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BEHIND THE PAPER

Resilience: Now more than ever

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Ambio – A journal of the Human Environment, was founded in 1972 in connection with the first UN conference on the human environment held in Stockholm, Sweden. Three decades later, in 2002, the UN convened the World Summit on Sustainable Development (WSSD), in Johannesburg, South Africa. In preparation for the WSSD, the Environmental Advisory Council to the Swedish Government invited the Swedish scientific community to present forward-looking, novel and important sustainability topics that would serve as input from the Swedish Government to the WSSD.

The topic resilience was selected as one of those and resulted in a 74 pages report 'Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations' (Folke et al. 2002). The report, discussed at a meeting in the Swedish Parliament in spring 2002, in which Neil Adger, Stephen Carpenter, and Carl Folke participated, and presented in Johannesburg in September 2002 by Johan Rockström, was very well received. In the preface, the Swedish Minister of the Environment writes that the report "is an up-to-date synthesis of case studies and recent insights on resilience and vulnerability in social-ecological systems. These insights have been developed in the context of emerging theories of complex system characterised by uncertainty and surprise. …. We hope that the report will be one of many contributions to a vivid and widespread discussion – before, during and after the WSSD in Johannesburg – on the necessary steps towards sustainable development."

We are excited that the summary article of the report, with the same title and also published in 2002 (Folke et al. 2002b), has been selected among those highlighted as part of *Ambio*'s fifty-year celebration, especially in the light of *Ambio*'s legacy. The article, with more than 3400 citations in Google Scholar, has certainly contributed to the widespread interest in resilience of integrated social-ecological systems in science, practice, business, and policy.

We, as authors of the article, followed with great interest the explosion of 'resilience thinking', as a framework that embraces human and natural systems as complex social-ecological entities, continually adapting and anticipating what cannot be foreseen (Walker and Salt 2006). It has been inspiring to witness the development of the resilience field from a perspective emerging through empirical observations at the fringe of scientific inquiry to a concept and approach at the very core of the science and practice of sustainability. Numerous resilience conferences have taken place, funders have run major programs on resilience thinking, international research centres on resilience have been established, artists have interpreted and exhibited works on resilience, and now NGOs, development organisations, governments and intergovernmental organisations have resilience high on their agenda.

The expansion of resilience scholarship has altered the way in which environmental change is conceptualized, which in turn has influenced how we act and intervene. Resilience of a social-ecological system is about thinking beyond incremental change and return to normalcy following a disaster. Indeed, protecting a system by keeping it robust and in a constant state of optimized productivity will reduce its resilience. As proffered in the *Ambio* article, resilience is about learning from and developing with change, rather than managing against change. Resilience is about having the capacities to live with complexity, uncertainty, and change, abrupt or incremental, and continue to develop with ever changing environments. This includes both adaptation and transformation.

Resilience is a fundamental property of a system and from a human perspective it can be either desirable or undesirable. Salinized landscapes or dictatorships can be

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very resilient and undesirable states. A resilient system contains, provides and nurtures the diverse social-ecological elements that are essential for reorganization, adaptation, and transformation in the face of novel, unexpected, and changing circumstances. A desirable resilient system involves adaptive management and governance with the capacity to navigate uncertainty, shocks and surprises in order to contribute to sustaining or improving human well-being, where human well-being implies a fairer and equitable world, accounting for power relations, and operating within planetary boundaries. Here, we focus on resilience as a desirable property of a system and where sustainability is the vision of societal development.

For the interested reader, there have been several reviews and syntheses describing the development of the field, and clarifying what resilience is and is not (e.g. Biggs et al. 2015; Folke 2016; Reyers et al. 2018; Walker 2020) and how it relates to sustainability (e.g. Anderies et al. 2013; Elmqvist et al. 2019).

In the early 1970s, C.S. 'Buzz' Holling introduced resilience in the context of multiple stability domains or multiple basins of attraction in ecosystems as a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist. Resilience, as the science of surprise, quickly began to influence work and discussions in fields outside ecology like anthropology, ecological economics, environmental psychology, human geography, management studies, among others.

The Beijer Institute of the Royal Swedish Academy of Sciences was restarted in 1991 with a focus on the interface of ecology and economics. In the diverse research programmes of the Institute, resilience appeared and reappeared as a central feature for understanding complex system dynamics. As a consequence, a research programme called the Resilience Network was initiated in the mid-1990s, through a collaboration of the Beijer Institute (Mäler and Folke) and University of Florida (Holling and Gunderson). The network engaged pioneering resilience thinkers and triggered interesting and path breaking work on resilience, including the by now classic Panarchy book edited by Gunderson and Holling in 2002. The Resilience Network transitioned into the Resilience Alliance and new institutes of integrative science were created, like the Stockholm Resilience Centre in 2007, which emerged from the Beijer Institute with support of the Resilience Alliance. The *Ambio* article and WSSD report were both a result of this dynamic network of scholars and practitioners.

The *Ambio* article emphasized that "managing for resilience enhances the likelihood of sustaining development in a changing world where surprise is likely" (Folke et al. 2002b) a statement of great relevance today and that was of significance in the discussions leading up to the adoption of the UN Sustainable Development Goals. That relevance is manifest in at least three developments.

First, humans have become a planetary force, resulting in a new geologic age, the Anthropocene, where the luxury of biosphere resilience that engendered development of civilizations can no longer be taken for granted. Instead, resilience of the Earth system for human wellbeing has to be actively managed and governed, a process referred to as Biosphere or Earth Stewardship (Chapin III et al. 2020). It implies governing society and nature as intertwined social-ecological systems within a safe operating space of Earth system constraints (Steffen et al. 2011; Folke et al. 2020).

Second, the new Anthropocene epoch is different and will become increasingly different from the accommodating and stable Holocene epoch of the last 11,000 years, within which all human civilizations have developed and the human dimension accelerated into a globalised society. The Anthropocene presents humanity with a new context and new intertwined dynamics of people and planet, where the interplay of scale, speed and connectivity become truly significant, unpredictable, uncertain and most likely much more turbulent.

Third, probabilities and consequences of the changes are not only scale-dependent, but also changing over time as a result of human actions. For example, extreme-weather and geopolitical events, interacting with the dynamics of the food system, can spill over multiple sectors and create synchronous challenges among disconnected areas and rapidly move across countries and regions (Liu et al. 2007; Rocha et al. 2018; Cottrell et al. 2019). The rise of antibiotic resistance, the rapid spread of the recent corona-pandemic, or human altered rainfall patterns across regions expose the intertwined world (Galaz et al. 2011; Jørgensen et al. 2018; Keys et al. 2019). These trends, coupled with the looming food-water-energy nexus, demand transformational changes in how human actions relate to the planet if major catastrophes are to be avoided.

In line with the concept of adaptive cycle dynamics encapsulated in resilience theory, crises such as the COVID-19 outbreak provide brief opportunities for initiating such major systemic changes. A recent article (Walker et al. 2020) describes the need for transformational change in several drivers of global dynamics. They include: the current economic system; the trend of homogenization of social-ecological landscapes and seascapes with its attendant decline in response diversity (a basic determinant of resilience) (Elmqvist et al. 2003, Grêt-Regamey et al. 2019); human population size, growth and densities; consumption patterns, human ethics and behaviour; and systems of governance. Without such changes the incompatibility in the current system of human global drivers with the resilience of the Earth system and the propensity to increase conflict will most likely lead to next

version of the COVID-19 calamity (Walker et al. 2020). Clearly, nurturing resilience is of great significance in such systemic transformational change towards sustainable futures and requires collective action on multiple fronts, action that is already being tested by increasing turbulence incurred by seemingly unrelated shocks.

When complex systems are in transition between stable pathways, their dynamics are unstable and variable, capable of exploring many alternative pathways, and could move in unpredictable ways toward a surprising pathway. Currently, it seems like societies are engaged in multi-faceted experimentation. In times of turbulent experimentation, resilience provides insurance and opportunity into an uncertain future (Carpenter et al. 2019). In the *Ambio* article, we emphasized the importance of policy that highlights interrelationships between the biosphere and the prosperous development of society; stressed the necessity of policy to create space for flexible and innovative collaboration towards sustainability, and also suggested policy directions for how to operationalize sustainability in the context of social-ecological resilience. These areas have significantly expanded options for engaging people in science, practice and policy as we begin to learn our way towards sustainable futures.

Dedication

We dedicate this short reflection to our dear friend, mentor and co-author of the 2002 article, CS 'Buzz' Holling, who passed away in the fall of 2019. His deep insights and intuition into the complexity of systems of people and nature were extraordinary and amazing. He has always been and will always remain a true source of inspiration (Carpenter and Peterson 2019; Gunderson et al. 2019).

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