The balance between concepts and complexity in ecology

Ecological concepts and their acronyms can obstruct understanding of complexity by providing seemingly simple and certain descriptions of the natural world. Their use requires a balanced approach.

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Ecological concepts provide simplified, approximate and generalized descriptions of the natural world. They help to capture central ideas, communicate efficiently, and identify patterns across species and ecosystems. However, they also risk oversimplifying ecological relationships, and may divert attention away from details and varieties that fall outside a concept's frame[1]. Concepts therefore require careful and critical consideration before they are used to describe and interpret research. Often this is not the case, and concepts and their acronyms are over- or misused. Many popular concepts, such as ecosystem services, invasive species and the ecological niche, have been substantially critiqued (see Table 1) but nevertheless continue to be widely applied in research as well as policy, without recognition of their relevant shortcomings. We believe a better balance is needed between concepts and complexity in ecological research.

Oversimplification

Simplification is often necessary to scale-up results and translate them into broad and transferrable conclusions. Identifying recurring patterns and functions in ecological systems is central and justifiable, as is simplification of scholarly texts to make key ideas accessible to wide audiences. However, simplification needs to be carefully weighed against understanding and preservation of the complexities inherent in ecological systems. Oversimplification through poorly defined or otherwise questionable concepts may be counterproductive to progress in ecological science as well as in environmental policy.

The prevalence of ecological concepts is arguably part of a broad trend away from plain description towards standardization and categorization[2]. This trend has been linked to a decrease in the explanatory power of ecological studies paired with increasingly broad-scale and generalized explanations of ecological phenomena[3]. This is possibly linked to a movement towards more complex study objects — such as ecosystems rather than single species — that necessitate increased degrees of simplification. An effort to make ecology measurable and comparable by categorizing it, referred to as 'measurementality', may even lead to 'an impoverished understanding of biodiversity itself'[4] by highlighting specific functions or outcomes rather than the complexity and connectivity between species, systems and conditions. For example, the popular but contested concept of 'ecosystem services', used to describe the basic notion that people depend on the natural world, illustrates how an overemphasis on measurementality can lead not just to simplification but even misrepresentation of the natural world. The notion of ecosystem services reduces complex ecological networks to specific functions, which are then commonly assigned a monetary value on the premise that this will help societies value them[5]. While in some cases this may be constructive, studies have demonstrated that the ecosystem services concept is fundamentally flawed because it separates an ecological function from the networks it is part of, and because it suggests that such a function can be assigned a single and objective value when opinions about its worth are in fact subjective and can vary greatly between individuals and groups[6–8]. Different values may also contradict rather than overlap each other, as shown for example in a study of tropical forests that found, perhaps contrary to assumptions, that areas with highly valued ecosystem services (such as carbon or water storage) are not necessarily congruent with areas of high biodiversity[9]. Conservation efforts focused on ecosystem services may therefore fail to protect biodiversity, and vice versa. Efforts to make ecology measurable may thus misrepresent the complexity and diversity of ecological systems, and hide differences of opinion and interest regarding their management. Although the concept of ecosystem services may still be useful and practicable in some circumstances, existing critique of the concept should caution how and when it is used to a further degree than is currently the case[4].

False impressions of certainty

Ecological science includes considerable degrees of uncertainty and error[10,11], and by default, concepts generalize observations and therefore de-emphasize these dimensions. Moreover, the meaning of concepts may change over time as understanding develops and new users join research communities. For example, the meaning of 'ecological niche' has changed repeatedly during the twentieth century, from being understood as a fixed section of an ecosystem to a tool for explaining first competition and then coexistence between species[12]. While such 'concept evolution' is common and expected, and often fruitful in terms of expanding ideas and forwarding research agendas, it can be detrimental to the definition and understanding of a concept, particularly if it is not accompanied by current details of how and why a concept is evolving the way it is. If this how and why are consistently neglected, the meaning of a concept can evolve to become significantly different from its original definition, yet lack the foundational knowledge that the original concept was built upon. This can lead to 'linguistic uncertainty' and 'semantic error', in which the meaning of the concept becomes unclear and may cause misguided impressions of a subject[13].

When used repeatedly without explanatory or context-dependent definitions, concepts can transform into what are known in the social sciences as 'black boxes', with unknown contents and assumed impressions of certainty (Box 1). The fundamental ecological concept 'ecosystem' can be used to illustrate this. There is no consensual definition of what an 'ecosystem' is either in theory or practice, yet the term is often used sweepingly and without contextualization[14]. While this is sometimes appropriate, it means that the ambiguity and uncertainties inherent in the ecosystem concept often go unrecognized[15]. For example, the notion of ecosystem can be

Table 1 | Popular but also critiqued ecological concepts

Concept	Acronym	Critique
Anthropocene	-	Descriptive rather than analytical or explanatory; disregards distribution of human impact on the environment[23]
Ecological niche	EN	Unclear, tautological, and represents nature as less dynamic and random than it might be[12]
Ecosystem-based management	EBM	Lacks definition in principle as well as regarding case-specific implementation[24]
Ecosystem services	ES	Represents a reductive view of nature–human relations; disregards differences in values assigned to nature by different people[6–8]
Invasive alien species	IAS	Misrepresents complex and dynamic ecological conditions; promotes militaristic attitudes towards nature[25]
Resilience	-	Lacks definition, is too broad and based on human values; risks naturalizing crises[26]
Social-ecological systems	SES	Discounts or overlooks proper theorization of the 'social' side of nature–society interactions[27,28]

used to represent the natural world as a set of bounded and stable systems, when it is inherently much more dynamic and open-ended.

When vague and ambiguous concepts are broadly and uncritically accepted, there is a risk that the concept becomes a passive and even incorrect addition to scientific studies rather than a meaningful and integrated tool for analysing, interpreting or describing research results. The uncertainties and complexities inherent in such concepts are hidden from view rather than brought into focus, even though they may in fact be critical in scientific as well as policy contexts[16].

Exclusivity

The involvement of the public and other non-expert stakeholders in the design and implementation of environmental policy is often desirable to de-centralize and democratize decision-making[16]. As many ecological studies are intended to be relevant for environmental management and policy, it is therefore important to make ecological literature understandable to a diverse audience[17]. Texts that are heavy with jargon seem counterproductive to that end. Unexplained concepts tend to favour the input and judgement of experts already specialized in the relevant fields, while making it harder for non-experts to comprehend and comment. This may promote unequal power relations between different stakeholders, and run the risk of favouring central and top-down governance over local decision-making. Top-down environmental governance may not only be less likely to lead to positive change than bottom-up initiatives[16], it is also contrary to many environmental policy declarations that pledge increased incorporation of local, indigenous, and other marginalized forms of ecological knowledge in decision-making and knowledge building[18]. Moreover, the uncertainties and simplifications embedded in many ecological concepts can be difficult to appreciate even for fellow scientists if they are unfamiliar with the immediate field of research, so that meaningful exchange and understanding between scientific disciplines as well as between science and society is hampered[19].

Box 1 | Black boxes and actor–network theory

Many concepts can be thought of as 'black boxes'[29]. In the social sciences, a black box refers to physical technologies and/or theoretical concepts that have reached 'closure', so that users do not need to consider how the technology or concept works (what is inside the box), but can simply use it without prior consideration. Black boxes are created when a technology or concept is accepted and supported by enough actors, institutions and practices. Sometimes, however, a black box may be closed before its inner workings are well understood. Such closures are premature to what can be considered 'legitimate closure' — when there is a working definition of what is inside the box[29]. We argue that many ecological concepts and acronyms can be thought of as black boxes that have been closed.

Actor–network theory can be used to describe how networks create acceptance and advancement of knowledge. It highlights how the success of a scientific theory or concept does not depend on whether it is true or false, but rather on the degree to which it is accepted and used by the scientific community, and eventually by broader society. The perpetuation of a scientific construct such as a concept thus depends on whether it is picked up and supported by relevant peers, rather than on whether it is 'true' or not[30].

Social-ecological systems

Research that combines social and ecological sciences is often at the heart of practical policy but lends itself even less to simplification than ecology alone. Social dimensions include moral values, cultures, traditions and other considerations that are fundamentally different from ecology, and especially resistant to reductive definitions and generalizations[20]. Descriptions of social-ecological systems based on concise but simplistic concepts can therefore be particularly detrimental to understanding the complex interactions between societies and their natural environments. To avoid misunderstandings between ecological and social sciences, and between science and policy, it is therefore essential that concepts do not oversimplify research and gloss over important details, leading to confusion and misrepresentations. In interdisciplinary studies — as in other contexts — concepts need to be considered carefully and critically before they are used to frame and interpret scientific results. Without attention to their context-specific purpose and relevance, ecological concepts may be counterproductive to the formulation of effective environmental policy.

Maintaining complexity

Complexity and uncertainty are dimensions that need to be placed centre stage rather than in the periphery to enable progress in ecological science, as well as in environmental policy[13]. Through standardization and simplification, ecological concepts can make margins of error, controversy, subjective judgements and differences of opinion less visible than full descriptions. Although such descriptions may seem long-winded, they can provide important details, and case and context specificity. A more careful use of ecological concepts is in line with recent calls to embrace complexity[21] and be more attentive to evidence produced by the scientific community[22]. Rather than hiding uncertainty and complexity behind apparently robust concepts, we believe

that maintaining intricacies and details through plain descriptions can increase the explanatory power of ecological science, and allow more parties and stakeholders to be actively involved in successful and democratic environmental management and decision-making. ❐

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https://doi.org/10.1038/s41559-018-0507-5

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Acknowledgements

This article has evolved following conversations in many multidisciplinary fora that have recognized common disconnects between researchers and policymakers, often driven by a lack of consensus on the meaning and appropriate use of certain ecological concepts. There are therefore many people from the ecological, social and economic sciences and the humanities as well as the environmental policy sector that we thank for their input. In particular, thanks go to M. Schlüter, H. Hinz, D. Dannecker, E. Olofsson, A. Walley, A. Åberg and P. Craze. A.F.J. was supported by NSF grant DEB-1632648 (2017/2018). S.L. was supported by the Swedish Research Council for Sustainable Development.

Author contributions

A.F.J. and S.L. conceived and wrote the work.

Competing interests

The authors declare no competing interests.