The Disaster Chronotope: Spatial and Temporal Learning in Governance of Extreme Events[1]

Abstract: 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. Four case studies build 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.

Keywords: disasters, resilience, adaptation, adaptive cycle, learning, panarchy, climate change, chronotope

2.1 INTRODUCTION: 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

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[1]An abridged version of this dissertation chapter is published as Blair, B., Lovecraft, A. L., Hum, R. (2018) The Disaster Chronotope: Spatial and Temporal Learning in Governance of Extreme Events. *In:* Bonati. S., Calandra, L. M., and G. Forino (eds.) *New Trends for Governance of Risks and Disasters: Theory and Practice*. Routledge: Abingdon, Oxfordshire, U.K.

words, disaster governance is a social activity, a process that can facilitate learning and adaptation 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 (Fig. 2.1).

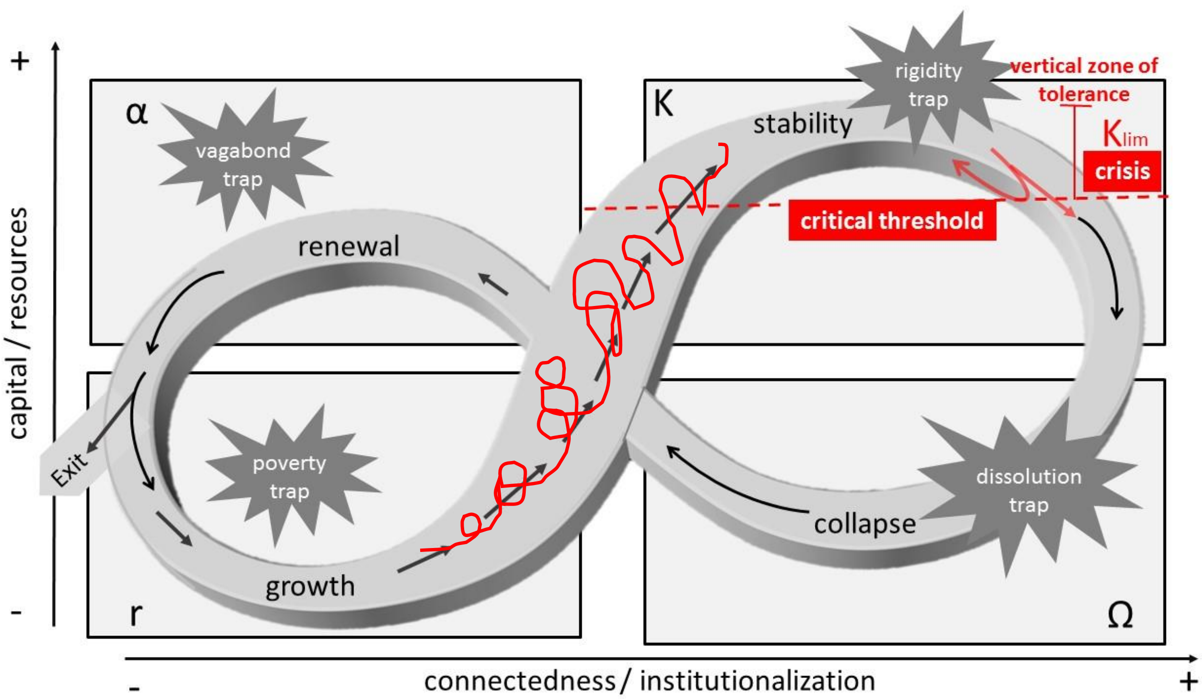

Fig 2.1 Stages and traps of the adaptive cycle. Adapted from Holling (2001) and Fath et al.(2015).

The adaptive cycle takes a long-term view of system change, focusing on stages of change cycles: growth (r), conservation or equilibrium (K), collapse and release (Ω) and reorganization (α) (Gunderson and Holling, 2002; Holling, 2001). If the reorganization stage requires such drastic changes that the system must undergo a regime shift (i.e. state change), it may exit the adaptive cycle to begin a new state governed by different underlying controls, instead of continuing on to the r-stage. From one stage to the next, the strengths and flexibility of the system changes, as does the system's resilience. The adaptive cycle is relevant to policy because knowing these properties of a system's dynamics inform decisions on when and where management interventions are needed, or what type of management might work with the feedback loops of the system. As a model of systemic change, the adaptive cycle is fundamental to this chapter (and indeed the entire dissertation) because we map risk and disaster response policy onto the adaptive cycle model, in order to understand opportunities for learning in social systems. Fath et al. (2015) build a social system model of the adaptive cycle based on a modified growth trajectory (Burkhard *et al.*, 2011) that is not monotonic (see red squiggly line Fig. 2.1), to propose a version of panarchy for social systems.[2] Here, a K_{lim} vertical range of tolerance for perturbations and crises marks a critical threshold that is not always crossed, but below which the system is propelled towards the release and renew stage.

2.1.1 Stages of the adaptive cycle and panarchy

In terms of risks and disasters, the K-stage is a time of pre-disaster stability, the Ω stage is a time of collapse following an event that overwhelms the system's coping ability, the α-stage is a time of reorganization and innovation during disaster response, and the r-stage begins growth and development, and signals the post-disaster recovery phase. It is the α-stage where resilience potentially peaks as new ideas, exploration of alternatives, and innovation may take place, setting the growth trajectory for the r-stage. The α-stage, therefore, is critical in determining whether any emergent entities and rules are institutionalized, and how much of "the old" stays in place, but even the r-K growth stage holds opportunities for small-scale experimentation and adjustments within the overall system trajectory (Fath *et al.*, 2015). Notably however, resilience decreases during this growth stage as

[2] Burkhard's model is also rotated at a 45° angle to avoid confusion via increasing abscissa values (increasing capital) in the Ω quadrat, saving this phenomenon for the reorganization phase. The reader is encouraged to explore their model; however for our purposes here the original model adequately approximates transitions between phases and this distinction is not made.

system complexity and connectivity increases, reaching its least-resilient state during collapse. The K_{lim} zone of tolerance is where crises may recur, but available plans and routines may facilitate a return to pre-crisis stability. These small-scale events are an opportunity for learning and adjusting plans and existing strategies.

There are some notable pathologies that prevent successful navigation of the full adaptive cycle. Carpenter and Brock (2008) outlined such traps, while other scholars have extended their model (e.g. Fath *et al.*, 2015). Poverty trap can occur when there is insufficient activation energy to initiate growth. Social-ecological systems exposed to frequent, recurring disasters experience poverty traps. Rigidity traps occur when a system is inflexible and stuck in status quo processes, blocking innovation and novelty. Control by corrupt political regimes and rigid class structures are examples of rigidity preventing renewal. Dissolution trap refers to inevitable collapse and entry into the omega phase, after the adaptive capacity of the system has been surpassed. Vagabond trap refers to the system's inability to enter the r-stage due to lack of resources, and underdeveloped relationships between system components preventing organized development. The capacities needed to enter and thrive in each phase of the adaptive cycle bear importance to disaster learning as detailed later.

Nested adaptive cycles form a panarchy (Fig. 2.2). Panarchy is a system model of cross-scale linkages of multiple adaptive cycles at multiple levels of organization, and thus provides a conceptualization of slow and fast changing variables of a nested system that may interact with or trigger stages of the adaptive cycle in one another (Holling 2001; Gunderson and Holling 2002). Revolt describes a feedback from the small and fast system, which has resulted from experimentation, testing and innovation that impacts the status quo of the system above. The larger, slow system, in turn, stabilizes and conserves or "remembers" accumulated knowledge of system dynamics for systems below.

Panarchy is, therefore, a useful paradigm to describe and 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 the system's capacity to adapt. We illustrate further the components of the adaptive cycle under the results section. Table 2.1 summarizes key concepts that are integral to our thesis.

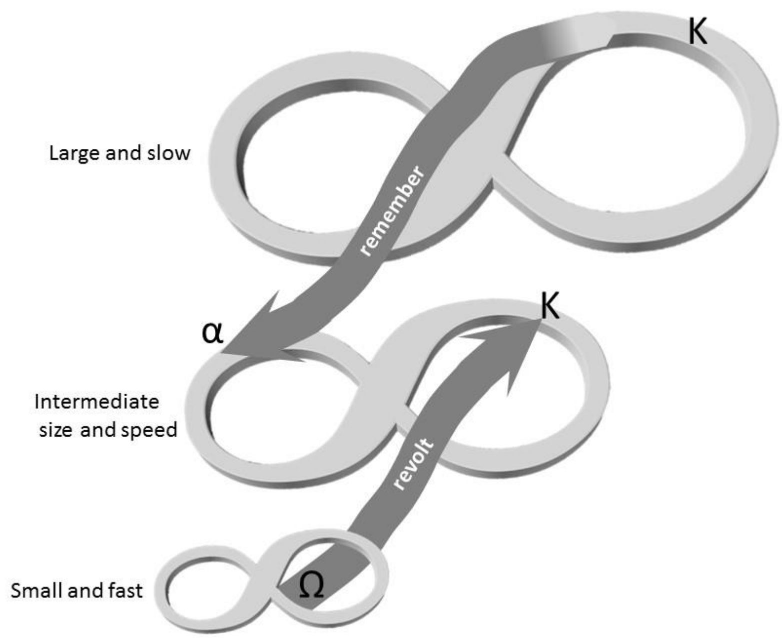

Fig. 2.2 Panarchy. Redrawn from Holling, Gunderson and Peterson (2002, p.75) (2002,

2.1.2 Learning in disaster governance

Dynes and Aguirre (1979) were among the first to question over-structured, normative crisis coordination and planning, advocating instead for organizational adaptiveness in times of crisis, and the useful role of emergent groups that operate under new norms. Dynes and Aguirre proposed that in the coordination of tasks and actors, there is a delicate balance within organizations between coordination by plan (pre-established, standardized functions) and by feedback (transmission of new information, adjustment of parts). An example of lack of balance is Marino's (2012) discussion of several rural Alaska villages in the process of a long struggle over relocation due to rapidly eroding coastlines. Her research notes that "established disaster response protocol through government agencies can be antithetical to climate change adaptation and preparation" (378). On the other hand, the greater the diversity of organizational structures, the greater the propensity to coordinate by feedback (Dynes and Aguirre, 1979). The greater the difference in power and status within the organization, the greater the emphasis on planning. Dynes and Aguirre concluded by remarking that disasters bring uncertainty, decentralization and diversity to organizations, while they also have a status-leveling effect. These factors increase communication and decrease formalizations, making coordination by feedback more likely, and leading to emergent groups operating under new norms carrying out new tasks.

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) (Fig. 2.2). The double-loop learning model is well-aligned to the adaptive cycle framework (Holling, 1986), in that each model 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. [3]

[3] In our framework we do not propose that the policy cycle, a model for diverse preconditions and factors impacting policy outcomes (May and Wildavsky, 1979) lines up with the double loop learning model, or the adaptive cycle itself. There are, however, interactions between the learning model, the adaptive cycle, and policy change resulting from disaster events, as noted throughout this chapter.

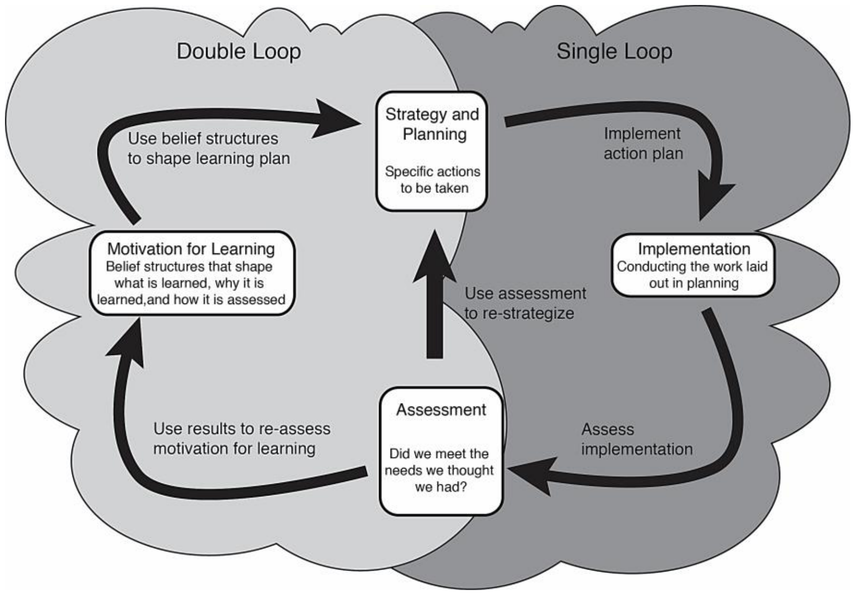

Fig 2.3 Double-loop and single-loop learning. Source: Adapted from Argyris (1976).

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 with deep refection of disaster events, responses, and recoveries are required to review and, where needed, 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 2.1 Key concepts

	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 dynamics, focusing on the states of change cycles: collapse (release), renewal (reorganization), growth (exploitation) and stability (equilibrium). The adaptive cycle 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	A social collective that exhibits adaptive capacity to apply new information through recognition of error or success to future policy decisions.	Mahler (1997); Busenberg (2001, 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 human systems (people and their relationships, institutions, actions) and natural systems (living and non-living components of the environment) that are complex and adaptive and have reciprocal feedbacks.	Berkes et al. (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)

2.2 METHODS

2.2.1 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 2.2 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. Another conceptual model, often used in ecology, frames these differences in speed of onset, and length of duration from impacts as short term “press” or long-term “pulse” (Glasby and Underwood, 1996). These models are discussed further in the results section.

As depicted in Table 2.2, *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. Consider the tragic second landslide in Badakhshan Afghanistan that was larger than the first and killed hundreds of rescue workers as they tried to dig out victims from the first slide. This is an example of a rapid onset event that is cyclical due to patterns of heavy rains; a landslide will not occur each rainy season but does occur routinely. Cyclical disaster events have a potential for cumulative impacts, 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 2.2 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*** duration of impacts considered from the perspective of social systems	**oil spill**	megatsunami	asteroid impact
	Cyclical	**typhoons**		heat waves	

2.2.2 Selection of case studies

We drew on four case studies to explore how the type of disaster affects the type of learning among key stakeholder groups. Cases include the Alaska earthquake (section 2.3.1) and the Exxon Valdez oil spill (section 2.3.2), which both have been studied extensively on long-term change and learning in the social systems. The Philippine typhoon case (section 2.3.3) was chosen to provide insights into disaster learning from a medium-income developing nation's perspective on frequent disasters that galvanize a multi-scalar response. In the coastal erosion case (section 2.3.4), we connect the slow-moving disaster potential of climate change and the global and local governance processes involved.

2.2.3 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 (Table 2.4).

2.2.4 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 *et al.*, 1997, p.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. Thus, our research approach introduces the *chronotope* (space-time) 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.

2.3 ANALYSIS OF CASE STUDIES AND RESULTS

The four case studies are presented based on the timeline of how each disaster event unfolded, and the governance of the impacts through the stages of adaptive cycle following disaster: the collapse, renewal, growth, and stability. In 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. Each case study analysis ends with a description of observed learning models. Table 2.3 is a summary overview of our findings on learning from disasters, while Table 2.4 provides further details on each case.

2.3.1 The 1964 Alaska Earthquake: Local scale, rapid onset and ordinary-term

On Friday, March 27 1964 an earthquake of magnitude 9.2 struck at the head of Prince William Sound in Alaska, the second largest earthquake 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. In this analysis, we consider the impacts ordinary-term only from the perspective of the social system. The geophysical (and some ecological) impacts from the event have had long-term impacts in the region.

2.3.1.1 Collapse

Alaska's unique geographic location with its proximity to potential enemy attacks prompted a large military presence before the disaster that turned out to be crucial in the immediate aftermath of the disaster. This presence 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*. The event itself was a major shock to the region’s SES, resulting in permanent and long-term geophysical and ecological shifts. The social system on the other hand rapidly entered the renewal phase.

2.3.1.2 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 of Alaska 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.

2.3.1.3 Growth

Despite calls for a federal flood and earthquake insurance program to systemically aid with the economic fallout of natural disasters, a comprehensive insurance program 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 in these activities 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 (i.e. rapid infrastructure repair), 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.

2.3.1.4 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 shaped building codes, warning systems, instrumentation, and public awareness, but perhaps most profoundly, these large-scale investigations grounded research for decades to come and signaled 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 and on-going monitoring through federal support.

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, a 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 across the state, as a whole, most people depend on outside (of state or community) flow of goods and services.

2.3.1.5 Learning model analysis: fixated, horizontal, single-loop

The Alaska earthquake of 1964 is an example of ways in which rapid onset events can result in greater focus on disaster relief than on mitigation, with a desire to return to pre-disaster norms (Birkland, 1997). 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. Though scientific learning was sizeable initially, investments in mitigation decreased significantly on the long run.

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 2.3 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) or "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:	**Slow**	**Case**	*Not covered in chapter*	**Coastal erosion and post-colonialism in Alaska Native villages**
		Disturbance type		Protracted press
		Cause		Continuous press from multi-scalar risk sources and social pathologies
		Effect		Continued press
		Learning model		**Disordered chronotope**
	Rapid	**Case**	**1964 Great Alaska Earthquake**	**Exxon Valdez Oil Spill**
		Disturbance type	Discrete pulse	Protracted pulse
		Cause	Short-term pulse	Short-term pulse
		Effect	Short-term pulse	Continued press
		Learning model	**Fixated, horizontal, single-loop**	**Pinball, potential double-loop**
	Cyclical	**Case**	**Typhoons in the Philippines**	
		Disturbance type	Protracted press & pulse from cumulative impacts	
		Cause	Recurring short-term pulses coupled with continuous press from social pathologies	
		Effect	Continued press	
		Learning model	**Stalled, reactive, vagabonding**	

2.3.2 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), the Exxon Valdez accident 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 the impacts of the spill remain over 25 years later. Aside from operator error, major systemic errors, such as a self-regulating industry, were identified as responsible for the accident. This event made clear not only that sweeping reforms were needed in the tanker industry, but that spill prevention and response regulations were wholly inadequate and in need of systems of accountability and citizen oversight.

2.3.2.1 Collapse

In the immediate aftermath of the disaster, there was a 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 were 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 manmade 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 devastation for the fishing communities and Alaska Native villages of Prince William Sound (AOSC, 1990).

2.3.2.2 Renewal

The media attention of the spill 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 (i.e. under-developed, unprepared nodes that were slow to mobilize) was noted as well. Emergent organizations in research, oversight, and advocacy soon developed such as the aforementioned Oil Spill Council and Regional Citizen's Advisory Council, subsequently 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, consistent with patterns of the renewal stage of the adaptive cycle.

2.3.2.3 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 returned to an equilibrium stage long ago. 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 is not adequate *buffer capacity* to prepare for another event like the Exxon spill, although changed practices by industry have resulted in some strides toward better 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. For example, the Regional Citizen's Advisory Council reviews spill prevention and response practices and policy with a strategic view of the long-term health of the Prince William Sound SES.

2.3.2.4 Learning model analysis: pinball, potential double-loop

The analysis of learning from the Exxon Valdez oil spill case supports previous theories on ways in which rapid onset events with extraordinary temporal scale impacts can create the activation energy to support pro-change groups (Birkland, 1997). The disaster as a focusing event sets the stage for learning and adaptation, but reform attempts may be stalled by special interest pushbacks, as demonstrated by the lax oversight of spill contingency that followed the Exxon disaster, and preceded the 2010 Deepwater Horizon disaster. 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.

2.3.3 Typhoons in the Philippines: Local scale, cyclical disasters

The Philippines is arguably one of the world's disaster hot spots. Seismic activities aside, typhoons 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.

2.3.3.1 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 (Fath *et al.*, 2015), inadequate leadership structures can 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.*

2.3.3.2 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 *et al.*, 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 without coordination, involving U.N., national, provincial and NGO actors. 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.

The differences between international and local planning time frames, and views on the boundaries between emergency relief and recovery, further complicate humanitarian efforts and the transition from relief to recovery in the Philippines (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* of typhoon disasters 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).

2.3.3.3 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 (Fath et al., 2015).* This could be said to be true within the Philippine disaster management structures, as proposals for policy change often lack activation energy, inhibiting *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 in the country, and provide livelihood seeding programs, education, shelter and basic needs.

2.3.3.4 Learning model analysis: 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 (Fath *et al.*, 2015). 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 Philippine local governments 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.

2.3.4 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 and Chapin, 2013). Residents of some of these villages face imminent loss of the current site and its infrastructures, which may have devastating effects on economic, social and cultural resources. The situation in these communities is worsened by the legacies of 20th century settlement policies that have decreased community resilience.

2.3.4.1 Collapse and renewal

The residents of the Alaska villages of Newtok, Shishmaref and Kivalina are likely to soon become climate refugees (Bronen and Chapin, 2013). Historically the ancestors of these villagers moved seasonally between summer and winter use areas to procure the subsistence resources available in the areas. These seasonal movements largely ended with policies that mandated permanent settlement in barge-accessible locations chosen, in many cases, by the federal government and enforced through mandatory schooling laws. The consequence resulted in new vulnerabilities and a reliance on government to provide services and to respond to environmental changes. Over the past two decades, all three communities have faced coastal erosion that threatens damage to infrastructure, and all have voted to relocate at various times. To date there is no federal agency set up to coordinate the relocation process (Bronen and Chapin, 2013).

Eicken and Lovecraft (2011), Bronen and Chapin (2013), and Marino (2012; 2015) provided 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 subsistence resources has been hampered by new norms and rules (i.e. land management and subsistence policies) superimposed over traditional practices, decreasing the availability of, and access to, *stored capital*. However, the tradition of cooperation in 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 has been 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. The Newtok 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.

2.3.4.2 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 impact. The impetus to do so, however, 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 limit adaptive capacity. However, the social ties that form around the harvesting and distribution 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 (Ashjian *et al.*, 2010). 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 to respond to relocation due to climate change, that most immediately impacts the adoption of actionable strategies (Kofinas *et al.*, 2013).

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 criteria for participation.

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 partner on this issue and enhance *bilateral information flows* on risks and impacts. Coastal communities of Alaska facing the challenges of coastal erosion and possible relocation 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.

2.3.4.3 Learning model analysis: 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, p.260), thanks to, for example, modern communication methods; and are paralyzed by 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 they may create the perception of lack of urgency. This situation can make it 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, such as a significant change in institutional arrangements, 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.

Table 2.4 Summary analysis of cases

Stages and features of preparedness needed to navigate to next stage (based on Fath et al. 2015) Parentheses indicate the stage where feature should be developed.				**Case studies:** Description of actions taken by entities from all levels including from systems above the impacted one (stages indicate the impacted system's stage). **Shaded areas signal lack of feature due to not having reached the K-(source) stage.**			
	Key feature (and source)	**Description**	**Resource examples & complementary theories**	**1964 Alaska earthquake**	**Exxon Valdez oil spill**	**Typhoons in the Philippines**	**Coastal erosion and post-colonialism in Alaska**
Ω-stage	Improvisation (α)	Suspending prescribed roles in response to immediate needs	Ability to improvise & leave old scripts behind; Solution-oriented culture[4]	Hundreds of civilian volunteers organized to help. Ad hoc group met within 24 hours to coordinate immediate public needs.	Worst-case scenario, lack of preparedness and inadequate technologies prevented novel actions.	Local risk-sharing networks; NGOs focus on citizen- based solutions & roots of vulnerability; Some provinces implement disaster-resilience	Novelty of problem and rigid legal structures hamper solution-oriented actions. Increased community vulnerability from socio-economic changes.
	Reduce fault cascade (r)	Preventing crises from spreading through early detection and organizational structure	Ability to form tight-knit communication channels and feedback loops[5]	Military, Civil Defense & Civil Air Patrol mobilized and coordinated rescue and initial recovery.	Spill prevention & response capacities were inadequate & underestimated needs.	Public disaster drills not regular; Communication of risks ineffective; Public may not understand warnings	Global processes induce fault cascade, socio-economic problems prevent response. Staying is increasingly unhealthy and risky.
	Cohesive leadership (K)	Key actors to provide financial support and help disseminate information	Ability to make fast, robust decisions[6]	Civil Defense relayed information between entities, federal government provided $350 million in aid.	Confusion over federal government's role and level of control in response efforts. No unified command system.	Hierarchical, reactive management approach on ad hoc platform without strategic framework. Large-scale impacts break leadership.	Legal obstacles hamper financial support. Legal attribution of responsibility absent, complicating matters of who should be in charge of problem.
	Maintain vital functions (Ω)	Identifying and maintaining functions essential to the continuity of minimum social utility	Ability to prioritize and protect according to vital survival functions[7]	Ad hoc group of civic & military leaders, heads of utility companies coordinated emergency needs.	Critical window of first 72 hours passed without significant containment of oil.	Large-scale impacts overwhelm response. Communication & power & transport routes are issues.	Sunk-cost effect increases with delayed relocation.

[4] Extending and emergent organizational behaviors (Dynes & Aguirre 1979); Tapping into existing social units as a resource (Dynes & Aguirre 1979)
[5] Double-loop learning (Argyris 1976); Coordination by feedback (Dynes & Aguirre 1979)
[6] Coordinate by feedback (Dynes & Aguirre 1979)
[7] Continuity, Coordination & Cooperation (Dynes & Aguirre 1979)

	Key feature (and source)	Description	Resource examples & complementary theories	1964 Alaska earthquake	Exxon Valdez oil spill	Typhoons in the Philippines	Coastal erosion and post-colonialism in Alaska
α –stage	Modularity (α)	Densely connected sets of nodes loosely connected to other subsets; distribution of tasks	High modularity of system components to prevent fault cascade[8]	National defense strategy resulted in connected, ready-to-mobilize nodes. Low population density of Alaska helped keep casualty low, prevented fault cascade	Research and expert network nodes were highly specialized, but cleanup crews and equipment were slow to mobilize	Many nodes, no clear chain of command. Relief & response structure a complex cluster of U.N., national, provincial & NGO systems that need coordinated.	Cultural practice of subsistence harvest-sharing and tightly connected households has aided resilience.
	Self-organization (r)	Capacity of system to restructure networks and develop new organizations from within	Empowerment from above to try new unconventional routes[9]	As a new state, systems were still dependent on federal support to reorganize. New networks mainly in area of research & monitoring	New entities in research & advocacy: Oil Spill Trustee Council; Regional Citizens' Advisory Council	National disaster management is highly dependent on donor and multilateral institutional assistance	Economic reliance on government increased due to forced settlement and influx of new problems. Strong will & activism for self-determination.
	Memory (Ω)	Remembering lessons of past crises and successes	Ability to analyze root causes, useful traditions and need for alternatives[10]	California quakes in decades prior, plus Alaska quake acted as focusing events for seismic risk reduction policies though resulted in inadequate changes on long run.	Past legislation found to be fragmented & inadequate; Conflicting values of oil development (jobs) vs. environmental health (renewable resources) came into spotlight	Task-focused culture at national level; NGOs more flexible to engage local populations as resource. Culture of "living with risks" and a history of "vagabond trap"	Indigenous knowledge informs community affairs. Federal Indian policy "pendulum" swings between assimilation, termination and self-determination
	Access to stored capital (K)	Access to a diverse portfolio of emergency resources and capital during and after crisis	Means & resources to carry out rapid prototyping and to set direction based on new visions[11]	Massive federal resource spent for reconstruction and development due to interest in stimulating growth in the new state.	State, federal, and settlement funds stimulated rehabilitation efforts; Political will increased for more stringent regulations in oil spill liability.	Network of local disaster coordinating councils inefficient in promoting disaster resilience. Disaster funds fraction of annual disaster costs.	Village access to resources hampered by new norms and rules superimposed over traditional practices.

[8] Coordination and cooperation (Dynes & Aguirre 1979)
[9] Coordination and cooperation (Dynes & Aguirre 1979)
[10] Panarchy's "remember" linkages (Gunderson and Holling 2002)
[11] Continuity, Coordination & Cooperation (Dynes & Aguirre 1979)

	Key feature (and source)	Description	Resource examples & complementary theories	1964 Alaska earthquake	Exxon Valdez oil spill	Typhoons in the Philippines	Coastal erosion and post-colonialism in Alaska
r-stage	Bilateral information flows (K)	Information flowing in both directions of system hierarchy	Seamless cooperation; Information can travel up the ladder quickly[12]	Good federal and state cooperation, local political representations were still underdeveloped in the new state**.**	Lack of baseline data on Prince William Sound ecosystem pre-spill hampered assessment of damages.	Static-reactive decision-making style; State still focused on returning to pre-disaster norms as the goal of recovery.	Slow to develop, tribes fought long and hard for political inclusion. Large-scale science and local, indigenous knowledge difficult to make mutually salient.
	Positive feedbacks (r)	Variable, process or signal changes reinforce further similar changes	Investments in growth and diffusion of innovation; Scalable, simple and reproducible solutions[13]	As a new & still developing state Alaska incorporated new guidelines, risk reduction strategies. Some communities relocated.	Spillover effects to other areas of policy (ANWR oil exploration forestalled).	International community trying to shift from mostly relief assistance to aiding with prevention and mitigation	Discovery of oil brought about the Alaska Native Claim Settlement Act (1971); increased political prominence
	Emergent leadership (Ω)	Emergence of new organizations and collaborations taking on crisis response tasks	Entrepreneurial leadership and activation energy to tap potential to grow[14]	Excellent crisis response coordination, followed by great growth but some underlying vulnerabilities were not addressed.	Environmental and advocacy groups gained increased prominence in policy change.	Proposals to policy change lack activation energy; Political corruption hampers long-lasting change to decrease community vulnerability	Post-1971 tribal governance increases as organized entities emerge on the state and federal political scenes.
	Adaptive capacity (α)	Recognizing opportunities to learn & adjust behavior	Trying, testing, innovating; Means to promote innovation[15]	NFIA 1968; NEHRP 1977; Investment in research & network of seismic monitoring eventually waned. Some "red" zones in Anchorage reopened for construction	1990 Oil Pollution Act; Better training of personnel; Advocacy; Settlement took 2 years to reach and 10 years to pay out to aid recovery.	Institutional inertia against increasing disaster resilience & reducing poverty; Livelihood needs continue to force people into high-risk behaviors	Village infrastructure and economy vulnerable. National disaster legislation evolves after 1950 with each disaster; but could not anticipate future needs from impacts of climate change.

[12] Double-loop learning (Argyris 1976)
[13] Coordinate by feedback (Dynes & Aguirre 1979)
[14] Poverty trap (Gunderson and Holling 2002); Extending and emergent organizational behaviors (Dynes & Aguirre 1979)
[15] Double-loop learning (Argyris 1976)

	Key feature (and source)	Description	Resource examples & complementary theories	1964 Alaska earthquake	Exxon Valdez oil spill	Typhoons in the Philippines**	Coastal erosion and post-colonialism in Alaska **
K-stage	Buffer capacity (α)	Stored capital and redundancies in the system	Building of reserves, redundancies & buffers of infrastructure, energy and information[16]	Fragile infrastructure connectivity; Reliance on "outside," though significant scientific learning occurred. Natural hazard insurance schemes are inadequate.	Still in process of recovering from 1989 spill, leaving little buffer capacity to handle another.	Underlying vulnerabilities such as poverty are not addressed or alleviated. Sectors & regions recover at different speeds & to varying degrees of vulnerability.	Villages: vulnerable State: Alaska Climate Change Impact Mitigation Program Federal government: mismatch of scale of needs & legislation; Hazard Mitigation Grant Program
	Maintain diversity (K)	Functional diversity of components and their relationships	Availability of specialists; Acceptance of diversity and ambiguity[17]	Well-developed local representation at higher levels but high cost to low population often diverts funds; still dependent on outside	Great diversity of interest groups and participants in oversight of region's resources, and monitoring of restoration.	Shift toward community-based disaster management not yet institutionalized; paradigm is still hierarchical	Risk source components scale up to and across the global community, creating a mismatch between management and problem scale when negotiating solutions.
	Small-scale disturbances (Ω)	Frequency and intensity of noncrisis disturbances	Scenarios planning to identify limits & thresholds; Infrastructure to implement crisis plans; Knowledge of best practices and standards of crisis management[14]	Despite frequent small-scale quakes the seismic network has grown little since the quake. No early warning system. Investment in technology lags behind other developed nations.	Regional Citizen's Advisory Council monitors, reviews & comments on spill prevention and response, industry practices and government policy with a strategic, long-range view of plans.	Regular disturbances occur but government efforts are saved for disaster relief instead of investment in mitigating the root causes of vulnerability.	Slow-moving biophysical processes & political disputes over science of causes, local-global linkages, and inequity of impacts prevent effective, global undertaking of mitigation.
	Negative feedbacks (r)	Structural characteristics that determine rate of growth	Lack of power struggles; Agility in communication	Geographic isolation, single-resource economy, vast land area, lack of transportation	Diverging risk perceptions & legislative needs of oil industry and locals	NGOs and state compete for funds, lacking trust toward each other; Government corruption weakens resilience; props up status quo	Global processes responsible for climate change make local impact mitigation legally difficult and costly. Socio-economic erosion of villages worsens.

[16]Adaptive Capacity (Gunderson and Holling 2002); Vulnerability (Adger 2006)
[17]Rigidity trap (Gunderson and Holling 2002)
** Because these systems never quite reached the stability of K-stage, descriptions pertain to features that weren't developed during previous stages (1st column, in parentheses). In this way this section lays out the pathologies that are evident in keeping the system "forever young" in the r-stage. Philippines: Local systems (impacted communities) and the nation state system as a whole cannot enter the K-stage due to chronic vulnerabilities and traps in the adaptive cycle. Alaska: Impacted villages are arguably were still in the r-stage of the adaptive cycle as they transitioned to the collapse stage due to coastal erosion, though the larger national system is indeed in the K-stage.

2.3.5 Discussion

The four cases of this paper show that 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 type of interaction potentially 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 results in a lack of adequate attention at the global scale, in addition to (1) cultural differences, (2) competing economic interests, and (3) scale and level assumptions that hamper response. Traditional transnational politics alone cannot yield the antidote to modern global risks, and the typhoon case study demonstrates this frequent disconnect between the realities of local disaster management and international humanitarian approaches. Strategic global capital and a global civil society are also needed to transcend uncertainty and conflict (Beck, 2005).

Disaster governance and relevant research are active at different scales. Researchers often study regional and global biophysical processes, while their results are applied at much lower (national and sub-national) levels 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 preparing for and responding to disasters of all kinds, and ultimately making progress towards 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. The Exxon spill 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 tested the adaptive capacity of these four systems, in some cases they also provided 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. This type of response can be especially true in cases where recovery happens quickly, such as in the case of the social system recovering following the Great Alaska Earthquake of 1964. 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 double-loop learning by allowing time for bridging organizations to form and act.

2.4 CONCLUSIONS

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 assumptions, 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, p.41).

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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2.6 APPENDIX

Coauthor permission

Permission from Dr. Richard Hum for inclusion of his contribution from our coauthored book chapter (Blair *et al*, in press) in this dissertation chapter.

May 30, 2017 Email communication—on file with the University of Alaska Fairbanks Graduate Office.

To whom it may concern,

As one of the co-authors of an article that Berill Blair (lead author) has extended upon and intends to include as part of her dissertation, it is my pleasure to grant permission for such.

--

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