



## **Situatedness and Problematic Boundaries: Conceptualizing Life's Complex Ecological Context**

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**Abstract.** A key challenge in conceptualizing ecological complexity is to allow simultaneously for particularity, contingency, and structure, and for such structure to be internally differentiated, dynamically tied to its context, and subject to restructuring. Because all organisms live in such dynamic ecological circumstances, philosophy of ecology could become the leading site for addressing difficult conceptual questions concerning the situatedness or positionality of organisms – humans included – in their changing and intersecting worlds.

**Key words:** boundary, complexity, ecology, history, models, scale, situatedness

### **Introduction**

Despite ever increasing attention in wider society to environmental issues, the recent flourishing of philosophy of biology has included only a little work on ecology (Haila and Taylor 2001). Yet all organisms live in an ecological context that has structure and dynamics, so all philosophy of biology depends on some conceptualization of ecology. These ideas have not always kept up with developments in ecological thinking. Most notably, philosophy of evolution treats ecology as the source of fitness parameters for the dynamics of consequence, namely, those of population genetics (Sober 1984). This approach requires, however, that the ecological context remain stable or repeatable with respect to the evolving populations of individuals, or that the

relevant processes are separable into “ecological” and “evolutionary” time scales (Taylor 2001). Both assumptions are difficult to reconcile with the picture of “unruly” complexity that has been emerging in ecology (Taylor 2000a).

This paper presents a map of the conceptual terrain intended to stimulate philosophical attention to ecological complexities. We begin by reviewing the recent history of ecological theory, identifying factors that contribute to the unruliness of ecological complexity and highlighting key challenges in conceptualizing life’s complex ecological context. Philosophy of ecology, by and large, has not addressed these challenges and, moreover, has been a marginal area within philosophy of biology. We discuss sources of potential vigor that might follow from problematizing boundaries, in particular, between well-bounded systems and their context, natural and social sciences, and scientists and the situations in which they make knowledge.

### **Recent history of ecological theory**

During the 1960s and 1970s many ecologists sought theories of ecological structure and function that would be general and not dependent on historical particularities (Kingsland 1995: 176–205). Systems ecologists, through extensions of thermodynamics and information theory to open biological systems, sought to explain complexity in terms of the nutrient, energy, and information flows within entire ecosystems. Community ecologists made theoretical propositions, often expressed as mathematical models, which focused on the regulation of population sizes and distributions through competition for limiting resources and other interactions. The two schools mapped broadly onto a series of conceptual-methodological contrasts: function and process vs. structure and demography; properties of wholes vs. explaining parts and building up from there; field measurements vs. mathematical modeling (Hagen 1989).

Levins’ (1966, 1968) essays on model building in ecology and population genetics opened up new paths for thinking about ecological theorizing. He viewed models heuristically, as necessarily “false, incomplete [and] inadequate,” but productive of qualitative and general insights. Discrepancies between a model and observations imply the need for additional biological postulates and, together with the qualitative insights, generate interesting questions to investigate. Eventually a model becomes “outgrown when the live issues are not any longer those for which it was designed” (Levins 1966; Wimsatt 1987; for recent assessments of Levins’ framework, see Orzack and Sober 1993; Palladino 1991; Taylor 2000a). In practice this strategy applied to community ecological models simple enough to be analyzed mathemat-

ically, not to highly parameterized systems ecological models that required computer simulation. This emphasis was taken up mathematical ecologists whose numbers grew markedly in the 1970s. They often, however, left ambiguous whether they saw their models as idealized representations of ecological reality (see, e.g., the “perfect crystals” of May 1973) or heuristic devices to formulate theoretical questions.

By the early 1980s ecologists of a particularistic bent were questioning many of community ecology’s models, rejecting them when their fit to data was no better than alternative “null” hypotheses or “random” models (Strong et al. 1984). (This move had been prefigured in plant ecology’s shift from predictable stages of succession to shifting associations of individual species determined by their particular life histories and environmental requirements, McIntosh 1985, Taylor 1992 – or even earlier in the third chapter of Darwin’s 1859 *On the Origin of Species*.) Scepticism about the possibility of general ecological theory became widely expressed. As Simberloff (1982) argued: Many factors operate in nature and in any particular case at least some of them will be significant. A model cannot capture the relevant factors and still have general application. Instead, ecologists should intensively investigate the natural history of particular situations and test specific hypotheses about these situations experimentally. They may be guided by knowledge about similar cases and may add to that knowledge, but they should not expect their results to be extrapolated readily to many other situations.

From several angles, scepticism about theory and a one-sided emphasis on hypothesis testing have been resisted. Observation and experiment can contribute to the generation of theory in ways other than through crucial hypothesis tests. Indeed, observations constructed for testing of a specific hypothesis may not be useful for thinking about anything beyond the local configuration observed. Theory generation draws on the many other faces of data: initial category-generating generalizations from observations, comparisons, analytic redescriptions (Haila 1988). This said, it should be kept in mind that process or dynamics are difficult to infer from patterns and that patterns are sensitive to the methods used to extract them from observational data (Austin 1980, 1999). Although these problems are not as acute for data from replicated, multi-factorial field experiments (Underwood 1997), causal conclusions from such experiments are, strictly speaking, local, that is, contingent on the configuration of other factors held experimentally or statistically constant for the experiment (Lewontin 1974).

Another angle of resistance to particularism and scepticism about theory comes from the continuing use of verbal and mathematical models to generate theoretical ideas. Philosophers have cautioned that the implications of models are not necessarily about actual ecological dynamics unless empirical corres-

pondence has been established for the distinguishing features that characterize any model and for its accessory conditions (Lloyd 1987; Taylor 2000b). Nevertheless, models need not be seen simply as representations intended to capture the necessary and sufficient conditions that explain observed phenomena. New concepts, questions, and hypotheses can, as Levins (1966, 1968) advocated, emerge through modeling. For example, flexible views of models and data in theory generation are evident in accounts of ecological complexity as a hierarchy of systems embedded within larger systems, with complementary processes and patterns at each level or scale, so that, if the right measure is found, a natural reduction of complexity might be achieved (Allen and Starr 1982).

Exploration of models had also played a central role in investigating how complexity of communities may be related to their persistence or stability. Originally, the possibility of achieving equilibrium in a community and ecological complexity was held to result from the underlying stability of the ecological system. Mathematical analysis during the 1970s and 80s showed, however, that complexity works strongly against stability unless the complexity is nearly decomposable, i.e., consists of loosely linked subsystems. Subsequently, a “landscape” view arose, which holds that a community may persist in a landscape of interconnected patches even though the community is transient in each of the patches (DeAngelis and Waterhouse 1987). Meta-population theory, an actively explored variant, examines the persistence not of communities, but of populations (or phoretic associations of communities on carrier species) in such a landscape (Hastings and Harrison 1994). Another variant of the landscape view emerges from construction of model systems by addition and elimination of populations. This exploration shows that complexity can persist – *at levels far greater than found in decomposable systems* – even when any particular system is transient. Under this “developmental” or “constructionist” view, investigations of ecological complexity should incorporate continuing species turnover, not only analysis of the stability and structure of the current configuration. This theoretically challenging insight warrants more attention (Taylor 1989, 2002; Nee 1990).

By reintroducing historical contingency, transient or non-equilibrium situations, and embeddedness in larger contexts, such exploratory modeling is one factor undermining the aspirations of earlier decades for identifying general principles about systems and communities (Kingsland 1995: 213–251). Since the 1980s ecologists in general have become increasingly aware that situations may vary according to historical trajectories that have led to them; that particularities of place and connections among places matter; that time and place is a matter of scales that differ among co-occurring species;

that variation among individuals can qualitatively alter the ecological process; that this variation is a result of ongoing differentiation occurring within populations – which are specifically located and inter-connected – and that interactions among the species under study can be artifacts of the indirect effects of other “hidden” species.

In patch dynamic studies, for example, the scale and frequency of disturbances that create open “patches” is now emphasized as much as species interactions in the periods between disturbances (Pickett and White 1985). Studies of succession and of the immigration and extinction dynamics for habitat patches pay attention to the particulars of species dispersal and the habitat being colonized, and how these determine successful colonization for different species (Gray et al. 1987). On a larger scale such a shift in focus is supported by biogeographic comparisons that show that continental floras and faunas are not necessarily in equilibrium with the extant environmental conditions (Haila and Järvinen 1990). From a different angle, models that distinguish among individual organisms (in their characteristics and spatial location) have been shown to generate certain observed ecological patterns, such as patterns of change in size distribution of individuals in a population over time, where large scale, aggregated models have not (Huston et al. 1988; Lomnicki 1988). And, the effects mediated through the dynamics of populations not immediately in focus, or, more generally, through “hidden variables,” upset the methodology of observing the direct interactions among populations and confound many principles, such as the competitive exclusion principle, derived on that basis (Wootton 1994; Taylor 2002).

Hidden variables and indirect effects have potentially profound consequences for philosophy of ecology. Consider the strategy of scientific simplification in which models refer only to a few populations, even though those populations are embedded in naturally variable and complex ecological situations. Unless ecologists know that the full community has been specified, their “simple” models are primarily redescrptions of the particular observations that do not provide, through their fit or lack of fit, sure or general insight about actual ecological relationships. It should be noted that progress in the physical sciences depends greatly on controlled experiments, in which systems are isolated from their context. Yet this model of science is not appropriate for understanding organisms embedded in a dynamic ecological context and responding to consumers and resources that are unevenly distributed across place and time. By extension, embeddedness should prod theoreticians to scrutinize the analogies and conceptual borrowings drawn from work on well-bounded systems. Similarly, the heterogeneity of units in ecology and their disparate temporal and spatial scales of activity might limit the relevance of complexity theory in which iterations of simple rules over

time and space lead to complex behaviors. Long-standing physical and chemical theories in which macro-regularities arise statistically from large numbers of similar entities would also seem problematic for explaining ecological complexity.

Notwithstanding these caveats about conceptual borrowing, the dynamics of non-linear systems far from equilibrium can be a source of stimulating heuristics for ecological theorists (Dyke 1997). The biosphere is sustained well away from thermodynamic equilibrium by the strong energy gradient from the sun to the surface of the earth and back to outer space (Morowitz 1968). Life's long history has enormously modified the biosphere's physico-chemical characteristics, but its self-organization has always occurred along such energy gradients – an insight captured in Schrödinger's (1948: 75) suggestive remark that life feeds on negentropy. A nonequilibrium thermodynamic perspective on ecology also shifts emphasis from interactions among supposedly stable entities to processes, cycles, and their entrainments on diurnal, annual, and ontogenetic time scales (Dyke 1994, 1997; Haila 1999). This perspective links ecology and physiology at several levels (Turner 2000) and points to the profound challenges of conceptualizing the temporality of dynamical processes (Winfrey 2001).

### **Moves towards conceptualizing unruly complexity**

For some ecologists the growing emphasis on situated, scale-crossing processes means that ecology needs to be reconceived as an “historical” science (Schluter and Ricklefs 1993). Like epidemiologists, paleontologists and historians, ecologists face the challenge of historical explanation. That is, they have to assemble a composite of past conditions sufficient for the subsequent outcomes to have followed and not some other, while, at the same time, they must not obscure the provisional quality such accounts have given the competition from other plausibly sufficient accounts (Taylor 1987; Miller 1991). This “composite of past conditions” would include considerable historical and geographical contingency (such as which organisms survived in pockets when Mt. St. Helens erupted, (Franklin and MacMahon 2000)) and the evolutionary particularity or “individuality” of species (Sterelny and Griffiths 1999: 253ff). Yet historicity need not eliminate ideas about regularities or structuredness of ecological patterns and processes. To say that ecological structure has a history could be to say that it changes in structure and is subject to contingent, spatially located events, while at the same time the structure constrains and facilitates the living activity that constitute any ecological phenomenon in its particular place.

Whether or not the label “historical” is used, a key challenge for philosophy of ecology is to conceptualize the “unruliness” of ecological complexity. That is, theory needs to allow for particularity and contingency intersecting with structure, and for that structure to change, be internally differentiated, and, because of overlapping scales of different species’ activities, have problematic boundaries. Systems that are well bounded or have simple relations with their external context, when they are encountered, could be viewed not as simple situations, but as special cases whose existence requires explanation. Yet explicit philosophical debates about ecology have scarcely begun to take on this challenge. For the purposes of philosophy of science, systems have been assumed well bounded; generalization has been equated to finding principles that transcend history and contingency.

Conceptual clarification of unruly ecological complexity may benefit from philosophers treating additional kinds of boundaries or positionings as problematic. The natural science of ecology could be informed by debates in social science if ecological situations were addressed as special cases of intersecting social-environmental processes, and less weight were given to cases in which human disturbance is minimal or constant. Moreover, if due attention were given to the fact that all organisms live in (and contribute to) structured, dynamic ecological contexts (Taylor 2001), ecology could move into the center of philosophy of biology.

Up to now, however, ecology has been positioned at the margins of philosophy of biology. As we discuss elsewhere, only 6.5% of articles and the same fraction of book reviews in the first 13 volumes of this journal dealt with ecology (Haila and Taylor 2001; but see Saarinen 1982; McIntosh 1985). We propose that ecology’s lack of appeal to philosophers may derive from the conventional orientation of philosophy of science towards established theories over emergent strands, fundamental science over applied, and unified theoretical frameworks over eclectic research practices (Haila and Taylor 2001). Moreover, the environmental awakening has not led ecological thinking to command philosophical attention, except in the area of environmental ethics. In that area, however, simple accounts of ecology prevail and a nature-culture dualism is assumed that perpetuates the search for foundations outside the social realm – in “nature” or natural principles (Haila 2000). In contrast, ethics could begin from the observation that idealizations about nature have through history been invoked by different groups to defend or promote their favored ideas about social order (Williams 1980). Simple ideas about nature and human-ecological relations restrain ethics and social theory from examining the complexity of social and natural relationships involved in human labor and discourse (Haila and Levins 1992).

On the other hand, the environmental awakening has stimulated considerable research on socio-environmental relationships. One strand in particular of anthropological and geographical research focuses on situated, scale-crossing processes, and so warrants attention from philosophers of ecology. This research analyzes environmental problems in terms of intersecting economic, social and ecological processes, which operate across various spatial and temporal scales and are mutually implicated in the production of any outcome and in their own ongoing transformation (Taylor and García-Barrios 1995; Peet and Watts 1996). Accounts of soil erosion or collapse of fish stocks, for example, may tie together the local and regional ecological characteristics, local institutions of production and associated agro- or aqua-ecologies, the social differentiation in a given community and its social psychology of norms and reciprocal expectations, and national and international political economic changes (Little 1987; García-Barrios and García-Barrios 1990).

Researchers who analyze “intersecting processes” have not articulated a mature conceptual framework, but explanations that preserve heterogeneity of causes and complexity of their interlinkages warrant much more attention from philosophers (Taylor 1995: 88ff). Philosophical work in this area would require, among other things, attention to researchers’ practice and engagement with the complexity studied (Haila and Levins 1992; Taylor 2002). Moreover, intersecting processes accounts expose multiple points of potential engagement – each one partial in the sense of being insufficient to overcome the focal problem, and thus needing to be inter-linked within the ongoing intersecting processes (Taylor 2000a).

Partiality is pertinent even when researchers do not focus on socio-environmental dynamics, but confine themselves to natural ecology. The exploratory use of models, mentioned earlier, retains support, in part, because of an unstated implication that, if the different exploratory models could be combined, they would yield an understanding of ecological phenomena that could not be achieved through the construction of all-encompassing systems models. For example, the idea that there is a limit to the similarity of co-existing species might be combined with the ideas that spatial heterogeneity or an intermediate level of disturbance promote diversity, and so on. But how? The means of weaving together or synthesizing necessarily partial models, or heuristics, has yet to be articulated. On the reasonable assumption that few ecologists can juggle more than a few heuristics, new approaches that bring different types of ecologists into sustained interaction need to be developed (Walters 1997; Wondolleck and Yaffee 2000).

Self-consciousness about social interactions involved in producing knowledge lay behind Levins’ strategy of modeling, which distinguished his



perspective from contemporaries in mathematical ecology. Levins has been concerned with the vitality of the modeling process – with a never-ending process of disturbing the provisional validity of models (Levins 1993, 1998; Taylor 2000b). His interest in the circumstances under which theoretical principles might be overthrown – circumstances that are not always apparent to scientists – has led him to consider the social conditions in which knowledge is produced (Haila and Levins 1992). For example, under a research and development system geared to firms making profits, pesticides have been favored over biological control of pests (Levins and Lewontin 1985: 238–241).

Recognition that social interactions are always involved in producing knowledge extends a post-modernist critique of unified science that argues that people's reasonings can only be rooted in historically specific life practices. The problem of acquiring adequate knowledge about the world is something we share with other organisms, which also lead flexible lives in changing environments. Philosophy of ecology, therefore, faces the challenge articulated in J. J. Gibson's ecological psychology that all organisms, humans included, find out what happens in the world only through actual encounters with the world (Gibson 1986). By developing tools to conceptualize the positionality or situatedness of humans and other organisms in their intersecting worlds, a vigorous philosophy of ecology could hasten the demise of the assumption that processes of nature can be adequately represented by defining their location in a unified, mathematizable Cartesian-Newtonian coordinate system (Haila 1998).

In short, how do we get to know ecological complexity? The answers may depend on paying more attention to who "we" are, to the associations different people make as they position themselves in relation to life's complex, changing, and rarely well-bounded ecological context.

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