The Disaster Chronotope: Spatial and Temporal Learning in Governance of Extreme Events

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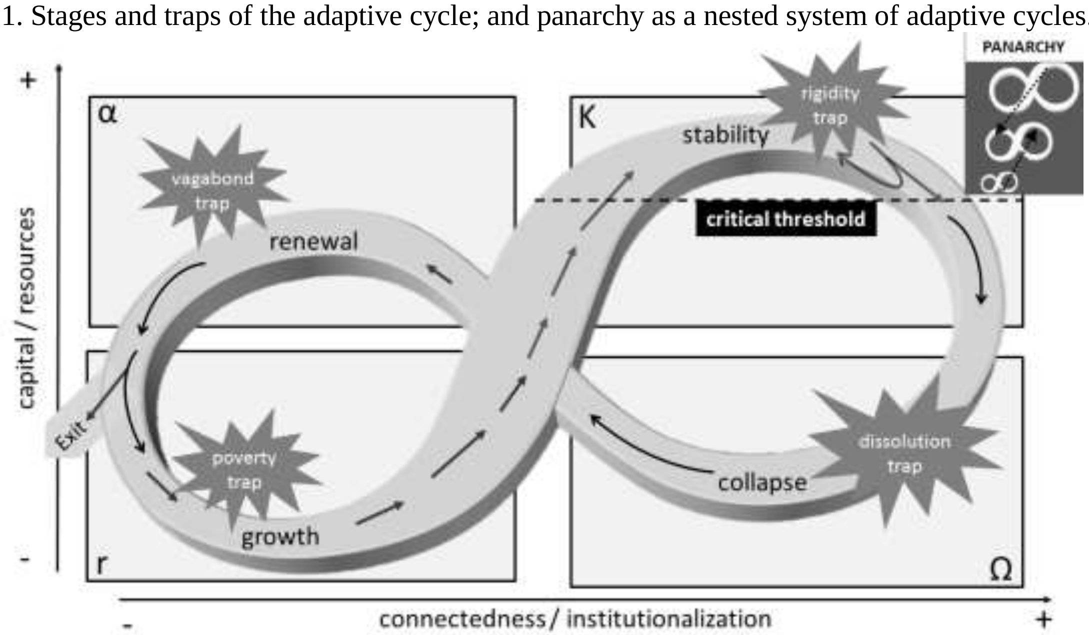
How does the type of disaster affect the learning among key stakeholder groups? This chapter provides a framework of disaster governance through examination of local and global response strategies based on the spatial and temporal attributes (or chronotope) of disaster events and related discourse. A series of case studies builds on the concept of "panarchy" in resilience and adaptation sciences to reveal the interaction between disasters and the capacity of various stakeholder groups to adjust the rules and assumptions that underlie disaster governance. With particular focus on patterns of learning, we map our findings in a matrix to reveal disasters as complex social-ecological processes at three levels: (1) the small fast-moving local system, (2) the nation-state as the intermediate level in speed and size, and (3) the global community of nation-states as the largest, slowest moving social system.

1. INTRODUCTION

1.1 Learning and disaster governance in a panarchy

Research demonstrates that the outcomes of disasters, as well as what qualifies as disaster, are, in part, socially constructed (Wisner et al. 2012; Marino 2012). We argue that any social system's drivers of change that impact both human and ecological systems' structures and functions merit a closer look. While disasters can be induced by natural phenomena or human negligence, the extent to which human populations are affected depends on a mixture of underlying vulnerabilities and resilience. In other words, disaster governance is a social activity, a process that can learn and adapt to mitigate disasters and improve governance. To this end, our work approaches disaster governance as a management process via decentralized, diverse and multi-scalar involvement of entities in a globalized world where disasters and societal responses blur borders (Tierney 2012). Still, governance outcomes are affected by a multi-scalar hierarchy of social adaptive systems; represented by nested, continuous 'figure 8' loops as modeled in the panarchy framework (Figure 1).

Figure 1. Stages and traps of the adaptive cycle; and panarchy as a nested system of adaptive cycles.

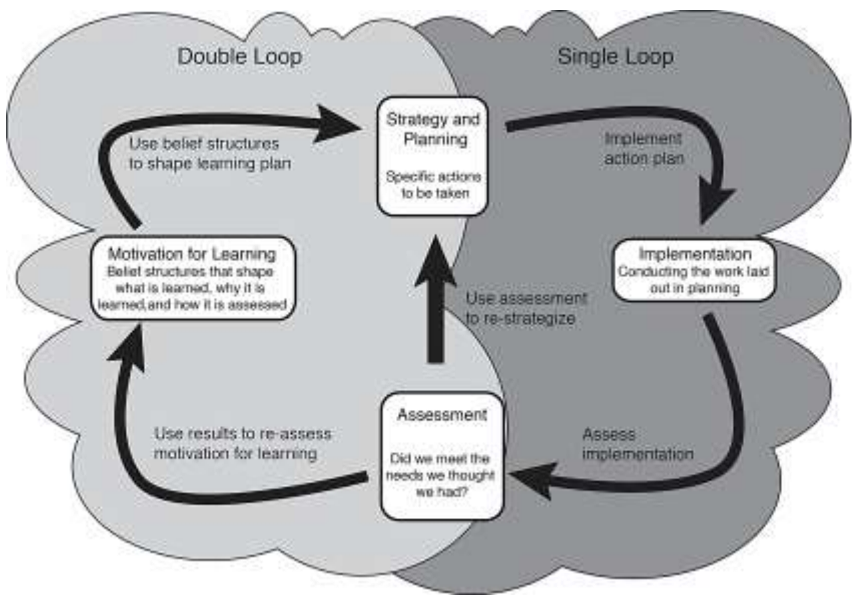


Source: Adapted from Gunderson and Holling (2002) and Fath et al. (2015). For a detailed discussion on the links between crises, disasters and the adaptive cycle, the reader is referred to the complete chapter in Blair 2017.

Panarchy is a useful paradigm to evaluate the learning and adaptive capacity of complex systems. The sequence of management actions in disaster governance (mitigation, preparedness, response, recovery) occur in various stages of the adaptive cycle (collapse, renewal, growth, stability) shedding light on the dynamics between the timing of disaster events and capacity to adapt. A critical threshold of tolerance (Fath et al. 2015) that is not always crossed, delineates a zone where crises may recur but if available plans and routines facilitate a return to pre-crisis stability, total collapse is avoided. These small-scale events provide opportunities for learning and making adjustments to plans and existing strategies. We illustrate further components of the adaptive cycle under the results section. Table 1 summarizes key concepts that are integral to our thesis.

We define learning in this context of disaster governance as the process of identifying and addressing error. Our focus is on single- and double-loop learning popularized by Argyris (1976, 2004) (Figure 2). The double-loop learning model is well-aligned to the adaptive cycle framework in that each assumes an iterative process of dynamic system change. From the adaptive cycle perspective, system change moves through phases of collapse, renewal, growth, and stability. Double-loop learning begins by identifying the four phases of single-loop learning: problem identification, planning, implementation, and assessment; followed by an assessment of the underlying values, assumptions, and objectives embedded in the first loop.

Figure 2. Double-loop and single-loop learning.



Source: Adapted from Argyris (1976).

Single-loop learning is task-driven; much in the same way traditional command and control disaster management tends to focus on returning society back to its pre-disaster state. Managing for resilience involves a second loop of questioning of what the system should look like after a change event, and where to innovate to increase resilience for future events. This means iterative studies of disaster events, responses, and recoveries are required to review and even alter the evaluation criteria used. Learning from disasters, and ultimately disaster governance, is ongoing with no static answer for any one region or disaster type. However, a broad view classification of disasters and comparison of outcomes can be made for policy information and management recommendations. We pose our results to aid in identifying planning tools that promote strategic flexibility and conflict resolution—critical components of disaster governance.

Table 1. Key concepts

Term	Concept	References
Adaptive capacity	A system’s ability to adjust responses to changing internal and external demands and drivers.	Holling 1973; Carpenter and Brock 2008
Adaptive cycle	A long-term view of system change focusing on change cycles and their stages: collapse (release), renewal (reorganization), growth (exploitation) and stability (equilibrium). It is visually represented by a continuous ‘figure 8’ loop that contains these phases.	Gunderson and Holling 2002; Fath et al. 2015
Chronotope	Configurations of space-time that provide grounds for human discourse and narratives.	Bakhtin 1981
Dissolution trap	Inability to enter the renewal stage following collapse; exiting the adaptive cycle at the collapse stage.	Fath et al. 2015
Learning organization	Exhibits adaptive capacity to apply new information through recognition of error or success to future policy decisions.	Mahler 1997; Busenberg 2001 and 2004
Panarchy	A nested hierarchy of adaptive cycles, panarchy depicts cross-scale relationships at multiple levels of organization.	Holling 2001; Gunderson and Holling 2002
Poverty trap	The system's inability to grow due to insufficient resources or activation energy to implement new ideas and plans.	Gunderson and Holling 2002
Resilience	A state of dynamic equilibrium punctuated by shocks that may cause the overall system to evolve. The system is resilient to shocks that do not overwhelm the capacity to adapt while relationships between internal components remain stable.	Holling 1973
Rigidity trap	A system is inflexible and stuck in status quo processes blocking innovation and novelty during the stability stage.	Gunderson and Holling 2002
Social-ecological systems	Coupled social and ecological systems that are complex and adaptive and have reciprocal feedbacks.	Berkes and Folke 1998; Gunderson and Holling 2002
Vagabond trap	Inability to reorient the components of the system or to reconnect its nodes in order to begin growth; being stuck in the renewal stage.	Fath et al. 2015
Vulnerability	A system's susceptibility to experience harm due to exposure to stressors and lack of ability to adapt.	Adger 2006

2. METHODS

2.1 A typology of disasters

Disasters are fluid and may take on different qualities from one occurrence to the next (Coppola 2011). This poses difficulty for classification and comparison. For analytic purposes we adopt a typology that highlights management-learning dimensions. Table 2 shows our typology in three dimensions: local vs global scale of impacts, ordinary vs extraordinary duration of impacts, and slow, rapid, or cyclical onset of disaster events.

A simplified, binary classification of *local* vs *global* impacts is used to distinguish learning processes that can be absorbed by sub-governments or nation-states from broader impacts that truly test the capacity of the international community to reorganize for “business as usual” after the event. Similarly, in *ordinary* timescale events, recovery time takes place in days, weeks, months, or a few years, while *extraordinary* timescale impacts mean that the disaster event carries the potential to endanger future generations. *Slow* onset events such as droughts or invasive species allow communities to strategize ahead and plan to mitigate and respond. *Rapid* onset events such as earthquakes or landslides come without much warning. As depicted in Table 2, *cyclical* disaster events are not broken out on the temporal scale of impacts. Their significance lies in a historical pattern of reoccurrence that provides a longitudinal glimpse at ways in which individuals and institutions cope with repeated disaster stimuli, sometimes without the chance to recover from previous events. Often these types of events occur after many false alarms, or low-level impact events before they cross the disaster-threshold. For example, hurricanes may or may not make landfall, and their intensity varies greatly. Cyclical disaster events have a cumulative impact potential, and any vulnerabilities, resilience, or learning that result are often a combination of impacts from many false alarms, small-scale crisis events and disasters.

Table 2. A typology of disasters. Selected case studies relate to the examples in bold typeface.

Impact dimensions:	Spatial scale:	Local		Global	
	Temporal scale:	Ordinary-term	Extraordinary-term	Ordinary-term	Extraordinary-term
Type of onset:	Slow-onset	drought	**coastal erosion**	economic crisis	sea level rise diminished sea ice
	Rapid-onset	**earthquake**	**oil spill**	megatsunami	asteroid impact
	Cyclical	**typhoons**		heat waves	

2.2 Selection of case studies

Four case studies explore how the type of disaster affects the type of learning among key stakeholder groups. The Alaska earthquake (3.1) and the Exxon Valdez oil spill (3.2) have been studied extensively on long-term change and learning. The Philippine typhoon case (3.3) was chosen to provide insights into disaster learning from a medium-income developing nation's perspective on frequent disasters that galvanize a multiscalar response. In the coastal erosion case (3.4) we connect the slow-moving disaster potential of climate change, and the global and local governance processes involved.

2. 3 Tracing the adaptive cycle

For each case study, we analyze the adaptive cycle to understand how the type of disaster has transformed governance and resilience through learning. Our analytic framework is based on Fath et al.'s (2015) description of key preparedness features needed in each stage of the adaptive cycle in order to navigate onto the next, and traps that may prevent progress—these are highlighted in our results.

2. 4 Analysis and interpretation

These case studies present instances of learning in social systems nested within a panarchy of interlinked social systems or communities. While communities can exhibit characteristics such as cooperation and common sense of identity, they are also an environment of heterogeneity, inequality, and competition for power and resources affecting overall disaster resilience in an ecological network of social systems (Peacock and Ragsdale 1997, 23). Our criteria for interpreting the findings is based on a social system's ability to navigate its adaptive cycle (Fath et al. 2015), the panarchy model (Gunderson and Holling 2002), and a descriptive-interpretive qualitative analysis (Merriam 1998) of the multiple levels of learning in a panarchy. Our research approach introduces the *chronotope* of social engagements (Bakhtin 1981) and learning under globally connected disaster processes. The chronotope is the realm of spatial and temporal indicators that reveal relations of power between social systems, groups, or individuals.

3. RESULTS

The four case studies are presented based on the timeline of the disaster event and the governance of the impacts through the stages of adaptive cycle following disaster: the collapse, renewal, growth, and stability. During our analysis we highlight the role of key resources needed to navigate to the next phase of the adaptive cycle (as per Fath et al. 2015) with italicized text. Table 3 is a summary overview of our findings on learning from disasters.

3. 1 The 1964 Alaska Earthquake: local scale, rapid onset and ordinary term

Friday, March 27 1964 an earthquake of magnitude 9.2 struck at the head of Prince William Sound in Alaska; the second largest earthquake ever recorded anywhere. The earth's surface was measurably displaced over an area greater than 100,000 square miles in mere minutes, the vibrations from which could even be felt atop Seattle's Space Needle 1,400 miles away. Over these few minutes southern Alaska lurched 20 meters seaward with a 10-meter uplift, generating a tsunami that devastated the port towns of Valdez, Seward, Whittier and several others (West et al. 2014). Overall, 131 deaths occurred as a result of the earthquake, with 119 of these attributed to the devastating tsunami waves that followed the initial shocks. Alaska's low population density at the time accounted for the comparatively low loss of life.

Collapse

Alaska's unique geographic location with its proximity to potential enemy attacks prompted a large military presence that turned out to be crucial in the immediate aftermath of the disaster. This translated to a *cohesive, well-trained leadership* to provide support and disseminate information. Hundreds of civilian volunteers organized to help and an ad hoc group met within 24 hours to coordinate *vital functions* in a show of *improvised responses* that helped *reduce fault cascades*.

Renewal

In two weeks' time the emergency relief scaled down and transitioned into recovery (USOCD n.d.). The connected, ready-to-mobilize nodes of leadership and resources resulted in *modularity* of system components, while a $350 million federal financial aid for reconstruction and development provided *access to stored capital* to stimulate growth. *Self-organization* at the state-level was less of a factor as the new state was still especially dependent on federal support. *Memory* of previous California quakes in decades prior created great public interest, and together with the Alaska earthquake acted as focusing events for seismic risk reduction policies and investment in research.

Growth

Despite calls for a federal flood and earthquake insurance program to systemically aid with the economic fallout of natural disasters, this did not materialize. The 1968 National Flood Insurance Act (NFIA) made available flood insurance to homeowners in participating communities. To date, earthquake insurance is available only via the private market where participation is low, costs are high and coverage is limited. The opportunity to increase *adaptive capacity* was mainly realized on the science and research front, but investment waned. Federal and state cooperation and *bilateral information flow* was efficient enough for the needs of the underdeveloped state. Alaska was somewhat of a blank canvas and able to incorporate new guidelines and risk reduction strategies in further development. In this sense, the fallout from the disaster created an environment of *positive feedback* ripe for innovation and learning. Crisis response was followed by great growth but some underlying vulnerabilities were not addressed. For example, some red seismic zones were reopened for construction in Anchorage, decreasing resilience in the most populous city of the state. *Emergent leadership* was strong in the realm of seismic research, but the political will not strong enough to enact federal earthquake insurance legislation.

Stability and signs of rigidity trap

The earthquake became a grand-scale scientific learning experience. By the mid-1970s a seismic network was put in place to monitor the south-central coast. The federal government initiated a series of investigations, resulting in an eight-volume comprehensive report (NRC 1973). Much of this information has shaped building codes, warning systems, instrumentation, and public awareness, but perhaps most profoundly, these large-scale investigations grounded research for decades to come and displayed great political will to overcome pressures for short-term returns (West et al. 2014). Over time funding and issue salience have decreased; what little political interest remains is mainly focused on transportation corridor safety.

Today's network of seismic hazard monitoring stations is behind the times in early warning capabilities (Martinson 2016). Despite frequent small-scale quakes or *disturbances*, the seismic network has grown little since the initial expansion. Crisis response is in a rigidity trap where the road and port system is highly vulnerable to disruptions of commerce from earthquake events. The economy and infrastructure still lack the functional *diversity* needed for disaster resilience. *Negative feedbacks* from geographic isolation, single-resource economy, a vast land area, and lack of transportation impact community vulnerability to disasters. In 1964 Alaska had little to no *buffer capacity* on its own and things have changed little. Alaska still relies on the flow of outside resources for basic livelihood and many communities are especially isolated. While individual and community resilience varies greatly in the state, as a whole most people depend on outside (of state or community) flow of goods and services.

The learning model: fixated, horizontal, single-loop

Rapid onset events tend to result in greater focus on disaster relief than on mitigation, with a desire to return to pre-disaster norms. This results in a form of single-loop learning, where pre-disaster methods are applied to post disaster conditions, giving the appearance of action without qualitatively changing the system's ability to respond to future events. This type of learning tends to fixate on previous ways of knowing; thereby stimulating horizontal growth and non-strategic thinking. Novel ideas during renewal may be dismissed without considerable public focus on the need for change, especially if recovery is quick and routine measures return life to pre-disaster state. This is due, in part, to the brief time period spent in the renewal phase when disaster impacts occur on an ordinary-term time scale. During renewal, learning can be radical and reforming, while the growth stage promotes slower, incremental learning.

Intervention by the intermediate, nation state level in the panarchy aids in the short term, but can hinder learning in the long run. Disaster relief as well as undervalued federal flood insurance can have a subsidizing effect on risk behaviors. Loss calculations are based on restoring what was; leaving little incentive for developers and homeowners to change risky behaviors.

Table 3. The Disaster Chronotope: Linking the construction and types of disasters with social learning models. The cause and effect relationship between disaster event and impacts is described as “press” (continuous perturbation) of “pulse" (short-term perturbation) as per Glasby and Underwood (1996). Cyclical disaster events are not broken out on the temporal scale due to their typically cumulative impacts.

Impacts:	**Spatial scale:**		**Local** **Global-scale impacts touched upon via linkages with the coastal erosion case study**	
	Temporal scale:		**Ordinary-term**	**Extraordinary-term**
Onset:		**Case**	*Not covered in chapter*	**Coastal erosion and post-colonialism in Alaska Native villages**
		Disturbance type		Protracted press
	Slow	**Cause**		Continuous press from multi-scalar risk sources and social pathologies
		Effect		Continued press
		Learning model		**Disordered chronotope**
		Case	**1964 Great Alaska Earthquake**	**Exxon Valdez Oil Spill**
		Disturbance type	Discrete pulse	Protracted pulse
	Rapid	**Cause**	Short-term pulse	Short-term pulse
		Effect	Short-term pulse	Continued press
		Learning model	**Fixated, horizontal, single-loop**	**Pinball, potential double-loop**
		Case	**Typhoons in the Philippines**	
		Disturbance type	Protracted press & pulse from cumulative impacts	
	Cyclical	**Cause**	Recurring short-term pulses coupled with continuous press from social pathologies	
		Effect	Continued press	
		Learning model	**Stalled, reactive, vagabonding**	

3.2 The Exxon Valdez Oil Spill: local scale, rapid onset and extraordinary term

On March 24, 1989 the oil tanker Exxon Valdez went aground in Alaska's Prince William Sound spilling roughly 260,000 barrels of crude oil. Prior to the 2010 Deepwater Horizon disaster, which released an estimated 4.9 million barrels of crude into the Gulf of Mexico (BOEMRE 2011), this was the largest single oil spill in U.S. history. Though there were no immediate human casualties, four deaths were associated with the cleanup effort and the losses to human livelihood and to wildlife were immense (AOSC 1990). The spill covered about 1,300 miles of coastline, and killed an estimated 250,000 seabirds, 2,800 sea otters, 300 harbor seals, 250 bald eagles, up to 22 killer whales, and billions of salmon and herring eggs (EVOSTC *n.d.*). Some of these impacts are still felt over 25 years later. Aside from operator error, major systemic errors such as a self-regulating industry were identified as culprits. This event made clear not only that sweeping reforms were needed in the tanker industry itself, but that spill prevention and response regulations were wholly inadequate.

Collapse

In the immediate aftermath of the disaster, there was an obvious lack of *cohesive leadership* due to confusion regarding the role of federal, state and industry entities. Previous legislation via the 1972 amendments to the Clean Water Act (CWA) established monetary liabilities of oil facilities and ship owners, but to what extent the federal government can compel the polluter to clean up, and who should command the deployment of responding vessels was not clear (Birkland and deYoung 2011). Initial response was slow to organize and ultimately failed to *reduce fault cascade*. Worst-case scenario, lack of preparedness and inadequate technologies prevented novel actions or *improvisation*. Due to the man-made nature of the disaster, the CWA preempted the 1988 Stafford Act, preventing a presidential declaration of disaster and flow of federal funds. Financial assistance to stakeholders would have to wait for negotiations with the responsible parties, or for litigious court processes to conclude. While *vital functions were maintained* in the basic sense of human survival, the scale of disaster caused economic and psychological devastation for the fishing communities and Alaska Native villages of Prince William Sound.

Renewal

The media fallout gripped the nation and was instrumental in the passing of the Oil Pollution Act of 1990 (OPA 90). OPA 90 established guidelines for spill response that essentially federalized the process (Birkland and deYoung 2011). Spills "of national significance" are now commanded by the federal government via Coast Guard leadership. The government may choose to clean up and hold the polluter liable for the cost, or monitor the polluter's efforts until deemed complete. The regulations also mandated the exclusive use of double-hull tankers by 2015, and set up a trust fund from oil taxes to fund potential cleanup of spills. Improvements have been made to operations including regular spill response drills, trained pilots that board tankers entering the sound to navigate to port, and stockpiling of containment booms and dispersants. The Exxon Valdez Oil Spill Trustee Council was founded using investment earnings from the civil settlement fund paid to the state and federal governments. Its mandate is to oversee research, monitoring, recovery and rehabilitation of Prince William Sound wildlife habitat with public input.

The inadequate *modularity* of relevant expert networks —under-developed, unprepared nodes that were slow to mobilize—was noted as well. Emergent organizations in research and advocacy soon developed such as the aforementioned Oil Spill Council and Regional Citizen's Advisory Council, showing capacity for *self-organization*, and supported by *access to stored capital* from state, federal, and settlement resources. Citizen advocacy grew quickly from radical learning typical during the renewal stage of the adaptive cycle.

Growth and near-stability

A lack of pre-spill baseline data on the Prince William Sound ecosystem hampered assessment of damages and *bilateral information flow* to aid disaster management. *Positive feedbacks* from spillover effects to other areas of policy (such as forestalled oil exploration in the Arctic National Wildlife Refuge) due to emergent leadership among advocacy groups were instrumental in policy change. In terms of adaptive capacity, OPA 90, better training of personnel and the emergent advocacy councils have shown increased learning among stakeholders.

Of the thirty-two injured resources monitored by the government, only fifteen were listed as recovered as of 2014 (EVOSTC 2014). We may consider the social-ecological system in a hybrid growth-stability stage: Some ecological resources and human communities are still recovering, but politically speaking the policy cycle adapted to the events long ago and returned to an equilibrium stage. The long-term policy impacts of OPA 90 are questionable. Offshore production continued to enjoy a close relationship with regulating agencies, and a systemic ignorance of lax contingency planning and repeated small-scale blowouts characterized the years prior to the 2010 Deepwater Horizon disaster (Birkland and deYoung 2011). These *small-scale events* and low-level crises represent a missed opportunity to evaluate and adjust crisis management during times of stability, resulting in a rigidity trap. A sense of complacency may build through frequent events not only in industry, but also in communities threatened by frequent storms or small seismic tremors as these can create a false sense of resilience.

There isn't adequate *buffer capacity* to prepare for another event like this; although changed industrial practices have made some strides toward mitigation and preparedness. Because the settlement took 2 years to reach and 10 years to pay out to aid recovery, *negative feedbacks* from the increased need for, and lack of access to capital, slowed rate of growth. The *diversity* of oversight from interest groups and ongoing monitoring of the recovery has been a long-term outcome. The Regional Citizen's Advisory Council reviews spill prevention and response practices and policy with a strategic, long-range view; considering thresholds and learning from diverse scenarios.

The learning model: pinball, potential double-loop

Rapid onset events with extraordinary temporal scale impacts can create the activation energy to support pro-change groups. The disaster as a focusing event sets the stage for learning and adaptation, but reform attempts may be stalled by special interest pushbacks. Due to slow recovery, issues can stay on the agenda for a long time, but speed of recovery also slows the testing and re-evaluation of outcomes from policy change to evaluate whether things are headed in the right direction. In short, a rapid onset disaster can exacerbate the challenges in avoiding scale mismatch and recognizing the plurality of assumptions in decision-making. Change can be guided by bridging organizations. Success depends on the system's capacity to act on the potential to innovate due to length of time spent in the renewal stage. The process resembles a pinball launched with great momentum and potential; entering a competitive playfield in which the trajectory is difficult to control and timing is key.

3.3 Typhoons in the Philippines: Local scale, cyclical disasters

The Philippines is arguably one of the world's disaster hot spots. Seismic activities aside, typhoons alone wreak havoc annually in this region with an average twenty cyclones moving through and four to six making landfall each year (Takagi and Esteban 2016). While the 2004 typhoon season killed over 1600 people—largely blamed on landslides worsened by the effects from illegal logging—the political fallout was short-lived, mired in corruption and resulted in little change. The devastating 2013 Typhoon Haiyan (Yolanda) left over 6000 people dead, 28,000 injured and millions displaced. Warnings came in the days and hours preceding landfall, but communication of risks to the public was ineffective (Neussner 2015). The effectiveness of the early warning system and relevant institutional arrangements are still under study after Haiyan, but lessons from previous disasters suggest that social and political forces, beyond the technical and scientific, contributed to community vulnerability.

Collapse

Philippine national disaster management leaves the coordination of relief and response to local governments. This policy is articulated as self-reliance and mutual assistance among local communities, allowing for higher-level assistance only if local resources are exhausted. The planning of emergency functions is entirely left to provincial and municipal governments, but many neither have such plans nor hold regular training and drills to prepare. This system has resulted in over 40,000 barangay (village), 1,400 municipal, 113 city, 81 provincial, and 17 regional disaster coordinating councils in addition to the national agency. While diversity and modularity can enhance disaster response, inadequate leadership structures will fall apart as they did after Haiyan: Power, communication and access routes to transport aid were inadequate or unavailable in most areas. Hazard maps and early warnings were not fully utilized, while the public was confused about the expected severity of the impending storm.

When large-scale impacts overwhelm response capacity, *maintaining vital functions* becomes impossible. A reactive management approach built on an ad hoc platform impedes *leadership*. While local risk-sharing networks and NGOs help reduce vulnerability and promote *improvisation,* the overall effect of systemic gaps, irregular disaster drills and ineffective risk communication hamper effective *reduction of fault cascade.*

Renewal

Philippine national disaster management is highly dependent on donor and multilateral institutional assistance due to a lack of *access to stored capital* and suboptimal *self-organization.* Domestic and international humanitarian organizations often find it hard to harmonize their actions within a system that is heavily political and out of step with needed response actions (van den Homberg 2014). While *modularity* of system components is desirable during this stage, without a clear chain of command the disaster relief structure is a complex cluster of U.N., national, provincial and NGO actors without coordination. A prolonged state in renewal without leadership and capacity development structures results in a vagabond trap of drifting with important nodes disconnected and unavailable to help perform vital tasks (Fath et al. 2015). This delays the growth phase.

Humanitarian efforts and the transition from relief to recovery can be hampered by differences between international and local planning time frames, and different views on the boundaries between emergency relief and recovery (Gocotano et al. 2015). The point of transition between the two post-disaster phases has important logistical and legal implications that also impact the flow of financial and technical assistance. System *memory* may move most effectively through NGOs, as they tend to seek root causes of vulnerability and tend to engage local populations as a resource (Bankoff and Hilhorst 2009).

Elusive growth and stability

The root causes of vulnerability that worsen disaster impacts are complex. Political corruption, the effects of landlessness, and food insecurity force a growing population to move into high-risk zones; taking on the risk of seasonal typhoons in a cost-benefit analysis for survival (Gaillard et al. 2007). A culture of static-reactive decision making hampers *bilateral information flows* and decreases *adaptive capacity.* Proposals for policy change lack activation energy and inhibit *emergent leadership.* There have been *positive recent feedbacks* from NGOs and the international community shifting paradigms from mostly relief assistance to also aiding with prevention and mitigation.

Following international standards such as the United Nation's Hyogo and Sendai frameworks, the Philippine Disaster Risk Reduction and Management Act of 2010 recognized vulnerability, and specifically poverty reduction as important facets of sustainable development and disaster risk reduction. Yet the scale of disaster hazards faced by the Philippines remains an immense challenge, one that continues to challenge institutional capacities and commitment to reform. Often, NGOs and the nation state compete for funds and lack trust toward each other (Bankoff and Hilhorst 2009) creating a *negative feedback* in the adaptive cycle worsened by systemic corruption.

Some communities are taking a proactive stance to increase their disaster resilience. The Provincial Government of Albay has integrated disaster risk reduction, environmental protection and development planning under a set of comprehensive guidelines as a means to reduce disaster risk. Public-private partnerships such as the Philippine Disaster Resilience Foundation, are also active in disaster readiness and response and provide livelihood seeding programs, education, shelter and basic needs. Only time will tell whether poverty and related vulnerabilities will improve following the 2010 Disaster Risk Reduction Act, as sectors and regions recover at different speeds and to varying degrees of vulnerability, challenging *buffer capacity*.

The learning model: stalled, reactive, vagabonding

Recurrence of disasters can provide the opportunity to test existing policies and adjust-monitor-evaluate with each event. However, the recurrent nature of disaster events, especially in developing countries, is a constant strain on the adaptive capacity and related resources of communities. The fast-paced learning that is needed in the renewal stage post-disaster is then stalled by lack of resources, leading to a vagabond trap of disconnected system components. Effective long-term strategizing depends on the ability to reduce fault cascade with each event; relying on accumulated buffer capacity, emergent leadership, and adaptive capacity to learn. These are traits of a stable social system. Communities lacking these resources can become locked in path dependency from cycles of disasters and extreme poverty, leading to reactive disaster governance.

While there may be a rich vault of memory or lessons learned from past events especially at the national-level (not all local governments may have dealt with repeated events), so too there are entrenched practices and norms that may become pathologies if they are resistant to change. The intermediate system of the nation state may be preoccupied about its own political sustainability, while the largest, global system finds disaster relief, and the stabilizing of small enterprises (e.g. public-private livelihood seeding programs) the most feasible route to assist.

3.4 Coastal erosion and post-colonialism in Alaska Native villages: Local scale, slow onset and extraordinary term

The cumulative effects of climate change have resulted in drastic changes in the extent and seasonal cycle of sea ice in the Bering and Chukchi Seas, leading to increased coastline erosion and shoreline flooding in coastal communities (Huggel et al. 2015). Reduced autumn sea ice level has resulted in amplified effects from storms since sea ice no longer acts as a barrier between the coast and storm surges. Over 6,000 miles of Alaska's coastline is subject to severe erosion and flooding with the majority of Alaska Native villages impacted. Thirty-one villages were in imminent danger as of 2009, up from four just six years prior (GAO 2009). Several villages have voted to relocate; some decades ago, but little progress has been made due to high-level institutional barriers and the novelty of the hazard and its cross-scale linkages (Marino 2012; Bronen & Chapin 2013). Residents of some of these villages face imminent loss of the current site and its infrastructures, which will have devastating effects on economic, social and cultural resources. Their situation is worsened by the legacies of 20th century settlement policies that have eroded community resilience.

Collapse and renewal

The residents of the Alaska villages of Newtok, Shishmaref and Kivalina are set to become climate refugees. Historically the ancestors of these villagers moved seasonally between summer and winter homes to procure the subsistence resources available in the areas. This ended with policies that mandated permanent settlement in barge-accessible locations chosen by the federal government and enforced through mandatory schooling laws; manufacturing systemic vulnerabilities and a reliance on government to provide services and to respond to environmental changes. Over the past two decades all three communities have voted to relocate at various times, but there is no federal agency set up to coordinate the process.

Eicken and Lovecraft (2011), Bronen and Chapin (2013) and Marino (2012; 2015) provide extensive analysis of the institutional processes that prevent response to the climate-induced disaster faced by many Alaska coastal communities. A major barrier to federal assistance is the statutory limitations of the Stafford Act in declaring erosion-induced hazards a disaster. With the legal obstacles hampering financial support and attribution of responsibility absent, there is no clear *cohesive leadership* in charge of the problem. The diffusion of liability across scales of local-global social-ecological processes hampers mitigation and prevents *reduction of fault cascade*.

The State of Alaska has created a Climate Change Impact Mitigation Program, and while it funds the planning stages of relocation it does not provide institutional or financial assistance with the implementation of the plan. *Maintaining vital functions* at this point only increases sunk-cost effects of delayed relocation, complicating the cost-benefit calculus on the upkeep of current infrastructure. Village access to resources has been hampered by new norms and rules superimposed over traditional practices, decreasing the availability of, and access to, *stored capital*. However, the tradition of subsistence harvest-sharing and tightly connected households has aided resilience (Burnsilver et al. 2016) creating an effective *modularity* of vital nodes and risk-sharing. While outside help is slow to materialize, traditional knowledge and a strong culture of self-determination contribute to *self-organization* and increasing political will. Newtok's progress is a good example via a boundary organization of federal, state, and tribal governmental and nongovernmental entities that formed, following initiative taken by the village to relocate on their own. This planning group operates without legal statutes or regulations in an intergovernmental learning process built on fund-sharing and pinning down emergent roles of each agency.

Growth and elusive stability

The large number of stakeholders impacted by climate change globally should in turn result in a pooling of resources to mitigate it; but the impetus to do so is disincentivized by the inequity of impacts and diffusion of liabilities—creating *negative feedbacks*. *Small-scale disturbances* such as malfunctioning water infrastructure of rural Alaska villages further try the limits of adaptive capacity. However, the social ties that form around the distributing of subsistence foods, and the networks that support sharing, act as a *buffer* that increases the resilience of these communities (Kofinas et al, 2010; Haley and Magdanz 2008). Cumulative impacts from resource development and climate change do affect the availability of, access to, and utility of subsistence resources. Local-scale policies and actions therefore become valuable allies in supporting subsistence: While they cannot counter the potential impacts of global risks, it is the availability of local capital in support of adaptive capacity that most immediately impacts the adoption of actionable strategies (Kofinas et al. 2013).

Perhaps unsurprisingly, ‘fate control’ has been found to be the single most important index of human well-being in Arctic communities (Larsen et al. 2010). Increased political prominence increases fate control, and *positive feedbacks* in the political landscape have, in the past, leveraged power such as that following the discovery of oil and the 1971 Alaska Native Claim Settlement Act. While *emergent leadership* in the post-1971 tribal governance era increased the number of organized interests, obstacles to fate control still occur in mismatch of resource policy and resource system parameters, and in legal frameworks that do not incorporate indigenous knowledge in hazard management. Arguably, the inequitable distribution of risks from climate change plaguing these communities signals a new wave of post-colonialism: to date, there exists no global liability and compensatory platform for climate impacts. The Warsaw Loss and Damage Mechanism (UNFCCC 2013) is a new, international, mostly technical and diplomatic forum set up for limited assistance of developing countries. Alaska villages, however closely they may resemble villages in developing countries (AFN 2012), do not meet this criterion.

The risk attribution framework (Huggel et al. 2013, 2015) shows promise in establishing liability and compensation based on dynamic analyses of risks over time and space. Large-scale science and local, indigenous knowledge can, and should, partner on this issue and enhance *bilateral information flows* on risks and impacts. Coastal communities have shown great *adaptive capacity* over the years, but cross-scale interactions with state and federal systems of governance have created vulnerabilities, the magnitude of which are not currently reflected in current disaster legislation.

The learning model: disordered chronotope

Climate change drivers scale far and wide both spatially and temporally, fracturing the chronotope between cause and effect, agents of change, and consumers of the impacts. This creates a mismatch between management and problem scale across levels of jurisdictions. We at once benefit from the compression of space-time (Harvey 1989, 260), thanks to, for example, modern communication methods; and are paralyzed by its systemic vulnerabilities for which our institutions cannot facilitate solutions. Assumptions of space and time behind questions to ask, areas to investigate, and explanations to formulate no longer scale across the panarchy. This chasm in the reciprocity of levels of social and ecological components hampers learning. Local disasters need global solutions, while a global solution is hostage to divergent local interests. The legacy of past gains is set to drive the losses of the future, threatening the social-ecological system with dissolution.

Slow-moving disasters leave a window of opportunity to prepare, strategize and mitigate but at the same time may create the perception of lack of urgency. It can be difficult to identify the critical threshold between crisis and disaster and to invoke pertinent legislation and response. Revolt may scale awareness of collapse upward in the panarchy, but adapting to impacts is often more feasible than achieving political and technical solution to source of problems. For local risk sources, lasting solutions are possible under learning-based, adaptive institutions. Transformative change is possible if political and economic interests align due to post-disaster pressures (forward-looking risk calculation and development: how to increase resilience), and if preparedness drills are built on **what could happen** as opposed to what can be handled with current capacity. Science is essential in connecting risks across scales of jurisdictions.

3.5 Summary findings

There are tradeoffs between taking the time to deliberate on what steps to take and having to act immediately using already available tools and techniques (Birkland 2006). Dekker and Hansen (2004) explain how public scrutiny may help or inhibit organizational learning in the public sector, noting that "public bureaucracies are challenged by an arduous paradox: the need for learning is regarded highest under circumstances in which it is most difficult to achieve" (211). In other words, a focusing event in which political scrutiny is brought to bear on organizational performance can present opportunities for learning and change as well as threaten the capacity of an organization to change. Real change in these types of situations occurs through a re-questioning of the values and beliefs that led to the failure of the system in the first place, followed by an adapted set of criteria to assess organizational activities —a type of double-loop learning. Such internal reflection is difficult and risky as it threatens power structures: deep reflective learning is threatened by after-the-event evaluation activities that may be loaded with political conflict over location of blame and agency responsibility; myriad turf battles among administrators, political officials, and policy communities; or even confusion as to what sorts of goals an agency really promotes. For example, the paralysis of government in the aftermath of hurricane Katrina demonstrated how “seeking culprits makes bad politics” and political scrutiny never came to bear on the underlying causes of the disaster, such as crumbling infrastructure and lack of social protections for the poor (Young 2006, 41).

Focusing events can create the required political capacity to act, but usually too late. This is where boundary and bridging organizations can be helpful to promote change where traditional processes have failed. Functionally, these types of organizations play an important system role because they serve as a conduit for established organizations and institutions to re-negotiate and align their end goals collaboratively. This creates an adaptive learning environment and double-loop learning that can help avoid system collapse, creating an alternative path from the growth to the renewal phase of the adaptive cycle without having to pass through a full release. We see this occurring in the relocation efforts of the Newtok Planning Group in Alaska.

The global community of nation states is collectively rich in resources to manage disasters. Total climate and ecosystem regime shifts provide impetus for mass collaboration, however for now, the most severely impacted populations, in terms of demographic scale, are small. This, in addition to (1) cultural differences, (2) competing economic interests, and (3) scale and level assumptions hamper response. Traditional transnational politics alone cannot yield the antidote to modern global risks. Strategic global capital and a global civil society are also needed to transcend uncertainty and conflict (Beck 2005). Participatory risk assessment, risk attribution science, and scenarios planning are promising tools to assist with futures planning (Blair 2017).

4. CONCLUSIONS

Disaster governance and relevant research work at different scales. Researchers often study regional and global biophysical processes while their results are applied at much lower (national and below) scales of policy. Climate change and seismic processes are examples where there is a scale mismatch between what is known and what is being managed. There is also a plurality of scale-related interests (Cash et al. 2006). For example, in the realm of climate change policy the foci at local levels may be on sea ice process changes and related hazards, while on the global levels there is greater emphasis on armed conflict, mass migration, economic development and food security. Identifying shared meanings over risks that threaten community sustainability at multiple levels; and finding overlapping interests between scales of governance are crucial to global sustainability. Such is the case in northern Alaska, where food security concerns at the global level are leveraged to build knowledge on physical processes impacting local level subsistence practices.

This mismatch of scale can occur on a temporal scale as well, as can be seen in the oil spill example, where the disaster impacts long outlived political election cycles and any policy change that followed. This was a disaster that collapsed the slow-moving ecological system whose transition to growth and stability has been arduous. Twenty-five years of research since Exxon Valdez has illuminated the long-term effects and chronic damage of the spill (Esler et al. 2015) despite extensive institutional and policy change and rehabilitation efforts.

While complex problems, surprises and crises test the thresholds and adaptive capacity of a system, they can also provide the potential for creativity and learning (Gunderson 2003). This learning can take on a variety of forms. Our case studies show that with rapid onset disasters there is a tendency for single-loop learning that can drive quick action by accessing established methods and tools without qualitatively increasing adaptive capacity, especially in cases where recovery happens quickly. There is, however, a greater likelihood of reevaluation of assumptions and norms in disasters with long-lasting impacts. The role of the Newtok Planning Group in responding to local impacts of climate change, illustrates how extraordinary-term impact disasters can promote to double-loop learning by allowing time for bridging organizations to form.

One factor that may promote constructive change following collapse is the identification of perverse subsidies that inhibit change (Holling 2003). In the US context, for example, this could mean reforming the threshold for federal disaster aid as well as the flood insurance program to incentivize safer building codes and to discourage the risky behaviors of developers and homeowners. Long term planning must aim to prepare for anything that may come via multi-scalar, competitive innovation, and adaptive management structures moving in unplanned directions (based on the evolution of perspectives, resources and needs) instead of a single pre-planned vision. To this end, all levels of the panarchy must take what Beck (2005) called the “quantum leap” towards a cosmopolitan system where a global civil society creates its sustainable futures.

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