Research Note

Embracing the Darkness: Methods for Tackling Uncertainty and Complexity in Environmental Disaster Risks

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Abstract
Environmental systems are complex and often difficult to predict. The interrelationships within such systems can create abrupt changes with lasting impacts, yet they are often overlooked until disasters occur. Mounting environmental and social crises demand the need to better understand both the role and consequences of emerging risks in global environmental politics (GEP). In this research note, we discuss scenarios and simulations as innovative tools that may help GEP scholars identify, assess, and communicate solutions to complex problems and systemic risks. We argue that scenarios and simulations are effective at providing context for interpreting “weak signals.” Applying simulations to research of complex risks also offers opportunities to address otherwise overwhelming uncertainty.

In May 2020, the New York Times reported on an announcement made by the state geologist of Alaska. The state government was relaying a warning from a group of fourteen international scientists who had recently uncovered evidence of a tsunami risk to the Prince William Sound area of south central Alaska, including the town of Whittier. Unlike previous tsunamis triggered by earthquakes or volcanic eruptions, the Barry Arm tsunami hazard was a product of climate change. A rapidly retreating glacier had left a steep hillside without structural support. A sudden collapse of the hillside would send millions of tons of earth into the fjord, creating a tsunami wave at least a hundred meters high. The warning also came with an important subtext—that this discovery was largely accidental and there were likely many more such potential disasters waiting near Arctic and alpine communities. This was a new mechanism with serious political, economic, and security implications that neither the geophysical community nor the US National Tsunami Warning Center had experience with.

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Accelerating environmental changes threaten our ability to make predictions. Effective environmental foresight requires addressing cognitive and institutional obstacles as well as detecting weak signals in complex environmental systems whose behavior is variable, nonlinear, and at times chaotic (Brassett and Holmes 2016; Brugnach et al. 2008). Weak signals represent pieces of information that may seem random but reveal important patterns if interpreted in a new context. Weak signals are, however, often lost, misinterpreted, or explained away in order not to disturb our established understanding of the world. This can have disastrous consequences, as demonstrated by perhaps the most famous example of missed weak signals—the Pearl Harbor attack (Betts 1978). Anticipating climate change–related disasters suffers from the same problem. For example, prior to Hurricanes Katrina and Harvey, expert warnings about the increased risks of flooding in New Orleans and Houston met with cognitive and organizational obstacles among decision makers, resulting in lack of preparedness when the hurricanes hit (Parker et al. 2009). In contingency planning, a number of strategies are available to interpret weak signals. Development of scenarios is one such approach to amplifying weak signals that is easily applicable in both research and instruction (Rossel 2012). The scenarios need not be static but can be explored in games or simulations that fully engage with uncertainties and perceptions of shifting global environmental politics (GEP).

In this research note, we discuss the past, present, and future of scenario analysis and simulations for enhancing thinking and research on environmental risks and disasters. For GEP communities, new constellations of environmental hazards, such as the Barry Arm tsunami, represent an opportunity to engage with “epistemic communities” and “knowledge brokers” to identify local impacts of processes like climate change or pandemics (Litfin 1994, 37; Young 1989). Scenario analysis can shed light on the areas of GEP that may have been overlooked, raising research or policy questions and illuminating research puzzles that may not yet be significant but may become crucial in the short, medium, or long term. In combination with simulations, scenarios have been used to help identify novel constellations of risks in environmental systems for future research and monitoring. They have also allowed both instruction and training on how complex issues fit together in political contexts.

Scenario Analysis: From Contingent Futures to Complex Scenarios

Scenarios are structured narratives of potential futures, often based on scientific estimations of plausible, emerging risks. They commonly rely on current trends and their extrapolation into the future, accounting for exogenous shocks and unexpected combinations of events (Barma et al. 2015). In different forms, scenarios have been used in both scholarship and practice for centuries.

References to “contingent futures” can be found as far back as the sixteenth-century writings of the Spanish Jesuit theologian Luis de Molina (Malaska and

3. We use the terms simulations and games/wargames interchangeably.
In the following centuries, scenario analysis has had an important role in strategic military planning, from the Prussian army in the nineteenth century to the Cold War military planning influenced by the work of Herman Kahn. Kahn, a military strategist at the RAND Corporation, led data-driven multivariate analyses that allowed the exploration of potential futures, an approach that later became widely accepted as a standard for analyzing energy security issues (Bradfield et al. 2005). Climate change scenarios that present future temperature charts linked to low or high greenhouse gas emission policies also rely on this approach (Moss et al. 2010). The Kahn approach to scenarios was influential but also often disastrous, influencing Vietnam War-era decisions that human security could be reduced to numbers and abstract rationality, thus losing the forest for the trees, metaphorically speaking (Mearsheimer and Shapley 1993).

In the corporate world, a slightly different type of scenario analysis was advanced by Royal Dutch Shell in the 1970s to integrate more human elements of decision-making. Pierre Wack, a Shell oil executive, began to develop scenarios less anchored in extrapolation of past trends and instead considered the possibility that the largest risks lie in uncertainty and even the unthinkable (Wack 1985a, 1985b). These were the “what-if” scenarios later used to examine some emerging environmental security risks, including abrupt, nonlinear changes in global environmental systems (Schwartz and Randall 2003). Shell was fairly successful at disseminating scenario outcomes to senior executives, often through creating country- and issue-specific scenarios (Garb et al. 2008). While Shell itself was hardly an exemplar of environmental stewardship, the lessons were important in highlighting how engagement with leadership was essential for acceptance of uncomfortable futures and that reliance upon purely probabilistic projections could often underestimate risk in areas where uncertainty was high and conditions were rapidly shifting.

Since the 1990s, scenarios have been growing in popularity in environmental scholarship, albeit less so in the social sciences (Pulver and VanDeveer 2009). Analyses of different futures have also become an important tool to anticipate governance challenges in both domestic and foreign policies of many countries, including the United States, the United Kingdom, Germany, Australia, and Singapore (Fuerth 2011; Mansted and Logan 2020; Peters 2018). The European Environment Agency, for example, has released numerous warnings of potential futures, and some European countries have used both regional scenarios and simulation results in addressing climate security (Expert Group of the IMCCS 2020). Modern scenario analysis, however, often suffers from three persistent problems: assumption of linearity, inability to handle too many variables, and disbelief in some scenario outcomes (typically those with disastrous risks). Climate-related risks embody all three problems at once (Dumaine and Mintzer 2015).

Many scenarios extrapolate existing trends into the future, assuming that the future will look very much like the present, only more so (Moss et al. 2010). Increasingly more disaster hazards, however, fall outside of historical averages. Historically based analyses and risk assessments thus tend to underestimate risk,
because they leave out data that are not yet observable or measurable. In the 1990s, early climate studies, for example, led many to believe that climate change would be gradual and its impacts mostly felt in less developed countries of Africa and Asia (e.g., Rosenzweig and Parry 1994). Throughout the 2000s, however, the growing scientific evidence about abrupt changes challenged these assumptions (Lenton et al. 2008). Environmental systems are highly sensitive to boundary shifts and fluctuations in background conditions. Minor changes in sea surface temperatures can shift ocean currents and, by extension, tropical storm tracks into areas that rarely experience them. Melting land ice in Greenland can spark feedback effects that accelerate destabilization of glaciers far beyond what might be predicted from a linear extrapolation (Lenton 2011). Scenarios exploring environmental and disaster risks need to consider how future drivers of change may influence a range of possible alternative futures, regardless of statistically generated probabilities.

Environmental disasters occur from constellations of hazards that overwhelm societal response capabilities. To assess environmental disaster risks, one must therefore understand the complex interactions of changing social and environmental systems—systems that present too many variables and causal pathways, resulting in too much “noise.” In the past, scenarios with a lot of noise simply held some variables constant, assuming that boundary conditions would not change (e.g., Davis 2003). Yet, having some problems fixed while others are variable may unintentionally draw attention to some risks but deflect it from other areas (Garb et al. 2008). Some components of complex ecological systems may be more sensitive to outside shocks; they may represent critical vulnerabilities prone to cascades (e.g., Walsh et al. 2016). Scenarios are useful at categorizing information that otherwise would be left out of context, but the scenario creation process must allow for interpretation and communication of weak signals within a proper framework (Rossel 2012; Schoemaker et al. 2013).

As a result of psychological barriers, people often discard scenarios that describe unfavorable futures, and this is especially evident in cases of complex or uncertain issues that are not encompassed by one’s experience or knowledge (Clarke and Eddy 2017; Slovic and Peters 2006). For example, climate-related disasters, such as superstorms affecting previously shielded areas, make the communication and acceptance of warnings difficult because such hazards seem improbable (Briggs and Matejova 2019, 76–79; Zscheischler et al. 2018). Scholars have long called for more attention to storytelling and scenario approaches that match stakeholders’ frames in specific contexts (Berkhout et al. 2014; Garb et al. 2008). In the mid-2000s, the US Department of Energy and later the Department of Defense, under programs like the Minerva Initiative, began to develop scenarios that would more effectively address the challenges of communicating scenario outcomes as well as the above problems of linear thinking and complexity.

Unlike popular accounts of climate change leading to violent conflict, much of the Minerva group’s research focused on systemic vulnerabilities and ways in

which geophysical changes could lead to disastrous outcomes (Carlsen et al. 2016). The process of developing new complex scenarios discarded assumptions of linearity and accounted for multiple changing variables (Briggs and Matejova 2019, 38–112). In 2012, the Minerva group applied this form of preplanning to Pacific islands, identifying the possibility of multiple tropical storms and/or tsunami impacts on the Hawaiian island of Oahu. These risks tracked with emerging geoscience research but not with historical records, meaning key infrastructure for food and energy was not designed for the new realities of environmental conditions and had to be identified in advance. Subsequent changes to Pacific sea surface temperatures and storm tracks occurred for the first time in 2013–2015, threatening port and energy facilities in a similar fashion as 2012’s Hurricane Sandy did in the US’s mid-Atlantic.

The Minerva group adopted a new approach to communicating this scenario, following the established practice among intelligence communities to separate the responsibility to give warnings from involvement in policy making. This was to avoid the linking of evidence of potential disaster hazards with prepackaged policy solutions. Under this approach, the scenarios became more extreme and at times hardly believable. To address the problem of disbelief, the group scrutinized the completed scenario assessments in search of critical nodes that would be of interest to the final audiences. Communicating such targeted risks made even the most extreme scenarios much more relatable (O’Lear et al. 2013). Risk can also be communicated more effectively by involving stakeholders in the scenario creation process or familiarizing them with potential future worlds through the use of games or simulations.

Environmental Disaster Gaming

Scenario analysis is often combined with simulations to test decision makers’ responses and potential vulnerabilities given unpredicted futures (Asal 2005). Post–World War II scenarios, while providing snapshots of potential futures, were disconnected from real-world decision-making contexts. Similarly, climate change scenarios have tended to steer clear of political considerations despite the fact that future climate conditions would be heavily shaped by political and economic decisions. Wargames and simulations create a realistic environment in which participants train for responding to new situations or test strategies for applications in the real world, including interpretation of weak signals (Li et al. 2013). The training generally accounts for the actual conditions, such as the existing resources, response capabilities, and standard operating procedures (Gillaspie 2001).

A simulation has a set objective, rules established in advance by a referee, and some element of chance (Perla 1990). Each game is also based on a scenario that determines the simulation’s boundaries, such as the geographic factors, time frame, and main actors (including adversaries). Scenarios can be fictional (e.g., using fictional but historically and/or politically accurate countries) or realistic. They can also be closed or open, meaning that participants respond to either the
information provided by the referee or the real-world events occurring during the simulation (which usually takes several days but can be stretched over months) (Wojtowicz 2020).

Modern wargaming, first recorded in 1812, was developed by the Prussian army. Kriegsspiel provided the Prussian officers with tactical and strategic training to tackle complexity and uncertainty in decision-making (Schoemaker 2004). By the end of the century, German officers were using Kriegsspiel as tabletop games, playing out military operations under various possible scenarios. In the early twentieth century, the US military used wargames while developing War Plan Orange, a strategy to defeat Japan in the event of war (and later used in World War II) (Smith 2010). Wargaming can also involve live-action exercises, albeit less frequently due to higher costs. For example, the US military annually conducts multinational live-action wargames in Thailand and the surrounding region. These exercises, known as Cobra Gold, provide opportunities for practicing complex coordination in multinational disaster relief operations like those following the 2004 Boxing Day tsunami and the 2013 Typhoon Haiyan.5 Gaming is not just about “war”; it is also used in addressing potential future impacts from risks on the “critical peripheries” of the Anthropocene, such as pandemics, forced migration, and new constellations of hybrid disasters. Programs such as the Multinational Planning Augmentation Team have created communities of security experts from across the Pacific Rim to game such scenarios every year as cooperative exercises, looking beyond traditional security definitions of zero-sum, violent contests (Robinson 2018; Tate et al. 2009).

Even “hard security” wargames can include environmental layers. Simulations may shed light on pressing environmental issues, such as illegal trade in resources, international fisheries disputes, and states taking advantage of disasters to take control of foreign territory or infrastructure. In 2008, for example, the Swedish Defense Research Agency (FOI) developed a scenario and related wargame to test potential NATO intervention in West Africa in response to a disaster. Long before NATO intervened in Libya, the wargame helped anticipate several potential difficulties, ranging from refugee flows and disease outbreaks to local perceptions of former colonial powers and worries over US military involvement (Briggs and Matejova 2019, 122–124). The significance of such wargames lies in their capacity to illustrate how topics fit together; why they are important; what topics are linked to greatest uncertainties; and how risks can be addressed via increased monitoring, research, or policy changes.

Wargames can emphasize either training or analytics, and the professional gaming community has at times been at odds over what the balance can or should be, a discussion primarily applied to professional military education and defense research.6 For civilian universities and academics, games present an alternative

approach to research-based pedagogy; they are an effective tool for teaching complexity in a realistic and comprehensible fashion. In research, simulations inject human elements into scenarios where cognitive uncertainty (i.e., how humans react) is high and otherwise largely unpredictable. Simulations can therefore assist in identifying how people might react to high-stress, high-uncertainty scenarios, actions that are often based on culturally encoded cognitive shortcuts (Lin-Greenberg et al. 2020). The lessons from gaming can be “harvested” into playbooks that identify where key uncertainties lie, where and when decisions will have to be made, who will be responsible, and whom to contact. While we cannot ensure that such playbooks will be used, their identification of uncertainties can be an enormous benefit to researchers as to where more research or monitoring is needed.7

Looking into the Future: Scenarios and Simulations in GEP Research

Since the 1990s, environmental security scholars have attempted to explain how different environmental variables affect potential conflict, from resource scarcity to resource abundance, from changes in rainfall to the incidence of diseases like HIV/AIDS (Homer-Dixon 1994; Le Billon 2004; Price-Smith 2009). Others have studied environmental cooperation and disasters’ impacts on diplomacy (Dabelko and Conca 2002; Kelman 2006). The growing frequency and intensity of environmental crises and disasters, however, calls for GEP scholars to conduct more anticipatory and practically oriented research. The challenge is in adapting research to examine hazards and vulnerabilities before they become disasters; this requires both an understanding of the complexity of systems and working to identify vulnerabilities and tipping points in advance.

In GEP research, scenario analysis can illuminate tipping points as well as new causal pathways, given the at times unexpected combinations of different geopolitical, environmental, technological, social, and other factors. Together with gaming, scenarios may reveal new areas of research significance, from overlooked hazards to insufficient policies to ill-suited institutions to unforeseen behavior in the face of emerging hazards or combinations of hazards. New interactions of political actors in contexts that are plausible yet uncommon may challenge our existing theories and understanding of environmental politics. In climate security, scenarios and simulations provide an analytical basis for “what-if” questions, for example, what happens to Indian and Bangladeshi security if monsoon rains become unstable? Applied scenarios can also test the realms of the possible in future worlds, for example, by proposing desired future conditions for a clean energy transition and then backcasting to determine how best to reach that desired outcome. GEP scholars are well positioned to play an active

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role in scenario creation and scenario use in environmental governance (Pulver and VanDeveer 2009).

Practically, scenario analysis can identify new policy problems, helping scholars conduct anticipatory research. Scenarios and simulations also force scholars to practice critical thinking and fight their own cognitive biases by introducing new patterns and unexpected combinations that challenge one’s expertise or experience (e.g., Tetlock 2005). Scenario creation workshops and gaming sessions provide collaborative opportunities for scientists, researchers, activists, and policy makers from different institutions and countries (Garb et al. 2008). Thus, while the scenario approach may focus on disaster planning, the real lessons come from partnership building, interdisciplinary collaboration, knowledge translation, and even diplomatic benefits.

Scenarios and simulations are, however, limited by plausibility, and our collective capacity to be surprised by reality is far from exhausted. The lesson of 2020 has been that our abilities to anticipate disasters, even with more advanced methods, cannot always keep pace with the reality of climate change, pandemics, and political responses to disasters. Communication of scenarios and gaming outcomes remains one of the most crucial challenges despite the successes of cross-disciplinary participatory approaches in creating and disseminating information about possible futures. Further challenges of future scenario development and disaster gaming are both conceptual and methodological.

As the name implies, wargames often focus on traditional security concerns like military interventions, counterterrorism, or counterinsurgency. The ability to model political dynamics around topics like biodiversity conservation or climate change adaptation requires an expansion of conventional wargaming concepts and approaches. This presents an opportunity for the academic community to take advantage of new research and collaborate with groups that are looking to develop realistic scenarios. Wargames that center around issues of GEP need experts from the field to help design the underlying scenarios and modeling and to draw interlinkages between emerging risks associated not only with climate change but also with public health, biodiversity protection, environmental justice, sustainability, energy security, and a host of related issues.

Adapting wargames into disaster games also requires consideration of topic areas that were previously challenged by demands of field research or the nature of future hypotheticals. Rather than considering average projections of climate change impacts in rural Cambodia, for example, scenario and game developers may engage experts and stakeholders in Cambodia to explain how a mix of climate- and non-climate-related environmental factors affects risk assessment and policy alternatives. Advancements in scenario creation and gaming now allow for greater participation from scholars and other civilian experts, including local stakeholders.

In the past, previously distributed and asynchronous wargames (i.e., “play-by-mail”) were possible but awkward outside of restricted military software. The professional wargaming communities are now developing new techniques,
methodologies, and platforms for conducting simulations without the need to meet in person (Reddie et al. 2018). As the virtual nature of scenarios and games expands, new methodologies may be required to capture both system dynamics and decision-making among participants (and address issues of digital privacy). Interaction between human participants and artificial intelligence systems and machine learning has sparked new concepts for how to model complex systems. These developments, however, are still largely focused on national security, leaving environmental governance as a peripheral issue (Lakkaraju et al. 2020).

In the past, scenarios have been used to describe the future. Going forward, environmental and disaster risk scenarios provide opportunities to shape the future, by exposing tipping points, translating weak signals, tracing potential cascades, and, in combination with simulations, training policy makers and experts. In the end, scenarios and simulations cannot help us predict specific disasters, but they can prepare us for constellations of risks that translate into specific impacts. By breaking down risks into recognizable categories, scenarios and games make even novel situations familiar, allowing suitable responses and reducing decision paralysis. They therefore allow training for many types of events, including those we suspect would happen and those we may hope never to see.

The tsunami risks in Alaska remain a case in point. Climatic changes have altered landscapes so abruptly that we are experiencing new hazards that could hardly have been imagined in prior years. The Anthropocene cannot be understood in terms of what came before, nor can the associated risks easily be addressed through traditional institutions and approaches. We are in a new era when scientific discoveries uncover emerging risks across political spectra. Understanding the political implications and potential responses cannot wait for events to occur and full information to present itself. As GEP researchers, we must get ahead of the coming waves.

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