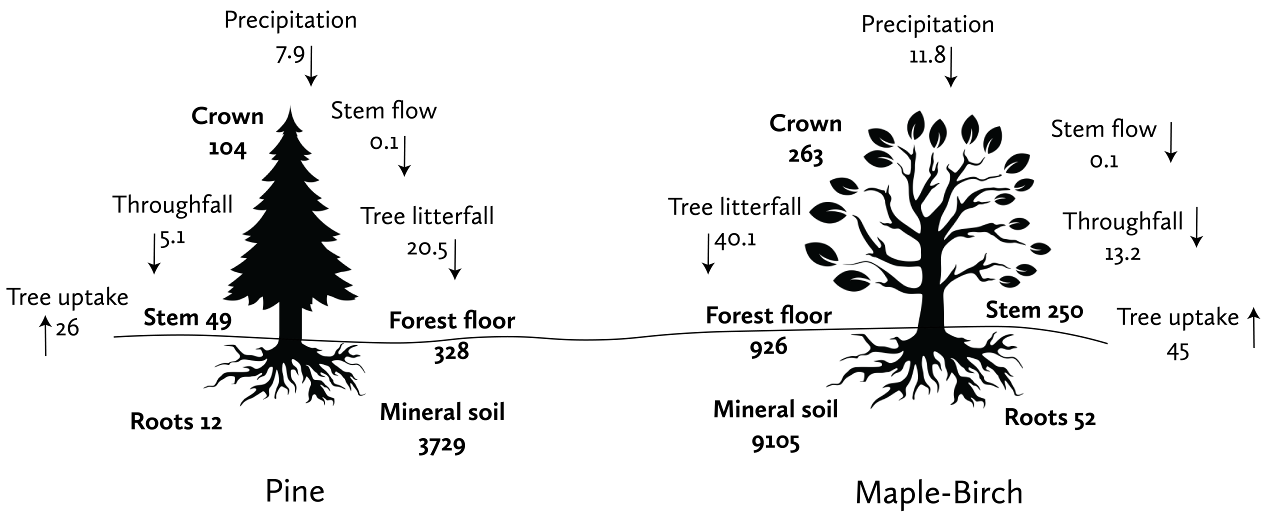

Figure 5.6: The distribution and annual cycling of N (kg ha^{-1}) in a 30 year old jack pine and a 135 year old sugar maple-yellow birch ecosystem. Modified from Mahendrappa et al. [38]. Bold type denotes N pools, non-bold type denotes fluxes. Some fluxes have been left out to simplify the diagram.

5.4 What is their ontological status?

In the last two sections, we considered—but didn't solve—the problems of definition and individuation.[19] Here, we want to consider whether, regardless of how we define and individuate communities or ecosystems, do they refer to something real, or are they just useful fictions that allow ecologists to make progress in the face of enormous complexity?[20] I first consider some historical views on the subject from ecologists. I then consider one previous attempt to address the ontological status from a metaphysical perspective.

5.4.1 Historical perspectives

When Arthur Tansley coined the term *ecosystem* in 1935 [13], it seems pretty clear that he thought of them as useful fictions:

> "These ecosystems, as we may call them, are of the most various kinds and sizes. ...The whole method of science, ...is to isolate systems mentally for the purposes of study, so that the series of

[19] The lack of clear boundaries might mean that we ought consider communities and ecosystems to be what philosophers call *vague objects*. There is much debate about whether vague objects are objects at all [see e.g., 39, for discussion]. This is an interesting debate, but beyond the scope of this essay.

[20] I have no animous toward operational definitions or useful fictions. They have helped ecologists make progress on a variety of very difficult problems. If pushed, I suspect that most community and ecosystem ecologists would be willing to stipulate that these concepts are just useful fictions if only to get out of having the discussion, regardless of what they really think!

> isolates we make become the actual objects of our study, whether the isolate be a solar system, a planet, a climatic region, a plant or animal community, an individual organism, an organic molecule or an atom. Actually the systems we isolate mentally are not only included as parts of larger ones, but they also overlap, interlock and interact with one another. The isolation is partly artificial, but is the only possible way in which we can proceed we can proceed." (p. 300)

In the previous section, I considered the problem of individuation. What exactly is the object we are calling a community? A problem we encountered there was what some have called "the boundary problem" [9]. However, the boundary problem does not necessarily speak to whether communities and ecosystems are real things that exist in nature and not merely useful mental constructs. A concrete example of an entity that exists in reality but cannot be individuated is a particular amount of a substance, such as a specific liter of water in the ocean. The water is undeniably real and exists as a constituent of the ocean, but it cannot be identified or separated as a distinct and separate entity. The water seamlessly integrates with the rest of the ocean, making it impossible to discern or isolate a specific litre without *artificial* demarcation. This notion commonly applies to substances or phenomena in which individual constituents are indistinguishable from the whole [16]. Are ecological communities this type of thing? I don't think so.

Species are the equivalent of water in this analogy. Yes, species are probably real,[21] just as water is real. However, the community is the equivalent of the litre. Species' abundances and distributions are perhaps not as homogeneously distributed as water molecules in a volume, but the community may be just as arbitrarily defined as the litre volume. The litre is not a quantum. It may have a precise definition—unlike a community—but it is still an arbitrary quantity.

Kurt Jax [11] presents the problem as follows.

> "Ecological units, like ecosystems, are sometimes seen as something that exists as such in nature, and thus has to be found and identified instead of being defined and delimited. This ontological approach to ecological units stands in contrast to a purely epistemological one, which perceives ecological units as abstractions an observer creates for the purposes of a specific task by selecting certain aspects from the whole of nature." (p. 243)

Jax reviewed nine different conceptions of *community* and concluded that for six, the authors intended these to be useful fictions—empistomologial in Jax's terms—two were 'unclear' and one author (Clements) seemed to view their conception as existing independently. Jax goes

[21] The species concept is also problematic, but perhaps less so than communities. See Newman et al. [1], chapter 9 for further discussion.

on to review nine conceptions of ecosystems and finds that the authors of four view them as useful fictions, three were unclear, and two the authors seemed to view their conception as existing independently. Of course, we are under no obligation to accept the authors' views on the matter. *If* they exist, they do so for reasons other than the authors' assurances that they do.

The question "do they exist?" has been debated amongst ecologists for decades. And despite Keddy's admonishment that this is not a question worth asking [25], I am going to press on anyway. Keddy's point was that it does not matter whether communities exist, it matters whether believing that they do is helpful for advancing ecology. I will stipulate that, as a mental construct, the community concept has been very helpful to ecologists. Wilson [24, p. 290] boldly claimed that:[22]

> "I conclude that the evidence for the existence of plant communities is even weaker than that for the Yeti."

The views differ by subdiscipline. Freshwater ecology has an advantage in that lakes, rivers, ponds, streams, etc., have something approaching an obvious boundary condition on the community or ecosystem. Island ecology also has this advantage. I think that in these subdisciplines, the existence of communities and ecosystems is less controversial. After all, seeing is believing.

5.4.2 Philosophical work: metaphysical existence

The work here falls into the category of metaphysics of existence. Philosopher Robert Garcia and I [2] have done some work on this issue. We were interested in the moral status of ecosystems, which is a moot question if ecosystems do not have a mind-independent existence. Our approach is sketched out in Figure 5.7. We start by considering the positions one could take in response to the question "are they real?" One would respond that "no, ecosystems are not real" if one adopted a *global anti-realism* view toward each and every ecosystem concept (e.g., Tables 5.1, 5.2), or "yes, ecosystems are real" if one took the view that at least one of these ecosystem concepts referred to a mind-independent entity. We labeled this view *realism*. There are three ways to be a realist. *Pluralism* is the view that there is more than one ecosystem concept because there is more than one kind of mind-independent ecosystem. *Monism* is the view that there is only one kind of mind-independent ecosystem.

[22]Wilson uses the Yeti as an example of something that might or might not exist as an analogy to plant communities.

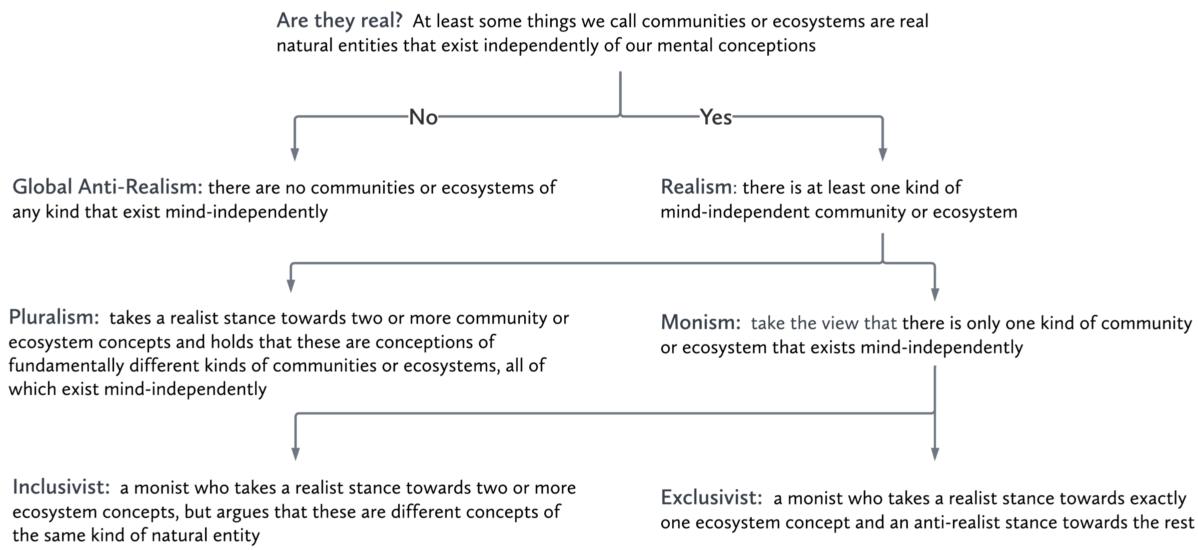

Figure 5.7: Taxonomy of ontological stances toward communities or ecosystems. Terminology and definitions from Garcia and Newman [2].

Within monism, one could be an *inclusivist* if one takes the view that two or more ecosystem concepts refer to real entities, but those concepts refer to the same kind of entity. And finally, one would be an *exclusivist* if one takes the view that one and only one of the ecosystem concepts refers to a real entity, and the rest do not.

There are different ways to examine the ontological status of concepts from a metaphysical perspective. One of these approaches is to consider the concept's theoretical indispensability and explanatory power. If an entity is essential to our most successful theories of the world, it is usually considered to exist. Moreover, if an entity has significant explanatory value in helping us understand different phenomena, it can also be deemed to exist because its presence can account for certain aspects of reality. This is the approach that we followed in our investigation. We asked whether a realist ecosystem ontology is favored by scientific evidence. After analyzing some of the arguments presented in this essay, Garcia and I concluded that:

> Thus, the Epistemic Case is unconvincing: the evidence fails to make realism more likely than global anti-realism. In fact, we think the evidence makes realism less likely than global anti-realism. (p. 174)

For our purposes in that paper, we did not need to defend a global anti-realism stance, only the weaker conclusion that realism is not more likely than global anti-realism. I do not believe that the concept of a community or ecosystem is theoretically *indispensable*. There are plenty of examples where researchers are clearly not taking a realist stance, yet they are able to make progress. Indeed, this is probably reflected in Keddy's [25] paper "Do ecological communities exist? A reply to Bastow Wilson":

> The point is that asking whether communities exist falls into a class of questions that may not be worth debating because they cannot be answered, and even if they are 'answered', probably will not advance the progress of ecology. More importantly, they may distract our attention as scientists from answerable questions.

The implication of Keddy's quote and the tenor of his reply is that ecologists have been getting along just fine without having to commit to a realist position toward community or ecosystem existence.

5.5 Conclusions

I hope by now the reader will see why these are perennially unanswered questions in ecology. My own feeling is that many of the communities and ecosystems referred to in the literature are actually useful fictions, but that some exist, mind-independently, as relatively discrete entities. These include ponds, lakes, islands, etc. In continental regions, communities and ecosystems are more continuous in nature, blending into each other or not individuated at all. As said earlier, I would guess that most ecologists do not dwell on or even care very much about the answers to these three questions, having either resigned themselves to the idea that they are unanswerable or have concluded that their answers do not affect the way they approach their work. However, diligent philosophical work can help clarify the answers to each question, and doing so would be a great benefit for applied ecologists, conservationists, and environmental philosophers as they grapple with challenges related to management and the moral status of these entities, assuming they exist.

Acknowledgements

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