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Letter

Mechanism, Process, and Causation in Ecological Models: A Reply to McGill and Potochnik

Sean R. Connolly,[1,*]
Sally A. Keith,[2,3]
Robert K. Colwell,[2,4,5] and
Carsten Rahbek[2,6]

We thank McGill and Potochnik (hereafter M&P) for a thoughtful and constructive response [1] to our paper [2]. In our view, there are two main elements to their response. First, they consider that our definition of a mechanistic model is too narrow. Second, they argue that the advantages that we attribute to what we term 'process-based' and 'mechanistic' models (PBMs and MMs, respectively) are shared by a broader class of 'causal' models, which include, but are not limited to, PBMs and MMs.

In our paper, we noted that some ecologists might consider PBMs to be distinct from MMs, while others might prefer to consider PBMs and 'component-based' models to be subclasses of MMs [2]. M&P fall into the latter camp. However, for many ecologists, the ecology of lower-level entities (typically individuals) must be explicitly considered in mechanistic explanations (see Box 2 in [2] for examples), a view shared by many philosophers of science [3–5]. In our original paper [2], we aimed to make a case for the advantages of PBMs (component based or not) that could be embraced by ecologists regardless of the restrictiveness or expansiveness of their concept of mechanism. Thus, we defined an overlapping but not identical class of models that we hoped would be agreeable to ecologists favoring the more restrictive view. M&P instead define mechanism ' . . . to include the processes responsible for some natural phenomenon' [1]. If these processes must be explicitly represented in a model for it to be considered mechanistic, then such models would satisfy our definition of PBMs and, thus, would be accounted for already in our framework.

M&P [1] argue that there is a broader class of 'causal models' that have the benefits we describe in our paper, but that are neither PBMs nor component-based MMs (hereafter CBMs). We agree with M&P that PBMs and CBMs are not the only forms of causal models, and we are open to the possibility that other classes of models represent causal structure in a way, or to a degree, that allows them to be used in many of these same ways. However, the representation of causal relationships alone is insufficient to meet this criterion. Consider a regression model fitted to observations of environmental temperature and species richness or metabolic rate. Ecologists typically use such analyses because they believe that there is a causal link between the explanatory and response variables. However, few, if any, ecologists would claim that such models could be used in the range of ways described in our paper for PBMs and CBMs (e.g., theoretical or virtual worlds modeling). Whether it is possible to distinguish between causal models that can and cannot be used in such ways (for instance, by operationalizing the term 'causal structure') is an open and interesting question.

M&P use the example of thermal niches to illustrate problems with a component-based conceptualization of mechanism [1]. They note that some factors likely to be included in a model of the phenomenon, such as air temperature, are problematic if conceptualized as components. Our Interactive Question 1 presents a closely analogous example (in the supplemental information online in [2]). However, not everything in a mechanistic model needs to be a component of the mechanism. For a physiologically based model of distribution or abundance, we think that most ecologists would consider the individuals to be the components, and air temperature to be an external factor influencing the physiological states of individuals. If the states of individuals were explicitly characterized in such a model, it would satisfy our definition of an MM. Regardless, however, if the model of the thermal niche characterizes 'responses of proteins . . . protein denaturation . . . [and] enzyme kinematics' [1], then the model should satisfy our definition of a PBM, since these are physiological processes.

In a second example, M&P note that body size distributions are often explained by applying the Central Limit Theorem to ontogenetic growth [1]. If we assume that the model implied here is a product of a large number of arbitrarily distributed random variables representing growth in a given year, then we concur with M&P that it is neither PBM nor CBM. However, it also lacks the advantages of such models that our paper highlighted. We do not think one would undertake theoretical analysis of such a model, or seek to independently estimate its parameters, for example. Moreover, we question whether 'it would be absurd to search deeper for a causal explanation' [1] for such phenomena. For instance, species-abundance distributions can be explained by reference to the Central Limit Theorem. However, theoretical analysis of process-based community dynamics models has revealed ways of using time series of species-abundance distributions to move beyond the shape and estimate the amount of variance in species abundances explained by species traits, environmental fluctuations, and demographic stochasticity [6]. In other words, they can yield insights that invocation of the Central Limit Theorem cannot.

[1]Marine Biology and Aquaculture, College of Science & Engineering, and ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD, Australia
[2]Center for Macroecology, Evolution, and Climate, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark
[3]Lancaster Environment Centre, Lancaster University, Lancaster, UK
[4]Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT, USA
[5]University of Colorado Museum of Natural History, Boulder, CO, USA
[6]Department of Life Sciences, Imperial College London, Ascot, UK

*Correspondence:
sean.connolly@jcu.edu.au (S.R. Connolly).
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