Resilience in ecology and sustainability science

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CHAPTER 6

Resilience

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Abstract

Resilience is a concept that is both foundational and, at the same time, relentlessly controversial in sustainability science. It is supposed to both provide a fundamental insight into how complex adaptive systems behave—an insight with substantial normative consequences—and serve as an interdisciplinary bridge linking the disparate worlds of the natural and the social sciences. Yet the concept of resilience is famously messy, along several conceptual dimensions, and seems to have become messier with time.

In order to better understand the potential and limitations of resilience in sustainability science, as well as explain why the concept has changed in the way that it has, it is useful to trace the notion back to its conceptual roots: the ecological debates of the late 1960s and early 1970s. The specific conditions under which

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the concept was deployed in that context have not persisted, as resilience has been incorporated into sustainability science. Narrow theoretical debates and formal styles of reasoning have been replaced with interdisciplinarity and solution-orientedness. The new context neither demands nor supports the fine concepts that were once so crucial for ecologists.

A Mess or a Multitude of Concepts?

To say that a system is resilient is to say something about how that system is able to handle disturbance and change. More resilient systems are less prone to collapse when faced with a change in their environment or a sudden disturbance. As a concept, resilience is foundational to sustainability science. It has been a crucial, theoretical component in formative debates about ecosystem services and strong sustainability, and it connects deeply to fundamental concerns and priorities of the field, such as the central emphases on uncertainty, risk, and the fickle dynamics of complex systems (see e.g. Levin et al. 1998). Indeed, resilience is a way of understanding sustainability itself, as resilient systems *ipso facto* also appear to be sustainable systems.

At the same time, resilience is notoriously controversial, and its usefulness in sustainability science—and social sciences more broadly—has been called into question (Chandler 2012; Davidson 2010; Hornborg 2013; Olsson et al. 2015; Thorén 2019; Thorén and Olsson 2018; Zebrowski 2013). A persistent issue is that we have ended up with what appears to be a multitude of concepts, none of which are entirely clear. Indeed, the literature reviewing different definitions and characterizations of resilience is a genre unto itself (see e.g. Brand and Jax 2007; Carro et al. 2018; Meerow, Newell and Stults 2016; Nikinimaa et al. 2020).

This multiplicity of concepts has more than one dimension. First, there are many varieties of the concept of resilience, such as *community resilience*, *social resilience, disaster resilience, individual resilience, urban resilience*, and so on. These are, it would seem, the application of the concept of resilience to specific systems or entities, or concerning particular types of disturbances.

Second, there are other concepts that are closely related to resilience, such as *robustness*, *complexity*, *self-organization*, *adaptive capacity*, *vulnerability*, *social learning*, and maybe *sustainability* itself. Some of these notions are, or have been used, interchangeably with resilience, or concern the mechanisms that realize resilience in specific systems. At other times they figure in definitions of resilience. Here is an example of the latter:

> Resilience, for social-ecological systems, is related to (i) the magnitude of shock that the system can absorb and remain within a given state; (ii) the degree to which the system is capable of self-organization; and (iii) the degree to which the system can build capacity for learning and adaptation
>
> (Folke et al. 2002)

At yet other times, concepts such as these occur as contrastive notions used to trace the boundaries of the concept of resilience more precisely. For example, Derissen, Quaas and Baumgärtner (2011) argue that an important difference between sustainability and resilience is that the former is a *normative* concept, whereas the latter is *descriptive*.

Third, the *term* 'resilience' is also used to denote more than one (abstract) *concept*. There is a fundamental difference between resilience as the ability to return to a reference state following a disturbance and resilience as maintaining some set of properties (function, identity, etc.) through a disturbance (Hansson and Helgesson 2003; Thorén 2014). This difference has occasionally been theoretically important (see below) but is lost or conflated in many contemporary definitions.[1]

As Fridolin Brand and Kurt Jax (2007) have noted in a widely cited review of the concept of resilience, we seem to have moved from having a precise (and descriptive) understanding of resilience to one that is vague (and normative). Although this vagueness is not without merits—it may serve interdisciplinary aims (see below)—it appears to come at a cost. They write: 'a scientific

[1] See Meerow, Newell and Stults (2016) for an example and Thorén (2019) for a discussion.

concept of resilience must have a clear and specified meaning that is constantly used in the same way' (Brand and Jax 2007). It is nonetheless surprising for a concept to change from precision to vagueness. As knowledge improves, should this not also be reflected in better (i.e. more precise) concepts? To fully understand this development, it is useful to go back to the roots of the concept of resilience in the context of sustainability science.

Ecological Roots

Whence sprung the resilience concept? One can find *scientific* uses of the term as far back as the late 1800s in materials science (e.g. Thurston 1874). Psychologists have used a notion of resilience since at least the 1980s (see e.g. Rutter 1985) primarily, but not exclusively, in the context of child and adolescent psychology. From a sustainability science point of view, however, it is the use of resilience in ecology—where the concept appears from the early 1970s and onward—that is the most relevant, as a strong continuum exists, both with respect to the genealogy of the concept and the individuals who have engaged with it (see e.g. Walker and Cooper 2011).

During the 1970s and the 1980s, ecology as a discipline went through a paradigm shift of sorts with respect to how to think about the dynamics of ecosystems. The received view before this time is captured by what is sometimes called the stability-diversity hypothesis (henceforth SDH; see deLaplante and Picasso 2011; Redfearn and Pimm 2000). The SDH states that more diverse (or more complex) ecosystems are also more stable, and that reducing the complexity of ecosystems—for instance, by removing species—makes those same ecosystems less stable. The idea was defended by almost all ecologists of some prominence around the middle of the last century, such as Eugene Odum, Robert MacArthur, and Charles Elton (see deLaplante and Picasso 2011).

The important theoretical problem for these ecologists was to show, and sometimes formally prove, how greater diversity or complexity in ecosystems indeed engendered more stable systems (under specific interpretations of these concepts). The preferred model was often the food-web, or *trophic-network* (see e.g. MacArthur 1955). In such a network, each species is a node connected to other nodes through the relationship of eating them or being eaten by them.

In the late 1960s and early 1970s, some ecologists (e.g. Stuart Pimm, Robert May, and Crawford Holling) began to question many aspects of these ideas and develop more complicated ways of analyzing stability in ecosystems. The most influential work within ecology was probably May's (1973) *Complexity and Stability in Model Ecosystems*, but it is Holling who has been the primary influence on sustainability science. His 1973 essay 'Resilience and Stability of Ecological Systems' remains widely cited among sustainability scientists to this day.

The crucial distinction in the title of the essay, between stability and resilience, is developed toward the end of the paper. Holling suggests that mathematical convenience—in particular, a focus on the dynamics of systems close to equilibrium—led some of his predecessors to confuse the distinct properties resilience and stability with one another. In particular, he is concerned with conflating ideas that have to do with the dynamic responses of systems around some equilibrium with issues pertaining to 'persistence and the probability of extinction' (Holling 1973: 17). Thus Holling proposes that we should reserve *stability* for the former and use *resilience* when talking about the latter.[2] Stability is the ability of a system to return to some reference state after a disturbance, '[t]he more rapidly it returns, and with the least fluctuation, the more stable it is' (Holling 1973: 17). Unstable systems tend to fluctuate more and wander around in their state space. Resilience, on the other hand, is a kind of buffer capacity of a system that allows it to absorb disturbances without suffering major rearrangements of its internal relationships. '[I]t is a measure,' he writes, 'of the

[2] Holling would later relabel the distinction as *engineering resilience* (stability) and *ecological resilience* (resilience) (Holling 1996).

ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist' (Holling 1973: 17).[3]

Armed with this distinction, Holling attempts to synthesize the numerous examples, observations, and theoretical exercises that make up most of his paper. There are several central points that deserve mention. One point is that resilience and stability are not always positive correlates, but in fact are sometimes negatively correlated. Roughly speaking, highly stable systems lack the flexibility to adapt to new conditions, and strategies that seek to increase stability in ecosystems—for example, by reducing fluctuations in various ways—can effectively hollow out the resilience of the system and make it susceptible to catastrophic collapse. The preferred metaphor is that of a ball resting in a cup. The cup is the domain of attraction; however, as the system is perturbed, it acts as forces pushing on the ball. But interventions on the system not only push the ball around the cup, but also change the dynamic landscape. The cup can be made shallower, and eventually, even minor disturbances can push the ball beyond the cup and set the system off toward some new equilibrium, or, if worst comes to worst, extinction.

The distinction is thus central to Holling's reasoning. It shifts his understanding of the SDH and potentially resolves apparent conflicts between proponents and critics of the hypothesis. There

[3] The stability/resilience distinction that is central to Holling's argument is common within ecology. The terms, however, are largely particular to him, and others have made similar conceptual distinctions using other terms (Grimm and Wissel 1997; Thorén 2014). Moreover, at a very high level of abstraction, Holling's distinction tracks fundamental differences between different stability concepts very closely. Helgesson and Hansson (2003) argue that there are only really three ways of understanding the umbrella concept stability. There is a kind non-dynamical or historical stability, stability as (for whatever reason) remaining unchanged. Then there are two dynamical stability concepts. One is the ability of a system to return to some reference state (Holling's stability). The other the ability of a system to keep some property, or feature, or function, fixed through a disturbance (Holling's resilience).

is no contradiction between more complex and diverse systems being more persistent in virtue of their resilience (one way of interpreting the SDH) while at the same time being less stable in the sense that they fluctuate more, as May (1973) had shown in his work.

Changing the Concepts

One should not over-state the conceptual clarity among ecologists. What the appropriate stability concepts and distinctions ultimately are is up for debate to some degree, and ecologists use an extensive, and somewhat fluid, typology for this (see Grimm, Schmidt and Wissel 1992; Grimm and Wissel 1997; Newton 2016). Nonetheless, given that Holling's work is so central to sustainability scientists, it is striking that the exact distinction upon which his arguments turn is regularly conflated. Consider this characterization offered by Sara Meerow and colleagues:

> Urban resilience refers to the ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—*to maintain or rapidly return to desired functions* in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.
>
> (Meerow et al. 2016: 45, *my emphasis*)

If one concern is that there are *many* concepts of resilience and it is difficult to keep use consistent across contexts as, for example, Brand and Jax indicate (2007), another problem is that there are paradoxically too few concepts and that apparently, crucial distinctions become lost.

Under New Conditions, Different Kinds of Concepts

A few aspects of the discussion in which Holling originally engaged stand out. One is that the discipline of ecology was to a considerable extent *concerned* with stability. Understanding what made ecosystems stable and what could possibly destabilize them was a central theoretical problem that was presumed to have considerable normative implications. No wonder, then, that there is interest in stability concepts generally (see Grimm and Wissel 1997).

Another aspect is the theoretical importance of the distinction itself. Making finely tuned distinctions between subtly different ways of understanding stability was a crucial part of achieving specific theoretical aims within ecology. It is precisely by distinguishing resilience from other stability concepts that the point can be conveyed; the relevant value is *resilience* and not *stability*, and, in fact. the pursuit of stability can be highly detrimental for preserving the resilience of some system, which in turn is associated with grave dangers.

A third is that these debates and discussions within ecology were carried out within a particular highly formalized and abstract space. It is theoretical work that only occasionally—and even then, quite weakly—connects to observations or data. Arguments frequently are presented as formal proofs. It exemplifies something akin to what Ian Hacking has called a *style of reasoning* (Hacking 1992). It is a way of conducting science and scientific enquiry with certain limitations and affordances, and one of those affordances is that it supports and encourages a conceptual apparatus with extraordinary precision.

Sustainability science presents itself as a different (inter-)discipline altogether. First, although this style of reasoning, or something approaching it, surely exists in sustainability science, it does not encapsulate any of the central debates in the same way. The interdisciplinary nature of sustainability science seems to prevent this from happening. Moreover, the transformative aims associated with sustainability science, and the ambition to be transdisciplinary, solution-oriented and relevant to policy (see e.g. Jerneck et al. 2011), generally mandate a different approach to, for lack of a better term, 'the real world'. Knowledge is meant to be immediately applicable in concrete, practical situations. It is a solution-oriented science. This orientation is often taken to run counter to the values associated with sciences that heavily rely on formal frameworks; the grit of the street wears quickly on the pristine machinery of mathematics.

Second, even though there is no shortage of central debates and disputes within sustainability—consider the intellectual conflict over strong versus weak interpretations of sustainability—they are rarely as well-behaved or easily confined as the conflict over the SDH. Again, the interdisciplinary nature of sustainability science often makes it difficult to discern clear lines of conflict.

Third, resilience is an important concept in sustainability science but it is crucially secondary to other concepts, such as sustainability itself. The concept of resilience is *one way* of approaching sustainability issues and as such highlights some features of a situation while overlooking others. From an interdisciplinary perspective, two important forces act on sustainability science: one is the coalescence around some disciplinary core; the other is the expansion and inclusion of further disciplines. These may well happen at the same time but along different dimensions. Thus, as the field successively acquires the trappings of conventional disciplines in institutional terms, it can also become increasingly theoretically and methodologically pluralist as new disciplines attach themselves to the field (see Chapter 2 on *Interdisciplinarity*; see also Chapter 7 on *Scales* in this book). One consequence of this is that theoretical frameworks and concepts that functioned well under certain more limited interdisciplinary constellations become less serviceable as those constellations are altered.

Finally, as Brand and Jax (2007) point out, interdisciplinarity imposes specific requirements that may divert from what is otherwise desirable. They suggest that resilience is a *boundary object*, which functions to tie disciplines together by virtue of how it can be adapted to local needs and thus link scientific communities that may otherwise be difficult to bridge. Be that as it may, it appears one might just as well argue that, if ever conceptual precision was important, it is precisely so in interdisciplinary situations where the risks of misunderstanding are overwhelming (c.f. Thorén 2014; also Strunz 2012). What the concept undoubtedly can do, and is doing, is supply research questions and hypotheses that span disciplinary boundaries. It is a productive concept in this way. It provides tentative links between theories and phenomena that are otherwise the domain of disparate disciplines and thus can direct attention toward, in the best of worlds, important problems the pursuit of which enrich our understanding of the world and how to make it more sustainable. In what way are social-ecological resilience, ecological resilience, psychological resilience, social resilience, and community resilience linked or distinct *as phenomena*?[4] A consequence of thinking about the concept in this way is that it puts the onus on the phenomena rather than the concepts and thus somewhat relieves us from excessive emphasis on the latter (Thorén and Persson 2015; see also Carpenter et al. 2001).

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[4] There are many examples of such work, two are Davidson (2010) and Adger (2000).

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