Mathematical modelling approaches of intermediate complexity

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Abstract

This contribution is part of Maja Schlüter and Orjan Bodin’s session "Towards an intermediate level of complexity in SES analysis". Mathematical approaches are also subject to the tension between the detailed and specific on the one hand and the simple and general on the other. Detailed models are often created in practice-based contexts, in order to reflect the contextual detail of specific cases, but it is often difficult to make general statements on the basis of these cases and can even be difficult to reliably validate the predictions for the specific system. At the other extreme, theoretical studies develop stylised models intended to represent the basic features of a class of systems, but these models can be so stylised that any connection to reality is obscured. At the same time, even these models have to be specified (functional forms chosen, parameters assigned) to such an extent that their generality becomes questionable. In mathematical modelling, as in other disciplines, approaches are needed that that acknowledge the complexity of social-ecological systems while also providing general insights. In this presentation, I will briefly describe some approaches towards filling this gap.

One approach that has become particularly prominent in the last couple of decades is that of networks. In networks it is the existence, or not, of relations between entities in the system that are analysed. Networks therefore capture a form of detail, structural detail, while still providing a basis for more general analyses, including comparing and testing general hypotheses across different systems.

Another method, and the one I would like to focus on, is particularly suited to a dynamical and systems perspective. Called 'generalised modelling’, this approach can analyse what system structures have the capacity to undergo sudden changes in their dynamics. One important type of 'sudden change’ is regime shifts, where the system abruptly jumps to another attractor.

Conceptually, generalised modelling shares some similarities with networks. In networks one begins with a complicated structure of interactions but then is only concerned with which interactions exist. In generalised modelling one begins with a dynamical system, for which a precise model would be very complicated, but is then only concerned with the existence of processes through which state variables affect other state variables. The ability of generalised modelling to predict dynamical patterns across a broad class of similar systems makes it particularly attractive for complex systems applications, where there

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often exists uncertainty about the precise form of a system. In social-ecological systems, generalised modelling could help to identify critical feedbacks that could aid, or alternatively presently hinder, change and transformation for desirable developmental pathways. Indeed, generalised modelling has recently been applied to study the influence of social feedbacks in the collapse of the Baltic Sea cod fishery in the 1980s.

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