On the Very Idea of an Ecosystem

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I. Introduction. In this essay, I consider several different issues. First, I examine how token ecosystems are individuated by ecologists. Second, I examine whether ecosystems or more specifically their components can have functions. Philosophers have offered two accounts of functions, *selected effects function account* and *systemic capacity function account*. The former of understood in terms of evolutionary history and the latter in terms of nested dispositions. Here I side with systemic capacity functions as providing the more reasonable account of functional ascriptions in ecosystem ecology. However, this has downstream implications with regard to the next topic. Thirdly, many ecologists and conservationists have taken to talking of "ecosystem health." Some treat this as mere metaphor but others construe it literally. The notion of ecosystem health is intimately tied to the notion of ecosystemic functions. However, the notion of a "healthy" or "diseased" state requires norms of performance which is noticeably absent on a systemic functions view. In summary, I offer an extended argument there are mind-independently existing ecosystems which have functions but which are neither healthy nor diseased.

II. Token Ecosystems. In the 1970s, the environmental writer Barry Commoner claimed the science of ecology demonstrates "everything is connected to everything else" – what he termed "ecology's first law." This mantra is often heard in environmental circles.[1] However, it is unclear what this even means. If everything is intimately connected to everything else why is there not simply one thing, the universe? Similarly, one might argue given these intimate connections that there are no objects since there is nothing to differentiate "it" from everything else. Every object has an "inside" and "outside" but the universe would not. For those mystically inclined, this might be satisfying but philosophically we must do better.

For clarity, let's circumscribe our discussion. First, in the beginning of this section, I will be considering objects qua *concrete particular.* A concrete particular is anything which exists in space-time.[2] Second, I will suppose if two or more objects are *connected*, then they are *causally connected*.[3] Third, since the sorts of objects under consideration are *ecological ones*, then the type of causal relation must be an *ecological relation*.[4] If someone claimed that all spatiotemporal objects are causally connected through gravitational attraction, then this might be true but irrelevant for our purposes. As examples of ecological causal relations, here

[1] For example, self-proclaimed "deep ecologists" (not to be confused with scientific ecologists) suggest that the fundamental norm of their favored environmental ethic is "Self-realization." Put less cryptically, there is but one thing. If we further add that one ought to promote one's self-interest, then one ought to promote the interest of the Self. Needless to say I suppose, there are several problems with this argument.

[2] If one believes for example that properties exist only if they are exemplified or instanced in space-time (e.g., David Armstrong), then one might add that a concrete particular is anything which exists in space-time which cannot be exemplified or instanced.

[3] Some philosophers hold that events are causally connected to another and not objects per se. Nothing hangs on talking about objects being causally related since one could rewrite this essay using the more cumbersome locution of event causation. Likewise, as an aside, one can substitute their preferred metaphysics of persistence – objects are "wholly present" whenever they exist, or have temporal parts, etc. One could rewrite this essay as an perdurantist or endurantist and the content not be substantially affected.

[4] It is doubtful that Commoner was attending to such niceties though if ecology teaches us that everything is connected to everything else, then surely this is because everything is *ecologically connected.*

are a few. Populations of organisms are those organisms which are causally connected through the relation of interbreeding which may be an evolutionary relation.[5] However, they are also connected through competition for shared resources such as food, light, and habitat. Likewise, ecological communities are those populations of species which are causally connected through predator-prey, interspecific competition, mutualism, amensalism, commensalism, etc. relations.[6] In this essay, we will be concerned primarily with the natural kind *ecosystem* and its associated ontology so let's begin there with some history.

The history of ecosystem ecology is rich and we certainly cannot do it justice.[7] Still, we can consider high points. In the 1920s, British ecologist Charles Elton noted that organisms living in the same place are linked through their feeding relationships. This he termed a "food chain" or what we now more generally call a "food web." For example, plants are eaten by animals which are eaten by other animals and so on. In effect, Elton notes that populations of species occupy *functional roles* including *autotroph*, *herbivore*, *carnivore*, and *detrivore*. An *autotroph* is any organism that produces organic compounds from inorganic molecules (i.e.,

[5] *Potential interbreeding* is a concept which deserves metaphysical scrutiny (see Kitcher ___). If organisms compose a population, then they must be *able* to interbreed. Clearly, we must "fix" certain properties of the organisms for this to make sense. For example, for some set of organisms, asexual organisms could interbreed with provided they might have been sexual, have the right breeding season, etc. By the same token we cannot construe populations in terms of actual interbreeding because some members/parts may never interbreed.

[6] This notion of an ecological community needs further refinement as well. I have provided a disjunction of causal relations which are "community-level" causal relations. However, what makes them community causal relations? One might define a community-level causal relation as any causal relation that holds between two or more species. This criterion provides the right answer when we consider competition between conspecifics for shared resources; however, this is insufficient since gravitational attraction could hold between two or more species as well. So, we should say that a community-level causal relation is any causal relation that holds between two or more species *qua species*.

[7] See Frank Golley (1993),…

photosynthesizes), a *carnivore* is any organism which consumes animals and only animals, and a *detrivore* is any organism which consumes dead animals and only dead animals. Elton was explicit about ecological niches being functional roles when he wrote, "When an ecologist says 'there goes a badger' he should include in his thoughts some definite idea of the animal's place in the community to which it belongs, just as if he had said 'there goes the vicar'" (1927, 64).

In 1935, the British ecologist A. G. Tansley explicitly articulated the concept of an *ecosystem*. Tansley rejects the concept of a ecological community in favor of the total biological (biotic) and physical (abiotic) system as he believes it is incomplete:

> 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…These *ecosystems*, as we may call them, are of the most various kinds and sizes. They form one category of the multitudinous physical systems of the universe, which range from the universe as a whole down to the atom. (1935)

Tansley's overzealousness is evident since ecosystems are objects composed by causal relations between biotic and abiotic components qua those types of components and this would apparently rule out the universe and atoms respectively.[8] Nevertheless, he is suggesting that we cannot understand or predict the changes in suites of species without taking into account their physical environment. For example, suppose a plant species is being

[8] When one considers causal relations between objects, we should distinguish between different types of causal relations. That is, objects can causally interact in different ways – gravitationally, chemically, ecologically, etc. Thus, one of way of putting this point is that *x* causally interacts with *y qua K* where *K* is some kind of causal relation. For example, the same set of populations can exhibit gravitational forces on one another and interact ecologically.

consumed by a predator species. If prey abundances are largely affected by nutrient availability, then one may not be able to predict or explain prey abundances simply in terms of predator abundances and their rate of consumption.

Thereafter ecologists began playing close to attention to several recognized facts. Plants transform light energy into chemical potential energy through photosynthesis. The accumulation of energy through photosynthesis is *primary production*. Of course, plants use some of the energy for their own maintenance and hence only part of primary production is available for herbivores. The total amount of production in an ecosystem is *gross primary production*. Gross primary production subtracting the energy used by plants is *net primary production*. Alfred J. Lotka continued developing the notion of an ecosystem by viewing it as a “energy-transforming machine” **(reference).** He suggested that one could describe set of biotic and abiotic components by equations representing exchanges of energy between them subject to principles of thermodynamics.

In 1942, Raymond Lindeman united Lotka’s and Tansley’s work suggesting that the ecosystem is the fundamental unit of ecology and that energy is transferred through links in the food web where each link is a trophic level. On the basis of account of ecosystems, he famously conducted research which allowed him to describe how energy flows through trophic levels and how inefficiencies invariably occur.[9]

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[9] Energy cannot be created or destroyed, only transformed from one state to another. However, energy transformations are inefficient. Thus, when one organism consumes another, some of the energy in the consumed organism will be lost as heat. The efficiency of these trophic transitions is extremely important in ecology because they constrain the way energy moves in ecosystems and ultimately its structure. For example, the number of “steps” in a food chain is dependent on the efficiency of the trophic transformations in the web and many believe this explains why there are so few links in food chains. As a rule of thumb, on 5 – 20% of energy is transferred from a trophic level to the very next level.

By the 1950s, Lindeman's "trophic-dynamic" account of ecosystems which considers kinds of organisms and studies the flow of energy between them was the basis of much research. However, Eugene Odum argued ecologists should also study various biogeochemical cycles which include the cycling of water, nitrogen, and carbon. He noted that though the flow of energy and cycling of nutrients were very different since energy enters an ecosystem as light and is degraded as heat though nutrients can cycle indefinitely where they are converted from inorganic to organic molecules. Still the cycling of nutrients can provide an index to the flow of energy since they can be tightly linked. Here organisms simply "drop out" and we have compartments through which flows and cycling occur. These compartments include atmospheric, mineral, and organic groups. Thus, the history of ecosystem ecology provides us with interesting different and nuanced ecosystem concepts such as *Lindeman-Elton ecosystems*, *Lotka ecosystems*, *Odum ecosystems*, and so forth (Odenbaugh 2007).

It is interesting to note that some have been skeptical that ecosystem ecology is part of the life sciences since Odum ecosystems are concerned with the flows of energy and nutrients like phosphorus, carbon, nitrogen, and so on. For example, philosopher Greg Cooper has suggested that ecosystem ecology is not part of ecology narrowly construed only broadly construed (2004). Thus, ecosystem ecology is simply a part of physics, chemistry, or possibly geology. Having said this, a worry of this sort is not applicable to the notion of Lindeman-Elton ecosystems because these are composed of biotic and abiotic parts. By the late twentieth century though, the concept of *ecosystem* is usually defined as "…a spatially explicit unit of the Earth that includes all of the organisms, along with all of components of the abiotic environment within its boundaries" (Likens, 1992).

There has been genuine skepticism concerning the existence of ecosystems in part due to the sort of boundaries Likens mentions. Philosopher Dale Jamieson articulates the worry in the following way,

> Skeptics say that talking about an ecosystem is simply a way of conceptualizing a collection of individual organisms and features of their environment. On this view, ecosystems are like constellations, while organisms and features of their environment are like stars. Talking about ecosystems (like talking about constellations) is a way of talking about other things. It may be useful to do so, but we shouldn't think that the world responds to every useful turn of phrase by manufacturing an entity (2008, 149).[10]

To make the point Jamieson is pushing vivid, consider what I call the "(n + 1)th problem" (Odenbaugh 2007). Imagine a group of n biotic and abiotic components at a particular place and time and suppose for the sake of argument they compose a token ecosystem. Now, if the group of n factors are an ecosystem, then why not some (n +1)th component as well? If everything is ecologically connected, then why are the n components on the "inside" but the (n + 1)th component not? There are two possible answers – either the n components compose an ecosystem because of some mind-independent or mind-dependent relation which holds between them and only them (supposing they are mutually exclusive – see below). Jamieson's concern is that there are no mind-independent ecosystemic causal

[10] One view of material composition – mereological universalism – states that any group of objects compose another object. If this view is correct, then Jamieson's worry can be answered but it has the very odd implication that for example the Eiffel Tower, my dog Evie, and Banff, Alberta compose an object.

relations which hold between just those components qua those components. Jamieson is not alone in his worries. Here is philosopher Katie McShane expressing similar thoughts.

> The worry is this: as we saw above, ecosystems are not natural kinds. What constitutes the ecosystem, where its boundaries are, and so on, are matters of decision and not simply discovery. The delineation of ecosystems is underdetermined by nature itself; so this isn't just in fact a matter of decision, it's necessarily and inescapably so (McShane 2004).

Finally, it is not just philosophers who are skeptical about ecosystems. The Department of Interior's Fuel Coordinator Allan Fitzsimmons has in fact written an entire book criticizing the ecosystem concept and ecosystem management (1999). He writes,

> The problem starts with the idea of an ecosystem itself. The term was coined by Arthur Tansley in 1935, who described them as physical systems encompassing living and nonliving things and their interactions. Ask the Forest Service, the Environmental Protection Agency, the Fish and Wildlife Service, and the Sierra Club to show you their maps of the ecosystems of the United States. They differ greatly. The so-called Greater Yellowstone Ecosystem can cover anywhere from 5 to 19 million acres, depending on who is defining it. These discrepancies occur because the human mind fabricates ecosystems. Nature does not put ecosystems on the land for researchers to discover. Ecosystems are only mental constructs, not real, discrete, or living things on the landscape. (1999, 3)

Jamieson is quite correct that ecosystems might be conventional (e.g., that is mind-dependent) as the skeptics suggest. However, there are several problems with the arguments of McShane and Fitzsimmons. First, ecosystems are concrete particulars as I suggested in beginning of this section. They are spatiotemporal objects which have beginnings and endings. Hence, they themselves are not natural kinds though I will argue the category *ecosystem* is. Second, the supposition that there is one and only one ecosystem present in a given region is false; ecosystems can exist at different scales and may be embedded in one another as parts to wholes. Third, different groups of mapmakers need not map the same token ecosystem in the same way. For any collection of objects, we can map them in a variety of different ways and this says nothing about the existence of the object in question. If one is in doubt, just consider some artifactual object like the London Tube (Kitcher 2001).

To answer this (n + 1)th problem, we must specify what type or types of causal relations must hold between biotic and abiotic components to compose an ecosystem. These are energy flows and biogeochemical cycles between biotic and abiotic components. Let us say an ecosystem exists just in case biotic and abiotic members of a set are closed under these ecosystemic causal relations. More generally, if we specify a causal relation R of interest, then an *interactive boundary* exists between the objects in a set S relative to a set S^* just in case the members of S bear R to each other and not to members of S^*.[11]

As an illustration, consider the relation *feeds on* which is essential to the notion of a trophic level. Suppose that S_1 feeds on S_2, S_2 feeds on S_3, S_3 feeds on S_3, S_4 feeds on no species in the set, and no species feeds on S_4 as depicted by Figure 1.[12]

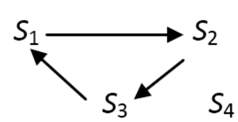

Figure 1. Populations of species causally closed under the relation *feeds on*.

Hence, the species are S_1, S_2, and S_3 are causally closed under the causal relation *feeds on* and there is an interactive boundary between them and S_4. Unfortunately, this proposal is simply

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[11] It should be noted that boundaries between objects can be vague; vagueness need not signal the absence of boundaries. For example, David Lewis has suggested that the Outback exists but has a vague boundary. There are many ways to make sense of such vague boundaries.

[12] This is an unusual topology for a food web. Generally one does not observe food cycles but that is immaterial to the points being made here.

too strong. The biotic and abiotic components in sets of interest may be causally closed under certain ecosystemic relations but will not be where nutrient cycling and energy flows are concerned. Consider again the example above but now let S_i be atmospheric, mineral, or organic sub-systems or compartments, the ecosystemic relation be *exchanging* CO_2 *with*, and the "weight" of the dashed line represent the strength of the interaction between S_i and S_j.

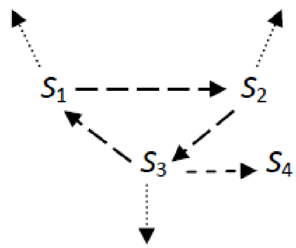

Figure 2. Ecosystemic sub-systems or sub-compartments not closed under the relation *exchanging* CO_2.

Clearly, the set $\{S_1, S_2, S_3, S_4\}$ is not closed under the relation *exchanges* CO_2 since they exchange CO_2 with sub-subsystems outside the set. Ecosystem ecologists implicit response to this sort of case that the S_4 is not part of the ecosystem composed of S_1, S_2, and S_3 because S_3 and S_4 only "weakly interact" and similarly for sub-systems outside of the set $\{S_1, S_2, S_3, S_4\}$ where the strength of interaction is even weaker. The "strength" of these causal relations or interactions may seem mysterious but need not. Ecologists have long been interested in the interaction strength or average interaction strength between species in a food web. Typically, they characterize it as follows. The strength of interaction between species N_i and N_j is equal to how a change in N_j leads to a change in N_i other things being equal.[13] More generally, the strength of an causal interaction between variables X_i and X_j (where $i \neq j$) relative to constant

[13] Thus, they represent the interaction strength between N_i and N_j as $\partial N_i/\partial N_j$.

background variables X_k (where $k \neq i, j$) is how a change in X_j results in a change in X_i against that constant background.

Provided that we can make metaphysical sense of the notion of causal or interaction strength along the lines mentioned above, how should this fit into our account of ecosystems? One might offer the following account:

> An ecosystem exists just in case biotic and abiotic members of a set are such that the minimal (or average interaction strength) is greater than or equal to *n*.

Now, this approach raises a variety of issues. First, if all that is required is minimal or average interaction strength $n > 0$, then weakly interacting biotic and abiotic components compose an ecosystem. Thus, we might find that the only ecosystem is all of planet Earth, or all of Earth and the Sun, or… We might suppose that there is some other value $n >> 0$ which determines ecosystem composition but it would seem arbitrary at best. Analogously, some philosophers argue that there is some number of hairs *n* such that one with hairs $m \geq n$ is hirsute and if $m < n$ then they are bald. Apart from the number of hairs being greater than zero, there is no non-arbitrary reason for choosing that value and not some other one.[14] That is, for any $m \neq n > 0$, there is no reason to be given for *m* which cannot also be given for *n*. Technically then, set of biotic and abiotic components are an ecosystem insofar as they instance an ecosystemic causal relation and the minimal or average interaction strength is greater than or equal to *n* and where $n > 0$. *However*, ecosystem ecologists proceed in a more specific manner. Typically, they will reason in the following way. Informally, they specify two sets *S* and S^* which is a

[14] Epistemicists about vagueness such as Timothy Williamson hold that for predicates such as "is thin" or "is bald" there is some number of hairs such that one is bald whether we know what that number is. One can argue that for any number it is unjustified. Therefore, there is no number which is justified. However, this argument would be fallacious – the only justifiable number is where the number is greater than zero.

proper subset of S' where S' is the complement of *S*. They then claim that *S* is an ecosystem relative to S^* given some ecosystem causal relation *R* of interest, since the average interaction strength between the members of *S* is greater than that between $S \cup S^*$.

Let's consider a concrete case. Here is an informal account of the concept of *ecosystem* which serves our purposes.

> An *ecosystem* is group of abiotic and biotic components which interact through the nutrients and energy that cycle or flow through them and which interact more strongly with respect to each other than with regard to a comparison group of abiotic and biotic components.

Here the issues of precision mentioned above fade away since one is concerned with making sure that the members of a set interact more strongly with each other than the with members of some other set. One way in which ecosystems are bounded interactively is through *watersheds.* A watershed is an area of land that drains water, sediment and dissolved materials to a common receiving body or outlet. The boundaries of a watershed follow major ridgelines around channels and meet at the bottom, where water flows out of the watershed into streams, rivers, or lakes. In this case, there are geomorphologic boundaries and these geomorphologic boundaries ensure that nutrient cycling and energetic flows have differential rates inside and outside the drainage basin. Thus, the biotic and abiotic components in a watershed causally interact qua ecosystem more strongly than those biotic and abiotic components outside the watershed.

Recognizing watersheds as token ecosystems is not only an instance of "ontology made concrete" but makes sence of the commitments of ecosystem ecologists in several ways. First, watersheds are multi-scalar; that is, within a watershed, there are sub-watersheds, and sub-sub-watersheds, and so on. Ecologists have long thought that ecosystems can be parts to wholes of each other as was mentioned above. Second, ecosystem ecologists have used watersheds to conduct experimental research with great success the most famous example being the Hubbard Brook Experiment Forest. The Hubbard Brook ecosystem is in the White Mountains national forest in New Hampshire with nine sub-watersheds which drain into Hubbard Brook and eventually the Atlantic Ocean. Gene Likens and Herbert Boorman (along with many others) have manipulated these sub-watersheds examining the effects of clear cutting, acid rain, and many other factors on ecosystem processes. Likens himself writes,

> F. Herbert Boorman, Robert S. Pierce and I recognized that watershed-ecosystems within the Hubbard Brook Experimental Forest with watertight basins, well-defined watershed boundaries, reasonably homogeneous geologic formations, uniform distribution of soil, vegetation and climate, year-round precipitation and streamflow and several clusters of three or more similar-sized watersheds provided ideal considerations where entire watersheds could be experimentally tested and compared to gain a clearer understanding about the ecology of forested landscapes.

There are several caveats and issues to pursue. First different ecosystem causal relations may specify distinct ecosystems (cycling of H_2O, C, P, and N for example). Second, causal relations are time-lagged and episodic and the degree of interaction strength is imprecise and this takes us deep into the waters of vagueness. Insofar as one is realist about ecosystems, it presuppose that their sub-systems or compartments have interactive boundaries in sense defined above; if these boundaries do not exist then we must be anti-realists about ecosystems.[15]

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[15] Some like Fitzsimmons might run the following argument: One can protect something only if it mind-independently exists. However, ecosystems by and large do not mind-independently exist. Hence, one cannot protect them. There are two problems with this argument. First, even if ecosystems do not mind-independently exist, abiotic and biotic entities do and we can protect them even if the "ecosystem" of which they are a part is

III. Ecosystem Functions. Consider the following claims made by ecosystem ecologists. A large amount of woody material falls to the floor of forests. This material is composed of cellulose and lignin which are indigestible by most animals. Fungi serve the important function of decomposing this plant material, thereby releasing nutrients into the soil for uptake by plants. Fungi consist of a network, or mycelium, of hyphae which are threadlike elements composed of cells connected end to end. Fungal hyphae are able to penetrate woody cells of plant litter that bacteria cannot reach. They secrete enzymes into the litter or wood and absorb the simple sugar and amino acid breakdown products of this extracellular digestion. Carbon accumulates in wood. Microorganisms and fungi break down wood and return carbon to the global cycles. If these organisms were absent, carbon would accumulate in the wood, where it could not be recycled into the environment. Ecologists thus claim that fungi decomposing woody products contributes to the cycling of carbon. So, we can summarize this functional claim as follows:

> (F_1) A function of fungi is to decompose woody products contributing to the carbon cycle.

The nitrogen cycle involves the movement of nitrogen and nitrogen-containing compounds through the biosphere. Our atmosphere is a reservoir of nitrogen in a gaseous form (N_2). N_2 is converted from its gaseous state to ammonia or nitrate by the process of nitrogen fixation which can result from physical or biological processes. Let's consider

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largely conventional (e.g., Greater Yellowstone Ecosystem). Second, even where ecosystems exist mind-independently, we can protect we can protect proper subsets of them which are defined in a mind-independent or conventional manner.

biological processes since 90% of nitrogen fixation results from them. Nitrogen fixation occurs biologically through free-living organisms such as *Azotobacter*, *Clostridium*, and cyanobacteria found in soil or water or by organisms such as *Rhizobium* bacteria which live in specialized root structures of some plants. In the case of *Rhizobium*, once nitrogen is converted to ammonia or nitrate, it can be assimilated in plant roots and ultimately the organic matter of consumers. Ecologists claim that *Rhizobium* bacteria fix nitrogen which contributes to the cycling of nitrogen. Let's summarize this functional claim as well:

(F_2) A function of *Rhizobium* is to fix nitrogen contributing to the nitrogen cycle.

Philosophers have spilt much ink attempting to make sense of functional claims. One of the most important proposals comes from Larry Wright (1973). On Wright's view,

The function of *x* is to *z* means

a. *x* is there because it *z*s, and
b. *z* is a consequence of *x* being there.[16]

A customary example is this: the function of the human heart is to circulate blood means the heart is there because it circulates blood, and circulating blood is a consequence of human hearts being there. This account was rejected due to many criticisms; here is one popular one proposed by Christopher Boorse (1976). Suppose in a scientist's lab there is a gas leak rendering the scientist unconscious; it appears that this case satisfies both (a) and (b) above. The function of the gas is to render the scientist unconscious means the gas leak is there

[16] Wright viewed his project as explicating the meaning of functional claims. Philosophers thereafter have not been so concerned whether they were explicating functional claims as much as making sense of scientific practice. Thus, it is possible that theories of functions would be inconsistent with ordinary usage. As an example, many of the folk still talk of living things as being designed. However, this claim many would argue has a false presupposition.

because it renders the scientist unconscious and the scientist's unconscious state is a consequence of the gas leak. Surely, the gas leak has no function or at least not this function.

The most common response to Wright's etiological account has been to couch it in the context of evolution by natural selection. The function of a trait *T* is that for which *T* evolved by natural selection in the recent past.[17] A trait *T* evolves by natural selection if, and only if, *T* is heritable, entities with *T* have greater reproductive success relative to alternatives due to possessing *T*, and there is variation with respect to *T*. Thus, the human heart has the function of circulating blood if, and only if, having a human heart is heritable, having a human heart contributed to the reproductive success of those who possessed it in the recent past by circulating blood relative to the alternatives, and there was variation in the recent past with respect to humans hearts concerning the circulation of blood. This selected effect account avoids Boorse's counterexample since *T* is a token of a "reproductive family"; that is, *T* is a copy of other tokens of the same kind. The gas leak is not a member of a reproductive family.

If we apply the selected effect account to (F_1) and (F_2), then we should find the following to be true:

1. Decomposing woody products is a heritable trait amongst fungi and fixing nitrogen is a heritable trait amongst *Rhizobium*.

[17] This may appear circular given the phrase "for which". However, here is a more complicated version of the account due to Peter Godfrey-Smith (….). The function of *m* is to *F* iff: (1) *m* is a member of family *T*, (2) members of family *T* are components of biologically real systems of type *S*, (3) among the properties copied between members of *T* is property or property cluster *C*, which can do *F*, (4) one reason members of *T* such as *m* exist now is the fact that past members of *T* were successful under selection in the recent past, through positively contributing to the fitness of systems of type *S*, and (5) members of *T* were selected because they did *F*, through having *C*.

2. Decomposing woody products contributed to the reproductive success of fungi relative to alternative traits in the recent past and fixing nitrogen contributed to the reproduced success of *Rhizobium* relative to alternative traits in the recent past.
3. There was variation in decomposing woody products amongst fungi and there was variation in fixing nitrogen amongst *Rhizobium*.

Now, we haven't examined the empirical details to substantiate these functional claims; however, it very well may be the case that there are true. If this is so, then fungi has the selected effects function and *Rhizobium* has the selected effects function of fixing nitrogen. However, it is important to note that these are not the only functional claims made in (F_1) and (F_2). Specifically, they claim that fungi decompose woody products which contributes to the carbon cycle and *Rhizobium* fixes nitrogen which contributes to the nitrogen cycle. Even if it is plausible to suppose (1) – (3) above are satisfied, it is extremely unlikely to suppose that contributing to the carbon cycle was selected for in fungi and contributing to the nitrogen cycle was selected for in *Rhizobium*. First, both of these traits benefit organisms other than just fungi and *Rhizobium* and thus would require large scale altruism which can occur but only under relatively stringent circumstances. Rather, these dispositions appear to be "side effects" or "by products" of those activities (Cahen 1988). Second, and more importantly, ecosystem ecologists also attribute functions to *abiotic components*. For example though 90% of nitrogen fixation is accomplished by living things, 10% is accomplished by non-living things. For example, lightning and volcanoes can fix nitrogen as well. Thus, an ecosystem ecologist could have made the following functional claim: a function of volcanoes is that they fix nitrogen contributing to the nitrogen cycle. Clearly, volcanoes do not reproduce and are not targets of natural selection. Hence, they do not evolve by natural selection. Therefore, they do not have selected effects functions. Thus, if we are to make sense of at least some of the functional claims in ecosystem ecology, then we need an alternative account. Fortunately, there is such an account on the books, the *systemic capacity account*.

Robert Cummins (1975) has articulated and defended what is termed the "systemic capacity account" of functions. Suppose that *x* is some part of a system *S*, has a disposition *F*, and *S* itself has some disposition *C*. Roughly then, the *systemic capacity function* of *x* in a system *S* is to *F* if, and only if, *x* is capable of *F*-ing and *x*'s capacity to *F* in part accounts for *S*'s capacity to *C*. Let's apply this account to (F_1) and (F_2).

> Fungi have the function of decomposing woody products in an ecosystem if, and only if, fungi are capable of decomposing woody products and fungi's capacity to decompose woody products in part accounts for an ecosystem's capacity to contribute to the carbon cycle.
>
> *Rhizobium* has the function of fixing nitrogen in an ecosystem if, and only if, *Rhizobium* are capable of fixing nitrogen and *Rhizobium*'s capacity to fix nitrogen in part accounts for an ecosystem's capacity to contribute to the nitrogen cycle.

The systemic capacity function account understands the function of *x* to *F* in terms of how the capacity or disposition to *F* contributes to a system *S*'s capacity or disposition to *C*. One disposition realizes – along with other dispositions possibly – some more general systemic disposition. This account applies very nicely in ecosystem ecology. Moreover, it applies as well when we consider abiotic components too.

> Volcanoes have the function of fixing nitrogen in an ecosystem if, and only if, volcanoes have the capacity to fix nitrogen and volcanoes capacity to fix nitrogen in part accounts for an ecosystems capacity to contribute to the nitrogen cycle.

This functional claim fits the systemic capacity account though it does not satisfy the selected effects account. If my arguments are sound, then selected effects functions cannot render the functional claims of ecosystem ecology sensible though the systemic capacity account can.

IV. Ecosystem Health. Many ecologists and conservationists argue that we should promote the health of ecosystems. However, it is very unclear what it means for an ecosystem to be "healthy." Though much has been written attributing states of health and disease in ecosystems, philosopher Katie McShane has provided the most thoughtful and philosophically rigorous account of ecosystem health. Most biologists and conservationists who accept that attributions of health and disease to ecosystems are sensible, simply assume what the healthy states of an ecosystem are and spend their time attempting to operationalize them. This is to put the empirical cart before the conceptual horse. Thus, it is useful to consider her account.

Considering something which is healthy, McShane writes,

> When it is in a state of perfect health, all of its essential parts are in good working order, and its vital processes are running smoothly or capable of running smoothly when called upon. Furthermore, when something is healthy, it is, in this regard, better off than it would be if it were unhealthy (2004, 230).[18]

She suggests that health ascriptions involve the following: An object must (a) have a structure, (b) parts with functions, and (c) the ability to be better/worse off (2004, 230). Let me say something briefly about each of these.

[18] When something is in perfect health, of course all of its essential properties are in good working order since without them the thing would not exist; however, I would also suggest that many accidental properties are important as well. For example, it is an accidental property of me that I have the heart that I do. If my heart did not function properly, I would be unhealthy though I would continue to exist after I received a transplant.

First, an object must maintain some structure to be healthy. McShane notes every object has some structure or other; it would not be an object otherwise.[19] Thus, we can say that "…healthy things are those that maintain the structure that they are *supposed* to have – the structure that is appropriate for them in their particular circumstances (age, environment, etc.)" (2004, 230). With respect to ecosystems, it is not clear how this normative language is to be grounded in the science, so we might provide an alternative. "We mean that they're healthy in virtue of maintaining a certain kind of structure" (2004, 231).

Second, in light of the above, we need an account of this *normativity*, or *proper function*. McShane uses Larry Wright's etiological account of functions we explored above. As we saw, Wright's account is subject to counterexamples. McShane accepts Boore's gas leak has a function of rendering the scientist unconscious and suggests that on Wright's view there are *lots* and *lots* of functions in the world.[20] One implication of this is that there will be functions which do not maintain health. So, there must be some criteria such that it sorts those functions that are and are not related to health which leads to the next component.

Third, the notion of health is a normative one. It concerns the "goodness" of a characteristic for an *x*. However, how do we unpack this? There are at least three ways of doing so – *moral* goodness, good of a *kind*, and good *for* (2004, 233-6). McShane suggests

[19] I suppose one might argue that simples – objects with no proper parts – do not have any structure. Presumably though they have properties in virtue of which they can causally interact with other objects. They have brute dispositions with which they interact with other simples. As an example, suppose electrons and protons are not composed of other objects (contrary to our best particle physics). One might suppose that the negative charge of an electron and positive charge of a proton are brute dispositions about how these objects behave with respect to one another.

[20] We might mitigate the force of this objection by noting that Wright distinguishes between *a* and *the* function of *X* as McShane suggests. However, this seems to do nothing in dealing with the gas leak case.

that the relevant notion of *good* is that of *good for*. Note also we say that *F* is *good for x* we mean to say that *F* is *pro tanto* good for *x*; there may be other considerations that may outweigh the fact that *F* is good for *x* (2004, 233). Clearly, we need some account or other for "well-being" of *x*. McShane suggests Stephen Darwall's account of rational care (2004, 234-5),

> Something is good for you if it would make sense for someone who cared for you to want it for you for your sake.

One could replace this account of well-being with others. Thus, by way of summary,

> *x*'s health consists in those functions of the structure of *x* such that are prima facie good for *x*; they contribute to the well being of *x*.

Finally, her account of ecosystem health consists in the following,

> An ecosystem is good for its own sake if it would make sense for someone who cared for it to want it to function properly for its own sake.

There are several serious problems with this account of ecosystem health and any which makes similar sorts of assumptions. First, the incorporation of Wright's etiological account of functions is plausibly false. Second, the notion of health presupposes a notion of *proper function*. That is, if some *x* has a function *F*, then *x ought to F*; there would thereby be *norms of performance*. One can plausibly argue that the selected effects account provides us with norms of performance since *x* has the selected function *F* in virtue of past *x*s *F*-ing even when *x* as a matter of fact cannot *F*. For example, a defective heart ought to circulate blood because past hearts were selected to do just circulate blood. However, the systemic capacity account ascribes functions even when no previous *x F*-ed. That is, we cannot ground norms of performance in terms of past *x*s *F*-ing. Thus, if ecosystem functions are systemic capacity functions and systemic capacity functions do not supply norms of performance, then ecosystem functions are not proper functions. However, the notion of ecosystem health requires ecosystem functions be proper functions. Therefore, the notion of ecosystem health is a nonstarter.

To summarize the arguments of this section, I have suggested that it would make sense to talk about ecosystem health, if the selected effects account were correct. But this account does not work for ecosystems; the best account for ecosystems is the systemic capacities account. But there is no normativity in the system capacities account, that would tell us what capacities are healthy and which are unhealthy. Thus, we should reject the notion of ecosystem health.

VI. Conclusion. In this essay, I have offered an extended argument for moderate realism about ecosystems. Likewise, I have provided an account of ecosystem functions which derives from the systemic capacity account used more generally. Finally, I attempted to show that the popular notion of ecosystem health cannot be sense of in terms of systemic capacity functions since they do not provide norms of performance which are required for any notion of health.

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