Building Disaster Resilience on the Edge of Chaos: A Systems Critique on Mechanistic Global Disaster Reduction Policies, Frameworks and Models

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Abstract Since the dawn of the renaissance scientific inquiry has been guided by a mechanistic view of the world. Accordingly, the understanding of scientific theories, natural environments and human interactions under this paradigm has always aimed to simplify complex ideas as a means to facilitate greater understanding and innovation. Although this paradigm has undoubtedly served humanity well, there is an increasing realisation that a mechanistic view of the world does not provide a complete understanding of phenomena that are subject to dynamic change. This is especially true of human-environmental systems such as disaster resilience that are constantly altered through their mutual interaction between humans and their specific disaster risk contexts. This chapter argues that in spite of this reality, the mechanistic paradigm, and the linear reasoning associated with it, still dominates the theories and policies aimed at understanding and building disaster resilience and reducing disaster risks. It is argued that the presence of this type of reasoning places a lesser importance on understanding contextually specific variables and their effect on resilience profiles as well as the dynamic interaction that subsume disaster resilience. This often leads to very shallow and oversimplified understandings of disaster resilience.

Keywords Resilience · Edge of chaos · Complexity · Systems theory

Introduction

Since the dawn of the renaissance scientific inquiry has been guided by a mechanistic view of the world. Accordingly the understanding of scientific theories, natural environments and human interactions under this paradigm has always aimed to

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J. Kendra et al. (eds.), *Disaster Research and the Second Environmental Crisis*, Environmental Hazards, https://doi.org/10.1007/978-3-030-04691-0_10

simplify complex ideas as a means to facilitate greater understanding and innovation. Although this paradigm has undoubtedly served humanity well, there is an increasing realisation that a mechanistic view of the world does not provide a complete understanding of phenomena that are subject to dynamic change. This is especially true of human-environmental systems such as disaster resilience that are constantly altered through their mutual interaction between humans and their specific disaster risk contexts. This chapter argues that in spite of this reality, the mechanistic paradigm, and the linear reasoning associated with it, still dominates the theories and policies aimed at understanding and building disaster resilience and reducing disaster risks. It is argued that the presence of this type of reasoning places a lesser importance on understanding contextually specific variables and their effect on resilience profiles as well as the dynamic interaction that subsume disaster resilience. This often leads to very shallow and oversimplified understandings of disaster resilience.

Consequently, this chapter will argue for the introduction of different theoretical perspectives by which our understanding of resilience can be enhanced. Many of these theories or concepts are linked to systems theory, and therefore aim to create a holistic understanding of the underlying processes that drive resilience building efforts in disaster affected communities. The argument is also made that for a community to move towards being more resilient we would also need to challenge the conventional wisdom of reducing vulnerability in its totality, as some vulnerability (or functioning at the edge of chaos) allows a community to be aware of their own risk, making them more agile, adaptable and resilient in the long run. As a point of departure the chapter will formulate a critique of the traditional mechanistic paradigm and its effect on our approach to building disaster resilience.

Traditional Paradigms of Scientific Argumentation

The mechanistic approach to scientific inquiry dates back to ancient Greece and medieval Christian Europe. This approach reached its zenith between the fourteenth and eighteenth century encompassing both the Renaissance and Enlightenment (Rihani and Geyer 2001:237; Schoones 1999:481; Wulun 2007:394–395). During this time, the approach has dominated scientific inquiry especially in western society by attempting to create a greater understanding of humans and the environment within which they are functioning (Rihani and Geyer 2001:238; Vallacher et al. 2002:266). The mechanistic approach to scientific inquiry postulates that complex human, environmental and psychological phenomena can be broken down into smaller components (reductionism), and through this reduction it becomes possible to determine the intricacies of larger systems behaviour (determinism). The combination of reductionism and determinism allows for the establishment of a linear relationship between micro and macro level systems components. This linear relationship is best typified by Isaac Newton's Third Law of motion: "*To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon* *each other are always equal, and directed to contrary parts*" (Hawking 1988:53–61; Rihani and Geyer 2001:238; Vallacher et al. 2002:266; Wulun 2007:394–39).

However, this traditional scientific paradigm is less satisfactory in explaining ever-changing complex phenomena, especially those at the interface between the environment and the society; for example disaster risks, disaster risk reduction (DRR), and climate change and adaptation (CCA) (Costanza et al. 1993:545; Wulun 2007:393; Levin 1998:433; Lichtenstein et al. 2006:3). According to Rihani and Geyer (2001:237) a prominent reason for why the traditional paradigm is less adequate to explain complexity and complex systems is that it entails problem solving from a closed-system perspective. Within this paradigm, a system is the sum of its individual parts (Vallacher et al. 2002:266; Wulun 2007:394–395). Therefore, the logical conclusion is that the components which could solve a problem, and also those that created the problem, are contained within a system's boundaries, and these only need to be identified, and undesirable components eliminated to ensure a system's return to normal functioning (Schoones 1999:482). According to Anderson (1999:219) and Morrel and Ramanujan (1999:279) a shift in thinking started to occur in the early twentieth century with the emergence of the systems movement.

The systems movement directly questioned the applicability of using mechanistic thinking to explain inherently complex systems[1] (Anderson 1999:219; Morrel and Ramanujan 1999:279). The basic premise of the systems paradigm is that some phenomena are subject to change and vary, and are therefore probabilistic by nature as opposed to deterministic as per the mechanistic paradigm (Rihani and Geyer 2001:238). The introduction of the probabilistic notion into the understanding of systems was significant as it recognised that all systems are not easy to understand, because constant change results in complex systems, which are more difficult to break down into parts because these parts are ever changing (Vallacher et al. 2002:266). This in turn triggered a growth in fields of inquiry pertaining to holism, general systems theory and complex adaptive system theory, all of which attempt to create a better understanding of the process of constant change (Von Bertalanffy 1968; Wulun 2007:398). The systems approach has introduced a different way of thinking in many scientific fields such as ecology, economics and physiology, but its use in explaining socio-ecological events such as disasters has been severely limited. This lack of different perspectives (including a systems perspective), being introduced to aid our understanding of disaster risk and disaster resilience, has meant that disaster theories and policies have mostly been formulated along the lines of the traditional mechanistic paradigm of scientific thought. The prevalence of mechanistic thinking can be identified in prominent disaster risk management theories and policies, and this can greatly affect our ability to build disaster resilient societies.

[1] Complexity in this instance refers not to "difficult", but to the number of interactions, linkages, components and feedbacks inherent to these systems.

Effects of Dominant Paradigm on the Understanding of Disasters and Disaster Resilience

A multitude of theories and policies have been developed to facilitate a comprehensive understanding of how disaster risk should be reduced and managed. Some of these theories, policies and tools include: the Pressure and Release Model (PAR) (Wisner et al. 2003; Kelman 2011:3), the Household Access Model (Wisner et al. 2003), the Sustainable Livelihoods Framework (Development:1999vq), Yokohama Strategy (1994), the International Strategy for Disaster Reduction (2001–2010), the Hyogo Framework for Action (2005–2015) and the Sendai Framework for Disaster Risk Reduction (2015–2030) (Birkmann 2006:10; Miller et al. 2010; Cimellaro et al. 2010; Blaikie et al. 2004). In spite of the quantity of theories, policies and models available to practitioners and scientists to reduce disaster losses and build disaster resilience, Cardona (2004:14) argues that these interventions have achieved limited success over the past 25 years. These failings are also recognised by both the Hyogo Framework for Action and Sendai Framework for DRR:

> Disaster loss is on the rise with grave consequences for the survival, dignity and livelihood of individuals, particularly the poor, and hard-won development gains. In the past two decades, on average more than 200 million people have been affected every year by disasters. (UN 2005:1)

and

> Over the same 10-year time frame (the period of implementation for the Hyogo Framework, 2005–2015), however, disasters have continued to exact a heavy toll, and as a result the well-being and safety of persons, communities and countries as a whole have been affected. Over 700 thousand people lost their lives, over 1.4 million were injured and approximately 23 million were made homeless as a result of disasters. Overall, more than 1.5 billion people were affected by disasters in various ways. Women, children and people in vulnerable situations were disproportionately affected. The total economic loss was more than $1.3 trillion. In addition, between 2008 and 2012, 144 million people were displaced by disasters. (UN 2015:4)

The reason for this might lie in mechanistic thinking involved in the formulation of their policies. Both policies reduce the problem of disaster risk into five (HFA) and four (Sendai Framework) priorities for action (reductionism), in order to move towards a certain stage where policy recommendations can be made to guide the risk reduction efforts of national and international governance structures. In both of the documents given in Table 1, is an assumption that there is a definite linear relationship between the increase in disaster losses in all contexts, and the lack of the implementation of the priority areas addressed by these documents (determinism). Both of these policies therefore argue that if progress is made in reducing and eliminating disaster losses, the primary focus should then be on the implementation of the priority areas (linear reasoning). Thus, once these priority areas are implemented, communities which are at risk will be rendered safer from disaster risk or a state of equilibrium will be achieved. Oxley (2015:7) and Wisner (2015), critique the mechanistic premise and subsequent implementation of the HFA and envision

Table 1 International disaster risk management policies and linear outcomes

Framework	Priority action areas	Policy targets
Hyogo framework for action (2005–2015)	1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	No specific policy targets outlined. The achievement of the five (5) priorities for actions serve as the main targets to be achieved
	2. Identify, assess and monitor disaster risks and enhance early warning	
	3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels	
	4. Reduce the underlying risk factors	
	5. Strengthen disaster preparedness for effective response at all levels	
Sendai framework for disaster risk reduction (2015–2030)	1. Understanding disaster risk	Substantially reduce global disaster mortality by 2030 aiming to lower per 100,000 global mortality between 2020 and 2030 compared to 2005–2015
	2. Strengthening disaster risk governance to manage disaster risk	Substantially reduce the number of affected people globally by 2030 aiming to lower the average global figure per 100,000 between 2020 and 2030 compared to 2005–2015
	3. Investing in disaster risk reduction for resilience	
	4. Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction	Reduce direct disaster economic loss in relation to global gross domestic product by 2030
		Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030
		Substantially increase the number of countries with national and local disaster reduction strategies by 2020
		Substantially enhance international cooperation to developing countries through adequate and sustainable support to compliment their national actions for implementation of this framework by 2030
		Substantially increase the availability of and access to multi hazard warning systems and disaster risk information and assessments to the people by 2030

practical difficulties in implementing its successor document the Sendai Framework for Disaster Risk Reduction by stating that both documents "lack appropriateness in contexts of complexity, uncertainty, informality, fragility, insecurity (including conflict)" and that "provision is not made for the consideration of system wide perspectives and holistic approaches". Both policies from a systems perspective, fail to take into account the dynamic nature of disaster risks and disaster events. This is problematic because it creates the impression that once these "arbitrary" targets have been achieved, communities will be safe. Therefore, through the linear reasoning and problem solving contained in these policies, risk reduction becomes an ideal outcome of risk reduction interventions and not as a constant process. It is therefore difficult for these global policies to be implemented and also adapted within different and dynamic contexts.

The influence of mechanistic thinking extends to theoretical tools that assist us in understanding disaster risks. A prominent example is the PAR model. The PAR model explains how societal vulnerability progresses from deeply embedded root causes to more observable dynamic pressures and specific unsafe conditions and how these interact with hazards to cause disasters (Blaikie et al. 1994; Fjord and Manderson 2009:67; Adger 2006:70; Birkmann 2006:29). Reducing the concept of vulnerability into three distinguishable categories is an attempt to simplify the complex disaster risk drivers that are societal vulnerabilities (Birkmann 2006:31; Kelman 2011:2; Cardona 2004:2). The assumption made by the model is that once remote root causes of vulnerability are identified, a departure point will be available to address more observable manifestations of vulnerability in the shape of dynamic pressures and unsafe conditions (Kelman 2011:4). The outcome of identifying and addressing the different levels of vulnerability is a less at-risk community (this being the ideal end state for a society) (Cardona 2004:7; Turner et al. 2003:8074). The PAR model displays the process and reasoning associated with mechanistic thinking, i.e. a problem reduced to its components (three levels of vulnerability), applying determinism to identify the linear relationship between components (root causes leading to dynamic pressures and unsafe conditions), and offering a linear solution to address the problem and reaching a desired end state (addressing root causes of vulnerability will eliminate undesirable dynamic pressures and unsafe condition and lead to a safer society) (Fig. 1).

This mechanistic argument encapsulated in the PAR model becomes problematic when viewed through the lens of a different paradigm such as a systems theory. Specifically, through this interpretive lens, it can be said that the PAR model fails to take into account two issues, namely, non-linearity of complex systems and dynamic interaction between systems components. In the case of the principle of non-linearity, the argument is made that the size of inputs into a system might not be proportional to expected outputs. Thus, this principle is that a perceived root cause may actually have a minimal effect or contribution to dynamic pressures and unsafe conditions in some contexts, while other root causes may have a major contribution (Birkmann 2006:31; Kelman 2011:5–6; Cardona 2004:7).

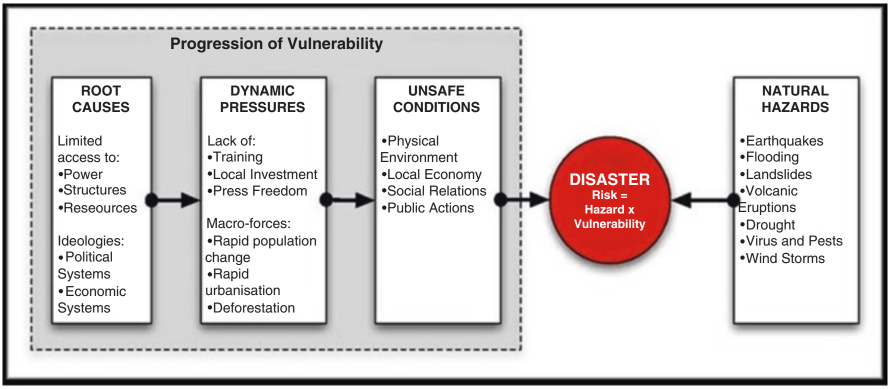

Fig. 1 Pressure and release model. (Blaikie et al. 1994; Wisner et al. 2003)

Underlying systems theory is the proposition that human-ecological systems are composed of a number of components that dynamically interact with each other to foster adaptation and system resilience (Railsback 2001; Boal and Schultz 2007). Thus, from a systems perspective the focus is not so much on being able to identify various components that make up a system (as per the PAR model), but also to examine the dynamic interaction between components and the system behavior that emerges from these interactions (Schneider and Somers 2006; Hartvigsen et al. 1998). Therefore, from this perspective, a root cause might lead to a certain level of vulnerability to disasters. Without the presence of root causes and the dynamic interactions they foster with other components, a social system could descend into chaos following a perturbation such as a disaster, thus making a society even more vulnerable (Heijmans 2001:6; Turner et al. 2003:8078; Adger 2006:275). It is not enough to reduce a problem like societal vulnerability to only root causes, dynamic pressure and unsafe conditions, without taking into account the dynamic interaction between the various components, their environment (context), temporal dimensions and the information exchange that subsumes adaptation within a system (Cutter et al. 2008:299; Cardona 2004:8). A failure to take into account the holistic nature of a problem fosters solutions that either promote stability or chaos, both of which are undesirable if the aim is to build more disaster resilient societies (Mathews et al. 1999:448; Turner et al. 2003:8076).

As can be seen from the systems critiques of contemporary mechanistic based disaster management policies and theories, it could be worthwhile to explore the possible contribution of different scientific paradigms in our endeavours to create a better understanding of disaster risk and disaster resilience. Two of these paradigms, including complex adaptive systems theory and resilience thinking, are briefly elaborated in the next section.

Complexity and Complex Adaptive Systems Theory

Complex adaptive systems theory (CAST) emerged in scientific fields such as ecology and biology as a means to explain natural systems that display non-linear adaptation behavior on micro and macro scales (Hartvigsen et al. 1998; Holden 2005; Ahmed et al. 2005; Levin 1998). Holland (1992:17) adds that CAST was developed to enhance our understanding of inherently non-linear systems such as economies, brain biology and immune systems that are impossible to accurately decipher using linear diagnostic tools and models. To create a better understanding of non-linearity and system complexity, CAST makes three basic assumptions: (1) complex behavior in systems emerges due to the interaction between inhomogeneous components at a micro level; (2) all complex systems learn from their environment; and (3) learning brings about adaptation or change to the system that helps it survive or absorb shocks to the system. Through these assumptions CAST has developed as a theory for analysing and understanding social dynamics (like building disaster resilience) not through the lens of society as a heterogeneous set of individuals, but as an aggregate of interacting diverse set of individuals. The benefit of analysing society in this way is that it gives more holistic impressions of population-level and community-level behaviours that either hamper or improve resilience building efforts (Railsback 2001; Hartvigsen et al. 1998). The CAS theory also contains various sub-theories that can be applied to enhance our understanding of how disaster resilience can be built.

Non-linearity

The basic premise of non-linearity in CAST is that the size of inputs into a system might not be proportional to expected outputs (Boal and Schultz 2007; Railsback 2001). Specifically, small seemingly insignificant variables or inputs in a system might fundamentally change the operation of a system whilst major inputs or variables might have no impact in changing the system at all (Schneider and Somers 2006; Plsek 2001). This notion is in line with the work of Lorenz (1963) and Chaos Theory. By viewing disaster resilience through the lens of non-linearity it might be possible to determine or track impact of individual variables on the overall generation of disaster resilience in a society.

Aggregation

According to Levin (1998:432), aggregation is the process whereby individuals in complex systems arrange themselves into sub-groups or hierarchal organisations that have similar interests, needs and practices. Once sub-groups are formed they do not remain isolated. Instead, multiple interactions are established between different sub-groups that allow for dynamic development and adaptation to changing environments (Railsback 2001; Boal and Schultz 2007). The concept of aggregation provides interesting avenues of exploration within the field of disaster resilience, as it would help to focus some attention on the role, correlation and total contribution of social coping mechanisms to the overall resilience of a society.

Emergent Behavior

According to Innes and Booher (1999:417) emergent behavior is one of the key characteristics of complex adaptive systems. Emergence refers to how system level properties, characteristics and patterns emerge from interaction between individual elements at a micro level, even though the individual elements bear no similarity to the final wider system characteristics (Railsback 2001; Schneider and Somers 2006; Hartvigsen et al. 1998). The concept of emergence could be useful in the exploration of disaster resilience as it will allow for the investigation into how an aggregation of smaller variables could lead to improving resilience profiles of disaster affected communities.

Feedback Loops and Adaptation

According to Walker et al. (2012) and Holden (2005) feedback loops play a crucial role in the development of complex adaptive systems by either enhancing, stimulating, detracting or inhibiting elements within the existing system. Through these processes feedback loops allow for learning and adaptation within a dynamic environment, thereby preventing the extinction of a system (Begun et al. 2003; Rammel et al. 2007; Innes and Booher 1999). The study of feedback loops allows for greater insight into how communities learn and adapt from past events to improve their overall level of disaster resilience. It could also provide insight into the second and third order knock-on effects of building disaster resilience within a specific community (Innes and Booher 1999).

Context Based Responses

A key aspect of CAST is its emphasis on the importance of context in the functioning of a system (Boal and Schultz 2007). According to Holden (2005) and Holland (1992) any complex system is inseparable from the context and history that it finds itself in. The influence of context on CAST is so extensive that it contributes to making each complex adaptive systems unique (Begun et al. 2003; Hartvigsen et al.

1998). However, the context of a CAS is not static and can also be altered due to the dynamic interaction between interconnected elements (Holden 2005). For instance, dramatic events at a local level (i.e. disaster in a community) do not only change the context of the community itself, but could also cause changes at national and regional level (e.g. changes in disaster risk management policies), which in turn would impact once again on the context of the community (Zhou et al. 2010; Schneider and Somers 2006). The emphasis on the understanding of the context provides an opportunity of not only studying the aggregation of unique elements that make a community resilient on a case to case basis, but also allows for the exploration of the interconnectedness of elements and how changes at lower levels of a system can change the wider context of resilience.

Resilience Thinking

Resilience thinking has circulated in scientific discourse as early as 1625 with a multitude of reiterations formulated in the centuries that followed (Dahlberg 2015:544). For the majority of the time period (up to the current time) resilience was linked to the ability of mechanical, economic and human systems to return to equilibrium or steady state after disruptions. However, this traditional conception of what resilience entails started to be challenged in the early 1970s within research fields that focused predominantly on the interaction between bound human and natural systems (Kuhlicke 2010; Rose 2007; Gaillard 2010; Klein et al. 2003; Cutter et al. 2008; Zhou et al. 2010; Hufschmidt 2011). One of the most significant works at this time was conducted by the ecologist, C.S Holling in 1973. The work of Holling was influential in that it challenged the notion that resilience equated to a system's return to static equilibrium or a steady state and that in fact the resilient systems in human-ecological systems are often characterised by dynamic change and movement between various states of equilibrium. The notion that resilience profiles can dynamically change and adapt has opened various avenues of inquiry that can be explored to gain a more holistic understanding of disaster resilience (Hufschmidt 2011; Gaillard 2010; Rose 2007). One such line of inquiry relates to the influence of context specific variables in facilitating movement between different states of equilibrium.

Authors such as Renschler et al. (2010), Alexander (2013), Mayunga (2007:3), and Zobel (2011) all agree that the role of a community's specific social, economic and political context in generating unique resilience profiles cannot be underestimated. No one community has the same set of socio-cultural or economic dynamics, therefore it follows logically that their relative resilience will differ and therefore the optimal way to build resilience will differ from community to community (Zhou et al. 2010). To illustrate this concept, a study conducted by Zhou et al. (2010) in Xinghe county in Northern China, compared the relative resilience of three sets of agricultural communities operating in differing geographical contexts (highlands, plains and mountains) to drought. The study found that not only did resilience differ between the larger geographic areas (i.e. the mountain and plain areas had significantly higher levels of resilience compared to the highland region), but also showed significant difference on a town-to-town basis within similar areas. The difference in relative resilience to prolonged periods of drought in communities that participated in the study was mostly ascribed to the influence, time, and learning of contextual factors such as physical location, climate topography, choice of irrigation method, agricultural type, condition of infrastructure, economic systems (markets), land use structure capacity and cultural practices. All of these factors, or combinations thereof greatly changed the adaptive resilience of individual communities in the larger regions and subregions. Contextual factors that influence resilience profiles also do not remain static and are in a constant state of change with new factors being added and others being discarded on a constant basis (Holland 1999:18; Plsek 2001). This is evident in the work of Fraser (2003) on the socio-ecological fragility associated with the Irish Potato Famine of 1845–1850.

The constant change in resilience profiles brought about by changes in context raises questions about building disaster resilience by using static parameters and objectives that are devoid of contextual sensitivity (Mayunga 2007; Zobel 2011). Instead the notion of viewing disaster resilience as a constant process of change can be introduced to our approach for building disaster resilience. Adopting a process approach provides a radical departure from the outcome-based resilience building paradigm visible in many DRR policies and theories (Sawyer 2004). Specifically, within the outcome-based orientation, disaster resilience within a society is treated as a closed-system or an ideal outcome, where the aim is to build resilience to the current disaster risk and render communities safe from risk (Manyena 2006). Although noble in itself, this approach often does not adequately recognise the fact that changes in the context might dramatically alter the efficacy of resilience building efforts in future (Manyena 2006; Von Bertalanffy 1950). Instead, adopting a process-oriented approach forces disaster practitioners and scientists to accept that disaster resilience is inherently an open-system process that will re-organise, change, and learn in response to shocks and stressors (Ahmed et al. 2005; Holden 2005; Lansing 2003). Thus within this orientation, disaster resilience is not treated as an end-point for a society to achieve, but rather a journey that will lead to constant adaptive change (Norris et al. 2008; Rose 2007). This philosophical orientation significantly increases our chances of gaining a holistic impression of societal resilience (Holland 1992).

On the Edge of Chaos

A final development that can be introduced into our conceptualisation of resilience, is the notion of building disaster resilience at the edge of chaos. The principle of edge of chaos has emerged within various scientific fields that describe behaviors, elements and systems (specifically complex adaptive, socio-ecologically linked systems) that are not inclined to total stability or total chaos (Wycisk et al. 2008:110;

Comfort et al. 2004:66; McCarthy et al. 2006:442). The edge of chaos aims to provide a relative balance between the poles of order and disorder and makes the argument that the only space in which human or environmental systems adapt, learn and evolve from dramatic changes to the system is, at the "edge of chaos" (Schneider and Somers 2006:356; Boal and Schultz 2007:412). The reasoning behind this argument is that systems that function at the edge of chaos are characterised by optimal internal and external information feedback loops that allow for interaction between different systems and components, which in turn facilitates adaptation and resilience building (these information feedback loops are limited in stable systems and too erratic and unpredictable in chaotic systems) (Holden 2005:656; McCarthy et al. 2006:451). Additionally, edge of chaos challenges the wisdom of removing all perceived vulnerabilities and risks from a system. Instead the argument is made that some vulnerabilities, although they place a system at risk (put it at the edge of chaos), these risks are acceptable as they serve as redundancies that allow for system flexibility, adaptation and resilience (Low et al. 2003; Colding et al. 2003:163). This allows a system to avoid total collapse following a perturbation. Holling (1973:19), and Hartvigsen et al. (1998:12) observe that elements which places a system at risk (such as hazards and vulnerabilities) could be necessary for the internal organisation of the system. This in turn contributes to the optimal level of adaptation, i.e. at the edge of chaos. The existence of such perceived negative elements in a system sparks positive and negative information feedback loops "that are innate to the interactive process between system levels and system states [and] could modify the initial function of an element to create new behaviour that could be beneficial to the system as a whole" (Coetzee and van Niekerk 2018).

Possible Contribution of New Paradigms to Resilience Theory and Policy

Disaster resilience is not fully understood or even measurable, due to the fact that the contextually based capacities lead to differing resilience profiles of communities, often within the same regions (Plsek 2001). Holland (1999:18), Rammel (2007:10), and Innes and Booher (1999:416) all emphasise that CAS would be an excellent tool to analyse systems that are constantly changing ("functioning at the edge of chaos") (Cutter et al. 2008). By using CAS and its associated concepts such as non-linearity, aggregation, emergent behaviour, feedback loops and adaptation and context based responses, it would be possible for disaster researchers to analyse the dynamic changes in societal resilience profiles, whilst also allowing for the tracking of micro level interactions and the complex changes they create for macro level disaster resilience in society. This might provide insight into those capacities that most likely contribute to positive emergent behaviour and improved disaster resilience within a specific context (Holden 2005; Rammel et al. 2007; Zhou et al. 2010). Importantly, by basing the analysis of resilience and the formulation of subsequent models for understanding resilience on CAS, there is an inherent understanding that resilience is not the end-point for a society to achieve, but rather a journey that will lead to constant adaptive change (Norris et al. 2008; Rose 2007), and imagining alternative futures. This philosophical orientation significantly increases our chances of gaining a holistic impression of societal resilience (Holland 1992). It has also been established that a disaster resilient system is inherently an open system that is able to anticipate, learn from previous disaster impacts and creatively adapt (from information feedback loops) (Ahmed et al. 2005; Holden 2005; Lansing 2003).

Three aspects of resilience thinking that can make a contribution to how disaster risk are reduced and resilience built are: the importance of considering contextual variations on risk and resilience profiles; the process nature of building resilience; and considering building disaster resilience at the edge of chaos. In the case of considering contextual influences, disaster scientists will be forced to move towards formulating theories that take into account contextual influences on changing risk profiles and formulation of tools and methodologies that are less generic in nature and move towards more flexible interventions that can be adapted to the unique nature of individual communities. On a practical level, the need to consider contextual factors in understanding risk profiles highlights the importance of community based disaster risk assessment to gain a deeper understanding of how contextual factors interact to bring about vulnerability, adaptation or resilience in a society. The focus of these disaster assessments should therefore no longer be just to determine what factors are perceived to cause risk, but to determine the interaction between parts and determine what negative or positive behavior emerges from these interactions in each context. What is also clear from the discussion of resilience thinking is that due to various influences within a system, be they economic, political or social in nature, resilience will never remain static and will constantly change. It therefore becomes crucial to recognise that resilience is not a desired outcome that will be achieved by setting pre-determined goals, but rather resilience outcomes will be achieved by setting fluid goals that can be easily adapted as the context changes (different communities), or starts to change within the same community. Recognising that resilience is a process could also have a major influence on how resilience building projects are funded and implemented. Specifically, the time scales of resilience building projects will need to be adapted from short term plans that aim to deliver a resilient society, to longer-term interventions over several decades that allow communities to have flexible resilience profiles. Monitoring and evaluation tools will also need to be developed to assist scientists, practitioners and communities to pick up variation in the resilience profiles (but not measure resilience) in order to ensure interventions are adapted accordingly. Finally, moving analytical and policy foci to the edge of chaos will change the focus of building resilience from merely building capacities and removing vulnerabilities, to a more critical process of determining the role of capacities or vulnerabilities in allowing a system to function at the edge of chaos, where optimal adaptation takes place. This might mean that our theoretical and practical orientation towards risk reduction should be adapted, as per the principle of edge of chaos, since some vulnerabilities might be acceptable or even needed for a system to be resilient.

Conclusion

The concept of disaster resilience is becoming a prominent issue in disaster risk reduction discourse. Over the years researchers have tried to simplify the understanding of the term "resilience", by providing a comprehensive understanding of how disaster resilience should be measured, managed and reduced. However, researchers and practitioners have achieved limited success in this regard, despite the various policies, theories and models that already exist. This proves that one should not have a shallow and oversimplified understanding of disaster resilience; instead it should be understood as a complex system with constant processes of change.

This chapter aimed at critiquing the different theoretical perspectives by which our understanding of disaster resilience can be enhanced. The main aim of these theories is to create a more holistic understanding of the concept of disaster resilience in communities that are affected by disasters. This chapter furthermore challenges the conventional wisdom of aiming to reduce all vulnerabilities, because this will result in systems that will not be able to function "at the edge of chaos". Systems (communities) that do function at the edge of chaos are characterised by the interaction between different systems and components. This will thus in turn facilitate the adaptation of disaster affected communities and result in truly building disaster resilience.

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