TOWARD ARCTIC TRANSITIONS AND SUSTAINABILITY:
MODELING RISKS AND RESILIENCE ACROSS SCALES OF GOVERNANCE

By

Berill Blair, B.S., M.A.

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APPROVED:

Amy Lauren Lovecraft, Committee Co-Chair, Chair
Department of Political Science
Gary P. Kofinas, Committee Co-Chair
School of Natural Resources and Extension
Hajo Eicken, Committee Member
Sharman Haley, Committee Member
Chanda Meek, Committee Member
David Valentine, Director of Academic Programs
School of Natural Resources and Extension
Joshua Greenberg, Chair
School of Natural Resources and Extension
Michael Castellini*, Dean of the Graduate School*

Abstract

The Arctic region has been the subject of international attention in recent years. The magnitude of impacts from global climate change, land-use change, and speculations about economic development and accessible polar shipping lanes have intensified this focus. As a result, the potential to manage complex ecological, social and political relationships in the context of changes, risks and opportunities is the focus of a large and growing body of research. This dissertation contributes to the expanding scholarship on managing arctic social-ecological systems for resilience by answering the question: What conditions improve cross-scale learning and resilience in nested social-ecological systems experiencing rapid changes? Using the framework of social-ecological systems and the drivers of change that can transform fundamental relationships within, three studies profile the spatial and temporal dimensions of learning and risk perceptions that impact nested social systems. The first study presents a spatial and temporal analysis of scale- and level-specific processes that impact learning from risks. It draws on four cases to underscore the need for a plurality of risk assumptions in learning for resilience, and sums up essential resources needed to support key decision points for increasing resilience. Two additional studies present research conducted with northern Alaska communities and resource managers. In these studies, I analyzed the extent to which perceptions of risks scale horizontally (between same-level jurisdictions), and vertically (between levels in a dominant jurisdictional structure). These examples illustrate the need for innovative institutions to enhance cross-scale learning, and to balance global drivers of change with local socioeconomic, cultural, and ecological interests. Based on findings of the dissertation research I propose recommendations to optimize the tools and processes of complex decision making under uncertainty.

Table of Contents Page

List of Figures Page

List of Tables

Page

List of Appendices Page

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

This dissertation explores learning and adaptive capacity as components of risk and disaster resilience. In the chapters that follow I apply the social-ecological systems (SES) framework (Berkes *et al.*, 1998; Gunderson and Holling, 2002) to evaluate multiple case studies. The case studies consider the drivers of change that can transform fundamental relationships within systems, and profile the dimensions of uncertainty, complexity, hazards and risks that may arise with transformative change. Fundamentally, this study examines how risks and their perceptions impact social systems. This research is part of an on-going and critically important dialogue on global impacts of human activities, the intensity of which has prompted discussions about an Anthropocene—the new epoch of anthropogenic environmental change (Crutzen, 2006). If indeed we are living in such an epoch where the greatest environmental changes are induced by human activities, then by extension, human decision making plays an important role in mitigating risks. An important question to ask is: How do we create shared meanings of societal risk?

Societal thresholds for coping with 21st century global challenges such as climate change, growing energy demands, water and food security, and biodiversity loss vary greatly (Cutter *et al.*, 2008). In many localities, socio-economic pathologies combine with impacts from environmental hazards to increase vulnerabilities to disasters. Some of the most vulnerable communities live under frequently recurring, and sustained, long-term disaster processes (Gaillard *et al.*, 2007). The ability of a community to recover from disasters can be thought of as resilience. Holling's original definition (1973) describes resilience as a system's ability to absorb change while still maintaining the relationships between its components. Throughout this dissertation I use resilience to describe a system's ability to navigate through change as per Fath et al (2015). Resilience is a learning process (Folke *et al.*, 2010), a complex task of (a) profiling change processes (risks, disasters) to understand how the features of each impact capacity to prepare and respond, (b) targeting the cross-scale root causes of risks and vulnerabilities, and (c) implementing complementary knowledge-to-action models to successfully adapt to change. Learning outcomes depend greatly on how well nested social systems are able to align their goals and resources to move toward mutually agreeable futures. This dissertation is fundamentally focused on patterns of learning from risks and disasters, and SES resilience; and the types of knowledge that translate into action on the policy stage.

1.2 MAIN QUESTIONS, METHODS AND OUTLINE OF DISSERTATION

This dissertation contributes to literatures on sustainability, risks and social-ecological resilience (Beck, 1992; Cash *et al.*, 2006; Crichton, 1999; Fath *et al.*, 2015; Fischer, 1993; Gunderson and Holling, 2002; Holling, 1973; Walker *et al.*, 2004). Relying on resilience theory (Holling, 1973) as its conceptual model, this research evaluates changing resources and evolving relationships in SESs in response to risk. The sustainability of SES depends on sustaining the evolving relationships, components, and resources of nested systems (Gunderson and Holling, 2002). The resilience of SES similarly depends on successfully navigating the cycle of change that occurs in the adaptive cycle. The externalities of these changes that are unanticipated, unmanageable, or unavoidable under the worst circumstances, or manageable with careful strategies under the best of circumstances, can be thought of as risks. The extent to which risks are manageable depends on the level and type of uncertainty surrounding the risks, the resources or buffer capacity available, and agreement on priorities and desired outcomes among decision makers (Fath *et al.*, 2015). Thus, overarching research question of this dissertation is: What conditions improve cross-scale learning (adaptation, capacity-building) in nested SES experiencing rapid changes?

To address this question, I address the following sub questions:

1. What scale- and level-specific processes impact learning from risks?
2. What role does risk perception play in the adaptive capacity of social systems?
3. What recommendations can be made to stakeholder groups, based on the findings from questions #1 and #2, to optimize decision making in nested SES?

To explore these questions, this chapter introduces relevant theories and concepts behind (i) resilience science; (ii) risk and risk perception; and (iii) learning.

The dissertation is organized as three publishable stand-alone chapters that address the overarching research question. Chapter 2 is a historical, descriptive-qualitative analysis of disaster preparedness, response and recovery, seeking answers to question 1 above. Using a disciplined-configurative approach (Eckstein, 1975), and descriptive-interpretive analysis of findings (Merriam, 1998), Chapter 2 examines four disaster case studies with distinct spatial and temporal features. The chapter introduces climate change as a slow-moving disaster, and the need to reimagine social-decision processes to compensate for unpredictable futures and increased uncertainties. An important finding calls for inclusion of plurality of risk assumptions, setting the stage for the studies outlined in Chapters 3 and 4.

Chapters 3 and 4 introduce case studies of stakeholder perceptions at different scales, regarding risks, changes and complexity of SES. These chapters are based on findings from survey research, and apply mixed methods including qualitative content analysis and univariate descriptive and multivariate inferential statistics, to compare group-level risk perceptions. Chapter 3 examines the extent to which risk perceptions scale horizontally, by comparing respondent feedback from two northern Alaska boroughs. This analysis provides insight into similarly positioned social systems, in this instance two boroughs that occupy different jurisdictional units, but are on the same jurisdictional level.

Chapter 4 presents the extent to which risk perceptions scale “vertically” between dissimilar jurisdictional levels, based on interviews with two groups. North Slope tribal council members comprise one group, who represent village-level tribal governments. The other group is composed of Alaska State and US Federal employees who have professional expertise in the region's resources, and who represent state and federal levels of government. The group of state and federal employees are not residents of the North Slope region, unlike the tribal council cohort. Interviewed agency staff reside in Fairbanks and Anchorage, two of Alaska's largest urban centers. Selection of respondents from the two groups was made to observe their respective perceptions about risks to community sustainability in the North Slope region.

Chapter 5 concludes the dissertation by addressing the questions asked in this introduction, summarizing the findings of each chapter about types of conditions that improve cross-scale learning (adaptation, capacity-building) in nested SES experiencing rapid changes. In this chapter I reframe social-decision processes, considering both the process itself (how social systems conceptualize change, risk and learning), and who makes decisions (at what scale are they examining the SES). This final chapter makes recommendations about conditions that enhance learning and capacity-building in social decision processes, and ultimately impact resilience at each level of nested SES. Fig. 1.1 outlines the chapters of this dissertation and their conceptual links.

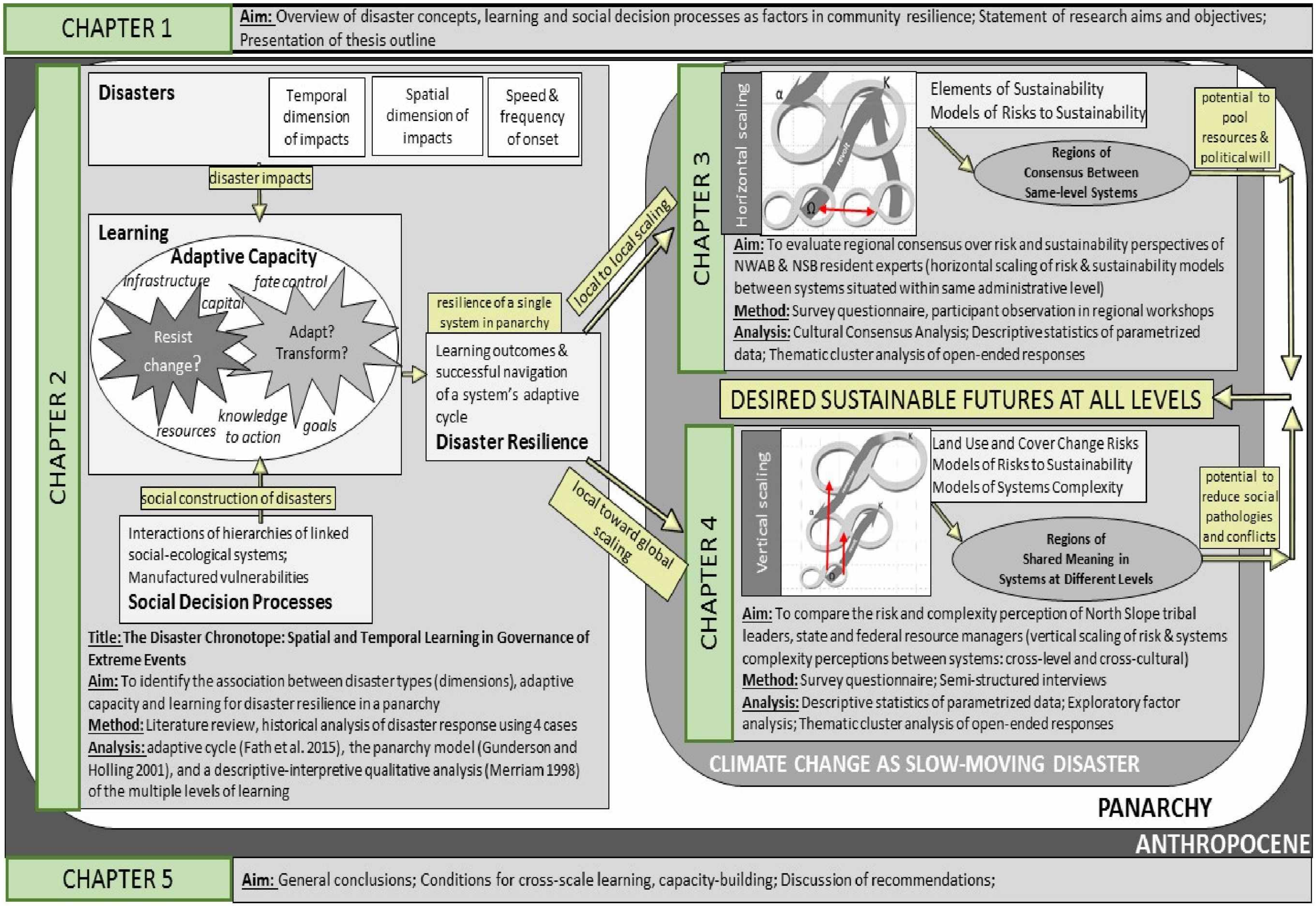

Fig. 1.1 Dissertation outline

1.3 MAIN CONCEPTS

1.3.1 Resilience science

Coupled SES are linked social systems (humans and their patterns of actions, relationships, institutions) and ecological systems (the living and non-living components of the environment) (Berkes *et al.*, 1998; Gunderson and Holling, 2002). Changes in coupled SES depend on variables that operate across a range of spatial and temporal scales (Chapin III *et al.*, 2009). Typically, ecological resilience is controlled by slow changing variables, while social resilience can be controlled by either slow or fast variables (Walker *et al.*, 2006). Because physical, social, and ecological processes are highly interconnected and driven to change constantly by both slow and fast variables, social-ecological systems have highly specialized networked sub-systems that have increased resilience to smaller shocks, but have also increased vulnerabilities to large, systemic shocks (Holling, 2001). This dynamic may mean that a source of risk that is localized to one area or region may initiate cascading events with global impacts. For example, if a region provides a specialized service on which other components of the system depend, the greater impacts can extend to other regions. The reverse of this is also true. A global scale risk, such as climate change, will impact local-level systems with varying intensity levels. Those most vulnerable will be impacted more, which brings about ethical issues that must be weighed during decision-making. Furthermore, the pace of global demographic and economic growth has also placed immense demands on ecosystem services (Hassan *et al.*, 2005), and the interaction of man-made risks that are contingent on human decisions, and so-called natural hazards such as earthquakes, have resulted in risks that are dynamic, multifaceted and scale-sensitive.

Vulnerability is the propensity of experiencing loss, or the degree to which a system is likely to experience harm due to exposure to a hazard (Turner *et al.*, 2003). Measuring vulnerability is difficult due to dynamic system states where physical and social processes interface (Adger, 2006). Because human agency is crucial to the adaptive capacity of social-ecological systems, the types of capital (natural, social, economic, infrastructure) available as a resource within the system to respond to perturbations, becomes an integral component of the resilience of communities to respond to change (Brown and Westaway, 2011; Kofinas *et al.*, 2010), and merit discussion.

Approaches to reducing vulnerability include (1) mitigation by reducing exposure to stressors; (2) sustaining natural capital and well-being in order to reduce sensitivities; and (3) increasing adaptive capacity and resilience (Turner *et al.*, 2003). Social capital and adaptive, learning-based institutions become important (Adger, 2000). Social capital can mean fate control, as in a community's capacity to make its own decisions and the resources to implement them or social learning, as in building consensus, empowering stakeholders to adapt, reducing conflicts, and increasing fairness (Lebel *et al.*, 2010). It is clear however, that adaptive capacity is crucial in reducing vulnerability, and human capital is a vital component of adaptive capacity (Turner *et al.*, 2003). Further discussion of adaptive capacity and resilience theory can be found in Chapter 2, detailing how these concepts support the chapter's methodology.

1.3.2 Risks and perceptions

1.3.2.1 Risks, hazards and disasters

Many definitions of risk exist in literature, as risk can evolve based on the scope of inquiry, be it social, economic, business, safety, military, or political risk (Kaplan and Garrick, 1981, p.11). Perhaps the most widespread conceptual model represents risk as a function of probability of occurrence times the magnitude of impact (e.g. Van Ryzin, 1980). A related model, the risk triangle, operationalizes probability of occurrence and magnitude of impact as the intersection of exposure, hazard and vulnerability (Crichton, 1999). Hancock and Holt (2003) note that risks can be typed as deterministic, statistical, uncertain, and emergent, based on the level of uncertainty about probability and outcomes (Kämpf and Haley, 2014, p.151). As the literature has expanded and grown beyond exclusively quantitative, technical formulas, risk has been acknowledged as a both analytic and perception-based normative concept. (Beck, 1992; Haimes, 2009; Klinke and Renn, 2002).

The United Nations defines disaster as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UNISDR, 2007). Hazard may refer to potential effects from natural (e.g. geophysical) or technological (man-made), or quasi-natural (interaction of both) processes, signaling a potential threat to humans and their welfare (Smith, 2013, p.11). Some definitions of hazard build on this concept, but clearly distinguish it from risk based on whether or not vulnerable system elements are exposed to the potential adverse effects: If vulnerable elements of the system are not yet exposed to potential harmful effects, we speak of a hazard. Risk, on the other hand, is an event, process or state, in which vulnerable elements of a system are exposed to hazard (e.g. Crichton, 1999).

1.3.2.2 Risk perception's role in risk management

Risk assessment is essential to risk management because only acknowledged risks can be eliminated, managed or compensated (Beck, 1992). Risk assessment techniques based on arithmetic calculations such as the statistical probability simulation model Monte Carlo, risk-ranking methods, and dose-response models provide technical analyses of risks (Burgman, 2005). Numerical risk assessments, however, cannot rule out uncertainty or bias because their underlying assumptions and models include pre-existing uncertainties and are bound and structured by what the analyst finds important (Burgman, 2005). Risk management practices tend to follow an expert science-based regulatory model, deficient in the deliberative processes that are now embedded in academic literature (Petts and Brooks, 2006). The governance of modern risks, however, requires dynamic, learning-based, and scale-sensitive institutions (Adger, 2000; Blair *et al.*, 2014). Exactly what such risk governing institutions should look like is unclear, and complicated by the nested layers of jurisdiction that characterize social systems. For this reason, the “fit” of institutions with the SES they are meant to govern is subject to much scrutiny, as policies are subject to election cycles and tend to prioritize short term problems and planning, while risks, hazards and vulnerabilities demand long term planning (Cash *et al.*, 2006; Galaz *et al.*, 2008).

The quantitative (mathematical-probabilistic) and qualitative (value-based, descriptive) approaches to risk and policymaking have resulted in distinct approaches to risk calculus (e.g. Kahneman and Tversky, 1979; Sjöberg, 2000). Purely quantitative calculations are not adequate in instances when risks become a policy matter, such as having to decide whether to employ risky technologies or not (Bennett *et al.*, 2009; Gooch, 2007; Nelson *et al.*, 2009; Raudsepp-Hearne *et al.*, 2010). In cases of divergence in epistemic perspectives during risk assessment, such as when Western science and other ways of knowing become complementary pillars in advising policy, there is a need for pluralism of values and knowledge systems (Barnhardt and Kawagley, 2005; Eicken *et al.*, 2009; Heazle, 2004; Mercer *et al.*, 2009).

An optimal design for risk assessment combines the technical and social dimensions, and involves stakeholders and experts in an iterative process (Burgman, 2005). Social scientists have undertaken the task of risk perception research, identifying the drivers behind variances in risk perception among individuals and across groups of people, because it may change the way we make decisions and we communicate risks (Douglas and Wildavsky, 1983; Fischhoff *et al.*, 1978).

Risk perception research has greatly evolved over the years and can provide a complementary social component to risk assessment. Efforts to tie theory to methodology so far have been grounded in specific disciplines, and with different units of analysis. For example, cultural risk theory (Douglas and Wildavsky, 1983) provides an anthropological perspective about the cultural processes that shape individual risk perception, while decision theory investigates risk disposition as a strategic construction of preference (e.g. Lichtenstein and Slovic, 2006). Psychometric theories focus on risks as social artifacts from feelings and affect (e.g. Slovic, 1992), while quantitative risk assessments attempt to define risks by calculating probabilities and outcomes (e.g. Van Ryzin, 1980). Decision theory evaluates individual reasoning behind choice under uncertainty (e.g. Tversky and Kahneman, 1986). Cultural Consensus Analysis (CCA) extrapolates group-level, culturally appropriate answers from individual-level data (Romney *et al.*, 1986), while the Social Amplification of Risk Framework (Kasperson *et al.*, 1988) provides a transdisciplinary conceptual model that explores the interplay between cultural, cognitive, and social processes in risk amplification and attenuation. However, the latter is not a method of risk perception measure. Rather it is a qualitative narrative of processes. Table 1.1 lists these theories, methods and their potential utility in considering systemic adaptive capacity.[1]

There are times when official risk warnings are attenuated within local cultural contexts (Gjernes, 2008). Kahan (2012) suggested that official framing of information and policies must bear a plurality of meanings that can be simultaneously endorsed by opposing cultural groups, a strategy for generating positive-sum solutions for cultural conflicts. Marris *et al.* (1998) warned that risk perception studies tend to focus too much on aggregate public risk definitions, and not enough on differences between individuals and groups within their specific social contexts. Cultural consensus analysis may assist in such endeavor because it conceptualizes idiosyncratic versus cultural variances (Romney *et al.*, 1986). For example, it can help identify shared cultural spaces, within which specific risk definitions exist.[2] Paton *et al.* (2008)

[1] Chapters 3 and 4 build on risk perception theories. Chapter 3 introduces a consensus-focused approach to risk perception assessment, while Chapter 4 is a mixed-method comparative analysis of between-group risk perceptions.
[2] Chapter 3 presents a case study relying on CCA, and provides further details about this method's applicability

Table 1.1 Summary of risk perception research theories, methods. The relevance of each theory to adaptation science is indicated.

Theory or Framework and Unit of Analysis	Hypothesis	Method (source)	Interaction with adaptive capacity
Cultural Theory Individual (Indirect group-level analysis of processes is possible with careful individual-level analysis)	Patterns of social relations drive risk perception.	Quantitative survey, four scales of cultural bias as per Douglas (Dake, 1991; Wildavsky and Dake, 1990)	CT informs adaptation research about individual biases towards risks as formed by adherence to social rules and relationships. *Example:* Individuals may be more or less likely to comply with official emergency preparedness bulletins based on hierarchical vs. individualist views.
Cultural Theory: Cultural Cognition Individual (Indirect group-level analysis of processes is possible with careful individual-level analysis)	The degree of attachment to patterns of social relations will impact risk perception.	Quantitative survey, spectral positioning on two continuous scales: hierarchy-egalitarianism and individualism-communitarianism (Kahan *et al.*, 2007)	CC informs adaptation research about individual biases towards risks as formed by adherence to social rules and relationships. *Example:* Individuals may be more or less likely to change habits, or to adopt risk mitigation measures based on whether they place as egalitarian individualists or hierarchical communitarianists.
Psychometric Social artifact (risk)	Risk exists only in cognitive and cultural spaces; it is a lack of knowledge such as uncertainty about probabilities; descriptive cognitive attributes of risk give reliable predictors of risk perception.	Quantitative survey; respondents rate risk sources, followed by data analysis across risk sources along nine attributes of risk: voluntariness, immediacy of effect, knowledge of risk, controllability, new, chronic/catastrophic, dread, severity of consequences to see which drives variance in risk perception of each hazard source. (Fischhoff *et al.*, 1978)	Psychometric research may inform adaptation studies and decision makers in particular about what drives some risks to the forefront of public interest, while others are ignored. *Example:* Public might rate a specific risk source as unacceptable due to high level of dread despite the low probability of occurrence. These risks require special treatment for increased public input during decision making.
Extended Psychometric Model: Tampering with Nature Social artifact (risk)	Risk exists in cognitive and cultural spaces; interest in risk is a predictor of demand for mitigation; risk perception should not be analyzed only with reference to negative feelings; tampering with nature as a factor of risk perception has greatest explanatory power.	Quantitative survey; respondents rate risk sources, followed by data analysis of individual responses along four factors (tampering with nature, dread, new, disaster) (Sjöberg, 2000)	Tampering with nature may inform adaptation studies and decision makers in particular about what attitudes and moral perspectives drive some risks to the forefront of public interest, while others are ignored. *Example:* Some groups might rate a specific risk source as unacceptable due to low interest in technology involved, or fear of immoral or "Franken" technology. These risks require special treatment for increased public input, consensus building during decision-making.
Social Amplification of Risk Framework Social interactions: The social processes that influence the passing / communications of risk issues.	Psychological, sociological and cultural processes together shape public response to hazards; public risk concerns may intensify or diminish through these processes.	Qualitative, interdisciplinary analysis of social processes rooted in communications theory (Kasperson *et al.*, 1988)	SARF may aid adaptation research by revealing ways in which risk communication at various levels of social organization impact public risk perception.
Decision Theory Individual	Individuals tend to act based upon self-interest, and guided by heuristics to simplify complex judgments; choices under both risk and benefit are governed by strategic decision making techniques.	Quantitative; expected utility theory; contingent valuation; prospect theory (e.g. Tversky and Kahneman, 1986)	Decision theory may aid adaptation research by revealing emergent risk attitudes / behaviors under changing conditions (economic, environmental, social etc.) *Example:* Game theory exercises help reveal coping mechanisms that may be employed by groups in dealing with the effects of a changing climate.
Cultural Consensus Analysis Group	Culturally appropriate answers as well as individual cultural competency can be extrapolated from individual-level data.	Quantitative; mathematical calculations from patterns in data. Individual responses are weighted based on competence, factor analysis to find cultural meaning at the aggregate level. (Romney *et al.*, 1986)	CCA may aid adaptation research by surveying group-level meanings of goals, values, risks or coping strategies. *Example:* CCA can give answers to questions such as what risks does a group find of utmost priority?

demonstrated that in terms of policy outcomes, risk perception is influential in managing risks, but posit that it is the quality of relationships and communication, and the levels of trust between people, communities and civic agencies that most strongly shape whether the public are receptive to hazard education. The flow of information and shared risk perceptions are closely examined via Arctic community case studies in Chapters 3 and 4. This research is done to evaluate the extent to which perceptions of risks scale between and among communities of people and agencies, in fast changing SES.

1.3.2.3 Learning as adaptation

A fundamental premise of this dissertation is that learning from risks and disasters is crucial to resilience (e.g. Folke *et al.*, 2002; O'Brien *et al.*, 2010). This seemingly simple premise however raises the question of what do we mean by learning?

The literature on learning is vast, but in many cases is vague in specifying who learns (May, 1992). Parson and Clark (1995) provide a robust theoretical overview of learning in the context of sustainable development. Their account is relevant to this dissertation because resilience shares with sustainable development many of the same attributes, challenges, and resources brought about by the complexities in the interactions between the natural and social systems. The authors note that social learning scholarship has no common theoretical perspective, rather its contributions are interdisciplinary and grounded in diverse definitions and approaches. The concept of social learning has roots in theories of individual learning as well as organizational learning. The authors also discussed scientific learning and political learning as two special cases in social aggregate (or organizational) learning. Within individual learning, social learning refers to an actor's learning in social settings shaped by social determinants. Some examples are cognitive dissonance theory, rational-actor models and their variants such as bounded-rationality , and cognitive science, all of which model individual learning from their respective approach (Parson and Clark, 1995). Some important lessons from these streams of scholarship come from observations on failure to learn processes and organizational routines under uncertainty (Table 1.2).

Learning in science focuses on collective learning to generate and establish truth via scientific inquiry, including extent to which social factors and political agendas may or may not permeate scientific lines of inquiry (Kuhn, 1970). A related type of social learning involves policy-making, where decision-makers rely on scientific findings to inform and arrive at a decision. Parson and Clark (1995) conclude their overview by identifying five groups of learners in sustainable development: i) decision-makers, ii) scientific communities, iii) industrial organizations, iv) NGOs, and v) citizenry. As to the question of what is learned, they caution that things learned move differently through the different groups, but state that in general, learning results in scientific models, policy theories, technologies, norms, preferences, and broad worldviews.

Table 1.2 Theories, models, approaches and focal questions in social learning (based on Parson and Clark 1995)

Individual learning theories and their focal questions	**Organizational learning theories** and example works
Social learning theory: the psychology of individual learning What are the social determinants of individual learning? (Bandura, 1969)	**Social learning theory: the sociology of shared learning** Organizations can and do learn by observing others. Such learning can be incremental (Argyris and Schön, 1978) or radical (Duchesneau *et al.*, 1979).
Cognitive science: What type of mental phenomena and modes of representation impact information processing in individuals? (Piaget, 1977)	**Decomposition**: group learning as the sum of its members. Complete learning cycle (March et al., 1976) accounts for incomplete learning via (1) role-constrained learning, (2) audience learning, (3) superstitious learning, (4) learning under ambiguity
Cognitive dissonance theory: How do tensions among cognitions or between cognition and behavior bring about changes in attitude and belief? (Festinger, 1962) **Bounded rationality models:** To what extent is it possible for individuals to fully account for and calculate all information and their constraints as they search for alternatives, make decisions, learn? (Simon, 1972)	**Analogy:** learning as autonomous, group-level processes Study of routines and procedures (Levitt and March, 1988) show that organizational routines are chosen based on legitimacy (as opposed to outcome calculations), actions are determined by past outcomes and adjusted incrementally, and are oriented to targets with learning typically coming into play due to shortfall or scarcity as opposed to success. **Behaviorist model**: successful routines will be repeated (Cyert and March, 1963)

Policy learning, in particular, is relevant to this dissertation because it is through the engagement of public and private stakeholder groups that diverse experiences, knowledge systems, assumptions and expectations can become legitimized or not. Policy scholars have long described learning based on patterns of change in policies: During times of stability, incrementalism (Lindblom, 1959), or small incremental trial-and-error style changes to existing policies is the dominant paradigm alternating with punctuated equilibrium or radical shifts following times of rapid changes (Baumgartner and Jones, 1993). The multiple streams theory recognizes that policy windows may open when problems, policies and politics converge, allowing room for reform if policy entrepreneurs seize the moment following a focusing event that captures the public's attention (Kingdon, 1984). Disasters have such an agenda-setting potential when, immediately following a disaster, the public and elected officials briefly show an increased interest in disaster preparedness, mitigation and response, but attention to this problem can quickly fade (Birkland, 1997). Policy networks and policy communities can be crucial in this process. Policy networks are essentially relationships that reflect the power of particular interests in a policy area and their potential to influence policy outcomes, whereas policy communities are a special type of policy network that are insulated from other networks and coalesce around a specific function of government (Rhodes, 1990, p.304). Through policy networks, local issues can jump scale to engage stakeholders beyond their formal political platforms, creating new networks of knowledge (Rhodes, 1990). Table 1.3 summarizes the leading streams of literature on policy learning, the actors involved and the type of learning that may result.

Streeck and Thelen's (2005, p.9) typology of institutional change juxtaposes the process of change (incremental or abrupt) with the result of change (continuity or discontinuity) to identify four types of institutional change. Of the four, they emphasize the role of so-called gradual transformation or incremental, creeping change that results in institutional discontinuity to be most influential in modern-day capitalist regimes. This gradual transformation may happen via one of five change processes:

displacement, layering, drift, conversion, and exhaustion. Their theory has been influential in institutional and policy analysis because of the underlying framework pairing changes and impacts.

Table 1.3 Types of policy learning. Source: adapted from Birkland (2006) with additions based on Trein *et al.*(2015)

<table>
<tr><th>Learning Type</th><th>Who learns</th><th>Learns What</th><th>Learns Why</th><th>To what effect</th><th>Important Parallel Research Streams:</th></tr>
<tr><td>Government learning</td><td>State officials</td><td>Process related</td><td>Improve organizational behavior</td><td>Organizational change (Etheredge, 1981)</td><td rowspan="4">Policy diffusion:
focus on agent interaction: coercion, competition, learning and emulation

Policy transfer:
focus on process of transfer, such as agents involved and obstacles to learning; (Dolowitz and Marsh, 2000; Rose, 1993)</td></tr>
<tr><td>Lesson drawing or instrumental policy learning</td><td>Policy networks</td><td>Instruments, means</td><td>Adopt new instruments, improve conditions</td><td>Program change (Heclo, 1974; Rose, 1993)</td></tr>
<tr><td>Social learning-type of policy learning</td><td>Policy communities</td><td>Ideas, goals (Sabatier,1988)</td><td>Solve issues, gain knowledge</td><td>Paradigm shift, policy change (Hall, 1993; Heclo, 1974)</td></tr>
<tr><td>Political learning</td><td>Political actors</td><td>Strategies</td><td>Maintain power, maximize legitimacy (Boswell, 2009)</td><td>Improved arguments for particular policies (May, 1992)</td></tr>
</table>

We expect to find increased innovation and investments in disaster avoidance in the case of slow-onset disasters due to the increased warning and window of opportunity to mitigate impacts, and greater emphasis on disaster relief in the case of rapid-onset events. We also expect to see variations in the extent and diffusion of learning patterns as mediated by the spatial scale of impacts: the smaller the community of impacted victims, the less likely that learning is large-scale and transformative. However, we expect other factors, such as the temporal scale of impacts, to also be influential, such as long-term impacts to catalyze change and learning. Furthermore, political hindrances to learning are expected to be present. For example, political demagoguery can be an effective vehicle for manufacturing uncertainties around science-based issues such as climate change (e.g. Nisbet, 2009). These hindrances present challenges to collective action and the overall resilience of social systems, as detailed in Chapter 2.

The resilience and adaptation framework is one starting point to understand changes in complex systems resulting from endogenous and exogenous drivers of change (Gunderson and Holling, 2002). The dynamic systemic evolution underlying adaptation in social systems can itself be taken to imply a type of social learning (Fazey *et al.*, 2007). Indeed, evolutionary models originally based in biology, have been applied to learning processes at the individual and organizational levels in an effort to account for the spread pattern of knowledge and norms through society (Parson and Clark, 1995). Individual learning and adaptation is an important foundation for building institutions that promote resilience, while collective learning, innovation and expertise increase resilience by building collective social capital (Folke *et al.*, 2005). Increased collective social capital may aid adaptive management (Holling, 1978) and adaptive governance functions (Dietz *et al.*, 2003); management tools that promote integrating lessons learned with policies via continuous evaluation of policy outcomes.

Looking at learning from the perspective of adaptation is not new in managing risks and disasters. Although the genesis of centralized, national disaster management during World War II flowed from a command and control management structure—via a single authority—some questioned over-structured, normative crisis coordination and planning: Dynes and Aguirre (1979) recognized the need for organizational adaptive management in times of crisis, and the useful role of emergent groups that operate under new norms (Table 1.4). Later they expanded their model to propose that in disaster planning the goal should be (1) problem-solving rather than chaos-avoiding in other words learning vs. avoidance; (2) tapping into the problem solving capacities of existing social units as opposed to treating them as the problems themselves in crisis times; (3) following the principles of continuity as opposed to chaos. Pre-disaster functions and behaviors of social units to make decisions remain a resource post-disaster; coordination as opposed to command: loosely pre-planned structure of authority that is adaptive and open to improvisation in facilitating the multi-organizational needs of each crisis; and cooperation as opposed to control: effective reallocation of human and material resources in communities (1994).

Table 1.4 Typology of organized behavior in disasters. Adapted from Dynes and Aguirre (1979).

Organized Behavior in Disasters	*Tasks*		*Norms*	
	Regular	*Non-Regular*	*Old*	*New*
1. Established Established group carrying out regular tasks. *Example:* police force engagement at impact zone	X		X	
2. Expanding Established group whose functions are only mobilized after the event. *Example:* Red Cross shelters	X			X
3. Extending Established group undertaking non-regular tasks. *Example:* construction company assisting with debris		X	X	
4. Emergent Ad hoc groups coordinating community response activities.		X		X

This shifting trend towards new hazard, disaster and risk management strategies has brought about changing functional applications towards a focus on vulnerability, dynamic risks managed by multiple actors carrying out situation-specific functions with a moderate to long-term planning outlook taking into account diverse perspectives (Jeggle, 2001, p.335). When mixed with adaptive management (Holling, 1978) and adaptive governance functions (Dietz *et al.*, 2003), the resulting learning-based, participatory management cycle better manages under uncertainty, incorporates knowledge and is better situated to overcome inertia where procedural changes are needed (Dietz *et al.*, 2003). Traditional command-and-control resource and risk management practices show weakness in operating under complex, cross-scale dynamics (Cash *et al.*, 2006). This dissertation approaches learning from a resilience and adaptation perspective to uncover the knowledge to action processes that may lead to increased community resilience.

1.4 CONCLUSION

Surprises and crises test the thresholds and adaptive capacity of a system, while they also provide the potential for creativity and learning (Gunderson, 2003). In evaluating the social and economic processes that create risks, care must be taken to avoid trivializing underlying vulnerabilities and dependencies that create institutional inertia against change (Lavell and Maskrey, 2014). Only by more emphasis on reducing exposure and vulnerability to the economic, social and territorial processes that construct new risks in the first place, may we foster resilience. Having proposed these points as central to this research, three chapters follow that examine the processes by which dependencies form, vulnerabilities emerge, and nested SES may act to counter risks. These three studies approach learning from a resilience and adaptation perspective to uncover the knowledge to action processes that may lead to increased community resilience. The findings support the shift towards new hazard, disaster and risk management strategies. The shift toward risk management paradigms that focus on moderate to long-term planning outlook taking into account diverse perspectives provide such an opportunity (Jeggle, 2001, p.335). Adaptive management (Holling, 1978) and adaptive governance (Dietz *et al.*, 2003) built on inclusive, learning-based institutions that take into consideration a plurality of knowledge forms potentially promote resilience (Lebel *et al.*, 2006). The societal challenges examined in this dissertation and findings of the research underscore the need for such adaptive forms of governance that build on long-term, multiscale considerations of risks.

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CHAPTER 2: 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.

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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 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).

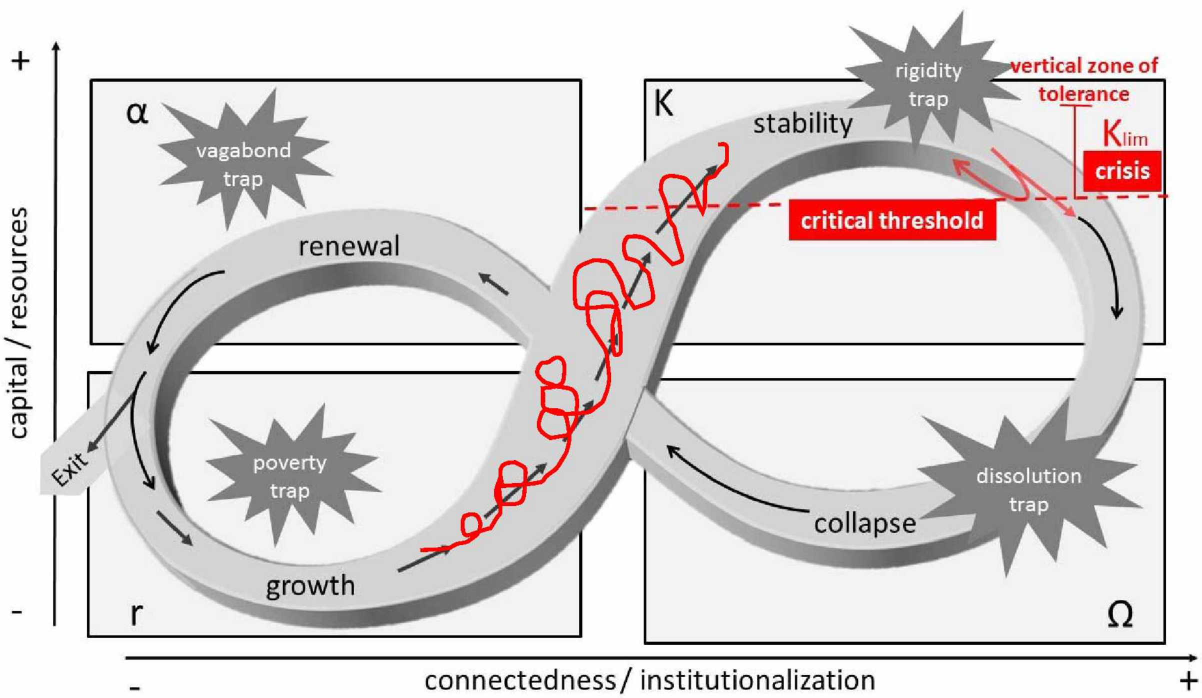

Fig 2.1 Stages and traps of the adaptive cycle. Adapted from Holling (2001) and Fath et al.(2015).

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

[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.

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 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.

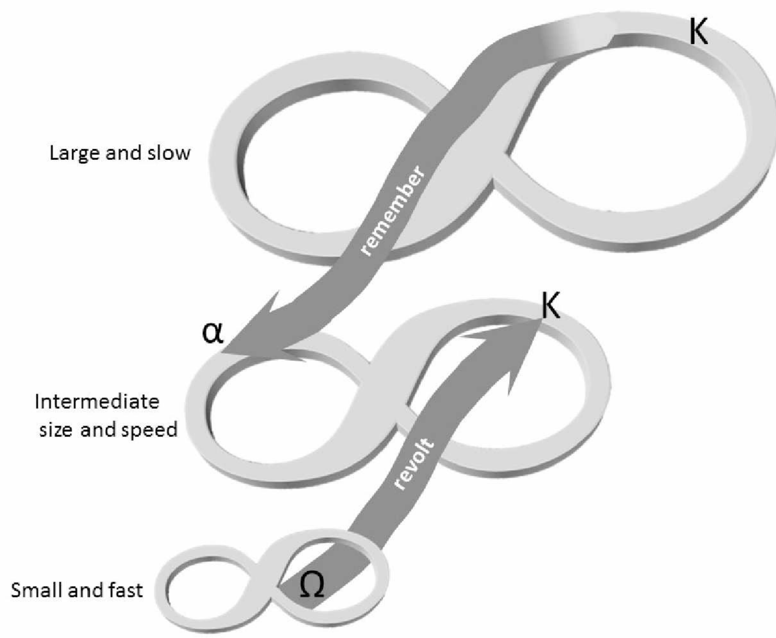

Fig. 2.2 Panarchy. Redrawn from Holling, Gunderson and Peterson (2002, p.75) (2002,

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.

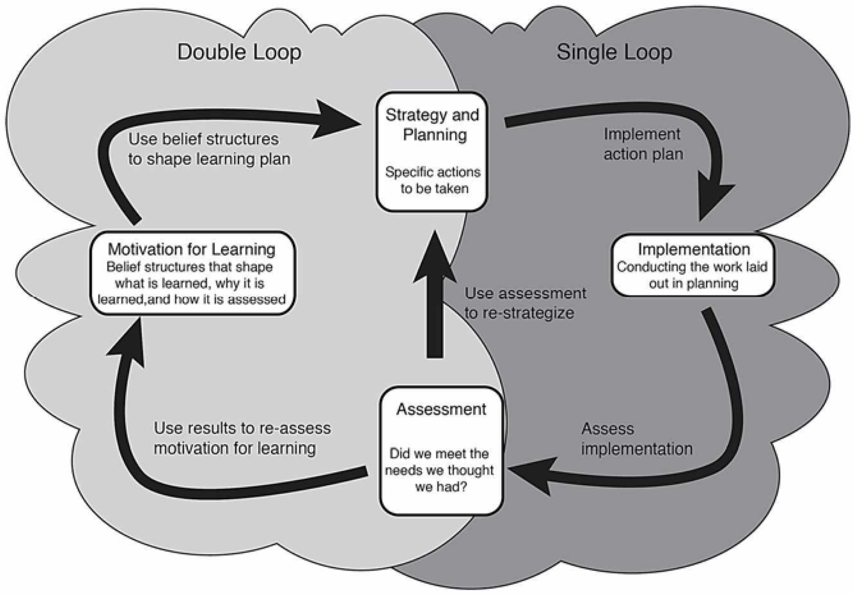

Fig 2.3 Double-loop and single-loop learning. Source: Adapted from Argyris (1976).

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:		**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**	

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.
r-stage	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
r-stage	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.
r-stage	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.

--

Dr. Richard E. Hum
Director, Alaska Native Knowledge Network
Faculty, Department of Cross-Cultural Studies
University of Alaska Fairbanks

CHAPTER 3: A HORIZONTAL SCALING OF RISK AND SUSTAINABILITY PERSPECTIVES: THE ROLE OF CONSENSUS IN ARCTIC ALASKA[1]

Abstract: This article explores the horizontal scalability of sustainability and risk perspectives across two Arctic Alaska boroughs. Its focus is a regional-scale cultural consensus analysis of risk to community sustainability. Local participants (N = 47) in a series of three community workshops provided input via a written survey. Risks to sustainability were evaluated in two phases. In the first phase, an open-ended question elicited participant feedback to establish a cultural domain of risks. Textual analysis of written responses to the questionnaire provided a set of codes, which were evaluated for common themes. In the second phase, participants rated these risk themes based on whether the items posed a risk to community sustainability, their impact, level of manageability, and historic change over time. Elements of sustainability established by previous research were ranked for relevance to current community sustainability. Results show that there is strong regional cultural consensus over what poses risks to community sustainability in the region. There is strong agreement as well on the prevailing elements of sustainability. The study describes the key drivers of change in the region's social-ecological system as understood by participants, and the role of deliberation and adaptive learning in managing risks.

Keywords: risks, Cultural Consensus Analysis, resilience, social-ecological systems, uncertainty, decision making, Arctic Alaska

[1] Blair, B. Social learning and the role of consensus in Arctic Alaska: A horizontal scaling of risk and sustainability perspectives. Prepared for submission in *Sustainability science.*

3.1 INTRODUCTION

This research builds on a series of participatory scenario workshops in northern Alaska called the Northern Alaska Scenarios Project (NASP). Residents from the North Slope Borough (NSB) and the Northwest Arctic Borough (NWAB) participated in three workshops in 2015 – 2016 to discuss the future of healthy, sustainable communities in the region. The three workshops were hosted in Utqiaġvik (formerly known as Barrow) in the NSB, in Kotzebue (NWAB), and Anchorage in southcentral Alaska. The Anchorage workshop was held outside the region of interest, as this last workshop coincided with the 2016 Alaska Forum on the Environment in Anchorage, attended by many of our workshop participants. The Alaska Forum was used as a platform to report progress on the project to the public, and finish the NASP deliberations off-site. In total, 51 participants attended at least one of our workshops to deliberate key variables for sustainable Arctic communities in Alaska. Of these 51 participants, 47 filled out our pre-workshop survey, and 34 filled out both the pre- and the post-workshop surveys.

Due to growing political and economic interest in the region and impacts of rapid climate change, it is increasingly difficult to ensure simultaneously viable, sustainable resource development and optimal environmental protection. This study followed the deliberative process of the NASP scenarios workshops to assess the scalability of definitions for community sustainability, risks and resilience across two boroughs that comprise Arctic Alaska. Though the two boroughs share a vast geographic region and social-ecological systems (SES) with many similarities, as well as a common cultural heritage, they also differ greatly in available resources, local and regional concerns and pressures from outside sources. This study considers the following two hypotheses:

> H1: NSB and NWAB participants share a cultural consensus view of risks to sustainability, as measured by Cultural Consensus Analysis (Romney et al. 1986)

H2: Participants' awareness of each other's borough-level sustainability goals, and the risks that threaten these goals will increase by participation in a workshop

3.1.1 Defining policy problems, finding common ground

There are a myriad of socio-economic conditions afflicting society at any given point in time yet few rise to the level of importance that gets governing bodies involved (Weller, 2007; Wood and Doan, 2003). Since one of the distinguishing characteristics of policy making is that it is problem-oriented (Lerner and Lasswell, 1951), it is not surprising that the process by which issues are identified as 'problems' becomes a focus of much critique and deliberation (Baber, 2004; Fischer, 1993; Lebel *et al.*, 2010). There is little disagreement that identifying and defining a problem is a highly normative activity (Harding and Figueroa, 2013; Schon and Rein, 1995; Vig and Kraft, 2012). Schon and Rein (1995) attribute its normative nature to a process that simplifies complex realities, framing information in ways that draws attention to some elements of a problem while minimizing others (Layzer, 2011). The process of who wins the battle to define what issue comes before decision makers, or who sets the agenda, bears great influence on policy outcomes. This type of influence is indirect power, as opposed to the direct power wielded by those who make the decisions. Nevertheless it is true power that drives government agenda. This underscores the importance of decision making processes, and the membership in those processes.

In a coupled social-ecological system (SES), mismanagement can occur when one SES is managed for stability at the expense of another SES. (Adger, 2000; Armitage, 2005). The devastating "Dust Bowl" drought and dust storms of the 1930s is one such example (Worster, 2004). Farmers in the Great Plains turned to deep plowing the top soil to convert the grasslands to cultivated crop land. The unanchored soil turned to dust and created devastating dust storms that travelled cross-country, impacting communities as far away as the East-Coast (Worster, 2004).

SES have unique properties and interactions that are not easily parsed for analyses. To generate robust decisions there needs to be broad citizen participation and deliberation so that policy reflects the needs and perspectives of citizens whose livelihoods are tied to the SES under analysis (Fischer, 1993). Equally importantly, deliberation requires that participants share some level of understanding of common concepts and knowledge. One implication is the increased need for more efficient and accurate risk communication (Buchecker *et al.*, 2013; Norris *et al.*, 2008). This includes creating common meanings and shared understandings, and a platform to articulate needs, views, and attitudes. This point underscores the importance of platforms that fit the social, political and cultural setting of the SES under review.

Scenario development can facilitate a decision process that engages a diverse set of stakeholders and their narratives in consideration of future outcomes (Cavana, 2010; Lindgren and Bandhold, 2009; Oteros-Rozas *et al.*, 2015; Sheppard *et al.*, 2011). Scenario development serves to help people understand the scope of all possible alternative futures, their impacts, and possible responses to changes (Duinker and Greig, 2007). Most basically, scenarios are used to talk about possible future events and risks in the present and can help identify key drivers of change to monitor, and identify important decision points for intervention.

This study describes the Northern Alaska SES as understood by local (NSB and NWAB resident) sustainability experts at our workshops. Invited participants with expertise across different sectors (education, justice, health, subsistence, youth, Iñupiaq values, and business development) deliberated healthy, sustainable communities in Arctic Alaska. This study probed the existence of a cultural consensus regarding risks among participants, and assessed the learning facilitated by the deliberative processes at the workshop.

3.2 METHODS

3.2.1 Survey instrument and analysis of data

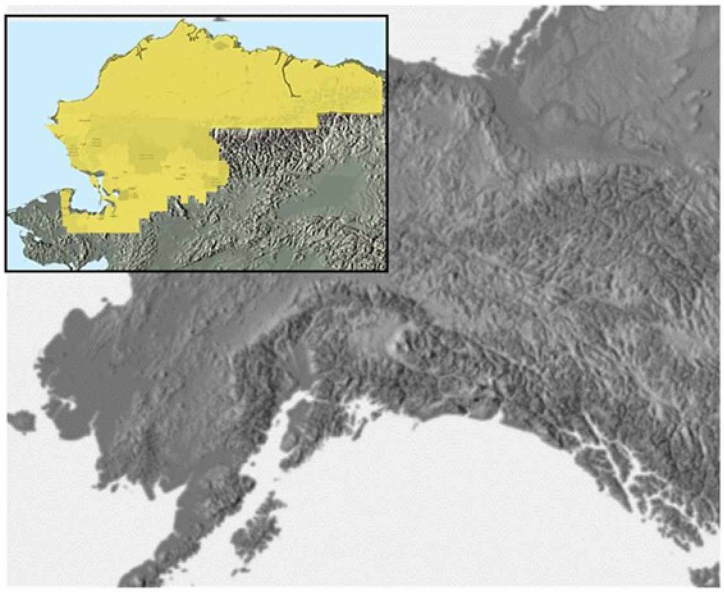

Fig. 3.1 Study area. The highlighted area (in yellow) encompasses the North Slope and Northwest Arctic Boroughs

3.2.1.1 Workshop poll

Two survey instruments collected data from workshop participants. The workshop poll (survey #1) was administered before and after each workshop to assess demographic information and participant level of knowledge about (i) risks that threaten sustainability in their own, as well as the other, borough; (ii) sustainability goals of the two boroughs; (iii) perceptions of community resilience in the region; and (iv) top five risk priorities in the region as a whole. Section iv builds on data from 47 workshop participants who took part in at least one NASP workshop, and filled out a survey before participation. Section iv asked the open-ended question, "what are the top five issues that threaten the success of healthy, sustainable communities in 2040?". This section sets up the premise for important drivers of change in Northern Alaska. Responses collected to this question at the first workshop also played a pivotal role in providing cultural domain data for the separate, Cultural Consensus Analysis (CCA) (Romney *et al.*, 1986; Weller, 2007)survey. The CCA survey was administered at the second and third workshop to a total of 28 participants. Table 3.1 presents descriptive statistical information about participants in both the workshop and CCA surveys.

Analysis of the workshop poll

Sections i-iii of the workshop poll served the basis for a within-subjects tests of knowledge before and after first participation. Of a total N = 47 who were polled, there were n = 36 participants who filled out both the before and after workshop surveys. These participants provided the data for a matched-pairs sample analysis of workshop effectiveness, based on self-evaluations of issue-awareness before and after participation.

To get a picture of the participants' understanding of important components of their SES, and key drivers of change, responses to the open-ended question (section iv) about the top five risks were analyzed using a grounded theory approach (Corbin and Strauss, 1990). In all, 47 first-time participants were polled before their first workshop. Their responses were iteratively coded in Atlas.ti (v.8.0) using a priori codes about socioeconomic and biophysical drivers of change that emerged through observations at all three workshops, and inductively coding themes that emerged from the written responses. This produced 40 codes in 7 dominant risk themes: decision making, health and health care, environmental change, cultural changes, industrial activities, education, and cost of living (Appendix 3A). Using the network view manager of Atlas.ti, the codes were modeled with their co-occurring codes and relationships to produce a heuristic model of causal and associative relationships among SES components. The final model was depicted in a stylized illustration of drivers of change in the region, as understood by participants (Fig. 3.2).

Table 3.1 Demographic information by survey instrument

		Workshop Poll N = 47			Cultural Consensus Analysis Survey N=26		
		n_{NSB}	n_{NWAB}	**% of total**	n_{NSB}	n_{NWAB}	**% of total**
Participants		23	24	100	12	14	100
Gender	Female	11	14	53	5	6	42
	Male	12	10	47	7	8	58
Age	18-29	8	5	28	5	2	27
	30-40	6	7	28	3	5	31
	41-65	9	12	44	4	7	42
*Education – TK**	Learned TK		*No data*		9	9	69
Education – Formal	Secondary with/without diploma	8	1	19	5	0	19
	Some college	5	5	22	3	1	15
	College degree	10	18	59	4	13	65
Affiliation	Tribal government	3	2	11	2	1	12
	Tribal non-profit, regional corp.	2	6	17	2	4	23
	Tribal for-profit, regional corp.	2	2	9	2	1	12
	Tribal for-profit, village corp.	7	1	17	4	0	15
	Borough	8	8	34	1	5	23
	Federal	0	1	2	0	1	4
	Private business	0	1	2	0	1	4
	Student	1	2	6	1	0	4

*TK = Traditional Knowledge

3.2.1.2 The Cultural Consensus Analysis survey

The CCA questionnaire (survey #2) followed recommendations by Weller (2007). CCA is a method for deducing culturally correct answers to questions based on informant responses. The answer key is the culture, or shared knowledge, and it is estimated mathematically from patterns in data.

The model relies on three basic steps (Dressler *et al.*, 2005):

1) CCA seeks to find cultural models or shared knowledge among groups of informants. The data analysis uses principal components analysis, with transposed data across participants as opposed to responses. Eigenvalues are evaluated to find "culturally appropriate" answers (answers that match the shared knowledge-domain of the group), determined by the presence of a single factor that explains most of the variation in their responses, with a first

to second eigenvalue ratio greater than, or equal to, 3.0.

2) CCA tests each individual informant's level of shared beliefs and perceptions via similarity coefficients to see how responses compare among each other; for example a so-called "cultural competence score" (CC score)[2] of 0.8 means the respondent has an estimated 80% command in, or knowledge of, this group-specific domain. Responses are prioritized by level of agreement, which is a mean response weighted in favor of competent participants. This helps minimize the influence of informant guesses, and enables the researcher to describe cultural spaces inhabited by respondents.

3) CCA asks what the culturally correct answers are to survey questions administered to a group, assuming "correct" to be what is most commonly held.

The CCA survey built on data collected at the first workshop (workshop poll section iv) and from literature (Carothers *et al.*, 2014). This literature served as background information in the assessment of shared perceptions related to community sustainability and risks in the Northern Alaska region. Fifteen potential risk items in total were presented to 28 participants in the CCA questionnaire, in dichotomous true / false format. Of these informants, 21 took the survey at the second (Kotzebue), and 7 at the third (Anchorage) workshop; 12 were first-time participants, and 14 were second-time participants. This list of risk items was supplemented using previous CCA research (Carothers *et al.*, 2014) of land cover changes in Northern Alaska based on observations from elders. While there are inherent limitations in the application of this list to North Slope communities due to its emphasis on riverine-based subsistence, the list is a useful basis to identify some of the land cover changes that are perceived as universally

[2] CCA uses "culture" and "cultural competence" in very context-specific ways. Culture refers to shared sets of beliefs among a group of people. Competence is the individual's level of knowledge of this group-specific domain.

problematic across the two boroughs. The true / false evaluations of these fifteen risk items comprised the CCA portion of the survey.

As part of the CCA survey instrument, but not included in consensus analysis, each risk item that was deemed “true” (the item is a risk to community sustainability), was further evaluated by informants using a three 5-point Likert-type question. These details elicited information about each risk’s impact on sustainability, level of manageability with locally available resources and direction of change over the past 20 years. If an item was not deemed a risk to sustainability, these questions were not asked.

In addition, the survey presented informants with six propositions about elements of sustainability in Arctic Alaska, based on research 20 years ago (Kruse *et al.*, 2004). While not a part of the consensus analysis, these propositions played a vital role in establishing participant perspectives about common themes on sustainability in Northern Alaska communities.

Analysis of the Cultural Consensus Analysis survey.

CCA data collected at the second and third workshop via the consensus instrument surveyed 15 men and 13 women from NSB (n = 12) and NWAB (n = 16). Two participants were not included due to too many missing responses, beyond the threshold for which the model can be corrected (Weller, 2007). This left 26 respondents (NSB = 12, NWAB = 14).

The Likert-type survey items that probed perceived risk impacts, local control, and change over time were analyzed using descriptive statistical methods. Median values, and interquartile ranges (IQR) were calculated by borough of residence for intra-region comparison (Appendix 3C). Similarly, the Likert-type propositions about elements of sustainability were evaluated using 5-point Likert-type questions, and calculated using median and IQR scores by borough (Table 3.2).

As a first step, it is important to elicit elements of a cultural domain, in order to present culturally relevant question items and relations in the CCA questionnaire (Borgatti, 1998). Participants in the first workshop in Utqiaġvik (N=29, n_{NSB} = 19, n_{NWAB} = 10) provided their perceptions of top five risks to sustainability in the region, elicited via the open-ended question (section iv) of the workshop poll. A textual analysis of written responses produced a total of 187 observations across the data set. Using MAXQDA (v.12.0) observations were sorted using textual content into several distinct risk themes. The analysis was further informed by participant observation over the course of the three-day workshop, where issues surrounding community sustainability were discussed at length. The result of the analysis yielded seven risk themes in the top five position (Table 3.3, items 9-15) based on code frequency.

Survey responses were entered into a matrix with respondent rows and proposition columns. As per Weller (2007), steps were taken to eliminate missing cells: One question item (#3, Table 3.3) was eliminated due to greater than 10% missing responses, as well as two participants who failed this criterion even after item #3 was eliminated. This left a total of 5 missing responses out of 364 (1%), which were imputed by random 1s and 0s as determined by a random integer-number generator. The match coefficient method of the formal consensus model was used (Romney *et al.*, 1986) in the Ucinet software package (Borgatti *et al.*, 2002) to assess agreement and the culturally correct answers. The match coefficient method was chosen instead of the covariance method (though either one is appropriate for dichotomous items), because the latter is sensitive to the balance of positive (true) and negative (false) items. This can lead to a failure to calculate agreement without adequate variance in responses per the 30-70 rule (Weller, 2007). The 30-70 rule warns that questionnaire items should be constructed to carefully balance the expected proportion of “true” responses. One way of achieving this is to alternate the positive and negative items to keep the proportion of positive responses between 30% and 70%, or inverting (reverse scoring) some of the responses ex post facto. The latter option, using the covariance method, gave nearly identical results to the match coefficient method during a trial run.

3.3 RESULTS

3.3.1 Social-ecological system and drivers of change: workshop poll

From the textual analysis of responses to the open-ended question "*what are the top five issues that threaten the success of healthy, sustainable communities in 2040?*" a picture of a complex SES emerged with numerous, interconnected drivers of change. We illustrated the elements of the system reported to us in Fig. 3.2. Respondents frequently attributed (frequency = 10, of a total 16 references to environmental issues; see Appendix 3A) observed environmental changes to climate change, and linked its impacts to infrastructure degradation, and changes in subsistence resource availability. Less frequently (frequency = 2), respondents mentioned thawing permafrost and coastal erosion, without explicitly referencing climate change. An overarching theme implicated decision making, mostly at the state and federal levels in excluding local interests from important decisions. Local political processes were also indicated in obstructing achieving healthy, sustainable communities. The code *divided local interests* represents remarks such as "disagreements among local governments," "lack of unity in terms of what's most important," and "lack of support and collaboration locally." As one participant put it: "We are all Iñupiaq, not corporation against corporation."

According to respondents, insufficient authority over decisions that impact local conditions affect local adaptive capacity. Inadequate access to vocational training and good quality, culturally appropriate education that would allow local youth to learn Traditional Knowledge (TK) as well and "walk in both worlds;" means that many struggle to participate in subsistence activities and / or wage employment. One participant stated that this risk stems from the "challenges to maintaining subsistence activities – scheduling, lack of time to learn, high costs, displacement by industry, and the education system not really preparing youth for either world." Participants reported that those who leave for education often

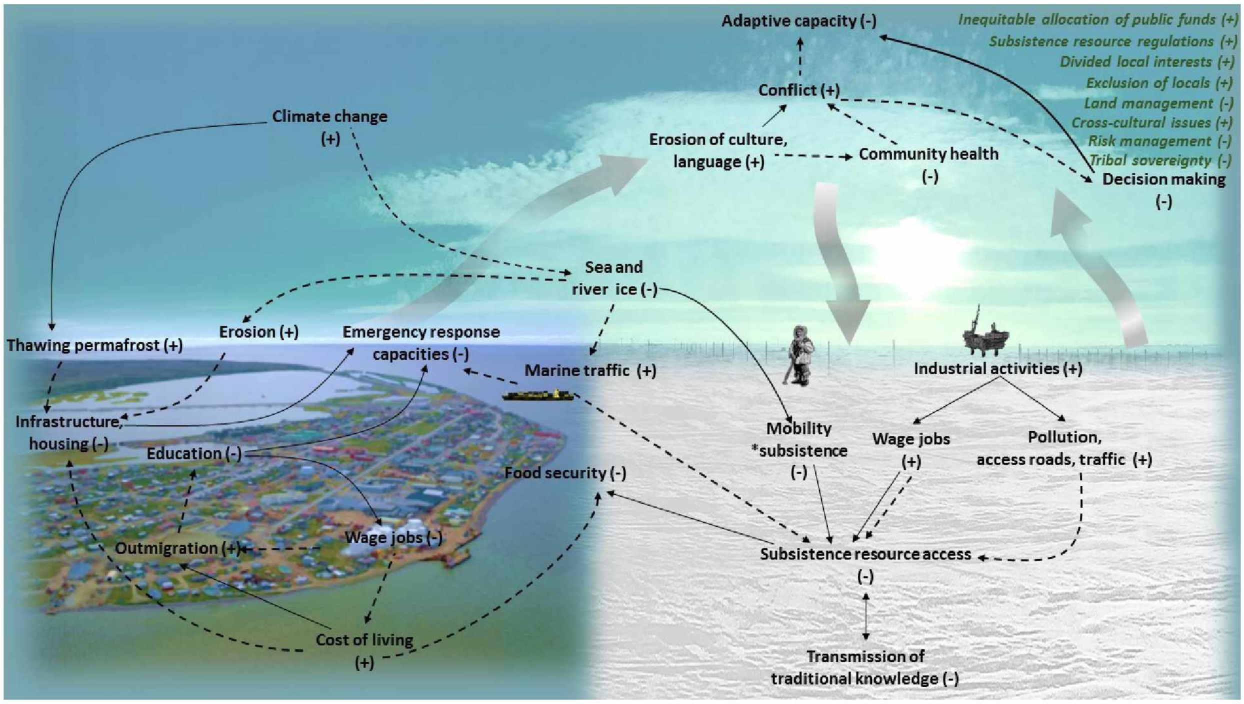

Fig. 3.2 Model of social-ecological drivers of change and community impacts. Model described by workshop participants (N = 47). Solid lines represent reinforcing or positive relationships, dashed lines represent weakening or inhibiting relationships between system components. Pluses indicate increasing trends, minuses indicate decreasing (or deteriorating) trends. The design concept behind this model draws on Hopping et al. (2016).

do not return to their communities. Others move away for jobs, or as one participant observed, "Children are educated to leave."

Wage employment is scarce, and while it provides cash funds to assist with the costs of subsistence activities, it reportedly takes time away from it. The high cost of living encourages outmigration, which impacts the availability of teachers and funding for education. Respondents admit that industrial development often provides jobs, but pointed out that it also affects subsistence resources because of noise pollution, air pollution, altering migration patterns and causing hunters to travel longer distances to find game. Subsistence activities are vital to food security, but climate change impacts, combined with development increasingly impact access, according to participants. Diminishing sea and river ice decrease hunter mobility, while the combination of reduced sea ice and industrial activities increase marine traffic. The reduced extent of sea ice was also viewed as responsible for coastal erosion, which reportedly threatens an already fragile infrastructure. One respondent pointed out that the combination of increased marine traffic, inadequate infrastructure, and local, trained personnel decrease emergency response capacities. All of these drivers of change are perceived as affecting culture (language, heritage) and transmission of traditional knowledge. As culture changes, socioeconomic pressures and conflict increase, and community health declines, according to participants.

Informants from both boroughs described aspects of these same processes. Slight differences were noted in terms of frequency of emergence, or priorities among these factors. The most frequently mentioned risk, *ineffective decision making*, was the same in both boroughs. The second most frequent was *health and health care issues.* In third was *industrial activities* tied with *environmental changes* in the NSB group; while *cost of living,* and *health and health care issues* came in second and third (respectively) in the NWAB group. A more detailed analysis of the differences and similarities between the two boroughs' risk perceptions is discussed in the next section. This cursory analysis of observed drivers of change is significant in providing a generalizable picture of a complex and rapidly changing Northern Alaska SES.

Perceptions of SES complexity and rate of changes

To complement the participants' model of their SES in Fig. 3.2, and to parse out the magnitude of perceived uncertainty in the SES, a 25-item questionnaire (see Chapter 4, Appendix 4C), asked participants for their perceptions of complexity and rate of changes in the North Slope region's social and environmental systems. The survey items, administered via the CCA survey (survey #2) in our Kotzebue and Anchorage workshops, were evaluated on a seven-point Likert scale from 1 (completely disagree) to 7 (completely agree).

Responses from the two groups (NWAB and NSB participants) were modeled in a coordinate system along the dimensions “rate of changes” (x axis) and “complexity” (y axis, see Fig. 3.3). Mid-range coordinates (4.0, 4.0) indicate perceptions of continuity in, and foresight of, the system's future states, while higher scores indicate a shift toward uncertainty, and decrease ability to control outcomes. The two group's initial composite scores (NWAB: $M_{changes}$=4.6, SD=0.8 and $M_{complexity}$=4.9, SD=0.9), (NSB $M_{changes}$=4.6, SD=0.7 and $M_{complexity}$=4.7, SD=1.3) are modeled using grey symbols labeled “outlook on future included” in Fig. 3.3. The two dimensions (complexity and changes) indicate that both groups rated their SES in the region of moderate-to-high uncertainty. These results indicate that high levels of perceived complexity and rate of changes are indeed factors in uncertainties in the SES. There was no significance of association between mean scores and group membership at the $p < .05$ level.

The calculations were repeated excluding four statements that belonged to a group of items from the SES “rate of changes” section. These items asked respondents to consider the future state of their SES, and evaluate whether the outlook was positive (i.e. expected prosperity in economic and natural resources). These items were originally reverse scored, ranging from a low score of 1 for strong agreement (signaling prosperity), to a high score of 7 for strong disagreement. The original rationale behind these statements was that an optimistic view of the future (i.e. things are headed in the right direction), presupposes continuity of trends, a sense of ability to forecast outcomes to steer the system toward desired futures. These are usually traits of *low* uncertainty in a system. Therefore, in the summative scores, highly negative responses to these questions on future outlook, *increased* overall change scores (towards increased uncertainty); while low scores (translating to a positive viewpoint) *decreased* them.

The “rate of change” scores were recalculated to test the effect of the four “outlook on future” statements on overall uncertainty. The idea behind this was to parse out attitudes about future uncertainty, from the rest of the statements that evaluate present uncertainties, and to find out whether scores shift significantly, and if so, in which direction. When recalculating change scores, omitting the group of four items on outlook, we see little change in the NWAB group's results (M_{change} = 4.65, SD = 1.0), and a clear increase in the NSB group's (M_{change} = 4.9, SD = 0.8). Fig. 3.3 depicts this final model for both groups (along with the original) in white, labeled "outlook on future excluded." This new model conveys a more positive outlook on the future among NSB participants than that of the NWAB group: The NSB group's original (grey diamond) change score was lower *with* the future outlook items included. This implies that the NSB group held a positive view of future prosperity , received low scores on the reverse coded scale as a result, which, in turn, *decreased* their perceived changes scores.

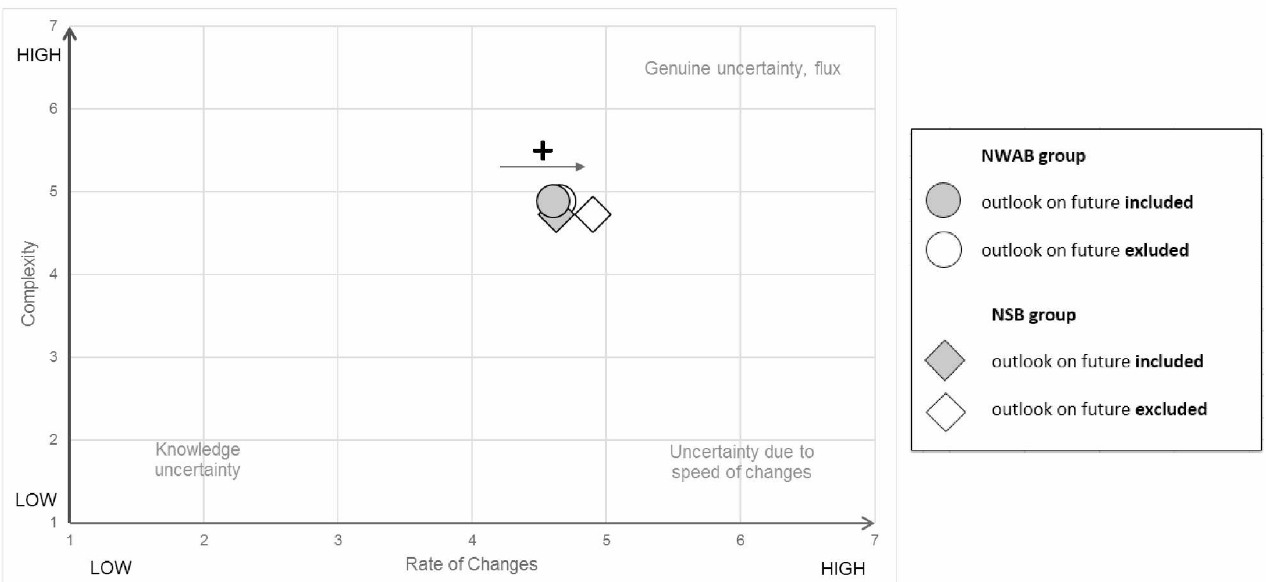

Fig. 3.3 SES complexity and uncertainty analysis results for the NSB and NWAB groups (N = 28). The figure includes results with and without "outlook on future" question items, and an arrow showing the direction of change in scores between these two perspectives. The chart shows different uncertainty types as factors of complexity and change levels, adapted from Lindgren and Bandhold (2009, 173).

In the model that excluded these items, the NSB group's perception of speed of changes increased, while the NWAB group's did not shift significantly. This suggests that the NWAB group held a somewhat neutral view of future prosperity, and therefore these items did not shift their scores significantly in any particular direction.

To sum up, there may be slightly different levels of concern between the NSB and NWAB groups, regarding the future prosperity of their SES. This difference in futures perspectives may possibly signal differences in evaluations of resources, buffers, and thresholds in SES adaptive capacity. Most importantly however, the results (depicted in Fig, 3,2 and Fig. 3.3) show that the northern Alaska region shares much of the same priorities over uncertainties and drivers of change. Both groups perceive their SES as one impacted by rapid, complex changes. These observations are perceived similarly by both NWAB and NSB participants, without significant discrepancies between the groups' perceptions of the two measured dimensions of uncertainty (rate of changes, complexity). These shared perceptions have relevance in discussions about finding consensus, and building a common ground for cross-scale strategies in planning sustainable communities.

3.3.2 Elements of sustainability, and a cultural consensus view of risks

3.3.2.1 Elements of sustainability

The Sustainability of Arctic Communities Project (Kruse *et al.*, 2004) worked with residents from northern Alaska and Canadian communities in the late 1990s to define important elements of sustainability. These elements were identified by community residents as serving an important role in supporting vital cultural, ecological, and socioeconomic functions that sustain their communities. The items in Table 3.2 are drawn from that research, and served this research as a starting point for defining community sustainability. Workshop participants (N = 28) were asked to evaluate whether these goals are still applicable for Arctic community sustainability today.

Table 3.2 Elements of community sustainability propositions (Kruse et al 2004)

N = 28	Median (IQR)*
Use of, and respect for, the land and animals in our homeland are very important to community sustainability.	5 (5-5)
A cash economy that is compatible with, and supports, continued local use of the land and animals is very important to community sustainability.	5 (4-5)
Local control, and responsibility for what is done in our village homelands and for what happens to resources used by the community and on our lands are very important to community sustainability.	5 (4-5)
Education of younger people in both traditional knowledge and western science is very important to community sustainability.	5 (4-5)
Education of the outside world about community goals and ways of living is very important to community sustainability.	4 (4-5)
A thriving culture that has a clear identity based on time on the land and language, which honors and respects elders, are very important to community sustainability.	5 (4-5)

* Calculated on a scale where: Strongly Agree =5, Agree =4, Neither Agree nor Disagree =3, Disagree = 2, Strongly Disagree = 1

Likert-type items asked respondents to rate each on a scale of 1 (strong disagreement) to 5 (strong agreement). Median results and interquartile ranges are presented in Table 3.2. The results show strong agreement on five, and agreement on one item with little variation in the distribution of responses. These results confirm the prevailing importance of homelands and resources, of autonomy over decisions, and of healthy economies to cultural continuity and community sustainability in the region.

3.3.2.2 The Cultural Consensus Analysis results

The CCA results indicated a good fit to the consensus model with a first to second largest eigenvalue ratio of 12.35 (Hypothesis 1). CCA signals a one-culture domain among the informants by evaluating the pattern of answers, determining a single dimension exists if this ratio is equal to, or greater than 3.0 (Weller, 2007). Overall group CC score was high at 0.80, SD= 0.3 (NSB cohort = 0.68, SD= 0.4, NWAB cohort = 0.91, SD= 0.1; see Appendix 3B), indicating that as a group, participants on average gave 80% correct answers according to the shared cultural domain. There was one negative CC score, signaling that the dominant knowledge culture model (shared truths within this group) likely does not fit this participant (i.e. this participant does not share the group's insights). However, because the sole negative

CC score was close to 0 (-0.1), and group average scores were otherwise high, the overall model is significant (Weller, 2007). The culturally correct answers (i.e. estimated correct responses based on the shared culture within the group) to the propositions and the frequency of response are presented in Table 3.3. The consensus analysis revealed that experts from the two boroughs agree about all observations about change and risks, and all items pose a risk to sustainability in the region.

Table 3.3 Cultural consensus questions. Created based on free lists of risks to sustainability (items 9-15) and previous cultural consensus work in the region by Carothers et al.(2014)–items 1-8. The answer column shows the culturally correct (i.e. in line with this group's shared beliefs) answer, and number of correct replies overall and per borough.

Cultural consensus questions **Is this a risk to community sustainability? True / False:** **N = 26**	**CC Answer**	All N = 26	NSB n = 12	NWAB n = 14
1. Less snow in winter *Impacts: food and water security*	**T**	25	10	14
2. Shallow river and lake waters *Impacts: fish migration, food and water security, travel*	**T**	24	10	14
3. High river water events are less common* *Impacts: travel*	*	*	*	*
4. Melting permafrost** increases erosion and drying *Impacts: difficult overland travel, less lake habitat, more grass habitat*	**T**	26	11	14
5. More wildfires *Impacts: respiratory problems from smoke, changes in subsistence*	**T**	20	7	13
6. Vegetation change *Impacts: changing migration patterns of wildlife, food security, invasive species*	**T**	22	9	12
7. Later fall freeze-up; new freeze-thaw cycle *Impacts: food preservation and fermentation, travel*	**T**	25	12	12
8. Earlier spring breakup; ice now melts in place *Impacts: travel, harvest seasons*	**T**	25	11	14
9. Health and health care issues *Example: access to care, substance abuse, mental health*	**T**	23	9	13
10. Environmental problems *Examples: climate change impacts (erosion, less sea and river ice, permafrost thaw)*	**T**	26	11	14
11. Education issues: formal schooling *Examples: teacher turnover, lack of local teachers*	**T**	25	9	14
12. Education issues: transmission of traditional knowledge *Examples: drop in youth-elder contact, conflicting school and subsistence schedules*	**T**	27	11	14
13. Ineffective decision making *Examples: misguided regulations, divided local interests, exclusion of local communities from decisions*	**T**	25	10	13
14. Industrial activities, issues from *Examples: irresponsible development, pollution, inability to mitigate industrial disasters*	**T**	24	8	13
15. Risks to culture *Examples: heritage loss, language loss*	**T**	25	10	15

*Item #3 was eliminated due to > 10% missing responses. **"Melting" permafrost refers to thawing permafrost: In this survey the author adhered to the original wording from the Carothers et al. (2014) study that relied on elder observations, preserving the culturally appropriate wording. Throughout this dissertation, when referring to the specific survey item, the phrase "melting" is used, while in discussions of the phenomenon as described in scientific literature, "thawing" will be used.

In order to visualize the patterns of responses beyond an array of CC scores, the agreement matrix was submitted to non-metric multidimensional scaling (MDS) in Ucinet. The agreement matrix is a respondent-by-respondent matrix that calculates the correlation coefficient between all pairs of respondents, and plays a role in calculating the culturally correct answers and individual CC scores. The proportion of similarities indicated in the agreement matrix can be represented as a pattern of proximities in a multidimensional space. Figure 3.4 shows the two dimension scaling solution (stress = 0.035, iterations = 50). The stress value is the degree of correspondence between the MDS model points, and the original matrix input (the distortion that occurs when data is transposed over multiple dimensions), and values below 0.1 are considered “excellent” or well-representative of the patterns in the data.(Borgatti, 1997).

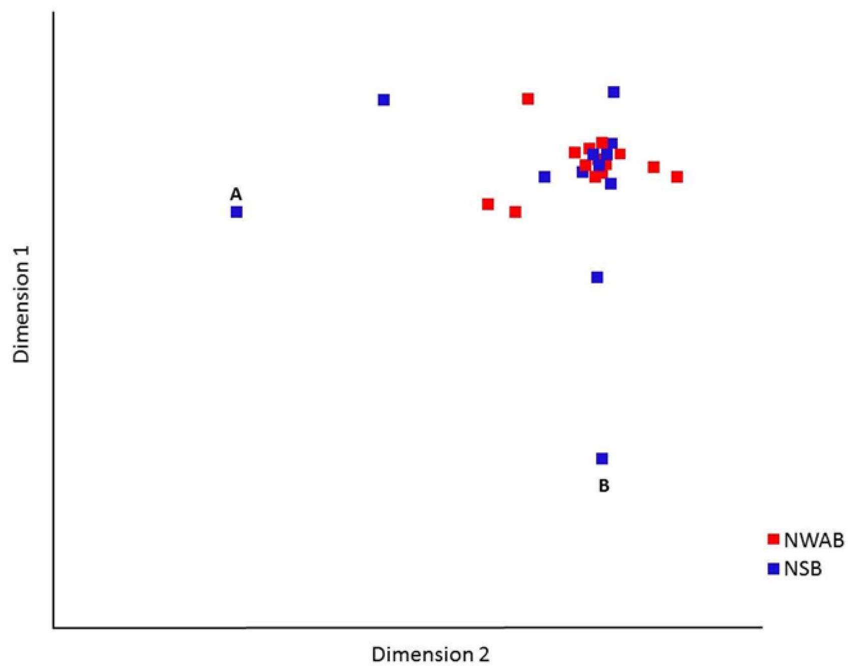

Fig. 3.4 Nonmetric multidimensional scaling of agreement. NSB (blue) and NWAB (red) respondents. The letter “A” marks the respondent with negative CC score, “B” marks the respondent with similarly low score (0.09). The x and y axes do not represent meaningful numeric values beyond communicating relative distance between objects.

The axes do not have any meaningful values in nonmetric MDS. The axes simply anchor the points in space, providing coordinates for each object only to the extent that the between-nodes distances remain in proportion with the underlying matrix (agreement matrix in this case). The consensus pattern can be seen clearly in the tight clustering and overlap of blue and red squares in the upper right of the plot. A few red and blue squares are situated a bit off from the main cluster, but are still close in space. The two informants who had very low CC scores (A, B), on the other hand, occupy spaces not only distant from the cluster, but also from one another. This is due to the fact that even among themselves, they had no consensus. Informant B rejected 5 of 7 culturally correct land cover risk propositions, compared with A's 3 of 7 incorrect answers here; while B incorrectly rejected only 1 of 7 risk items from the mainly socio-economic risk list (items 9-15, Table 3.3), while A incorrectly (based on consensus) rejected 5 of 7.

Testing for knowledge subgroups

A least squares multiple linear regression in JMP pro (version 11.2.1) tested the effects of six independent variables (age, borough of residence, gender, first or second time participant, formal education and traditional knowledge) and any potential interactions with CC scores. Gender and borough of residence included two, while age and education included three levels (Table 3.1). For the purposes of effect testing, the eight-level affiliation was re-coded into a dichotomous *tribal* and *non-tribal* variable. Though the resulting six-factor interaction model was significant at the $p < .05$ level ($F_{9, 16} = 4.9$, $p = .0028$, $r^2 = 0.73$, Adj. $r^2 = 0.58$), only education had statistically significant association with CC scores (sig. = .0028). A one-way between subjects ANOVA of scores among the education levels showed the between-group to within-group variation increasing greatly to a ratio of 24.9 (Table 3.4).

A post-hoc Tukey-Kramer HSD test confirmed association between membership in the "college degree" and "some college" groups, and higher CC scores than those from the "secondary education" group. The dominant, shared knowledge culture among our participants, therefore, is associated with higher levels of formal education. While age did not show correlation with CC scores, it is perhaps worth noting that the two CC score outliers (Fig. 3.4) came from—one each—the youngest (under 22) and oldest (over 60) cohorts in the group. It is possible that people at the two ends of the age spectrum comprise their own knowledge domains. For example, it may be that these two age groups do not engage in the same social

Table 3.4 Results from the regression of cultural competence scores by type of education

	Tests for Knowledge Subgroup by Education:							
	Formal education			Traditional knowledge		Formal education and traditional knowledge		
N = 26	College degree	Some college	Secondary education	TRUE	FALSE	College degree	Some college	Secondary education
Members n =	17	4	5	18	8	10	5	3
Avg. age =	45.05	32.75	32.0	39.2	43.9	43.6	32.75	34.75
Women n =	8	3	0	8	3	5	3	0
NSB n =	4	3	5	9	3	2	3	4
CC score Mean =	0.94	0.84	0.31	0.76	0.89	0.95	0.84	0.22
SD =	0.04	0.09	0.08	0.34	0.15	0.05	0.08	0.08
Test statistic: CC score by knowledge group	$F_{2, 23} = 24.9$ $r^2 = 0.68$ Adj. $r^2 = 0.66$			$F_{1, 24} = 1.03$		$F_{2, 15} = 29.4$ $r^2 = 0.80$ Adj. $r^2 = 0.77$		
p-value	**p = .0001**			p = .319		**p = .0001**		
Post-hoc Tukey-Kramer HSD	**College degree – Secondary sig. = .0001** **Some college – Secondary sig. = .0005**			---		**College degree – Secondary sig. = .0001** **Some college – Secondary sig. = .0002**		

learning activities as the 25-55 age group. Because the results otherwise did not show significance of association between age and CC scores, these points remain speculative suggestions. The two participants in question were both NSB residents, explaining this group's lower average score compared with NWAB scores.

Taking a cursory look at descriptive statistics related to TK (Table 3.4), we can see that those who had TK (M = 0.76) and those who didn't (M = 0.89) both had high CC scores. This confirms that TK education is not a factor in the variance in the group's CC scores. However, the within-group CC score variation in the TK-educated group is double that in the non-TK group, indicating a somewhat less-homogenous cohort in terms of sharing the consensus view. Because of this variance, as a next step, the effect of formal education on CC scores within the TK-educated group was examined. Table 3.4 shows the significance test and post hoc analysis for this group (n = 18) who had both types of education. Between-group (levels of education) variance, as well as the coefficient of determination increased, indicating that formal education explains 80% of the variability in responses in the traditional knowledge (TK) educated group.

This means that not only is formal education strongly associated with a participant's level of sharing the dominant group's knowledge, but that this association is even stronger in the TK-educated group. The majority (69%) learned TK while growing up, and a large majority (80%) had either a college degree or some years of college education, making this a highly educated cohort of participants with a plurality of worldviews.

Due to the function of the workshop (the focus on a northern Alaska-resident, expert cohort) it was expected that the group would be highly educated in both traditional and formal knowledge The results of the CCA showed via correlation between high levels of formal education and high CC scores, that the shared cultural domain is likely influenced by formal education. While there was no significance of association between TK education and CC scores, we cannot exclude that the two types of education (formal and TK) *together* formed the shared knowledge domain of the group. For example, because TK education was measured by a dichotomous Yes / No question, as opposed to a spectrum of levels as was the case with formal education, the question remains as to what extent varying degrees or levels of TK education may have shaped the shared domain of the group. A lack of negative correlation between TK education and CC scores indicates that the shared domain of the group is likely not antithetical to TK values.

Among respondents from the two boroughs, there seems to be consensus over important drivers of change. This result is reflected in the strong consensus and high competence scores of participants. The number of outliers in the group, in terms of CC scores, was quite small, and group-level CC scores correlated with formal education. These results indicate that this small, outlier subgroup is not from the same epistemic community as the majority of participants. For example, they may not have had access to the scientific information, or the tools to interpret them that is shared by the majority. In sum, the CCA results indicate that consensus on perceived risks to sustainability can be found in spite of diversity in a number of factors (age, gender, borough of residence, affiliation). An important factor in this group's common knowledge domain seemed to be a common epistemic background (i.e. participants have had similar access to science and TK), resulting in multiple ways of knowing that are shared.

Risk dimensions: impacts, control and change

Following the consensus analysis, each risk proposition was analyzed for respondent input along three risk dimensions: impact, control and change (Appendix 3C). For any risk proposition the informant found true, they were asked to rate its impact on sustainability, the extent to which they agree that it is being managed or controlled locally, and any change in intensity over the past two decades. This part of the study was not designed for consensus analysis, for two reasons: First, it was not expected that the two boroughs, situated in a vast and diverse land area, would perceive identical risk conditions and capacities to handle them in the region. Second, in this part of the study the differences between perceptions of the residents of these two boroughs, as opposed to similarities, is of greater interest. Which risks does each group perceive as having increased in the region, which ones are not manageable with local resources, and which ones exert greater impacts on sustainability?

Fig. 3.5 depicts these observation trends in both groups. Along the dimension of risk change, the NSB group either agrees or agrees strongly with all risk items having increased in recent years. The NWAB group rated two risk items as having stayed the same (ineffective decision making, and education issues: formal schooling), on the other hand they agreed with the NSB group that thawing permafrost increased greatly, as well as later fall freeze-up, and earlier spring breakup. The control dimension revealed that the NSB group is neutral on the local manageability of most risk items, except later fall freeze-up, education issues: traditional knowledge, and risks to culture; all of which they consider manageable. Conversely, the NWAB group disagrees with the local controllability of most items, except for education issues: formal schooling, and risks to culture.

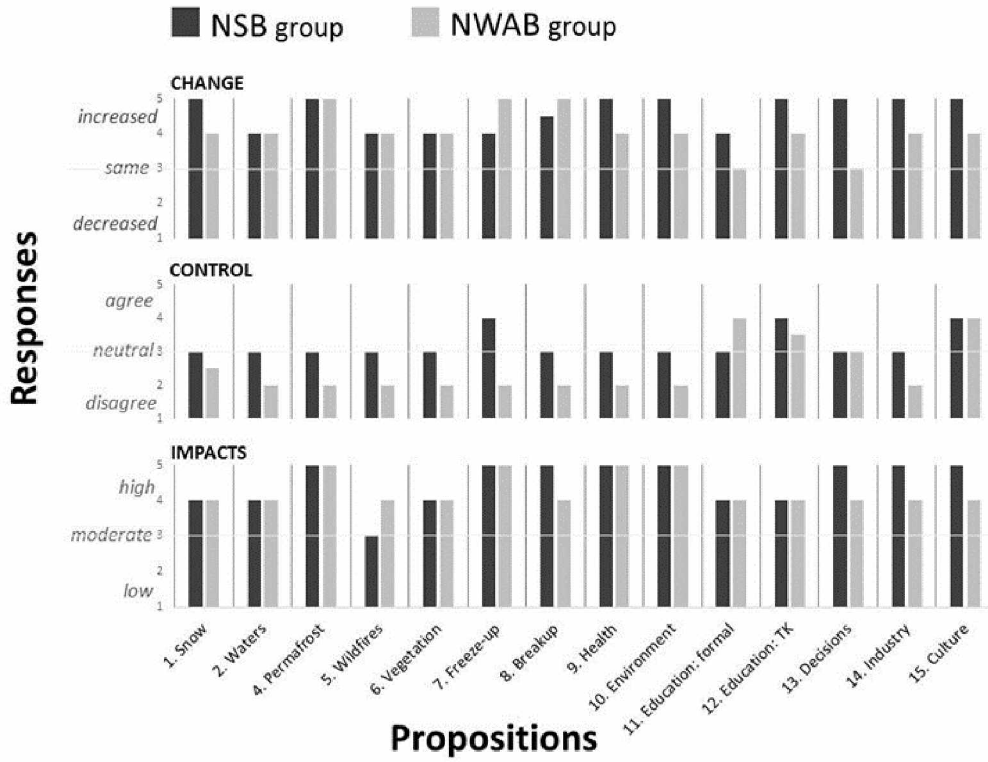

Fig. 3.5 Trends in three dimensions of risk propositions. Impacts, control, change as observed by participants by borough of residence. Responses were solicited by the following prompts using a 5-point Likert-type response: IMPACTS "Impacts from this risk on community sustainability are:" (high, moderate, low). CONTROL "Northern Alaska communities are currently managing or controlling this risk by adapting to, eliminating, lessening, avoiding it:" (agree, neutral, disagree). CHANGE "Over the past two decades this risk has:" (increased, stayed the same, decreased). The numbered risk propositions (abbreviated in this chart) refer to the list of risks in Table 3.3.

The NSB group found impacts from all risk items high or very high (except wildfires), with agreement from the NWAB group on all items (except wildfires, which the NWAB group did rate as high-impact). Three risk items found stronger agreement on impacts (very high) from the NSB group, compared with the NWAB group's high rating; these were ineffective decision making, industrial activities, and risks to culture.

Overall, it was the control dimension that indicated the greatest departure in trend between the two groups. The NSB group did not have strong opinions about a lack of ability to manage these risks. The NWAB group on the other hand indicated a lack of capacity to control or mitigate, or adapt to the impacts of most risks. This could convey a difference between the two boroughs in terms of available resources to address one risk and not the other.

3.3.3 Workshop poll: participant evaluations of workshop learning

Up to this point, reported findings have focused on the scalability of SES risk perceptions across two, same-level administrative units (boroughs in this case) that share a geographic region, rather than the scenario workshop process itself. This part of the study was designed to gauge the extent to which a diverse group of locals, each with a background in some aspect of community sustainability, but residing in separate boroughs, agree on risks that threaten community sustainability. A constraint that this study had to overcome was the fact that of the 26 participants who ultimately provided the data for the CCA survey, 12 took it before their first, and 14 before their second participation in a workshop. This sequence had the potential to introduce effects from workshop deliberation into the consensus model. The results, however, showed no correlation between new and return participants' cultural competence scores. A trial CCA run separately on these two groups ($n_{\text{first time}} = 12$, $n_{\text{return}} = 14$) confirmed no significant change in the consensus model when considered as separate cohorts. First to second eigenvalue ratios were 4.15 and 7.5 (respectively), suggesting a one-culture model, with no negative competence scores in the first group (M = 0.89 , SD = 0.14), and one negative competence score, and one very low score in the second group from the same participants as the original model (M = 0.73, SD = 0.38). In sum, results suggest that the cultural knowledge domain of risks and sustainability, and the consensus model provided by informant input come from a knowledge space that the participants formed prior to the workshops.

Iterative cycles of reflection, joint exploration, diverse storylines and deliberation lead to social learning help to expand community-based adaptation repertoires" (Tschakert *et al.*, 2014). This section presents the self-evaluations of participants before and after participation in their first workshop, to measure their perceptions of learning about sustainability issues. Six evaluative statements prompted input about perceptions of community resilience, the value of the boroughs working together, community goals, and risks that threaten those goals in each borough (Table 3.5). The goal was to check shifts that may occur in these views after the experience, especially with respect of one borough's familiarity with issues of the other borough. A total of 36 first-time participants filled out both the before- and after-workshop poll, providing dependent samples data to test for effects. As a first step the group as a whole was evaluated without distinction for place of residence. The before (t0) and after (t1) workshop scores from single proposition items were assessed with nonparametric Wilcoxon signed-rank tests for significance. Two evaluative statements served as a proxy for community resilience, prompting participants to consider whether the region has the capacity to thrive in challenging economic and environmental times. The composite score calculated from the mean responses to these two questions comprised a "resilience score." A two-tailed t-test confirmed significance (significant at $p < .05$) between t0 and t1, as agreement with the *resilience* propositions increased significantly after participation. . Awareness of *NSB goals* and *risks* median scores changed significantly: *goals* scores went from neutral to agreement, while *NSB risks* stayed at agreement level, with significant shift occurring in IQR values, away from disagreement and toward strong agreement. The *working together* proposition (Table 3.5) started and ended at strong agreement with no significant change.

Table 3.5 Evaluative statements. Results from before (t0) and after (t1) first participation

Proposition N = 36		Level of agreement with propositions before (t0) and after (t1) first participation
Resilience		
My community is prepared to face future economic and environmental challenges.		
My community is prepared to prosper even in turbulent times.		
		Mean* (SD)
	t0	3.11 (1.13)
	t1	3.6 (0.90)
	Sig.	t (34) = 3.82 p = .0005
Working together		
Northern Alaska can benefit more from the two boroughs working together, instead of separately		
		Median* (IQR)
	t0	5.0 (4.0 – 5.0)
	t1	5.0 (4.0 – 5.0)
	Sig.	--
I am aware of **Northwest Arctic Borough goals** *considered most important to the communities of the Northwest Arctic Borough*		Median* (IQR)
	t0	4.0 (3.0 – 4.0)
	t1	4.0 (3.0 – 4.0)
	Sig.	--
I am aware of **Northwest Arctic Borough risks** *- challenges that may threaten these goals*		
		Median* (IQR)
	t0	4.0 (3.0 – 5.0)
	t1	4.0 (3.25 – 5.0)
	Sig.	--
I am aware of **North Slope Borough goals** *considered most important to the communities of the North Slope Borough.*		Median* (IQR)
	t0	3.0 (2.0 – 4.0)
	t1	4.0 (4.0 – 5.0)
	Sig.	W = -89 p = .0001
I am aware of **North Slope Borough risks** *- challenges that may threaten these goals*		
		Median* (IQR)
	t0	4.0 (2.0 – 4.75)
	t1	4.0 (3.25 – 5.0)
	Sig.	W = 77.00 p = .0009

*Calculated on a scale where 5 = Very True, 4 = Somewhat True, 3 = Neutral, 2 = Somewhat Untrue, 1 = Untrue

These trends indicate that participants' view of their own awareness of community goals, risks to sustainability, and community resilience shows improvement following workshop deliberations (Hypothesis 2). Participants may have felt encouraged by their participation and synergies found with other viewpoints. While *NWAB goals* and *risk* awareness did not change, participants indicated a high-level baseline awareness in the beginning. This is unlike the *NSB goals* and *risks* propositions, which exhibit low scores (2.0 in both cases) at the 25th percentile mark before the workshop. In comparison, the 25th percentile of the after workshop scores (*NSB goals* = 4.0, *NSB risk* = 3.25) show great improvement.

In order to detect significant differences that may exist in the extent to which awareness of issues changed during the workshop, NWAB and NSB participants were separately evaluated (Fig 3.6). A separate calculation was done to create groups by location: workshop 1 (in Utqiaġvik) versus workshops 2 and 3 (Kotzebue and Anchorage), to check for differences in learning in different settings and with different workshop components. The numeric scale responses to propositions at t0 were deducted from each participant's response at t1. The resulting integer values, either positive or negative, denote the direction each participant's' self-evaluation shifted. The average (median value, denoted by a white X symbol) and variation (IQR, denoted by boxes) of these values were calculated per proposition. The

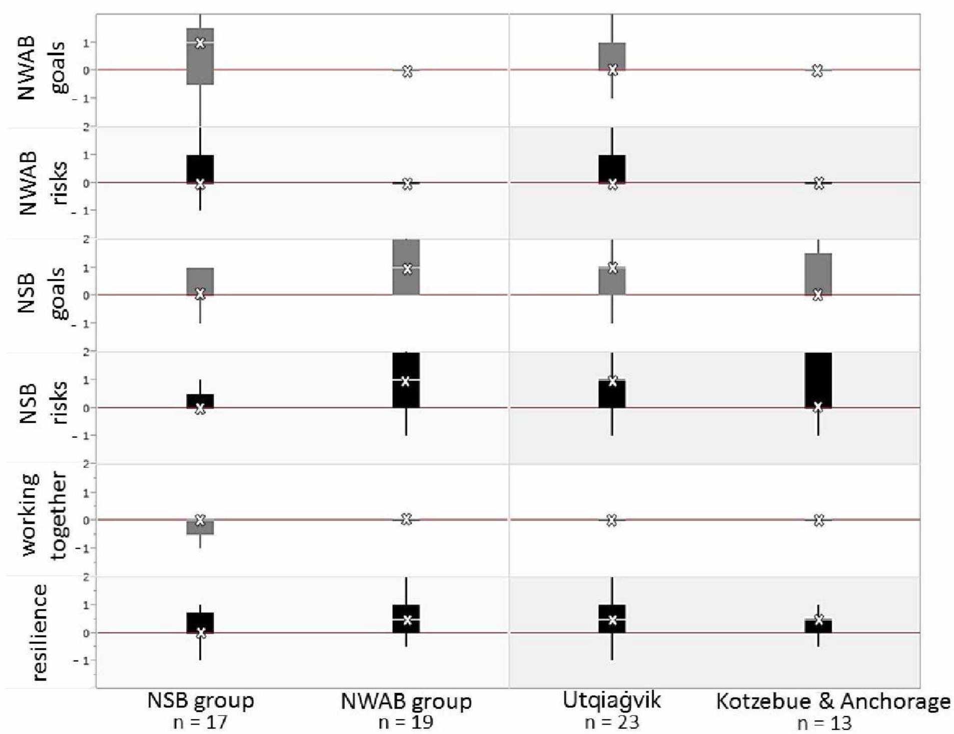

Fig. 3.6 Difference in levels of agreement. Propositions evaluated before (t0) and after (t1) first participation: The zero change level is denoted with red lines, and the X symbol indicates median change. The boxplots indicate the IQR (spread between the 25th and 75th percentile). The analysis shows between borough and between workshop results. Anchorage (our 3rd workshop in the series) data were combined with Kotzebue (2nd in the series) as only 3 first-time participants were polled in Anchorage.

resulting boxplots convey this movement in relation to the 0 (no change) mark. When the boxplot sits above the red line, it means the group exhibited a trend towards increased values (agreement with propositions) at t1.

While in Table 3.5 the median values conveyed a lack of a learning curve in propositions NWAB goals and risks, Figure 3.5 6 tells of a NSB subgroup who did report greater awareness after the workshop on these points (Hypothesis 2). These trends mirror the Utqiagvik group's trends. This suggests that the first workshop in the NSB was informative for participants on NWAB issues. We see a similar trend under *NSB goals* and *NSB risks.* It is the NWAB group who reports greater awareness along these lines, although we do see NSB participants themselves feeling increased awareness at t1. *Working together* remains virtually unchanged in all assessment, and reflects high agreement independent of workshop effects. Perceptions of *resilience* scores were impacted positively in all respondent groups.

3.4 DISCUSSION

Environmental risks are often incalculable (Beck, 1992; Burgman, 2005). Consequently, public discourse frequently focuses on the acceptability of the outcome and not the probability of occurrence. Risk management processes, therefore, are inherently political and need to incorporate scientific as well as cultural perspectives on risk. This study approached the culture of risk from a test case of consensus analysis of experts from two Alaska boroughs. It aimed to assess whether a diverse group of experts coming together to workshop about the region's future and sustainability, have a unifying concept of risk (to sustainable communities) that transcends differences in agendas and policy subsystems.

3.4.1 Consensus, risk perceptions and their significance in Arctic Alaska

The strong consensus found over risk concepts confirmed that although these boroughs operate in different parts of the Arctic and are based on different resources, contingents, pressure groups, and challenges, the overarching risks to sustainability are of a one-culture risk concept. The participants of this study were all experts in some area of community sustainability, and were educated both in the formal school system and in TK. Their diverse backgrounds ensure that the shared cultural domain is inclusive of diverse sustainability perspectives (e.g. subsistence, health, business development). The one-culture risk model that has resulted from CCA is representative of this demographic. In other words, the shared risk culture is likely scalable in the region, holding true for any mixed group of practitioners in education, subsistence, community health, criminal justice, government and the region's youth when considering their communities' sustainable futures (Hypothesis 1). This does not mean, however, that this group universally represents the collective perspective of all residents of northern Alaska. There may be multiple cultural domains about the meaning of community sustainability and the risks that threaten sustainability. When examining risk dimensions (Appendix 3C), it appears that NSB residents have a wider range of opinion on most local control issues than NWAB residents, based on the interquartile range of responses. On the other hand, NWAB residents feel much less control over resource development, environment and community health, than do NSB residents. This supports a picture of a heterogeneous region in terms of available resources that can be mobilized to respond to vulnerabilities (or level of control over risks), impacting how risks may be prioritized during decision making. Identifying vulnerabilities that are not shared (at least not to the same degree) between the two boroughs can help locate surplus resources (assets, networks, social capital) in one borough, to share with the other borough and increase its buffer capacity. As such, the significance of the particular cultural domain uncovered in this chapter lies in its potential to facilitate "horizontal networks" that stimulate collective social learning, and increase adaptive capacity (Adger *et al.*, 2005). In vulnerable SES impacted by climate change and disaster risks, adaptations including "self-mobilization in civil society and private corporations (…) and the promotion of strong local cohesion and mechanisms for collective action have all enhanced resilience" (Adger *et al.*, 2005, p.1038). Agreement over sustainability issues, such as those that threaten sustainable futures, makes possible collective action. Without some common ground on what the issues are, it is unlikely that strong local cohesion and self-mobilization develops into actionable strategies.

The participants' model of the region's SES (Fig. 3.2 and Fig. 3.3) tells of mutually reinforcing feedbacks between social and environmental shifts, and ever-increasing complexities and changes. These feedbacks, and cascading effects can increase uncertainty, and decrease adaptive capacity (Adger *et al.*, 2005). Decision making under uncertainty demands the ability to anticipate, and prepare for, future risks and issues that may emerge (e.g. Stacey, 2007; Tschakert *et al.*, 2014). When uncertainty is high and consensus is low; traditional risk management approaches do not work, and new, innovative solutions are needed (Cavana, 2010). The Stacey Matrix (Fig 3.7) is a good approximation of the general circumstances created at the crux of (un)certainty and consensus. Though its usability is limited by the necessary distortions that occur between abstract, stylized models of complex systems and their real-life evolution in the human sphere, it still is a helpful visual for the complexities of decision making. In the Stacey model, uncertainty tends to force decisions towards the "edge of chaos" where there is great uncertainty about outcomes, and no consensus on what to do. The less we speak in terms of uncertainty (ambiguity), the more we move toward risks management and rational decision making. Not all risks are calculable of course, but in the case of many risks, past precedent provides for calculus of likelihood of occurrence and potential magnitude of impacts. In the case of known outcomes, and consensus on how to handle them, Stacey considers deliberations rational decision making. Far from consensus but with

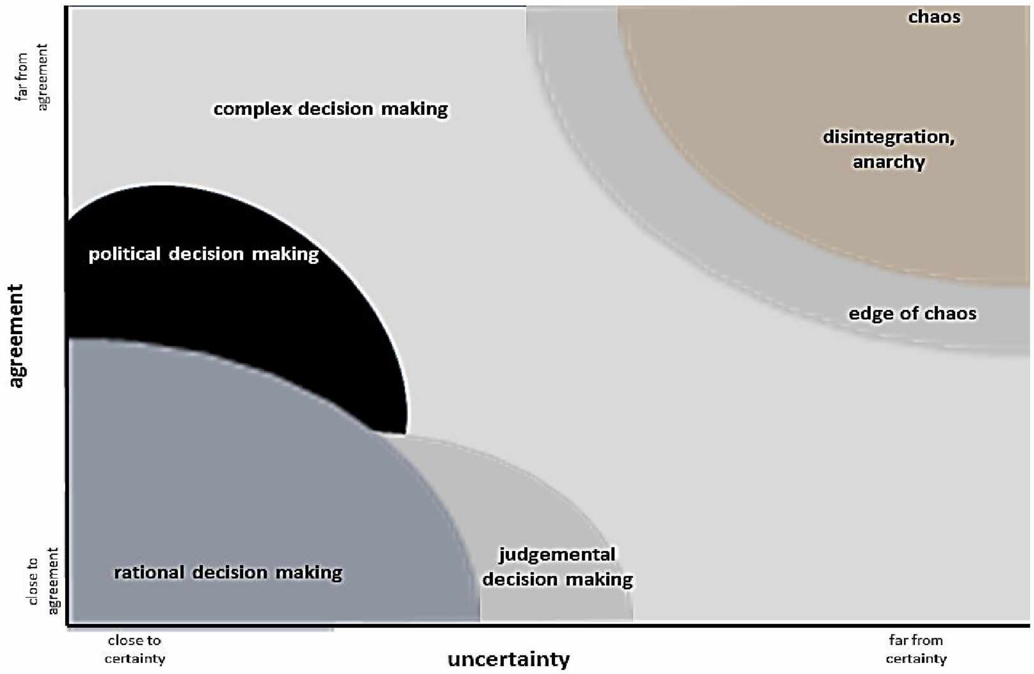

Fig. 3.7 Stacey Matrix. Adapted from Stacey (2007).

some level of certainty about outcomes creates conditions for complex decision making. This is an area of decision making with relevance to our study. If northern Alaska stakeholders identify high uncertainty in the SES, but there are issues over which they may form agreement (consensus), they may remain within the complex decision making zone, and away from chaos (or little to no control over outcomes).

Fath and colleagues (2015) noted some of the key features needed to avoid chaos, and sudden SES collapse (see Chapter 2, Table 2.4). These key features include availability of specialists (experts in a diverse array of system components), diversity of knowledge forms, and knowledge of limits and thresholds in the system (Fath *et al.*, 2015). Local experts who are familiar with various sustainability sectors are such specialists, with a diverse knowledge base who can help identify thresholds in the system that are indicative of vulnerabilities and potential crises. Based on the Stacey matrix (2007) and Fath's and colleagues' (2015) recommendations, the northern Alaska region can benefit from pooling resources to advocate for common goals. Finding the baseline for common goals, and the risks that threaten their success, can be achieved through participatory processes in planning and deliberation (Baber, 2004; Gutmann and Thompson, 2009; Lebel *et al.*, 2010; Tschakert *et al.*, 2014).

3.4.2 Workshops, deliberation and learning

While the main research focus of this dissertation is on the sustainability and risk perceptions of NSB and NWAB resident experts, the participatory scenarios workshop setting, in which the data was collected, comes into focus briefly in this discussion. The series of workshops provided a highly participatory and deliberative environment for the participants. It was beyond the scope of this research to evaluate the consensus-building potential of participatory scenarios workshops. However, the workshop's potential to increase individual participant awareness of sustainability issues was assessed.

The results from workshop learning (section 3.3.3) indicate that deliberation can increase understanding and awareness of issues among stakeholders. Participants' awareness of their neighboring borough's sustainability goals and risks increased (Fig. 3.6). In the case of the NSB group, participant awareness of these issues in their own borough increased as well.

These learning shifts speak to the role of process in collaboration, in particular the importance of participation and the plurality of knowledge included in deliberation. By extension, collaboration and deliberation may increase consensus as well: Underlying the concept of deliberation is the cooperative search for agreement. Deliberation can change opinions as participants gain knowledge (Muhlberger and Weber, 2006; Tschakert *et al.*, 2014). Policy subsystems benefit from deliberation as the outcomes produced by deliberation are more likely to be the least unsatisfactory ones, albeit not always the most just or perfect (Gutmann and Thompson, 2009). Deliberation and the inclusion of a plurality of knowledge forms has become a staple topic in climate change and adaptation inquiry (e.g.Brunner and

Lynch, 2013; Haley *et al.*, 2011; Tompkins and Adger, 2004) Participatory vulnerability and adaptation assessments are an example of the acknowledged role of legitimacy, agency, and coproduction of nonscientific inquiry in making decisions under uncertainty (Tschakert *et al.*, 2014).

3.4.3 A note on scenarios and their potential in decision making under uncertainty

Up to this point, the scenarios-building component of the NASP workshops has only been mentioned in passing in this chapter. This brief discussion is intended to bring into focus ways in which participatory scenarios exercises may fill the void that exists at the "edge of chaos" (Stacey, 2007), by providing a decision making platform that can operate under uncertainty, and plurality of opinions. Scenarios enhance deliberations by bringing together a diverse set of stakeholders who share information with one another and deliberate on shared values, and possible indicators by which future decision points can be gauged. Scenarios can help groups at various levels develop robust strategies for the future, as the process can be an effective learning tool (Lindgren and Bandhold, 2009). At a time when multiple stresses from environmental change and human development create a complex environment for decision-making, a lack of consensus about what to do, and high levels of uncertainty about the future, scenarios may enable subsystems to explore risks and sensitivities (Lindgren and Bandhold, 2009). By stimulating thinking about (1) possible future outcomes, (2) their consequences, and (3) the repertoire of possible responses (without said situation having occurred), the process enables strategic thinking in anticipation of emerging problems.

Scenarios can reveal where the uncertainty lies within models (Walker *et al.*, 2006). Scenarios planning can compensate for common decision-making mistakes, such as over- and underestimating changes and their consequences, pushing planning towards a middle ground by shifting focus away from what is most likely to occur, towards what the consequences and appropriate responses may be of various circumstances (Duinker and Greig, 2007). These types of benefits of scenarios planning have great relevance for decision makers in rapidly changing SES.

3.5 CONCLUSION

Global sustainability targets in times of extreme events from climate change, growing energy demands, water and food insecurity, and biodiversity loss demand multi-scalar collaboration. Resource development goals, however, often create high-stakes, low-consensus policy processes. Because knowledge is held and perceived differently at different levels, there is a political economy unique to the multi-stakeholder risk (cost/benefit) calculus in sustainable development, climate change adaptation and disaster resilience. Areas of consensus in sustainability and risk perceptions that scale across administrative jurisdictions, and diverse SES, are important components of collaborative planning, and capacity-building. The changing perceptions of workshop participants on their levels of issue- and risk-awareness before and after deliberations, suggest that investments made in optimizing collaborative, participatory processes, have payoff in learning. By increasing collective learning via deliberations, indeed we may better facilitate strategic futures thinking. Risk issues, that scale horizontally between same-level (e.g. borough) systems, can provide context for large-scale participatory learning and pooling of resources. These can act as buffers in the SES against emerging risks, and increase the capacity of social systems to respond, to take action. When lower jurisdictional level-systems (e.g. boroughs) engage in such collaboration, they increase their potential to (1) manage the SES toward mutually desirable futures, and (2) increase their political capacity to engage with dominant, higher level jurisdictions (e.g. state and federal governing bodies) and advocate for, or deliberate over, salient local issues. Ultimately, this may pave the way for the formation, and movement of, collective risk perceptions across and within scales and levels of governance, and enhance the plurality of knowledge that is fundamental for managing SES for resilience.

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3.7 APPENDICES
APPENDIX 3A
Codebook

Table 3A-1 Textual analysis of top 5 risks. Open-ended question results

N = 47 Code	Groundedness (frequency)	Density (links with other codes)	Interaction (which other codes linked with)
DECISION-MAKING	**42**		
General, unspecified	1	1	food security
Risk management	6	1	adaptability
Exclusion of locals	6	2	industrial activity, allocation of public funds
Allocation of public funds	5	2	exclusion of locals, cost of living
Tribal sovereignty -regulations	1	4	substance abuse, subsistence resources: availability, food security, land management
Subsistence regulations	3	3	subsistence resources: availability, food security, land management
Land management	2	1	tribal sovereignty, subsistence regulations
Divided local interests and leadership	12	2	cross-cultural issues, conflict
Cross-cultural issues	6	3	cash economy, divided local interests, conflict
SUBSISTENCE RESOURCES: AVAILABILITY	**6**		
General (unspecified)	5	7	climate change, industrial activities, cost of living, food security, subsistence regulations, tribal sovereignty, transmission of TK
Mobility, access to	1	2	erosion &permafrost thaw, sea & river ice changes
FOOD SECURITY	**5**		
General, unspecified	5	4	tribal sovereignty, subsistence regulations, subsistence resources: availability, cost of living
ENVIRONMENTAL CHANGE	**16**		
General, unspecified	3	0	
Climate change	10	3	sea & river ice changes, erosion &permafrost thaw, subsistence resources: availability
Erosion and permafrost thaw (without explicit reference to climate change)	2	3	climate change, mobility & access to subsistence resources: availability, infrastructure & housing
Sea and river ice changes	1	4	climate change, marine traffic, mobility & access to subsistence resources: availability
INDUSTRIAL ACTIVITIES	**11**		
General, unspecified	5	2	exclusion of locals, subsistence resources: availability
Industrial access roads	1	1	subsistence resources: availability
Industrial accidents, pollution	3	1	health & health care
Increased marine transport, traffic	1	2	sea & river ice changes
Oil spill	1	3	health & health care,

			formal & vocational training, infrastructure & housing
HEALTH AND HEALTH CARE SYSTEM	**23**		
General, unspecified	5	2	accidents / pollution, oil spills
Suicide rates	2	2	access to health services, substance abuse, cultural changes
Substance abuse and related social challenges	10	5	access to health services, tribal sovereignty, cultural change, poverty, conflict
Access to quality health services	6	3	suicide & mental health, substance abuse, conflict
EDUCATION	**12**		
General, unspecified	7	0	
Transmission of traditional knowledge	1		adaptability, subsistence resources: availability
Formal education, vocational training: availability, quality	4	2	outmigration, oil spill (ability to respond)
CULTURAL CHANGES	**12**		
Erosion of language and traditions	12	5	outmigration, cash economy, conflict, substance abuse, suicide and mental health
CASH ECONOMY	**13**		
General, unspecified	1	1	cross-cultural issues, cultural change, cost of living
Wage jobs -availability for local workforce	6	1	outmigration
Single-resource economy	3	1	cost of living
Poverty	3	1	substance abuse
COST OF LIVING	**17**		
General, unspecified	8	5	allocation of public funds, single-resource economy, subsistence resources: availability, food security, cash economy
Transportation	3	0	
Energy and fuel	4	0	
Infrastructure, housing –cost, quality and availability	2	2	erosion &permafrost thaw, oil spill (ability to respond)
OUTMIGRATION	**5**		
Outmigration	5	3	cultural change, wage jobs, formal education & training
CONFLICT	**3**		
Conflict (political conflict & crime / violence)	3	5	divided local interests, cultural changes, cross-cultural issues, substance abuse, access to health care
ADAPTABILITY	**2**		
Adaptability (adapting to change)	2	2	risk management, transmission of TK

Appendix 3B

Cultural Consensus Analysis data

Table 3B-1 Whole-group CC scores

Participant	CC score
1	0.999
2	0.999
3	0.727
4	0.999
5	0.999
6	0.746
7	0.999
8	0.722
9	0.873
10	0.999
11	0.999
12	0.584
13	0.999
14	0.999
15	0.853
16	0.999
17	0.999
18	0.999
19	0.733
20	-0.104
21	0.999
22	0.301
23	0.999
24	0.693
25	0.701
26	0.09
Avg.	**0.80**

Table 3B-2 CC scores by borough

NWAB CC scores	**NSB** CC scores
0.999	0.999
0.999	0.746
0.727	0.873
0.999	0.584
0.999	0.999
0.722	0.999
0.999	**-0.104**
0.999	0.999
0.999	0.301
0.999	0.999
0.853	0.701
0.999	**0.09**
0.733	Avg. 0.68
0.693	
Avg. 0.91	

APPENDIX 3C

Risk survey results

Table 3C-1 Land Cover Changes as risks. Results: North Slope and Northwest Arctic Borough Experts and Opinion Leaders (number of replies & median values)*

N(NSB)=12 N(NWAB)=16	RISK **"This is a risk"**		IMPACT **"Impacts from this risk are:"**		
	True	False	High	Moderate	Low
LCC #1 Less snow in winter					
NSB participants	**10**	1	8	2	0
**Median (IQR)	--	--		**4** (3.75-5)	
NWAB participants	**14**	0	11	4	0
**Median (IQR)	--	--		**4** (3-4)	
LCC #2 Shallow river and lake waters					
NSB participants	**10**	2	6	4	0
**Median (IQR)	--	--		**4** (3-5)	
NWAB participants	**14**	0	11	3	0
**Median (IQR)	--	--		**4** (3.75-4)	
LCC #3 High river water events are less common					
NSB participants	**6**	4	1	5	1
**Median (IQR)	--	--		**3** (3-3)	
NWAB participants	**8**	3	5	3	1
**Median (IQR)	--	--		**4** (3-4)	
LCC #4 Melting permafrost increases erosion and drying					
NSB participants	**11**	1	10	1	0
**Median (IQR)	--	--		**5** (4-5)	
NWAB participants	**14**	0	15	0	0
**Median (IQR)	--	--		**5** (4-5)	
LCC #5 More wildfires					
NSB participants	**7**	3	2	5	0
**Median (IQR)	--	--		**3** (3-5)	
NWAB participants	**13**	1	8	5	1
**Median (IQR)	--	--		**4** (3-4)	
LCC #6 Vegetation change					
NSB participants	**9**	3	5	4	0

N(NSB)=12 N(NWAB)=16	CONTROL **"NS communities are currently managing this risk"**			CHANGE **"Over the past two decades this risk has:"**		
	Agree	Neither	Disagree	Increased	Stayed	Decreased
LCC #1 Less snow in winter						
NSB participants	4	3	3	9	0	0
**Median (IQR)		**3** (2-4)			**5** (4-5)	
NWAB participants	2	5	8	15	0	0
**Median (IQR)		**2.5** (2-3)			**4** (4-5)	
LCC #2 Shallow river and lake waters						
NSB participants	2	6	3	8	1	0
**Median (IQR)		**3** (2-3.25)			**4** (4-5)	
NWAB participants	2	3	9	13	1	0
**Median (IQR)		**2** (1.75-3)			**4** (4-4.25)	
LCC #3 High river water events are less common						
NSB participants	3	1	3	5	2	0
**Median (IQR)		**3** (2-4)			**4** (3-5)	
NWAB participants	0	5	4	6	3	0
**Median (IQR)		**3** (2-3)			**4** (3-4)	
LCC #4 Melting permafrost increases erosion and drying						
NSB participants	3	3	5	10	0	0
**Median (IQR)		**3** (2-4)			**5** (4-5)	
NWAB participants	4	0	11	14	1	0
**Median (IQR)		**2** (1-4)			**5** (4-5)	
LCC #5 More wildfires						
NSB participants	3	3	1	5	1	1
**Median (IQR)		**3** (3-4)			**4** (3-5)	
NWAB participants	4	1	9	11	3	0
**Median (IQR)		**2** (2-4)			**4** (3.75-4.25)	
LCC #6 Vegetation change						
NSB participants	4	5	0	6	2	0

**Median (IQR)	--	--		**4** (3-5)			**3** (3-4)			**4** (3-5)	
NWAB participants	**12**	1	8	5	0	3	3	7	12	1	0
**Median (IQR)	--	--		**4** (3-4)			**2** (2-3.75)			**4** (4-4.75)	
LCC #7 Later fall freeze-up; new freeze-thaw cycle											
NSB participants	**12**	0	9	3	0	7	2	3	8	3	0
**Median (IQR)	--	--		**5** (3.25-5)			**4** (2.25-4)			**4.5** (3.25-5)	
NWAB participants	**12**	2	10	4	0	3	4	7	13	0	1
**Median (IQR)	--	--		**4** (3-5)			**2** (1-3.5)			**5** (4-5)	
LCC #8 Earlier spring breakup; ice now melts in place											
NSB participants	**11**	1	9	1	1	5	3	3	9	1	0
**Median (IQR)	--	--		**5** (4-5)			**3** (2-4)			**4.5** (4-5)	
NWAB participants	**14**	0	11	3	0	2	4	8	14	0	0
**Median (IQR)	--	--		**4** (3.75-4.25)			**2** (1-3)			**5** (4-5)	

* Respondents choosing "False" --as in the item is not a risk— did not answer impact, control and change questions.
Table only shows agreement / disagreement and mid-point values:
High = High + Very High;
Low = Low + Very Low;
Agree = Agree + Strongly Agree;
Disagree = Disagree + Strongly Disagree;
Increased = Increased + Greatly Increased;
Decreased = Decreased + Greatly Decreased.

** Calculated on a 5-point scale where:

Very High = 5	Strongly Agree =5	Greatly Increased = 5
High = 4	Agree =4	Increased = 4
Moderate = 3	Neither Agree nor Disagree =3	Stayed the Same = 3
Low = 2	Disagree = 2	Decreased = 2
Very Low = 1	Strongly Disagree = 1	Greatly Decreased = 1

List of land cover changes were drawn from the work of Carothers et al. (2014)

Table 3C-2 Socioeconomic risks to sustainability. Results: North Slope and Northwest Arctic Borough Experts and Opinion Leaders (number of replies & median values)*

N(NSB)=12 N(NWAB)=16	RISK **"This is a risk"**		IMPACT **"Impacts from this risk are:""**			CONTROL **"NS communities are currently managing this risk"**			CHANGE **"Over the past two decades this risk has:"**		
	True	False	High	Moderate	Low	Agree	Neither	Disagree	Increased	Stayed	Decrease d
Risk #1 Community health and health services problems											
NSB participants	**9**	3	9	0	0	4	1	4	7	1	0
**Median (IQR)	--	--		**5** (4.5-5)			**3** (1.5-4.5)			**5** (4.25-5)	
NWAB participants	**13**	1	11	3	0	4	2	8	9	3	1
**Median (IQR)	--	--		**5** (4-5)			**2** (1-4)			**4** (3-5)	
Risk #2 Environmental problems											
NSB participants	**11**	1	10	1	0	4	2	5	10	0	0
**Median (IQR)	--	--		**5** (4-5)			**3** (2-4)			**5** (4.75-5)	
NWAB participants	**14**	0	14	1	0	0	4	10	14	0	0
**Median (IQR)	--	--		**5** (4-5)			**2** (1.5-2.5)			**4** (4-5)	
Risk #3 Problems with education from issues in the school system											
NSB participants	**9**	3	8	1	0	4	3	2	5	3	0
**Median (IQR)	--	--		**4** (4-5)			**3** (2-5)			**4** (3-5)	
NWAB participants	**14**	0	11	4	1	8	0	6	5	8	0
**Median (IQR)	--	--		**4** (3-5)			**4** (2-4)			**3** (3-4)	
Risk #4 Challenges to the transmission of traditional knowledge											
NSB participants	**11**	1	9	1	1	6	4	1	7	3	0
**Median (IQR)	--	--		**4** (4-5)			**4** (3-5)			**5** (3-5)	
NWAB participants	**14**	0	10	4	2	9	4	3	9	6	0
**Median (IQR)	--	--		**4** (3-4)			**3.5** (2.75-4)			**4** (3-4)	
Risk #5 Problems with effective decision-making											
NSB participants	**10**	2	8	2	0	4	4	2	7	2	0
**Median (IQR)	--	--		**5** (3.75-5)			**3** (2.75-4.25)			**5** (3.5-5)	
NWAB participants	**13**	1	11	4	0	5	5	5	5	8	1
**Median (IQR)	--	--		**4** (3-4)			**3** (2-3.5)			**3** (3-4)	
Risk #6 Problems with issues with industrial and resource development											
NSB participants	**8**	3	7	1	0	4	0	4	6	1	0
**Median (IQR)	--	--		**5** (4.25-5)			**3** (1-4)			**5** (4-5)	

NWAB participants	**12**	2	10	2	1	2	3	8	10	2	0
**Median (IQR)	--	--		**4** (3.25-4)			**2** (2-3)			**4** (4-5)	
Risk #7 Risks to culture											
NSB participants	**10**	2	9	1	0	7	1	2	8	1	0
**Median (IQR)	--	--		**5** (4-5)			**4** (2.75-4.25)			**5** (4-5)	
NWAB participants	**13**	1	13	1	1	11	1	3	11	3	0
**Median (IQR)	--	--		**4** (4-5)			**4** (3-4)			**4** (3.5-4)	

* Respondents choosing "False" --as in the item is not a risk— did not answer impact, control and change questions.
Table only shows agreement / disagreement and mid-point values:
High = High + Very High;
Low = Low + Very Low;
Agree = Agree + Strongly Agree;
Disagree = Disagree + Strongly Disagree;
Increased = Increased + Greatly Increased;
Decreased = Decreased + Greatly Decreased.

** Calculated on a 5-point scale where:

Very High = 5	Strongly Agree =5	Greatly Increased = 5
High = 4	Agree =4	Increased = 4
Moderate = 3	Neither Agree nor Disagree =3	Stayed the Same = 3
Low = 2	Disagree = 2	Decreased = 2
Very Low = 1	Strongly Disagree = 1	Greatly Decreased = 1

CHAPTER 4: COMPARING VERTICAL SCALES OF RISK PERCEPTIONS AMONG NORTH SLOPE TRIBAL LEADERS AND ALASKA STATE AND US FEDERAL EXPERTS[1]

Abstract: This study explores the vertical scalability of risk perspectives between North Slope (Alaska) Iñupiat tribal leaders and state and federal employees charged with monitoring, researching, and or managing the region's resources, but who do not reside in the region. Participants were asked a series of questions about North Slope land cover changes and risks to North Slope community sustainability, as well as perspectives on the complexity of North Slope social and environmental systems. Five of the eight North Slope village tribal councils, totaling 29 participants, and 32 state and federal employees participated in our survey. Likert-type question items were analyzed using descriptive and inferential statistics, and exploratory factor analysis. Risk items were mapped in a heat map based on three risk dimensions (impact, control, change), while open-ended questions were analyzed thematically using qualitative content analysis. Results show that while risk impacts are assessed similarly between the two groups, there are important differences in how risks are prioritized, conceptualized, and perceived to interact with community resilience.

Keywords: adaptive capacity, risk perception, social-ecological systems, resilience, North Slope, Alaska, Iñupiaq villages

4.1 INTRODUCTION

Community sustainability in Arctic Alaska has been at the center of research efforts for over two decades (e.g. Berman *et al.*, 2004; Kruse *et al.*, 2004; Larsen *et al.*, 2010). Studies have been motivated by rapid changes resulting from biophysical (e.g. land cover, sea ice quality and extent, hydrological regime,

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[1] Blair, B. Comparing scales of risk perceptions among North Slope tribal leaders and Alaska State and US Federal experts. Prepared for submission in *Frontiers in Ecology and the Environment.*

seasonality), and socioeconomic (e.g. demographic, economic, health, development infrastructure) drivers (Andrew, 2014). These rapid changes increasingly stress North Slope social systems, including subsistence activities (Eicken, 2010; Lynch and Brunner, 2007; Oswald *et al.*, 2014). Ecosystems have, in the past, adapted to large changes in climate, however, the predicted rate of change that is set to occur in the coming century is as much as 50 times faster than the warming from the previous ice age (Dessler, 2015). Because the warming trend is expected to continue, increased attention has been paid to adaptive capacity and the social limits of adaptation to climate change impacts—such as the decision-making processes that underpin adaptation (Adger *et al.*, 2009; Arctic_Council, 2016; Berman *et al.*, 2004).

Many North Slope (NS), Alaska communities are concurrently affected by rapid climate change and rapid industrial development (Raynolds *et al.*, 2014; Walker *et al.*, 1987). The cumulative impacts from rapid changes and local control over decisions and outcomes are at the crosshairs of local entities advocating a strong role in governance of resources and Iñupiat ways of life. As noted by the Alaska Native Science Commission's response to the Bureau of Land Management's Social Science Plan for the National Petroleum Reserve-Alaska (NPR-A):

> "Community discourse, cohesion, consensus building, and decision making should be studied to better understand internal practices and their relationship to the practices and timelines of external agencies. (…) Individual and community sense of control over events and activities that affect them should be evaluated (…) such an evaluation should examine perceptions as well as records of past decisions" (ANSC, 2009, p.21).

This study brings prominence to the North Slope village tribal perspective on rapid changes, risks, and control in a comparison with the perspective of external agencies. Tribal perspectives on risks and sustainability are important, because tribes are influential entities with an indigenous view of life and ancestral ties to the lands. This perspective is sometimes lost when combined with other perspectives.

The goal of this analysis is to examine how NS tribal leaders perceive risks to community sustainability, what factors are most prominent in forming these perceptions, and how these points compare to those of U.S. federal and State of Alaska experts.

A community-level survey was administered to interview NS village tribal council members and state and federal employees who monitor, research, or manage or NS resources, but do not reside in the region. The interview posed questions about land cover changes, as well as socioeconomic issues to evaluate each as a potential risk to sustainability. Further questions probed the perceived complexity and rate of changes of local social-ecological systems (SES), and overall community resilience. To provide context for sustainable communities, the study also re-evaluated a set of sustainability elements defined twenty years ago among Arctic Alaska communities, to see whether these still proved significant today (Kruse *et al.*, 2004). This work examines several hypotheses:

H1: A pattern can be identified in perceptions of uncertainty that is distinct to each group.

H2: A pattern can be identified in perceptions of risks that is distinct to each group.

H3: Elements of sustainability relevant two decades ago are still important today.

H4: Perceptions of risks and uncertainty correlate with community resilience[2] in both subject groups.

4.2. STATE OF KNOWLEDGE AND ANALYTICAL FRAMEWORK

4.2.1 Risks and vulnerabilities

Uncertainty, risk, vulnerability and resilience have synergistic relationships (Chapin III *et al.*, 2009). Uncertainties may arise from imperfect knowledge or the inherent variability of complex systems. The

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[2] See this chapter's working definition for resilience in section 4.2.1

extent of uncertainty, or the level of uncertainty can vary from statistically describable, to so-called recognized ignorance—uncertainty surrounding the functional relationships under study (Kahneman and Tversky, 1982; Walker *et al.*, 2003). The difference between uncertainty and risk is that while risk can, in some contexts, be quantified statistically based on past precedent, uncertainty is not easily quantifiable (Gooch, 2007). For example, statistics on seatbelt use and associated reduction in transportation fatalities over time, facilitate rational decision making (low uncertainty and high agreement) on whether or not to enact mandatory use laws. Risks are, in some contexts, considered a measurable uncertainty (Knight, 2012), although this perspective is not universally shared (Samson *et al.*, 2009). Vulnerability is the degree of likely harm a system is to experience due to the system's exposure to the harm and its sensitivity to specific stresses or hazards (e.g. Turner *et al.*, 2003). Resilience is the capacity of a system to adapt to change without transforming the internal feedbacks and relationships of the system. Resilience is tied with adaptive capacity and the system's threshold of adaptability (e.g Chapin III *et al.*, 2009; Walker *et al.*, 2004). Social-ecological systems often demonstrate cycles of change, called the adaptive cycle (Gunderson and Holling, 2002) including process of navigating change in the availability of resources, and evolving components and their relationships (Holling, 1986). The resources needed by humans to navigate the adaptive cycle and limit unwanted changes or risks, compete, and often conflict, at different levels of social systems (Adger, 2000; Armitage, 2005).

In this study I focus on social resilience, defined as the ability of social systems to cope with stresses as a result of social, political and environmental change (Adger, 2000, p.347). However, while resilience can be a unifying concept in uncertain times by allowing the assessment of multiple risks and their SES impacts, it is critical to also consider systemic vulnerabilities (i.e. poverty, skewed development) to avoid the traps of rigid social pathologies (Mitchell and Harris, 2012). Approaches to reducing vulnerability include: (1) mitigation by reducing exposure to stressors; (2) sustaining natural capital and well-being in order to reduce sensitivities; and (3) increasing adaptive capacity (Turner *et al.*, 2003).

4.2.2 The links between risk perception and adaptive capacity

Risks are perceived differently by people depending on a variety of human factors such as epistemic and cultural backgrounds and moral values, as well as circumstantial factors such as novelty (unfamiliar risk) and voluntariness (self-imposed exposure—such as smoking—or not) (Fischhoff *et al.*, 1978). Risk perception, in essence, is formed from individual and group-level biases that drives emergent risk attitudes, behaviors and coping strategies under changing socioeconomic and environmental conditions (Dake, 1991; Douglas and Wildavsky, 1982; Kahan, 2012; Slovic, 1995; Slovic, 1992; Wildavsky and Dake, 1990). Decisions, on the other hand, are based on which risks rise to the forefront of public interest, and which ones are ignored (Fischhoff *et al.*, 1978; Kasperson *et al.*, 1988; Sjöberg, 2000). In other words, the processes by which risk priorities are set at all levels, be they individual, group, or policy level, hold great relevance for responding to risks (i.e. risk management), and therefore for SES resilience.

A helpful visual for understanding the role of risk perception in the adaptive capacity of SES, is the risk triangle (Crichton, 1999). In this model risk is depicted as the intersection of vulnerability, exposure and hazard—in other words, the sensitivity to, and contact with, stressors (Fig. 4.1). In this adaptation, vulnerability is depicted in greater detail than in the original risk triangle, as the intersection of exposure and sensitivity to hazards (or potential impacts from stressors), and adaptive capacity (ability to cope), as consistent with the climate change adaptation, and vulnerability assessment frameworks (e.g. Parry, 2007).

Whatever strategy is used to manage risks—be it mitigation, avoidance, or adaptation—people must first have awareness of their potential vulnerabilities, including their exposure, sensitivities to hazards, and adaptive capacity limitations. Perception is a fundamental component of risk awareness, and therefore of risk management, and by extension, of the adaptive capacity of SES.

Fig. 4.1 The risk triangle. Adapted from Crichton (1999), with *vulnerability* depicted in relation to *adaptive capacity, exposure* and *sensitivity*.

The uncertainties surrounding many risks, be they uncertainty about the probability of occurrence or the magnitude and acceptability of outcome, make risk management a complex endeavor (Beck, 1992). When conventional management systems cannot handle complex issues within the realm of rational decision-making—where outcomes are known and there is consensus on how to handle them—new, innovative approaches are needed to explore risks and sensitivities (Cardona *et al.*, 2012; Vis *et al.*, 2003). An important aspect of managing for SES resilience is the inclusion of a plurality of perspectives and knowledge forms in decisions (Berkes *et al.*, 1998; Cash *et al.*, 2006; Fath *et al.*, 2015). Resilience-based risk management approaches, such as adaptive co-management for social-ecological complexity (Armitage *et al.*, 2008), emphasize the importance of adaptation and collaboration at each phase of the knowledge pipeline as an effective strategy to manage uncertainty, build trust and promote institutional development and social learning (Argyris, 2004; Armitage *et al.*, 2008; Tschakert *et al.*, 2014).

This chapter examines perceptions of risks to NS community sustainability, among NS indigenous tribal leaders, and state and federal resource experts, in order to evaluate the extent these groups share an understanding of some of the region's pressing sustainability issues. Such inquiry is important because reducing vulnerability demands the reduction of exposure to stressors; the sustaining of natural capital and well-being, and increasing adaptive capacity[3] (Turner *et al.*, 2003). Perspectives on exposure, vulnerabilities, and well-being in the SES become relevant in decision making processes. Significant differences in perspectives decrease cross-scale collaboration, which in turn decreases the capital (or resources) required to respond and to take action in the SES against emerging risks (Fath *et al.*, 2015). Fig. 4.2 depicts the links between exposure to complex changes in the SES, risk perceptions and adaptive capacity.

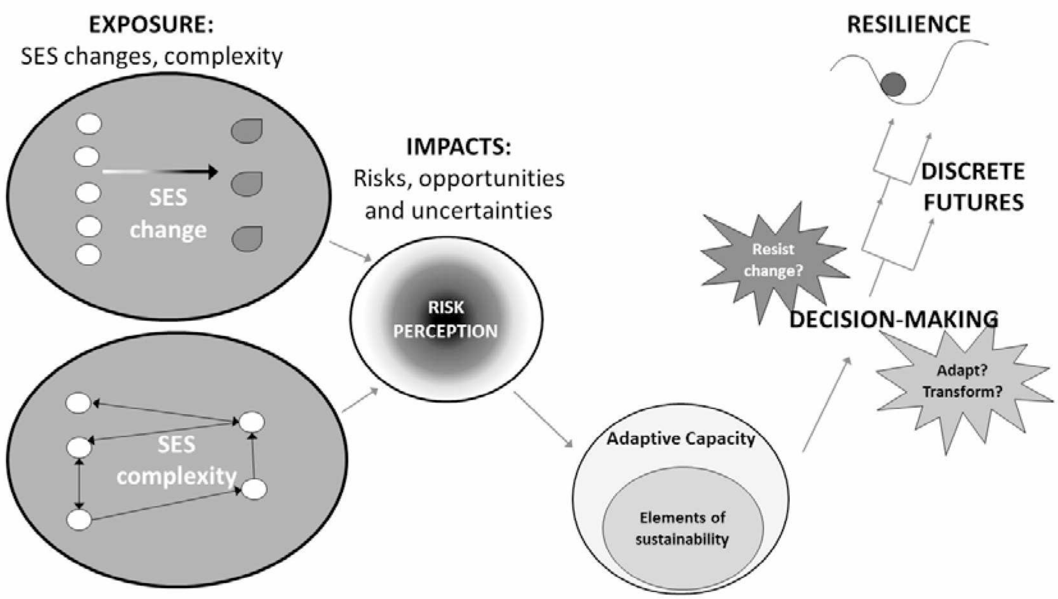

Fig. 4.2 Perceived social-ecological system changes, complexity, and risks. Diagram shows links with community adaptive capacity and resilience.

4.3 STUDY AREA AND PARTICIPANTS

Alaska's North Slope Borough (NSB) covers a vast land area at nearly 90 thousand square miles (approximately 233 thousand square kilometers). It is home to eight villages whose population is predominately Iñupiat (Fig. 4.3). The NSB receives tax revenue from oil and gas properties, and depends on these cash resources for providing basic services and maintaining village infrastructure. As well, much of

[3] Turner (2003) referred to adaptive capacity as being synonymous with resilience

the employment in villages is derived from NSB revenue sources (Kofinas *et al.*, 2016). Subsistence hunting, fishing and gathering are important activities to NSB residents, as processes by which they draw resources from the environment and maintain their culture and wellbeing (Haley and Magdanz, 2008). Subsistence species (terrestrial and marine plants and animals) vary by location.

The political status of Alaska Natives and scope of tribal powers are influential factors in determining interaction between local, regional and global entities. Numerous legal and legislative initiatives establish tribal status. The 1934 Indian Reorganization Act (IRA) established federal recognition of Alaska Native villages as tribal entities, and as a result, each NS village has an elected tribal council. An especially important milestone was the 1994 Tribal List Act, which gave Congressional recognition of 229 tribes in Alaska and eligibility for federal aid (Bodin *et al.*, 2016), however, scope of tribal powers remains an evolving issue (Case and Voluck, 2012). Tribes possess the powers of self-government with some

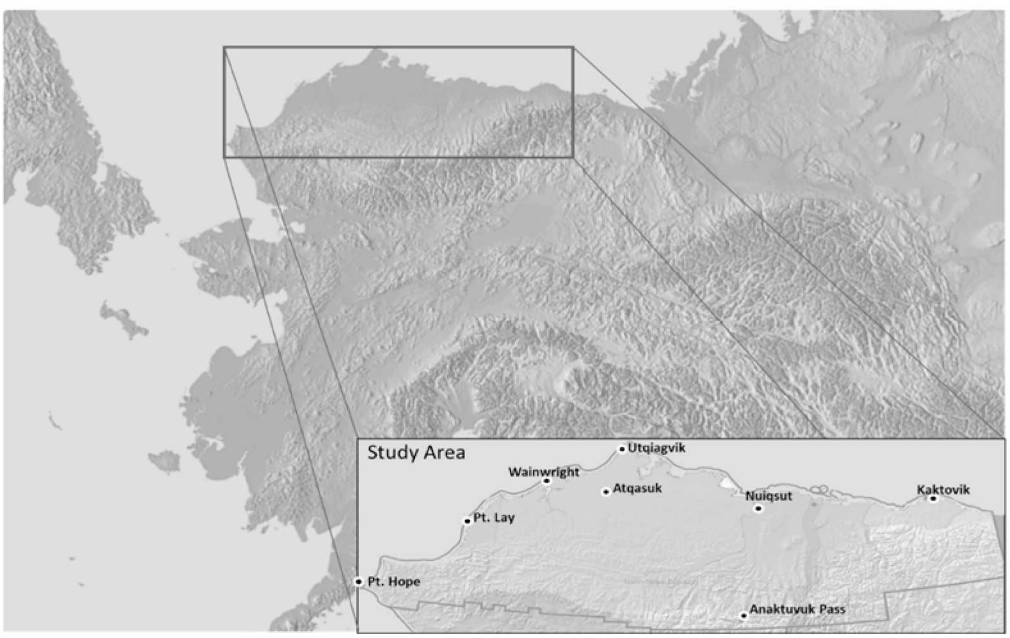

Fig. 4.3 Study area location: Villages of North Slope Borough, Alaska

limitations as superseded by acts of Congress. An elected tribal council has the authority to represent the tribe in negotiations with federal, state, and local governments (Case and Voluck, 2012). The Iñupiat

Community of the Arctic Slope is the regional IRA tribal entity representing NS villages, while the Alaska Federation of Natives is a prominent, statewide tribal organization of all Alaska Native villages.

Economically, most Alaska Native villages are dependent on federal funds, and uniform federal contracts applied across regions via corporations set up via the 1972 Alaska Native Claims Settlement Act (ANCSA). The ANCSA village and regional corporations perform a wide variety of services, from delivering important community services in health, and education, to managing natural resources and generating revenue for their shareholders. Alaska Native tribes do not recognize ANCSA corporations as tribal government. However, the federal government, in its legal and political definitions of for-profit corporations, recognizes them as "tribes," and "governing bodies" for certain purposes (Case and Voluck, 2012, p.336).

As a result, community involvement in decision-making occurs through many organizations and at multiple levels, in a conglomeration of village-to-borough-level governing structures, including native corporations, tribal governments, city governments, and other groups (e.g. subsistence advisory councils) representing specific interests. There is often a political fragmentation of interests with stakeholders representing multiple, at times conflicting, interests. For example, individuals may have a stake in, and act on behalf of, multiple political and economic entities (borough government, tribal government, Native corporations).

This study is focused on the tribal government perspectives of NS villages through focus on elected tribal council members. In an effort to compare the sustainability perspectives of formal governing bodies in the political hierarchy, perspectives within the local, traditional, indigenous government are compared with state and federal agency managers. As such, the results reflect the risk perceptions of NS tribal council members, which may be similar to, or different from, board members of ANCSA corporations. Since tribal council members in some cases sit on the board of directors of ANCSA corporations, and municipal or borough-level government councils, their views may incorporate the diversity of knowledge, opinions and perceptions that impact decision making. Choosing tribal councils as the unit of analysis to gauge local perspectives frames this research in recognition of the prominence of Indigenous Knowledge (IK), self-government, and elected representatives.

Five of the eight village tribal councils agreed to participate in this study. In observance of the wishes of some of these councils, the village-level results are not reported, with each council represented with a randomly assigned alphabetical letter as code. The tribal council cohort is referred to as "council group" throughout this study.

Thirty-two state and federal employees, who are experts in NS resources, but reside outside the region, participated in the survey. This group is referred to as the "manager" group. This terminology is a shorthand reference, as not all participants make decisions over resources, some partaking in monitoring and research. Collectively, however, this group's expertise bears significance for management decisions by informing policy makers and the public on the findings of science, and in some cases, directly advising decision makers. The manager group is affiliated with four state, and four federal agencies, representing a broad range of expert perspectives from the natural and social sciences. These agencies manage natural resources in the state.

A limitation to this study may arise from the sole focus on tribal councils as well as the absence of input from specifically social services-oriented branches of government, such as the Alaska Department of Health and Social Services. However, though this may seem to tip the balance of expertise toward the ecological system, most respondents hold positions at the intersection of social and ecological issues (drinking water, solid waste, subsistence, sociocultural issues, community liaison) requiring some knowledge of NS social systems as well. Table 4.1 contains details on affiliations in both groups. Each tribal council has seven seats total; in all but one case six members were able to participate.

Table 4.1 Participants

	Number of participants
Council Group	**N =29**
Village A	n = 6
Village B	n = 6
Village C	n = 6
Village D	n = 6
Village E	n = 5
Resource Manager Group	**N =32**
Alaska Department of Environmental Conservation	n = 6
Alaska Department of Fish and Game	n = 2
Alaska Department of Transportation	n = 5
Alaska Department of Natural Resources	n = 6
U.S. Bureau of Land Management	n = 3
U.S. Bureau of Ocean Energy Management	n = 5
U.S. Fish and Wildlife Management Service	n = 4
U.S. National Park Service	n = 1

4.4 METHODS

Prior to recruitment and data collection, the research procedures were approved for use with human subjects (University of Alaska Fairbanks IRB# 764745-5, Appendix 4A) and informed consent was obtained from all participants.

4.4.1 The instrument

Via a custom survey instrument, this study employed qualitative content analysis, and multivariate statistics to measure participants' risk perceptions. The survey instrument design was based on (i) previous research on elements of sustainability in Arctic Alaska communities (Kruse *et al.*, 2004), (ii) data gathered at a participatory scenarios workshop held in Barrow, Alaska in February 2015, (iii) previous research on shared perceptions about land cover changes in Northern Alaska using cultural consensus analysis of observations from elders (Carothers *et al.*, 2014), and (iv) complexity and uncertainty analysis (Lindgren and Bandhold, 2009). The data gathered from these approaches yielded the following survey sections (respectively):

(i) ELEMENTS OF COMMUNITY SUSTAINABILITY: Six propositions based on results from the Sustainability of Arctic Communities Project (Kruse et al 2004) identified elements of community sustainability in Arctic Alaska 20 years ago. The council group was presented with 5-point Likert items to evaluate if the statements stand true today (Table 4.8). This approach was used to establish what sustainability means in their communities and make the term operational in our research.

(ii) SOCIOECONOMIC RISKS: Seven potential risks to NS community sustainability were used to ask our participants to confirm whether each item was indeed a risk (true/false). Each risk item was followed by three, 5-point Likert-type question items about impacts to sustainability, level of manageability with locally available resources, and direction of change over the past 20 years (see Table 4.2). These questions were only asked if the item was deemed a risk to community sustainability. Evaluations of these comprised the risk dimensions *impact, control,* and *change.* The list of seven risk items was a product of a community workshop held in in Utqiaġvik (formerly known as Barrow), in February, 2015 (see Appendix 4B).

(iii) LAND COVER CHANGES AS RISKS: A list of eight potential land cover change risks was used to ask our participants to confirm whether each item was indeed a risk to NS community sustainability (true/false. Each risk item was followed by three, 5-point Likert-type question items about impacts to sustainability, level of manageability with locally available resources, and direction of change over the past 20 years (Table 4.2). While there are inherent limitations in the application of this list to North Slope communities due to its emphasis on riverine-based subsistence (and lack of data from marine-based),the list provides a useful basis to identify those land cover changes that are universally problematic across diverse regions of Arctic Alaska.

(iv) CROSS-IMPACT ANALYSIS: A twenty-five-item, 7-point Likert scale questionnaire probed perceptions of complexity and speed of changes in NS social and ecological environments (see

Appendix 4C). Because not all risks are foreseeable or easily framed, this section was intended to map conditions that complicate risk assessment and related decision-making.

An open-ended question was also presented at the beginning of the survey to generate undirected data on respondents' risk perceptions:

(v) FREE LIST / RISKS AND READINESS: At the beginning of the survey, respondents were asked the open-ended question, "What are the five things that pose the greatest risk to the creation of healthy, sustainable communities in Northern Alaska?"

(vi) RESILIENCE: At the end of the survey, respondents were asked to evaluate the resilience of NS communities (i.e., readiness of community to cope with possible futures) via two propositions with a Likert-type response format:

(a) "Northern Alaska communities are prepared to face future economic and environmental challenges" and (b) "Northern Alaska communities are prepared to prosper even in turbulent times" The entire survey protocol is presented in Appendix 4C.

4.4.2 Construct validity and reliability of scales

The risks of land cover change (LCC) and socioeconomic (SECON) change were initially evaluated by participants, based on whether or not they were seen as posing a risk to community sustainability. For each item that respondents considered a risk, they were then asked three questions about its i) impacts, ii) local control, and iii) changes in intensity over time. Items that were not considered to pose a risk by at least 70% of council group participants (LCC risk 3) or items that had a significance of association with place of residence (LCC risks 2,5,6) were eliminated from further group-level analyses. These item-level results can be found in Appendix 4E. Four LCC items were considered a risk by these criteria, and were analyzed based on impacts, controllability, and direction of change. The 5-point Likert-type item results were aggregated, using the arithmetic means across all items to provide overall composite scores for LCC and SECON risks based on these three dimensions. Items in the cross-impact analysis (Lindgren and Bandhold, 2009), were modified to measure perceptions of uncertainty about Northern Alaska's SES. Table 4.2 provides information about the scales and reliability measures. Cronbach's alpha value of 0.7 is recommended for social science research, 0.8 is desirable (George and Mallery, 2003). All scales met these criteria.

For individual items, median results and non-parametric tests of significance, such as Mann-Whitney U-test, are reported to aid between-group, item-wise comparisons (Appendix 4E). When examining overall LCC and SECON risk dimensions using summative scores, such as average risk impacts, results are reported using mean and standard deviation, and tested with independent samples t-test. This is also true in the case of the cross-impact analysis built on a 7-point response format, comprising of two Likert scales with 13 and 12 items for system complexity and changes (respectively). It has been argued that Likert-type

Table 4.2 Scale information and internal consistency reliability.

LCC risks	**Scale**	**Items**	**Cronbach's α**
1.Less snow in winter 2.Melting* permafrost increases erosion and drying 3.Later fall freeze-up 4.Earlier spring break-up	Impact Control Change	4 4 4	0.77 0.71 0.79
SECON risks			
1 Ineffective decision-making 2 Community health and health services problems 3 Environmental problems 4 Education: school system Education: transmission of traditional knowledge 5. Problems from industrial and resource development Risks to culture	Impact Control Change	7 7 7	0.75 0.86 0.76
Cross-impact analysis (itemized description in Appendix 4C)			
Social-ecological systems complexity	Complexity	13	0.77
Social-ecological systems rate of changes	Change	12	0.77
Community resilience (itemized description in Appendix 4C)			
	Resilience	2	0.8

***"Melting" permafrost refers to thawing permafrost: In this survey the author adhered to the original culturally-appropriate wording from the Carothers et al. (2014) study that relied on elder observations.

question items yield ordinal data that are not appropriate for parametric statistics (Kampen and Swyngedouw, 2000; Kuzon Jr *et al.*, 1996), consequently median and interquartile range are the proper path to a measure of central tendency (Jamieson, 2004). However, the robustness of parametric statistics performed on data from multi-item, proper Likert-scales (Likert, 1932), has been established (e.g. Carifio and Perla, 2008; Carifio and Perla, 2007). Furthermore, the robustness of parametric tests performed on individual Likert-type questions have also been proven to show superior performance than non-parametric ones (Norman, 2010).

4.5 RESULTS

The presentation of survey results follows the schematics of Fig. 4.2. First, the results of the cross-impact analysis scales measuring perceptions of SES changes and complexity are discussed to gauge observations of systemic uncertainty between the two participant groups. The results are further evaluated based on exploratory factor analysis to identify underlying dimensions that explain variations in the perceptions of the two groups. Next LCC and SECON risk results are presented to convey risk trends observed by participants. To complement this section, results from the open-ended risk question are reported as well. The third section presents findings related to elements of community sustainability in Arctic Alaska building on research by Kruse et al. (2004), and links between specific risks identified by our respondents and these elements. Finally, we discuss the synergies between adaptive capacity, decision-making and resilience. This discussion is framed by the context from our respondents' views on community resilience.

4.5.1 Cross-impact analysis: Perceptions of uncertainty

The 25-item uncertainty analysis gives an overview of perceptions of complexity and rate of changes in the North Slope region's social and environmental systems. Initially, scores were derived from 12 statements concerning changes, and 13 statements concerning the complexity of SES components, which were evaluated on a seven-point Likert scale from 1 (completely disagree) to 7 (completely agree). Mid-range coordinates (4.0, 4.0) indicate perceptions of continuity in, and foresight of, the system's future states, while higher scores indicate a shift toward uncertainty, and decreased ability to control outcomes. The council group's initial composite scores ($M_{changes}$=4.8, SD=0.71 and $M_{complexity}$=5.3, SD=0.69), and the manager group's scores ($M_{changes}$=4.5, SD=0.57 and $M_{complexity}$=4.6, SD=0.81) are modeled using grey symbols labeled "outlook on future included" in Fig. 4.4. These two dimensions indicated the council group falling closer towards the region of uncertainty than managers. While the two groups rated changes similarly, along the complexity dimension the difference between results increases to a statistically significant mean difference of 0.72; t(59)=3.7, p= .001. The results seemed to suggest that regardless of group membership, participants consider the rate of changes in the SES to be moderately high, while in the case of complexity membership shows a significance of association with higher scores in the council group.

4.5.1.1 Factor analysis

Next, the cross-impact questionnaire was evaluated using exploratory factor analysis (EFA) in order to uncover latent factors that may explain group-specific trends in how participants related to question items. In simple terms, factors refer to groupings of similar variables into common dimensions that explain their variations. The goal was to examine each cluster to identify emergent themes. For example, whether certain patterns emerge in the complexity model that are different from ones under changes. Such analysis helped to observe differences in the organizing principles between the two groups' perceptions. Furthermore, factors identified can later be analyzed in terms of any potential correlations with LCC and SOCECON risk dimensions (impacts, control and change). Though sample sizes were small here, satisfactory factor recovery was possible under such conditions. De Winter found that with a sample size N = 17-21, recovery can be successful at factor loadings λ = 0.8, number of factors f= 3-4, and number of variables p = 6-12 (de Winter *et al.,* 2009).

Variables were derived from the cross-impact questionnaire, preserving the grouping of 12 change and 13 complexity items, which were separately subjected to EFA. Initially, factorability of items was examined in both the council and manager groups. All items correlated at least .3 with at least one other item, with the exception of 2 change items in the councils group, suggesting reasonable factorability. Kaiser-Meyer-Olkin measure of sampling adequacy in our final models was above the recommended value of .5 (Kaiser, 1974), the diagonals of the anti-image correlation matrix were also above 0.5, and Bartlett's test of sphericity was significant in all cases (Appendix 4D).

Principal axis factoring with oblique (promax) rotation was chosen to extract the factors. For social science studies, principal axis factoring is often preferred because it makes no assumptions about data distribution, while oblique rotation is preferred because it creates a solution that leaves room for factors to be correlated (Baglin, 2014). We retained factors based on the Kaiser Criterion, Scree test and cumulative percent of variance, in order to retain meaningful factors with satisfactory eigenvalues. Using λ factor loadings -the degree of association each observed variable has with the underlying latent factor- cross-loadings of items were examined to find items with significant correlation with multiple factors. Variables with λ below 0.3 were eliminated one at a time and the factor extraction repeated. Final models were chosen based on (i) the leveling off of eigenvalues on the scree plot, (ii) difficulty of interpreting subsequent factors (insufficient λ values, heavy cross-loadings), and (iii) final factor correlation matrix with all correlations less than 0.6. Variables eliminated based on these criteria are indicated along with final results in Table 4.3.

The factors were given descriptive labels based on interpretations of common themes and relationships between the variables. In naming the clusters, attention was paid to the λ values. Any factor loading above 0.6 is considered a strong association, and above 0.4 is considered moderate (Comrey and Lee, 1992; Matsunaga, 2015). Based on these, the relative prominence of variables in addition to their theme played a role in the chosen labels. Where possible and applicable, identical names were given to factors in the

Table 4.3 Exploratory factor analysis results. Social-ecological system changes and complexity models shown. Variable names: SC = social system change, EC = environmental system change, SX = social system complexity, EX = environmental system complexity. *Reverse coded variables: Items worded positively, where higher scores indicate less uncertainty in the environment, and ability to forecast future trends, were reverse scored in order to keep them on the same scale as the rest of the variables.

SES changes factors:

Council Group	**λ**
Unpredictable risks	
EC_6 The sustainability of Northern Alaska communities is highly influenced by unpredictable environmental challenges.	0.77
SC_3 The two boroughs are constantly having to cope with risks that are changing	0.75
EC_5 Environmental research and monitoring needs in Northern Alaska are constantly changing	0.56
Shifting social and political capital	
SC_4 The regulatory environment is continually changing	0.84
SC_5 Social values in society are continually changing	0.81
Negative outlook	
revEC_1* The future of Northern Alaska's environment looks positive in the coming years.	0.81
revEC_2* Northern Alaska's environment will support the sustainability goals of its communities in the coming years.	0.50
Kaiser-Meyer-Olkin measure: .63	
Bartlett's Test – Sig. .001	
Eliminated variables: EC_3, EC_4, SC_1, SC_2, SC_6	

Manager Group	**λ**
Negative outlook	
revEC_1* The future of Northern Alaska's environment looks positive in the coming years.	0.84
revEC_2* Northern Alaska's environment will support the sustainability goals of its communities in the coming years.	0.73
revSC_2* Opportunities for the two boroughs look good for the next few years	0.72
revSC_1* Regional and global markets will grow for several years in ways that support sustainability in the two boroughs.	0.68
Shifting knowledge demands	
SC_6 There is high demand placed on Northern Alaska communities having to innovate because of new rules and regulations	0.87
SC_4 The regulatory environment is continually changing	0.63
EC_5 Environmental research and monitoring needs in Northern Alaska are constantly changing	0.58
Kaiser-Meyer-Olkin measure: .59	
Bartlett's Test – Sig. .001	
Eliminated variables: EC_3, EC_4, EC_6, SC-3, SC_5	

SES complexity factors:

Council Group	**λ**
Global-local links	
EX_2 The Arctic environment is very complex with many unclear factors and relationships influencing the two boroughs.	0.90
SX_3 Actions taken at the Pan-Arctic level affect lives strongly in the two boroughs.	0.60
EX_4 New and unpredictable environmental changes are constantly occurring.	0.43
Unpredictable policies	
SX_6 The sustainability of Northern Alaska communities is highly influenced by unpredictable public policies	0.79
EX_5 The two borough's environment is highly influenced by unpredictable public policies.	0.71
Changing economy & environment	
SX_2 The business environment is very complex with many unclear factors and relationships affecting the two boroughs	0.86
EX_1 Environmental changes in the northern region of Alaska will affect the state and region strongly	0.42
Kaiser-Meyer-Olkin measure: .63	
Bartlett's Test – Sig. .02	
Eliminated: EX_6, SX_1, SX_3, SX_4, SX_5, SX_7	

Manager Group	**λ**
Unpredictable environmental changes	
EX_6 The sustainability of Northern Alaska communities is highly influenced by unpredictable environmental challenges	0.94
EX_4 New and unpredictable environmental changes are constantly occurring	0.69
EX_1 Environmental changes in the northern region of Alaska will affect the state and region strongly	0.65
EX_2 The Arctic environment is very complex with many unclear factors and relationships influencing the two boroughs.	0.56
SX_7 There are many unexpected threats that the two boroughs have to cope with.	0.51
Unpredictable policies	
SX_6 The sustainability of Northern Alaska communities is highly influenced by unpredictable public policies	0.94
EX_5 The two borough's environment is highly influenced by unpredictable public policies.	0.77
SX_4 New and unpredictable economic and political events and interests in the Arctic are constantly occurring	0.50
Kaiser-Meyer-Olkin measure: .70	
Bartlett's Test – Sig. .001	
Eliminated: EX_3, SX_1, SX_2, SX_3, SX_5	

council and manager groups if the combination of variables expressed identical themes, even if the exact combination of items was different.

In the council group's SES changes model, three factors accounted for a cumulative variance of 75%; with each explaining 38%, 22%, and 15%, respectively (percent values correspond to the order in which factors appear in tables). In the manager group, two factors explained a total of 66% variance, at 39% and 27% each. In the SES complexity model, three factors explained 33%, 23%, and 15% of an overall 71% cumulative variance in the council group; while in the manager group two factors explained 47%, and 17% of variance each, for a total of 64%. As a final step, composite scores were created for each of the factors, based on the mean of the items in each, ignoring λ values (Table 4.4). DiStefano et al. (2009) noted that this unrefined method has been established as appropriate for exploratory research (Hair *et al.*, 2009; Tabachnick *et al.*, 2001). Because this study aims to simplify complex and dynamic human perceptions, but without claiming to predict them, EFA and unrefined factor scores produce adequate basis for such initial analyses.

Table 4.4 Factor scores

Council Group	**Factor score**	**SD**
SES Changes		
1. Unpredictable risks	5.3	1.3
2. Shifting social and political capital	5.3	1.2
3. Negative outlook	3.4	1.4
SES Complexity		
1. Global-local links	5.7	1.2
2. Unpredictable policies	5.1	1.5
3. Changing economy and environment	5.0	1.3
Manager Group		
SES Changes		
1. Negative outlook	4.4	1.2
2. Shifting knowledge demands	4.4	1.2
SES Complexity		
1. Unpredictable environmental changes	4.9	1.1
2. Unpredictable policies	4.2	1.2

The factor *negative outlook* (Table 4.3) appeared in both groups' SES changes model. In the manager group, this factor includes both social and environmental system variables. In the council group, this factor is comprised of only environmental system variables, indicating prominence over social ones in explaining total variance. The variables in question (EC_1, EC_2, SC_1, SC_2) belonged to a group of 4 items that asked respondents to consider the future state of their SES, and evaluate whether the outlook was good or bad. The rationale behind this area of inquiry was that an optimistic view of the future (i.e. the stance that things are headed in the right direction), presupposes continuity of current trends, a sense of control, and the ability to project outcomes to steer the system toward desired futures. These are usually traits of low uncertainty in a system (Stacey, 2007; Tschakert *et al.*, 2014). Therefore, in the summative scores, highly negative responses to these questions increased overall change scores (towards increased uncertainty), while low scores (translating to a positive viewpoint) decreased them.

When examining results further, it became clear that assumptions regarding a negative correlation between future outlook and perceptions of change do not hold up to scrutiny in the council group. The factor score (Table 4.4) for *negative outlook* on the council group's side (M = 3.4) sharply deviates from the other two factors in the model, *unpredictable risks* (M = 5.3) and *shifting social and political capital* (M =5.3). These two dimensions communicate high rates of changes, or tendency to move to the right of the mid-point in Figure 4.4 toward uncertainty, while the council's low score on *negative outlook* shifts to the left of the 4.0 mid-point. The council group's less negative outlook was also statistically significant from the manager group's (M = 4.4, SD = 1.2); $t(59) = 3.2$, $p = .002$. This showed that there were underlying differences between the two groups in terms of future projections, causing the inclusion of "outlook on future" question items with the other change items to skew results. This ended up muting the otherwise high perception of change in the council cohort. High complexity, rate of changes, and uncertainty do not preclude a positive outlook in the council group (Hypothesis 1).

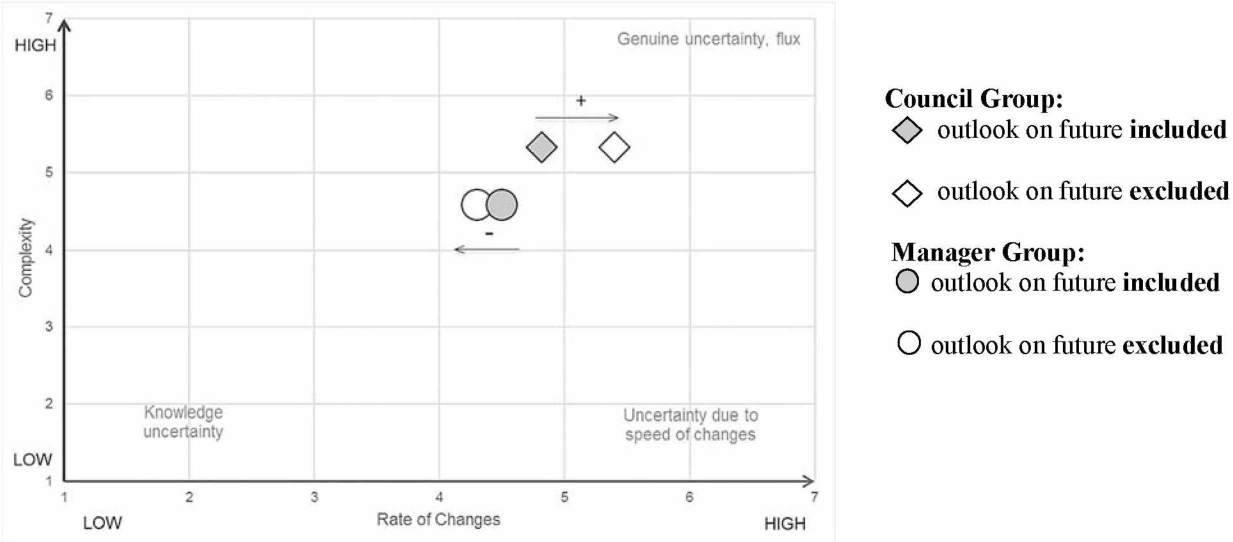

Fig. 4.4 SES complexity and uncertainty analysis results for the council and manager groups. The figure includes results with and without "outlook on future" items (these are the same item that, when reverse scored, make up the *negative outlook* factor in Table 4.3), and direction of change in scores. The chart shows different uncertainty types as factors of complexity and change levels, adapted from Lindgren and Bandhold (2009, 173).

When recalculating cross-impact change scores, omitting the group of four items on future outlook, we see a sharp increase in the council group's results (M = 5.4, SD = 1.0), and a decrease in the manager group's (M = 4.2, SD = 0.87); and this time, change scores also have a strong correlation with membership; t(59) = 4.03, p = .001. Fig. 4.4 depicts this final model for both groups along with the initial one in white, labeled "outlook on future excluded." This new model shows that the council group rates both changes and complexity much higher than the manager group.

Tellingly, under the manager group, *shifting knowledge demands* is based on concerns regarding a constantly changing regulatory and research environments. Of its variables, EC_5, speaking to ever-changing research and monitoring needs in Northern Alaska, had the highest central tendency (M = 4.8, SD = 1.4), suggesting that the experts involved in the management and monitoring in the region, recognize the challenges posed by changing research demands. Unpredictable policies in the SES complexity model are also a testament to a volatile regulatory environment, however, the overall factor score (M =4.2) suggests a close to neutral stance. On the council group side, the top complexity factor is *global-local links.* The variables under this dimension speak to the complex relationships between the local and regional and global environments, and decisions from outside that bring about change. On the managers' side, *unpredictable environmental changes* is most prominent.

Overall, council members' perception of uncertainty was most influenced by the unpredictability of changes that are occurring, and by the complexity of global connections in the region's SES. (Table 4.4). This perceived uncertainty is compounded by a difficult regulatory environment, but mitigated by a somewhat positive outlook on the future, that is independent of change and complexity. This situation is due, perhaps, to a sense of resilience. In the manager group, rapid environmental changes are a most prominent factor in an otherwise moderate sense of uncertainty, and these correspond with a somewhat negative outlook on future sustainability in the region.

4.5.2 Perceptions of risk

Following the analysis of changes and complexity in the SES, the study turns to what participants identify as observed risks to community sustainability. Four out of eight LCC items (Table 4.2), and all seven SECON items were identified risks by the councils group by at least a 7/10 consensus ratio using true / false question format. For each confirmed risk item, respondents were asked to rate three dimensions using a 5-point Likert-type response: impact on sustainability (5 = very high, 3 = moderate, 1 = very low); agreement on existing local capacity to control risk (5 = strong agreement, 3 = neutral, 1 = strong disagreement); and change in risk (5 = increased greatly, 3 = stayed the same, 1 = decreased greatly).

4.5.2.1 Analysis of cumulative risk

Initially, the three dimensions were evaluated by taking the arithmetic mean of responses across all LCC risks, and all SECON risks. These cumulative results (Table 4.5) are depicted in the risk heat matrix in Fig. 4.5 with the two axes representing impact and change dimensions, while the size of the symbols indicate either existing control (decreased risk, smaller size) or no control (increased risk, larger size). Heat maps

Fig. 4.5 Risk heat map. Map shows perceptions of land cover changes and socioeconomic issues as risks to sustainability among North Slope tribal councils and resource managers who do not reside in the NS region.

are color-coded cross-impact cluster analyses that provide a glimpse into a system's risk profile, aiming to aid the prioritizing of risks. Management decisions can be made based on the positioning of items in the matrix. For example, by dividing the matrix into action-quadrants one can indicate appropriate treatment plans based on which items to ignore or monitor, and which items need urgent attention. From the positioning of items, we may conclude that both groups perceive LCC and SECON risks to be highly impactful on sustainability, and having increased in intensity in the past 20 years.

Cumulative risk control scores did not yield significant results in the case of LCC risks. The council cohort's mean score of M =3.35 (SD = 0.75), and the manager group's M =3.0 (SD=0.70) speaks to both groups trending around a neutral mid-point. In the case of SECON risks however, the council group's mean score of 3.60 against the manager group's 3.10 showed significance at the $p < .05$ level. In this case, council members, but not managers, lean towards agreement about local capacity to control these risks. LCC impact, and SECON impact and change were evaluated by the council group slightly higher than the manager group with significance at the $p < .5$ level (Table 4.5).

Table 4.5 LCC and SECON risk scales. Mean (SD) and test of significance results.

LCC risks	**Impact**	**Control**	**Change**
Tribal Councils	4.16 (0.55)	3.35 (0.75)	4.42 (0.59)
Resource Managers	3.67 (0.77)**	3.0 (0.70)	4.3 (0.54)
Sig.	t(57)=2.79, p= .007	-	-
SECON risks			
Tribal Councils	4.36 (0.47)	3.62 (0.87)	4.3 (0.46)
Resource Managers	3.97 (0.57)**	3.1 (0.73)*	3.89 (0.47)**
Sig.	t(59)=2.9, p= .005	t(58)=2.5, p= .015	t(59)=3.3, p= .002

4.5.2.2 Analysis of individual risk items

Subsequently each risk item was assessed individually to see if any significant differences in the two groups may have been lost at the aggregate level. Appendix 4E contains all descriptive and inferential statistical analysis of the LCC and SECON risk items. For increased readability, we created a visualization (Table 4.6) similar to heat map 4.x to aid in the cursory examination of results. Colors correspond to numbers as shown in the legend beneath the diagram. The colored cells communicate the median and interquartile range (IQR) of the two participant groups; for each risk's impact, control, and change dimension. The graduation of color corresponds to the IQR, with the middle color corresponding to the median value. For example, see LCC#1 under impact; the council group median value of 4 is conveyed by the red mid-point, while the IQR of 3-5 is conveyed by the graduation from orange (3) to deep red (5). IQR

Table 4.6 Heat map showing itemized risk observations. Color coding is based on median and interquartile ranges with red (green) indicating higher (lower) impacts, incapacity (capacity) to control, and increase (decrease) in risk over the past two decades.

	Impact Very low (1) Very high (5)	**Local Control** Currently capable of (1) Currently uncapable of (5)	**Change** Decreased greatly (1) Increased greatly (5)
LCC_1 Less snow in winter			
Tribal Councils	4 (3-5)	3 (2-3)	5 (4-5)
Resource Managers	3 (3-4)	3 (2.75-3.25)	4 (4-5)
LCC_4 Melting permafrost increases erosion and drying			
Tribal Councils	4 (3.75-5)	2.5 (2-3)	4.5 (4-5)
Resource Managers	4 (3-5)	3 (2-4)	4 (4-5)
LCC_7 Later fall freeze-up; new freeze-thaw cycle			
Tribal Councils	4 (4-5)	3 (2-3)	5 (4-5)
Resource Managers	4 (3-4)	3 (2-4)	4 (4-5)
LCC_8 Earlier spring breakup; ice now melts in place			
Tribal Councils	5 (4-5)	3 (2-3)	5 (4-5)
Resource Managers	4 (3-4)	3 (2-4)	4 (4-5)
SECON_1 Community health and health services problems			
Tribal Councils	5 (4-5)	2 (2-4)	5 (4-5)
Resource Managers	4 (4-5)	3 (2-4)	4 (3-4)
SECON_2 Environmental problems			
Tribal Councils	5 (4-5)	2.5 (2-3)	5 (4-5)
Resource Managers	4 (3-5)	3 (3-4)	4.5 (4-5)
SECON_3 Problems with education from issues in the school system			
Tribal Councils	5 (3-5)	2 (2-3)	4 (4-5)
Resource Managers	4 (3-5)	3 (2-4)	3 (3-4)
SECON_4 Challenges to the transmission of traditional knowledge			
Tribal Councils	4 (4-5)	2 (2-3)	4 (4-5)
Resource Managers	4 (4-4.25)	2 (2-3)	4 (3.5-5)
SECON_5 Ineffective decision-making			
Tribal Councils	4 (3-5)	2 (2-3)	4 (3-5)
Resource Managers	4 (4-5)	3 (2-4)	3 (3-4)
SECON_6 Problems from industrial and resource development			
Tribal Councils	5 (4-5)	2 (1-3)	5 (4-5)
Resource Managers	4 (3-4.25)	2 (2-3)	4 (3-4)
SECON_7 Risks to culture			
Tribal Councils	5 (4-5)	2 (1-2.5)	4 (4-5)
Resource Managers	4 (3-4)	2 (2-3)	4 (3.5-5)

Legend	1	2	3	4	5

scores enrich our understanding of patterns between the two groups, by communicating variability of feedback, or the middle 50% of statistical dispersion. If the observer approaches the diagram with the understanding that green and yellow mean “good” (low perceived risk), while red means “bad” (high perceived risk), some of these patterns become immediately apparent.

In this interpretation of results, control scores were reverse coded: High scores on this item originally corresponded with greater control, and therefore decreased risk. However, in the color coded heat map, higher values (and therefore more red) represent greater risks. The reverse coded control dimension is now represented on the same scale with impact and change, where low scores equal less risk, and less red.

Under the change dimension, LCC change results are similar between the two groups, with both noting risks as increased (manager group) or greatly increased (council group). Looking further down under SECON risks, these differences increase further, with the manager group's low quartile IQR values dropping to 3 (risk stayed the same). LCC control IQR scores indicate a slightly positive attitude from the council group towards capacity to control risks. Capacity to control all seven SECON items was also affirmed by the council group, with the manager group concurring in three cases. Checking under the impact dimension, LCC 1 "less snow in winter" stands out as the only item that received a score below 4.0 (high impact); ending up with a 3.0 for "moderate" with the manager group.

4.5.2.3 Free-listing of perceived risks: mental models

Responses to the open-ended risk question: "What are the five things that pose the greatest risk to the creation of healthy, sustainable communities in Northern Alaska?" yielded additional, complementary insights to group-level risk models. A textual content analysis of 61 written responses produced a total of 248 observations across the data set. Using MAXQDA (v.12.0), observations were sorted using textual content into several distinct risk themes using a code system (Appendix 4F). The result of the analysis yielded ten risk themes, shown in Table 4.7. For high-frequency themes, top sub-categories are indicated in cases where the risk theme was further delineated. Based on code frequency, the top three threats to sustainability on the council group's side were: risks from industrial development, ineffective decision making, and community health and health system issues. On the manager group's side struggling cash economy, and environmental issues were in the top two spots, while ineffective decision making, and community health and health system issues were the third highest. Notably, the manager group's greatest perceived risk for communities, cash economy, emerged in first place by a large margin in the council group, with a code frequency nearly double that of second-place environmental issues. Environmental issues were identified as risks to sustainability, with near identical frequency by both groups, and linked to climate change in most cases. In most cases, industrial development as a risk was reported by the council group as referring to ongoing heavy air pollution from onshore activities, and risks from offshore accidents. Ineffective decision making ranked high in both groups; unsurprising in a highly complex SES.

Table 4.7 Coded risks: frequency results (see code book in Appendix 4F)

	Frequency	
Top-level theme	Council Group	Manager Group
Struggling cash economy	8	32[e]
High cost of living	6	6
Risks to culture	17	8
Ineffective decision making	23[a]	16[b]
Risks from industrial development	25[d]	6
Education issues	6	7
Environmental issues (separate from industrial development)	19[c]	18[c]
Community health and health system issues	22[f]	16[f]
Risks to subsistence	1	2
Demographic changes	1	9

Top sub-categories: [a] misguided regulations; [b] divided local interests; [c] climate change; [d] air pollution, offshore accidents; [e] single-resource economy; [f] substance abuse. These were the most frequently cited risk items under these overarching themes (Appendix 4F).

4.5.3 Elements of community sustainability

Next, the study turns to identifying elements of sustainability that contribute to community adaptive capacity (Fig. 4.2). The Sustainability of Arctic Communities project (Kruse et al. (2004) worked with residents from five arctic communities of Alaska and Canada in the late 1990s to define sustainability, looking for common ground among Arctic Alaska communities. The project identified common elements of sustainability, which were used in this study as listed in Table 4.8. We presented this list to participants from the council cohort and asked if these goals are applicable to their community today. Likert-type items asked respondents to rate each on a scale of 1 (strong disagreement) to 5 (strong agreement). Median results and interquartile ranges are presented. The results show strong agreement on four, and agreement on two items with little to no variation in the distribution of responses (Hypothesis 3).

Table 4.8 Elements of community sustainability propositions: Council cohort only

	Median (IQR)*
Use of, and respect for, the land and animals in our homeland are very important to community sustainability.	5 (5-5)
A cash economy that is compatible with, and supports, continued local use of the land and animals is very important to community sustainability.	4 (4-5)
Local control, and responsibility for what is done in our village homelands and for what happens to resources used by the community and on our lands are very important to community sustainability.	5 (5-5)
Education of younger people in both traditional knowledge and western science is very important to community sustainability.	5 (4-5)
Education of the outside world about community goals and ways of living is very important to community sustainability.	4 (4-5)
A thriving culture that has a clear identity based on time on the land and language, which honors and respects elders, are very important to community sustainability.	5 (5-5)

* Calculated on a scale where: Strongly Agree =5, Agree =4, Neither Agree nor Disagree =3, Disagree = 2, Strongly Disagree = 1

4.5.4 Perceptions of community resilience

In Fig. 4.2, following elements of sustainability and adaptive capacity, the model branches off into distinct futures via decision points. Resilience in the SES is a possible outcome. In order to gauge how the two participant groups perceive future resilience in NS communities, two questions asked participants to consider whether North Slope communities are prepared to thrive in times of economic and environmental challenges. Calculated on a 5-point scale where 5 = strong agreement, 3 = neutral, 1 = strong disagreement, the composite score from these questions provides the basis for comparison of the two groups' perceptions of community resilience. An independent-samples t-test was conducted to compare scores. There was a significant difference in the scores in the council group mean scores (M = 3.7, SD = 1.1), and the manager group (M = 2.3, SC= 0.99); t(58) = 5.1, p = .001. Median (IQR) values of central tendency and Mann-Whitney test confirm these same results with a composite score of Mdn = 4 (3.25-4.5) in the council group, and Mdn = 2 (1.6-3.0) in the manager group, *U* = 155.5, p = .001.

To test the final hypothesis of this research, results of cumulative risk (Table 4.5) were first checked for potential correlation between factors that emerged in the SES models (Table 4.3). The heuristic models in Fig. 4.6 and Fig. 4.7 capture the risk perception formation process in the context of uncertainty, impacts, control and change. The council group's model shows the only relationship between SES complexity factors and risk dimensions was found in the positive correlation between global-local links and LCC change. This finding provides further evidence of how large-scale processes are perceived to affect local environmental changes and create uncertainty for the future.

In Fig. 4.6, the SES change model shows that *negative outlook* had a negative correlation with the control dimension of LCC and SECON risks. Greater control correlated with less negative (positive) attitudes. In Table 4.6 we see that control values for the council group's IQR ranged between agreement and the neutral mid-point for LCC and SECON risk items. *Negative outlook* also had a negative correlation with resilience, supporting a model where less negative outlook correlates with higher sense of resilience. Ultimately there wasn't a clear path to resilience from observed LCC and SECON risk items, with future outlook playing the only significant role.

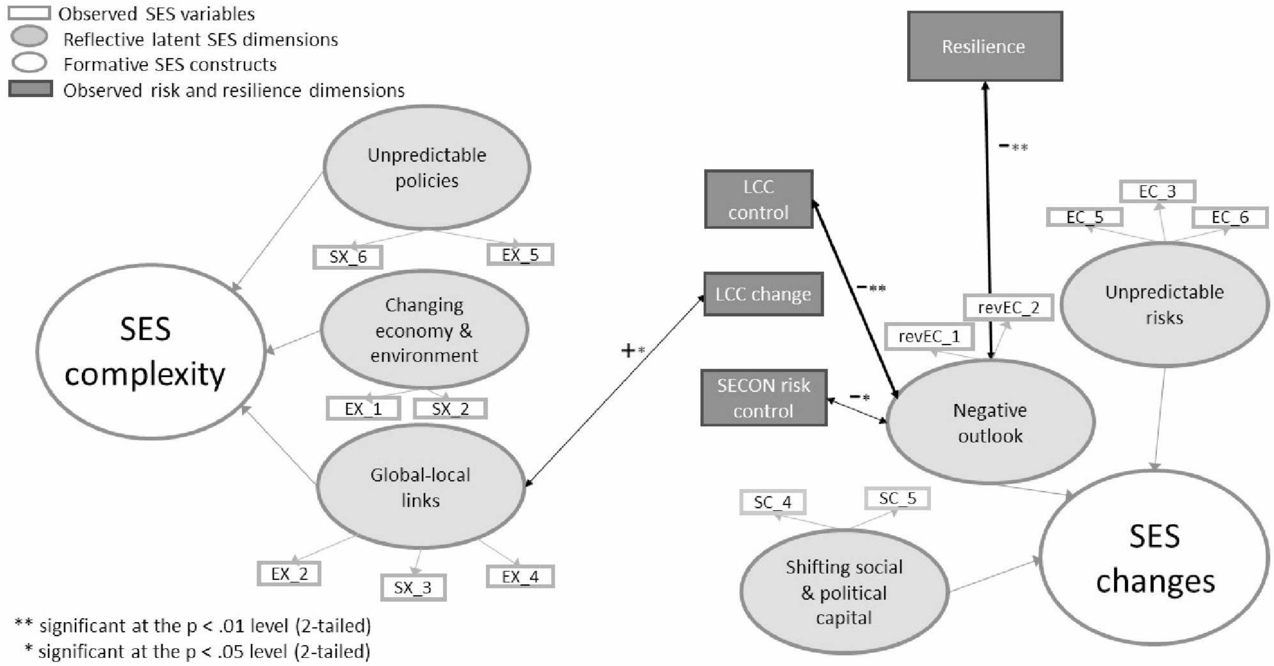

Fig. 4.6 Council Group: Heuristic path model. Model represents social-ecological system complexity and change construct formation, and relationships with observed risk and resilience variables.

The manager group's model (Fig. 4.7) shows correlation between several variables. Most notably, *negative outlook* in the SES changes model interacts only with LCC risks, but with all three dimensions. Negative views increase with increased impacts and changes, and decrease with increased control. This model suggests that the manager group's views on the future are linked with LCC risks, but not SECON risks, at least as it concerns the specific list of items presented on the survey. Counterintuitively perhaps, the factor *unpredictable policies* shows a positive correlation with control. Most notably however, both LCC and SECON risk dimensions show correlation with perceptions of resilience. This suggests that in the case of the manager group, North Slope community resilience can be understood in terms of, and modeled by, risk concepts (Hypothesis 4). An interesting point to note, and a possible area for future research, is the degree to which levels of government (state versus federal) diverge in their respective perceptions of sustainability, risks and resilience. A cursive examination of these subgroups in the manager cohort indicates that there may be identifiable patterns. At the $p < .05$ level, there was a statistically significant *decrease* in resilience scores among federal employees (M = 1.9, SD = 1.0) compared with state employees (M = 2.6, SD = 0.88); *increase* in LCC change scores in the federal (M = 4.6, SD = 0.41) compared to state (M = 4.1, SD = 0.51) group; and again *increase* in negative outlook scores in the federal (M = 5.1, SD = 1.2) compared to state (M = 3.99, SD = 0.92) employees.

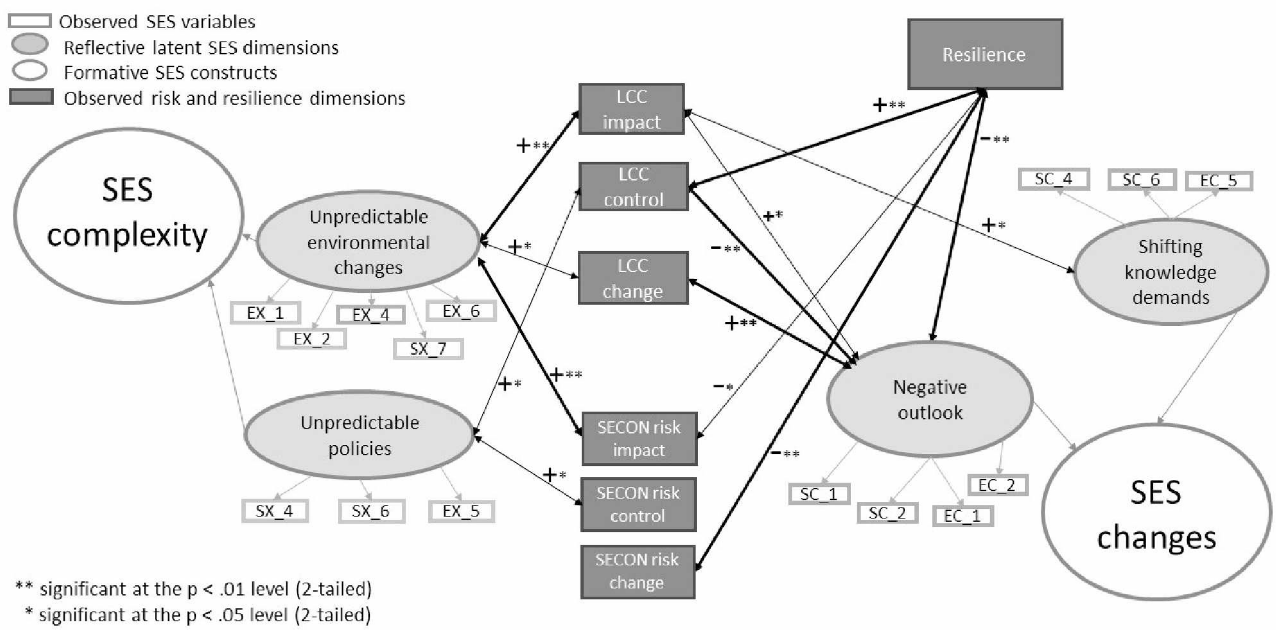

Fig. 4.7 Manager Group: Heuristic path model. Model represents social-ecological system complexity and change construct formation, and relationships with observed risk and resilience variables.

4.6 DISCUSSION

The results of the cross-impact analysis (section 4.5.1) suggest that the council group perceives higher rate of changes and greater complexity in their SES than the manager group (Hypothesis 1). The results of exploratory factor analysis (Tables 4.3 and 4.4) enhanced highlighted this point by revealing significant differences between how the council and manager groups viewed the future of NS community sustainability: The council group had an overall positive view of the future, despite perceiving greater uncertainties (change, complexity) in the SES than the manager group. The manager group on the other hand had an overall negative view of future sustainability in the NS region, despite perceiving less uncertainty in the SES (Hypothesis 1). These differences may signal a perception of resilience in the council group that is not rooted in calculations on the extent of complexity and change in the SES (Hypothesis 4). Such perception of resilience may, in part, be an artifact of history where local people have endured many externally imposed changes in the past and managed to sustain their lifeways in spite of those changes.

Section 4.5.2 presents results on risk perception analyses, pointing to subtle, yet clear distinctions in how risks are conceptualized by the two groups (Hypothesis 2). In the case of cumulative risks (Table 4.5), there was statistical significance in higher impact (LCC and SECON risks), change (SECON risks only) and control (SECON risks only) scores in the council group. Higher control scores in the council group suggest they have greater confidence—compared with the manager group—in community capacity to manage risks. This positive view of risk control underscores findings about perceptions of high resilience among the council group (Hypothesis 4).

In the analysis of individual risk items (Table 4.6) this same trend was observed in the council group: High impacts scores, and change scores were observed, along with mainly neutral to neutral-high control scores. As much as one may have expected to find that perceptions of high impacts, and increases in risks evokes a feeling of loss of control, this is not true in the council group (Hypothesis 2). There may be several reasons why this isn't so. One possibility is that the concept of risk control is more abstract, and therefore more difficult to evaluate, than impact and change. This would prompt more participants to choose the neutral midpoint value 3.0. Another point to consider is that there may be a hesitance to think of diminishing control as a lack of capacity; as this could be perceived as a desire for outside intervention, the legacies of which have had detrimental results on Alaska indigenous communities in the past (Evans-Campbell, 2008). Finally, it is possible that the same sense of resilience that was implied in the cross-impact analysis, prompts participants to focus on the history of successful adaptation and resilience that has allowed their communities to manage risks and thrive under adverse conditions (Hypothesis 4).

The fact that risk impacts and changes were perceived similarly by both groups suggests that the sharing of knowledge across-scales has successfully communicated basic risk perspectives from the local to higher jurisdictional levels. On the other hand, differences exist in the way risks and adaptive capacity are conceptualized and prioritized. The open-ended risk question results showed differences in the way the two groups conceptualize and prioritize risks (Hypothesis 2). The council group identified outside interference such as detrimental effects of industrial development, and unpredictable or misguided policies as most prominent threats. This view conveys threats to their vibrant subsistence economy, community health, and tribal sovereignty as priorities. The manager group perceived a struggling cash economy as most threatening to sustainability. This could result in differences in how the two groups approach solutions and managing risks. It may be that the council group sees sovereignty to make decisions and to govern resources as most vital to sustainability, with other risks manageable so long as this is achieved. The manager cohort, on the other hand, clearly sees economic growth, wage jobs, and improved infrastructure as requiring the most urgent attention.

In section 4.5.3, the importance of six elements of community sustainability (Table 4.8) were confirmed by the council group. This clearly underscores the prevailing importance of lands and resources, control over decisions relating to each, and healthy economies and cultural continuity to community sustainability. In turn, these elements underscore the importance of perceived risks (vulnerabilities, hazards, exposure), in managing the SES for resilience, and agency (control) over risk decisions.

Perceptions of resilience results (section 4.5.4) indicate that the council group (Fig. 4.6) had a higher level of confidence in their communities' capacity to thrive, while the manager group had less confidence. This complements previous findings regarding sense of control over risks, and positive future outlook in the council group. A sense of control, or of adaptability, resilience, and hope for the future seem to be linked in the council group. The sparsely correlated relationships between variables is notable in the council group. This could mean that risk items not represented on the survey play influential roles in the model. Or, more likely, this means that the worldview underlying resilience in the council group, cannot be captured by a model whose boundaries are defined in terms of risks. In case of the manager group (Fig. 4.7), NS community resilience was more readily modeled by risk concepts, as evidenced by the numerous correlations between risk dimensions (Hypothesis 4).

Considering these results when retracing the components of Fig. 4.2, decision points emerge where participatory, inclusive decision processes become vital in bridging the knowledge divide (i.e. diverging risk perspectives, opinions on what action to take, plurality of knowledge forms). Perceptions of risk are formed via a complex process determined by individual traits, social and cultural influences, and lived experiences (Douglas and Wildavsky, 1982; Fischhoff *et al.*, 1978; Kasperson *et al.*, 1988; Slovic, 1992). Consequently, and by extension, there are diverse perspectives and attitudes toward vulnerabilities, hazards and exposure. These attitudes, in turn, shape behavior such as adaptive action taken in response to risks. The council group is comprised of NS residents who are in close physical, cultural and historical proximity to lands and resources. Stakeholders with such deep connections with their SES tend to perceive risks and vulnerabilities differently from other stakeholder groups, who lack similar ties (e.g. Beck, 1992). As a consequence, local knowledge (such as awareness of risks, vulnerabilities and adaptive capacity), become pertinent in expert judgments of risks: These are decision processes that are embedded in social practices, norms and institutions, and therefore benefit from a plurality of opinions (Jasanoff, 2004, p. 3).

The findings of this research underscore that scales and levels of meaning often correspond to the scale of decision-making bodies. If this is so, then scales and levels of risk meanings, or risk perspectives, impact decisions and actions. Because in complex, rapidly changing SES there is a risk for managing one level at the expense of another (Adger, 2000; Armitage, 2005), the findings of this study confirm that care must be taken at decision points to consider cross-scale risks, and risk perspectives. While the specific perspectives represented by the groups involved in this research may not represent the perspectives of all NS village residents, or all state and federal experts, they are representative of the types of diversity that underlies complex, adaptive social processes such as risk perception (Blair *et al.*, 2014).

4.7 Conclusion

The challenges of social-ecological governance are not confined to the problem of quantifying risk probabilities and magnitude of impact. Decision makers are tasked with navigating highly complex risks spread across equally complex systems. The prevailing consensus among proponents of systemic, or holistic approaches to risk assessment is that we can no longer settle for a linear risk management model and top-down solutions (Klinke and Renn, 2002), but must opt instead for collaborative and flexible, adaptive models.

This study presented a comparison of these perceptions to identify levels of meaning in North Slope tribal council and manager groups. The results showed that these two groups have unique mental models of risks and resilience. This analysis is important because scale choices are a form of inclusion or exclusion: Power is reflected in the capacity to define the problem, and ultimately, capture resources, from different levels (Lebel *et al.*, 2005). As the Alaska Native Science Commission states: "The degree to which community-based processes and externally based processes are not compatible may help illuminate causes of ineffective participation by communities in various public forums" (ANSC, 2009, p.21). Because risk attitudes and behaviors impact what types of resources are employed to mitigate current risks, and buffer against future risks in the adaptive cycle (Fath *et al.*, 2015), risk perception plays a prominent role in the adaptive capacity of social-ecological systems.

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4.9 APPENDICES

APPENDIX 4A

IRB approval

UNIVERSITY OF ALASKA FAIRBANKS
Institutional Review Board
909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270
(907) 474-7800
(907) 474-5444 fax
uaf-irb@alaska.edu
www.uaf.edu/irb

June 30, 2015

To: Gary Kofinas, PhD Principal Investigator

From: University of Alaska Fairbanks IRB

Re: [764745-2] North Slope Communities Navigating Sustainability and Risks in the New Millennium :Important Questions for the North Slope Region

Thank you for submitting the New Project referenced below. The submission was handled by Expedited Review under the requirements of 45 CFR 46.110, which identifies the categories of research eligible for expedited review.

Title:	North Slope Communities Navigating Sustainability and Risks in the New Millennium :Important Questions for the North Slope Region
Received:	June 29, 2015
Expedited Category:	2
Action:	EXEMPT
Effective Date:	June 30, 2015
Expiration Date:	June 30, 2016

Required Information:

This project can be handled by Exempt review in the future.

This action is included on the July 15, 2015 IRB Agenda.

No changes may be made to this project without the prior review and approval of the IRB. This includes, but is not limited to, changes in research scope, research tools, consent documents, personnel, or record storage location.

APPENDIX 4B

Method of data analysis

Data analysis yielding the list of top 5 risks (in Table 4.2) presented to participants

Resident experts (n=29) from the North Slope (n=19) and Northwest Arctic Boroughs (n=10) (Alaska, USA) participating in a Barrow, Alaska workshop (February 2015) organized under the "Northern Alaska Scenarios Project" (funded by the National Science Foundation -ArcSEES Program#1263850) answered the question "*what are the top five issues that threaten the success of healthy, sustainable communities in 2040?*" before (n=29) and after (n=26) the workshop. The workshop provided a convenience sample of local perspectives on risks to sustainability in the Northern Alaska region.

A textual analysis of 55 written responses (before and after workshop surveys combined) produced a total of 187 observations across the data set. Using MAXQDA (version12) observations were sorted using textual content into several distinct risk themes. The analysis was further informed by participant observation over the course of the three-day workshop, where issues surrounding community sustainability were discussed at length. The result of the analysis yielded six risk themes in the top five position (Table 2, SECON risks) based on code frequency; and this list was presented to our participants in this study for further evaluation.

APPENDIX 4C

Interview protocol

OPEN-ENDED RISK QUESTION: Briefly, what are the five things that pose the greatest risk to the creation of healthy, sustainable communities in Northern Alaska?

TRUE / FALSE QUESTIONS: This is a risk to North Slope community sustainability. *True / False*

(see Appendix 4E for detailed list of risk items)

DIMENSIONS OF RISK QUESTIONS (where risk=true):

- **IMPACTS:** Impacts from this risk on community sustainability are: *Very high, High, Moderate, Low, Very Low.*
- **CONTROL:** North Slope communities are currently capable of managing or controlling this risk (adapting to, eliminating, lessening, avoiding): *Strongly agree, Agree, Neither agree / nor disagree, Disagree, Strongly disagree.*
- **CHANGE:** Over the past two decades this risk has: *Increased greatly, Increased somewhat, Stayed the same, Decreased somewhat, Decreased greatly.*

RESILIENCE QUESTIONS: *Very true, Somewhat true, Neutral, Somewhat Untrue, Not true.*

a. Northern Alaska communities are prepared to face future economic and environmental challenges

b. Northern Alaska communities are prepared to prosper even in turbulent times

SOCIAL-ECOLOGICAL COMPLEXITY QUESTIONS: *Completely disagree (1)--- Completely agree (7)*

***a)* SOCIAL COMPLEXITY INDEX:**

SX_1 Actions taken by and in the two boroughs affect the State of Alaska and region strongly.

SX_2 The business environment is very complex with many unclear factors and relationships affecting the two boroughs

SX_3 Actions taken at the Pan-Arctic level affect lives strongly in the two boroughs.

SX_4 New and unpredictable economic and political events and interests in the Arctic are constantly occurring

SX_5 It is very difficult to foresee and anticipate future changes in Northern Alaska.

SX_6 The sustainability of Northern Alaska communities is highly influenced by unpredictable public policies

SX_7 There are many unexpected threats that the two boroughs have to cope with.

***b)* ENVIRONMENTAL COMPLEXITY INDEX:**

EX_1 Environmental changes in the northern region of Alaska will affect the state and region strongly

EX_2 The Arctic environment is very complex with many unclear factors and relationships influencing the two boroughs.

EX_3 It is very difficult to foresee environmental change

EX_4 New and unpredictable environmental changes are constantly occurring

EX_5 The two borough's environment is highly influenced by unpredictable public policies.

EX_6 The sustainability of Northern Alaska communities is highly influenced by unpredictable environmental challenges.

***c)* SOCIAL SPEED OF CHANGES INDEX:**

SC_1 *(reverse scored)* Regional and global markets will grow for several years in ways that support sustainability in the two boroughs.

SC_2 *(reverse scored)* Opportunities for the two boroughs look good for the next few years.

SC_3 The two boroughs are constantly having to cope with risks that are changing.

SC_4 The regulatory environment is continually changing.

SC_5 Social values in society are continually changing.

SC_6 There is high demand placed on Northern Alaska communities having to innovate because of new rules and regulations.

***d)* ENVIRONMENTAL SPEED OF CHANGES INDEX:**

EC_1 *(reverse scored)* The future of Northern Alaska's environment looks positive in the coming years.

EC_2 *(reverse scored)* Northern Alaska's environment will support the sustainability goals of its communities in the coming years.

EC_3 There is high demand placed on northern Alaska's environment to provide resources to meet demands from users.

EC_4 Social values outside our Northern Alaska region toward the environment are continually changing

EC_5 Environmental research and monitoring needs in Northern Alaska are constantly

changing.

EC_6 The rate of innovation in environmental research and stewardship is high.

ELEMENTS OF SUSTAINABILITY QUESTIONS: *Strongly Agree, Agree, Neither Agree nor disagree, Disagree, Strongly Disagree*

I believe that:

1. Use of, and respect for, the land and animals in our homeland are very important to community sustainability.
2. A cash economy that is compatible with, and supports, continued local use of the land and animals is very important to community sustainability.
3. Local control, and responsibility for what is done in village homelands and for what happens to resources used by the community and on our lands are very important to community sustainability.
4. Education of younger people in both traditional knowledge and western science is very important to community sustainability.
5. Education of the outside world about community goals and ways of living is very important to community sustainability.
6. A thriving culture that has a clear identity based on time on the land and language, which honors and respects elders, are very important to community sustainability.

APPENDIX 4D

Exploratory factor analysis raw results from SPSS

Council group matrix results: SES changes

Council Group: SES Changes
Pattern Matrix[a]

	Factor		
	1	2	3
ENVIRONMENTAL CHANGES #6 (Q12)	.796		
SOCIAL CHANGES #3 (Q10)	.754		
ENVIRONMENTAL CHANGES #5 (Q11)	.563		
SOCIAL CHANGES #4 (Q11)		.845	
SOCIAL CHANGES #5 (Q12)		.813	
ENVIRONMENTAL CHANGES #1 (Q7)			.811
ENVIRONMENTAL CHANGES #2 (Q8)			.498

Factor loadings below 0.3 are suppressed.
Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.[a]
a. Rotation converged in 4 iterations.

Council Group SES Changes: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.625
Bartlett's Test of Sphericity	Approx. Chi-Square	52.071
	df	21
	Sig.	.000

Council Group: SES Changes: Anti-image Matrices

		EC #1 (Q7)	EC #2 (Q8)	EC #5 (Q11)	EC #6 (Q12)	SC #3 (Q10)	SC #4 (Q11)	SC #5 (Q12)
Anti-image Correlation	EC #1 (Q7)	**.491[a]**	-.256	-.212	.303	-.337	.117	-.305
	EC #2 (Q8)	-.256	**.623[a]**	.138	.127	-.105	.240	-.104
	EC #5 (Q11)	-.212	.138	**.791[a]**	-.296	-.153	-.073	-.078
	EC #6 (Q12)	.303	.127	-.296	**.633[a]**	-.429	-.148	.069
	SC #3 (Q10)	-.337	-.105	-.153	-.429	**.654[a]**	-.172	.099
	SC #4 (Q11)	.117	.240	-.073	-.148	-.172	**.625[a]**	-.634
	SC #5 (Q12)	-.305	-.104	-.078	.069	.099	-.634	**.563[a]**

a. Measures of Sampling Adequacy(MSA)

Council Group: SES Changes: Correlation Matrix

		EC #1 (Q7)	EC #2 (Q8)	EC #5 (Q11)	EC #6 (Q12)	SC #3 (Q10)	SC #4 (Q11)	SC #5 (Q12)
Correlation	EC #1 (Q7)	1.000	.323	.221	-.142	.306	.101	.361
	EC #2 (Q8)	.323	1.000	-.180	-.298	-.013	-.269	.002
	EC #5 (Q11)	.221	-.180	1.000	.452	.440	.377	.292
	EC #6 (Q12)	-.142	-.298	.452	1.000	.492	.366	.099
	SC #3 (Q10)	.306	-.013	.440	.492	1.000	.350	.220
	SC #4 (Q11)	.101	-.269	.377	.366	.350	1.000	.636
	SC #5 (Q12)	.361	.002	.292	.099	.220	.636	1.000

Council group matrix results: SES complexity

Council Group: SES Complexity: Pattern Matrix[a]

	Factor		
	1	2	3
ENVIRONMENTAL COMPLEXITY #2	.896		
SOCIAL COMPLEXITY #3	.603		
ENVIRONMENTAL COMPLEXITY #4	.432		
SOCIAL COMPLEXITY #6		.793	
ENVIRONMENTAL COMPLEXITY #5		.714	
SOCIAL COMPLEXITY #2			.860
ENVIRONMENTAL COMPLEXITY #1			.423

Factor loadings below 0.3 are suppressed.
Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.[a]
a. Rotation converged in 4 iterations.

Council Group: SES Complexity: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.627
Bartlett's Test of Sphericity	Approx. Chi-Square	36.406
	df	21
	Sig.	.020

Council Group: SES Complexity: Anti-image Matrices

		EX #1	EX #2	EX #4	EX #5	SX #2	SX #3	SX #6
Anti-image Correlation	EX #1	**.705**[a]	-.100	-.118	-.055	-.382	-.172	-.148
	EX #2	-.100	**.581**[a]	-.356	.092	.044	-.465	.041
	EX #4	-.118	-.356	**.674**[a]	.041	-.093	.038	-.064
	EX #5	-.055	.092	.041	**.611**[a]	-.097	-.039	-.515
	SX #2	-.382	.044	-.093	-.097	**.618**[a]	.189	-.091
	SX #3	-.172	-.465	.038	-.039	.189	**.582**[a]	-.115
	SX #6	-.148	.041	-.064	-.515	-.091	-.115	**.637**[a]

a. Measures of Sampling Adequacy(MSA)

Council Group: SES Complexity: Correlation Matrix

		EX #1	EX #2	EX #4	EX #5	SX #2	SX #3	SX #6
Correlation	EX #1	1.000	.237	.265	.245	.421	.251	.332
	EX #2	.237	1.000	.415	-.057	-.021	.520	.044
	EX #4	.265	.415	1.000	.025	.151	.202	.125
	EX #5	.245	-.057	.025	1.000	.248	.076	.569
	SX #2	.421	-.021	.151	.248	1.000	-.081	.267
	SX #3	.251	.520	.202	.076	-.081	1.000	.168
	SX #6	.332	.044	.125	.569	.267	.168	1.000

Manager group matrix results: SES changes

Manager Group SES Changes: Pattern Matrix[a]

	Factor	
	1	2
ENVIRONMENTAL CHANGES #1 (Q7)	.843	
ENVIRONMENTAL CHANGES #2 (Q8)	.732	
SOCIAL CHANGES #2 (Q9)	.721	
SOCIAL CHANGES #1 (Q8)	.677	
SOCIAL CHANGES #6 (Q13)		.865
SOCIAL CHANGES #4 (Q11)		.629
ENVIRONMENTAL CHANGES #5 (Q11)		.576

Factor loadings below 0.3 are suppressed.
Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.[a]
a. Rotation converged in 3 iterations.

Manager Group SES Changes: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.588
Bartlett's Test of Sphericity	Approx. Chi-Square	75.469
	df	21
	Sig.	.000

Manager Group SES Changes: Anti-image Matrices

		EC #1 (Q7)	EC #2 (Q8)	EC #5 (Q11)	SC #1 (Q8)	SC #2 (Q9)	SC #4 (Q11)	SC #6 (Q13)
Anti-image Correlation	EC #1 (Q7)	.559[a]	-.722	.170	.168	-.434	.090	-.322
	EC #2 (Q8)	-.722	.554[a]	-.235	-.333	.202	.059	.298
	EC #5 (Q11)	.170	-.235	.587[a]	.023	.133	-.182	-.429
	SC #1 (Q8)	.168	-.333	.023	.657[a]	-.563	.018	-.032
	SC #2 (Q9)	-.434	.202	.133	-.563	.618[a]	-.147	.041
	SC #4 (Q11)	.090	.059	-.182	.018	-.147	.685[a]	-.385
	SC #6 (Q13)	-.322	.298	-.429	-.032	.041	-.385	.512[a]

a. Measures of Sampling Adequacy(MSA)

Manager Group SES Changes Correlation Matrix

		EC #1 (Q7)	EC #2 (Q8)	EC #5 (Q11)	SC #1 (Q8)	SC #2 (Q9)	SC #4 (Q11)	SC #6 (Q13)
Correlation	EC #1 (Q7)	1.000	.750	-.092	.445	.576	-.088	.070
	EC #2 (Q8)	.750	1.000	-.034	.489	.402	-.185	-.134
	EC #5 (Q11)	-.092	-.034	1.000	-.115	-.181	.384	.502
	SC #1 (Q8)	.445	.489	-.115	1.000	.650	-.045	-.049
	SC #2 (Q9)	.576	.402	-.181	.650	1.000	.031	.013
	SC #4 (Q11)	-.088	-.185	.384	-.045	.031	1.000	.526
	SC #6 (Q13)	.070	-.134	.502	-.049	.013	.526	1.000

Manager group matrix results: SES complexity

Manager Group SES Complexity: Pattern Matrix[a]

	Factor	
	1	2
ENVIRONMENTAL COMPLEXITY #6	.941	
ENVIRONMENTAL COMPLEXITY #4	.686	
ENVIRONMENTAL COMPLEXITY #1	.650	
ENVIRONMENTAL COMPLEXITY #2	.556	
SOCIAL COMPLEXITY #7	.513	.335
SOCIAL COMPLEXITY #6		.935
ENVIRONMENTAL COMPLEXITY #5		.771
SOCIAL COMPLEXITY #4		.495

Factor loadings below 0.3 are suppressed
Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.[a]
a. Rotation converged in 3 iterations.

Manager Group SES Complexity: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.695
Bartlett's Test of Sphericity	Approx. Chi-Square	107.043
	df	28
	Sig.	.000

Manager Group SES Complexity: Anti-image Matrices

		SX #4	SX #6	SX #7	EX #1	EX #2	EX #4	EX #5	EX #6
Anti-image Correlation	SX #4	**.760**[a]	-.181	-.325	-.209	-.041	-.059	-.199	.195
	SX #6	-.181	**.591**[a]	-.086	.119	.292	.361	-.526	-.351
	SX #7	-.325	-.086	**.839**[a]	.174	.010	-.173	.064	-.367
	EX #1	-.209	.119	.174	**.748**[a]	-.133	-.027	.118	-.311
	EX #2	-.041	.292	.010	-.133	**.565**[a]	.395	-.216	-.513
	EX #4	-.059	.361	-.173	-.027	.395	**.656**[a]	-.233	-.613
	EX #5	-.199	-.526	.064	.118	-.216	-.233	**.749**[a]	.001
	EX #6	.195	-.351	-.367	-.311	-.513	-.613	.001	**.673**[a]

a. Measures of Sampling Adequacy(MSA)

Manager Group SES Complexity: Correlation Matrix

		SX #4	SX #6	SX #7	EX #1	EX #2	EX #4	EX #5	EX #6
Correlation	SX #4	1.000	.415	.462	.211	.166	.288	.446	.318
	SX #6	.415	1.000	.406	.028	.105	.203	.643	.406
	SX #7	.462	.406	1.000	.249	.321	.623	.435	.709
	EX #1	.211	.028	.249	1.000	.395	.360	.114	.490
	EX #2	.166	.105	.321	.395	1.000	.238	.286	.553
	EX #4	.288	.203	.623	.360	.238	1.000	.402	.755
	EX #5	.446	.643	.435	.114	.286	.402	1.000	.490
	EX #6	.318	.406	.709	.490	.553	.755	.490	1.000

APPENDIX 4E

Risk survey results

Table 4E-1 Land cover changes as risks

Land Cover Changes as Risk to Sustainability Among North Slope Tribal Councils and Non-local Experts (% & Median)* Orange highlight denotes items where Fisher's Exact Test showed statistical significance between the two groups' responses at the p< .05 level. In cases where there was a within group significance of association in responses, median values are denoted for each subgroup in the cell beneath the group results. Land cover changes #2, #5 and #6 showed a statistical significance of association with place of residence (p, .05) and are marked in red; statistics shown only for councils where risk = true. No such associations were found in the T/F questions in the resource manager group based on membership (state v. federal agency).

N(tribal council)=29 N(state & federal expert)=34	**"This is a risk"**		**IMPACT** **"Impacts from this risk are:"**			**CONTROL** **"Our communities are currently managing this risk"**			**CHANGE** **"Over the past two decades this risk has:"**		
	True	False	High	Moderate	Low	Agree	Neither	Disagree	Increased	Stayed	Decreased
LCC #1 Less snow in winter											
Tribal Council Group	**72**	28	52	21	0	28	31	14	72	0	0
**Median (IQR)	--	--		**4** (3-5)			**3** (3-4)			**5** (4-5)[1]	
Resource Manager Group	**82**	12	38	35	9	18	44	18	68	6	3
**Median (IQR)	--	--		**3** (3-4)			**3** (3-3)			**4** (4-5)[1]	
LCC #2 Shallow river and lake waters[a]											
True for Tribal Councils C & D (n=12)	**92**	0	75	17	0	33	50	8	92	0	0
**Median (IQR)	--	--		**5** (4-5)			**3** (3-4)			**5** (4-5)	
Resource Manager Group	**71**	21	41	18	12	26	26	15	50	18	0
**Median (IQR)	--	--		**4** (3-4)			**3** (3-4)			**4** (3-5)	
LCC #3 High river water events are less common (hinders waterways transportation)											
Tribal Council Group	28	**62**	*False*			*False*			*False*		
**Median (IQR)	--	--									
Resource Manager Group	32	**59**	*False*			*False*			*False*		
**Median (IQR)	--	--									
LCC #4 Melting permafrost increases erosion and drying											
Tribal Council Group	**90**	10	69	17	3	45	31	14	83	7	0
**Median (IQR)	--	--		**4** (3.75-5)			**3.5** (3-5)			**4.5** (4-5)	
Resource Manager Group	**91**	6	59	18	12	35	21	29	82	6	0
**Median (IQR)	--	--		**4** (3-5)			**3** (2-4)			**4** (4-5) *STATE=4 FEDERAL=5*	

LCC #5 More wildfires[b]										
True for tribal Councils A & C & E (n=17)	**77**	23	47	29	0	23	35	18	65	12	0
**Median (IQR)	--	--		**4** (3-5)			**4** (2.5-4)			**4** (4-5)	
Resource Manager Group	**71**	24	29	21	21	12	24	32	68	3	0
**Median (IQR)	--	--		**3** (2-4.75)			**3** (2-3)			**4** (4-5)	
LCC #6 Vegetation change[c]											
True for tribal Councils C & D only (n=12)	**83**	17	58	25	0	25	33	25	83	0	0
**Median (IQR)	--	--		**4** (3-5)[2]			**3** (2-4)			**5** (4-5)[3]	
Resource Manager Group	**76**	18	32	29	15	26	18	29	59	18	0
**Median (IQR)	--	--		**3** (3-4)			**3** (2-4)			**4** (3.5-4.25)	
LCC #7 Later fall freeze-up; new freeze-thaw cycle											
Tribal Council Group	**93**	7	72	21	0	41	31	21	76	14	3
**Median (IQR)	--	--		**4** (4-5)			**3** (3-4)			**5** (4-5)	
Resource Manager Group	**85**	9	53	29	3	35	21	26	82	3	0
**Median (IQR)	--	--		**4** (3-4)			**3** (2-4)			**4** (4-5) *STATE=4 FEDERAL=5*	
LCC #8 Earlier spring breakup; ice now melts in place											
Tribal Council Group	**83**	17	69	14	0	41	24	17	83	0	0
**Median (IQR)	--	--		**5** (4-5)			**4** (2-4)			**5** (4-5)	
Resource Manager Group	**79**	15	53	21	6	21	21	35	79	0	0
**Median (IQR)	--	--		**4** (3-4)			**3** (2-4)			**4** (4-5) *STATE=4 FEDERAL=5*	

*Percent values may not add up to 100% due to missing values, most commonly from participants who marked FALSE on the risk.

Table only shows agreement / disagreement and mid-point values: High = High + Very High; Low = Low + Very Low; Agree = Agree + Strongly Agree; Disagree = Disagree + Strongly Disagree; Increased = Increased + Greatly Increased; Decreased = Decreased + Greatly Decreased.

**Calculated on a scale where:

Very High = 5	Strongly Agree =5	Greatly Increased = 5
High = 4	Agree =4	Increased = 4
Moderate = 3	Neither Agree nor Disagree =3	Stayed the Same = 3
Low = 2	Disagree = 2	Decreased = 2
Very Low = 1	Strongly Disagree = 1	Greatly Decreased = 1

At the p=0.05 significance level a Kruskal-Wallis Test indicated that:

[1]The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=6.9488, df=1, p=.0084

[2] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=5.7078, df=1, p=.0169

[3] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=4.4265, df=1, p=.0354

a Land cover change #2: True/False answer showed significance of association with place of residence: Fisher's Exact Test p = .0131

b Land cover change #5: True/False answered showed significance of association with place of residence: Fisher's Exact Test .0316

c Land cover change #2: True/False answer showed significance of association with place of residence: Fisher's Exact Test .0131

List of land cover changes were drawn from the work of Carothers et al. (2014)

Table 4E-2 Socioeconomic risks to sustainability

Perceptions of Risks to Sustainability Among North Slope Tribal Councils and Non-local Experts (% & Median)* Orange highlight denotes items where Fisher's Exact Test showed statistical significance between the two groups' responses at the p< .05 level. In cases where there was a within group significance of association in responses, the median values are denoted for each subgroup in the cell beneath the group results.

N(tribal council)=29 N(state & federal expert)=34	**"This is a risk"**		**IMPACT** **"Impacts from this risk are:"**			**CONTROL** **"Our communities are currently managing this risk"**			**CHANGE** **"Over the past two decades this risk has:"**		
	True	False	High	Moderate	Low	Agree	Neither	Disagree	Increased	Stayed	Decreased
Risk #1 Community health and health services problems											
Tribal Council Group	**90**	10	83	7	0	44	14	28	86	4	0
**Median (IQR)	--	--		**5** (4-5)			**4** (2-4)			**5** (4-5)[1] *COUNCILS A=3.5 B&D=3 E&C=4*	
Resource Manager Group	**88**	6	71	12	3	30	18	35	50	24	9
**Median (IQR)	--	--		**4** (4-5)			**3** (2-4)			**4** (3-4)[1]	
Risk #2 Environmental problems											
Tribal Council Group	**90**	10	86	4	0	45	24	21	86	4	0
**Median (IQR)	--	--		**5** (4-5)[2]			**3.5** (2.75-4)[3]			**5** (4-5)	
Resource Manager Group	**91**	6	62	21	6	18	35	32	82	6	0
**Median (IQR)	--	--		**4** (3-5)			**3** (2-3)			**4.5** (4-5)	
Risk #3 Problems with education from issues in the school system											
Tribal Council Group	**76**	24	59	17	0	45	14	14	69	7	0
**Median (IQR)	--	--		**5** (3-5)			**4** (3-4)[4]			**4** (4-5)[5]	
Resource Manager Group	**82**	6	56	26	0	21	29	29	29	44	3
**Median (IQR)	--	--		**4** (3-5)			**3** (2-4)			**3** (3-4)	
Risk #4 Challenges to the transmission of traditional knowledge											
Tribal Council Group	**79**	21	65	14	0	48	21	10	65	14	0
**Median (IQR)	--	--		**4** (4-5)			**4** (3-4)			**4** (4-5)	
Resource Manager Group	**79**	12	62	12	3	41	24	9	56	18	0
**Median (IQR)	--	--		**4** (4-4.25)			**4** (3-4)			**4** (3.5-5)	
Risk #5 Ineffective decision-making											
Tribal Council Group	**76**	24	52	17	7	48	17	10	45	21	10
**Median (IQR)	--	--		**4** (3-5)			**4** (3-4.25)[6]			**4** (3-5)	
Resource Manager Group	**74**	15	59	15	0	29	9	32	32	29	6
**Median (IQR)	--	--		**4** (4-5)			**3** (2-4)			**3** (3-4)	
Risk #6 Problems with industrial / resource development											

Tribal Council Group	**76**	24	69	7	0	38	24	10	69	7	0
**Median (IQR)	--	--		**5** (4-5)[7]			**4** (3-5)			**5** (4-5)[8]	
Resource Manager Group	**65**	29	35	21	9	32	18	12	41	12	9
**Median (IQR)	--	--		**4** (3-4.25)			**4** (3-4)			**4** (3-4)	
Risk #7 Risks to culture											
Tribal Council Group	**86**	14	79	7	0	65	7	14	83	3	0
**Median (IQR)	--	--		**5** (4-5)[9]			**4** (3.5-5)			**4** (4-5)[10]	
Resource Manager Group	**85**	6	56	26	3	50	18	15	65	21	0
**Median (IQR)	--	--		**4** (3-4)			**4** (3-4)			**4** (3.5-4)	

*Percent values may not add up to 100% due to missing values, most commonly from participants who marked FALSE on the risk.

Table only shows agreement / disagreement and mid-point values: High = High + Very High; Low = Low + Very Low; Agree = Agree + Strongly Agree; Disagree = Disagree + Strongly Disagree; Increased = Increased + Greatly Increased; Decreased = Decreased + Greatly Decreased.

** Calculated on a scale where:

Very High = 5	Strongly Agree =5	Greatly Increased = 5
High = 4	Agree =4	Increased = 4
Moderate = 3	Neither Agree nor Disagree =3	Stayed the Same = 3
Low = 2	Disagree = 2	Decreased = 2
Very Low = 1	Strongly Disagree = 1	Greatly Decreased = 1

At the p=0.05 significance level a Kruskal-Wallis Test indicated that:

[1] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=11.4329, df=1, p=.0007.

[2] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=4.6453, df=1, p=.0311.

[3] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=4.6598, df=1, p=.0309.

[4] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=4.889, df=1, p=.0341.

[5] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=11.551, df=1, p=.007.

[6] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=4.1774, df=1, p=.0410.

[7] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=10.7739, df=1, p=.001.

[8] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=8.6771, df=1, p=.0032.

[9] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=9.2221, df=1, p=.0024.

[10] The tribal council group's rating of this attribute was statistically significantly higher than the resource manager group's, Kruskal-Wallis chi-squared=10.9299, df=1, p=.0009.

APPENDIX 4F

CODEBOOK

Table F-1 Content Analysis Codebook. Sub-codes that have their own sub-codes are noted in italic typeface, and the definition provides details on points of distinction for further granularity

Code and total code frequency	Sub-code	Definition
Struggling cash economy	Lack of wage employment	Concerns raised regarding wage employment opportunities.
	Single-resource economy	Heavy reliance on a single industrial sector for revenue, lack of development leading to unsustainable economies
High cost of living	--------	Energy, housing, transportation costs due to isolated geographic location
Risks to Culture	--------	Eroding traditions and loss of Alaska Native languages
Ineffective decision making	Divided local interests	Disagreements among local entities, and governments
	Inclusion	Inclusion of local communities in higher-level decision-making
	Regulation	Regulatory issues such as effectiveness, or transparency of, policies concerning for example (i) subsistence, (ii) tribal sovereignty.
	Cross-cultural issues	Misunderstanding of local needs by outside decision makers
Risks from industrial development	Industrial accidents	Problems from negative externalities of industrial development; Industrial disaster as risk to sustainability
	Offshore	Offshore oil development as a potential risk to sustainability
	Increased marine traffic	Risks from increased marine traffic, dated regulations not up-to-date with opening of routes
Education issues	---------	Issues with the quality of the local school system, such as high turnover or lack of local teachers.
Environmental issues	Climate change impacts	Respondent specifically mentions climate change impacts as a community concern.
	Erosion, permafrost thaw - without explicit reference to climate change	Permafrost thaw, erosion and other land cover changes, but without explicit reference to climate change as the risk source.
Community health and health system issues	General	Unspecified concern for community health
	Services	Concern over access to, and quality of, care; the portfolio of services available such as health education, preventative services, behavioral health, long-term care; and whether said services are culturally appropriate
	Substance abuse	Concern over rates of substance abuse in communities
	Suicide	Concern over suicide rates in communities
Risks to subsistence	-------	Concern about the health of subsistence economy: access to resources, transmission of traditional knowledge
Demographic changes	------	Concern over aspects of in- or outmigration impacting the cultural pillars of communities

CHAPTER 5: CONCLUSIONS

5.1 MANAGING THE UNAVOIDABLE TO AVOID THE UNMANAGABLE

The complexity of environmental and political factors that define challenges of sustainability in Alaska holds great relevance globally. Potential regime shifts and related risks that are diffused across local and global systems have made the Arctic a laboratory for understanding the process of change, vulnerability, resilience, and sustainability in the Anthropocene. Understanding change and learning to respond to changes are important elements of adaptive capacity in social-ecological systems (SES) (Fath *et al.*, 2015; Fazey *et al.*, 2007; Lebel *et al.*, 2010).

SES are a type of complex adaptive system. Complex adaptive systems are made of self-organized agents, or components that undergo co-evolutionary processes through varying degrees of equilibrium in the overall system's state. Inherent to this evolutionary (change) process is the limited predictability of thresholds (tipping points), where surprises can trigger cascading and transforming changes (Duit and Galaz, 2008, p.313). Cross-scale dynamics and feedback loops further increase uncertainty in SES (Walker *et al.*, 2006), hampering the understanding and governance, of change. New strategies of adaptive governance have become increasingly important in the field of resilience management. The idea of adaptive governance builds on principles such as consensus-oriented decision making, (Ansell and Gash, 2008; Innes and Booher, 1999), social learning (Ensor and Harvey, 2015; Lebel *et al.*, 2010), de)liberation (Baber, 2004; Elster, 1998; Fishkin, 1991; Gutmann and Thompson, 2009; Muhlberger and Weber, 2006; Petts and Brooks, 2006), knowledge co-production (Armitage *et al.*, 2011; Cash *et al.*, 2006; Kofinas, 2009) and community-based scenario building (Enfors *et al.*, 2008; Oteros-Rozas *et al.*, 2015; Sheppard *et al.*, 2011). At the heart of all these approaches is the goal of adaptive, anticipatory decision making that is equipped to help the SES navigate change and uncertainties.

The three research questions asked in Chapter 1 are situated at the crux of cross-scale dynamics, uncertainties and risks, and adaptive, anticipatory decision making. The questions were addressed in the three studies (chapters 2-4) of this dissertation. This chapter is a discussion of the overall findings of the dissertation, focusing on interactions between scales of risks, change, and decision making, and the learning processes that help manage the SES for resilience.

5.2 SCALE AND LEVEL-SPECIFIC LESSONS: HOW DO WE LEARN FROM RISKS AND DISASTERS?

5.2.1 Chapter 2: Lessons from the disaster chronotope

Risk and disaster governance operate within complex and dynamic social-ecological systems. Decision makers face a number of constraints in their endeavor to learn from disasters. First is the challenge of what criteria are applied to accepting a phenomenon as learning. Any attempt to complete an assessment across diverse scales and actors based on the successes of policy changes is doomed to fail, because optimal policy evades definition and policy changes are greater part experiment than they are science (Ostrom, 1999). To complicate matters, there has been little systemic research to compare the organizational features of central governments and their impacts on disaster management (Britton, 2007). Each community, region, and nation has seen the evolution of its own disaster policies, and even within nations, disaster planning isn't necessarily uniform; rather, it typically varies across hazard types. This situation has resulted in a vast array of disaster management approaches under centralized (top-down) national disaster management authorities, and decentralized (bottom-up) models for coordinating preparedness, relief and recovery through local governments and civil defense departments.

Chapter 2 presented a wide-angle view of interactions, evolving relationships, changing rules, coalitions and policies, before and after disaster events as stakeholders attempted to positively impact their futures. It did so by noting how events and institutions impacted the adaptive actions that may have occurred pre- and post-disaster; as a proxy for learning. As well, the four cases studies proved especially useful in identifying conditions for cross-scale learning as a factor of disaster type. As Birkland (2006) noted, learning from disasters is a bounded rational process, in which rational decision making (within the limits of analysis capacity) mixes with adaptive learning behaviors. Relying, in part, on Jones' (2001) review of social and behavioral scholarship, Birkland outlines why collective learning in general, while goal-oriented and adaptive, is subject to capture by focusing events such as disasters. Disasters and disaster risks tend to receive a disproportionate amount of attention (regardless of overall risk or pervious interest), following sudden calamities that captivate the public's attention. This temporary attention paves the way to learning. However, if done in haste and with incomplete information (and under pressure), actors who may intend to make the best available choices can deviate from them for one reason or another. The window of opportunity for corrective, collective action, such as policy or institutional change, is brief and closes with the end of the public attention.

Through the four case studies of Chapter 2, the essential role of temporal and spatial scales in learning became apparent. On the one hand, the causes of these systemic disturbances took on spatial and temporal qualities. Be it the duration of disturbance event (a short-term pulse or a long-term press), or the speed with which the disturbance emerges (rapid or slow onset), there is an observable temporal scale to the initial shock that influenced how much time there is to respond. The impacts of the disasters exhibit temporal qualities, due in part, to the particular vulnerabilities of the SES In some cases, like the Exxon Valdez oil spill, its impacts on the SES still continue today, while in others, such as the 1964 Great Alaska Earthquake, the social system's rebound was relatively fast (permanent geologic shifts notwithstanding). Spatial scales from disaster impacts, in addition to the temporal, also drive the actors who get involved in pre- and post-disaster governance, and the type of learning that takes place. In a panarchy, jurisdictionally removed stakeholder groups may be governing or impacting (by action, inaction, or systemic vulnerabilities) the same disaster hazards without coordination (e.g., Katrina). If hazard impacts scale proportionately (or if vulnerabilities are shared), collective action is more likely. When impacts are disproportionate—due to either uneven spatial dispersion or varying degrees of vulnerabilities—collective response is slow. This was the case in the Alaska coastal erosion example that highlights the challenge of global-local interactions.

The resulting learning models evolve according to how much these processes set the course for post-disaster learning and building adaptive capacity. If recovery is quick and public interest in reform is low, learning fixates on previous ways of knowing and established institutions. When recovery takes a long time, the public may be invested in reform. However, success depends on the activation energy to support it, level of knowledge supporting the science of reform, and consensus among actors on the desired trajectory forward. This results in a pinball (i.e. erratically behaving) environment, where timing and competition are key factors in driving the outcomes. In disaster environments where the local system is in a constant state of collapse and reorganization, and the decision making environment is rigid—fixated in dysfunctional relationships— even when infused with global support, learning is vagabond and tangled in social pathologies. I suggest that a truly global disaster processes can similarly stunt adaptive learning when spatial and temporal boundaries are erased between action and effect. When attribution of responsibility and corrective action span several continents and generations, the chronotope of regular social contracts (hierarchies of actors and sources of political, financial, technical, and scientific support) are disordered. Furthermore, the interactions among the exposure, vulnerability, adaptive capacity of systems at different levels are often not known *a priori* (Smit and Wandel, 2006); increasing the level of uncertainty in future planning. This new chronotope demands new systems of risk and disaster governance because responsibility and action span continents and generations, and are thus beyond the reach of existing social institutions.

5.2.2 Chapters 3 and 4: Globally relevant lessons from the Arctic

The complex and rapid changes that are underway in Arctic SES provide a rich learning opportunity about cross-scale interactions. Two cases were presented to discuss spatial scales of risk perceptions in the Arctic Alaska context in Chapters 3 and 4. We learned from resident experts of two boroughs that there can be a shared culture of risk within same-level jurisdictional units that transcends policy subsystems. The strong consensus found about perceived risks shows that risks (depending on vulnerabilities and exposure) have level-specific dimensions that make them tractable beyond political borders. These studies also show how transcendence of scale has implications for political discourse. When exposure to the same drivers of change and shared vulnerabilities result in collective risk impacts, it may prompt mergers and coalitions of interests, a pooling of political will, and greater joint political influence upstream.

On the other hand, risk concepts may or may not scale vertically between hierarchies of administrative jurisdictions. The case study that compared North Slope tribal council members' and state and federal employees' perceptions of risks (Chapter 4) showed how years of interactions and information exchange resulted in a good degree of shared understandings over risks, historical change, and their impacts to the system. However, the comparison also outlined underlying differences in how level-specific risks are prioritized. The degree to which level-specific perceptions and processes are compatible has bearing on the extent to which actors (communities) at the different levels will be able to participate in, negotiate over, and ultimately, control the fate of public discourse on risks. The institutions and norms of cooperation, such as those established to reduce uncertainties and to achieve SES predictability and stability, thrive on homogeneity or consensus of opinions (Duit and Galaz, 2008). Yet simultaneously, risk and disaster resilience benefit from a rich vault of memory (Fath *et al.*, 2015) of past disasters. For example, large populations in the Philippines have lived through numerous typhoon events, and local and individual adaptive actions may help survival. Higher (e.g. nation state) level adaptive action is hampered if political systems are corrupt, or economic capital is absent.

5.3 RISK PERCEPTION AND ADAPTIVE CAPACITY: LINKS

5.3.1 Chapter 2: Lessons from the disaster chronotope

The social-ecological system depends on changes and stability to occur during critical phases of the adaptive cycle for long-term stability (Chapin III *et al.*, 2009, p. 15). It is through the interactions and feedbacks from these processes that communities may anticipate and minimize potential destructive forces. This iterative learning process is ideally adaptive. These studies support the assertion that adaptive learning from disaster greatly impacts risk perception, leading to increased understanding about the underlying vulnerabilities of a system, and the interactions between risk and disaster processes with these vulnerabilities. As a result, cognition about drivers of change (stresses) and the portfolio of proactive / reactive actions available evolves. Such mental models are a part of risk perception. Thus, learning, adapting, thinking, and perceiving directly impact a system's overall adaptive capacity. Following the Exxon Valdez disaster, the founding of the Oil Spill Council and Regional Citizen's Advisory Council ensured the long-term, collective, adaptive learning in the region's SES. In the case of typhoons in the Philippines, the stressors (the disaster events) came with relative frequency, and were amplified by the social vulnerabilities of large segments of the population. These impacts drain the resources that would be needed for long-term change. The Great Alaska Earthquake resulted in large-scale, technological and scientific learning, yet the basic vulnerabilities of the social system (isolation, dependence on outside flow of goods, limited and vulnerable transportation routes) have remained unchanged. The Alaska Coastal erosion case exhibited the kind of inertia that can occur at the highest, slowest=moving levels (state, federal, international) of governance, when risks are (1) creeping and thresholds are hard to identify, (2) large-scale, and (3) unequal in their impacts. The fast-moving speed of lower systems, in comparison with higher level ones, was demonstrated via the activities of the Newtok Planning Group in Chapter 2.

5.3.2 Chapters 3 and 4: Adaptive learning in the panarchy: Globally relevant lessons from the Arctic

In lower-level systems, practices are supported by a knowledge-base that places a high value on longitudinal knowledge (Young, 2006). This lower-level regime is the fast-moving system in the panarchy in which experimentation, trial and adjustment of behavior can move faster than in the larger, slower systems. This dynamic is also a supporting argument for collaboration of same-level social units. Thus, mutually agreeable initiatives can be implemented with relative speed. Often times, however, there is an inability to relate an understanding of larger-scale SES dynamics to the policy needs of lower-level actors—and vice versa (Cash *et al.*, 2006). While managerial and knowledge-sharing interactions among the different levels happens most often among close neighbors on the jurisdictional scale (state and borough, state and national, borough and national), such sharing is not always the case. Rarely, but on occasion, the lowest and highest level regimes experience cross-scale interactions, such as international organizations with a mandate for marine life conservation and aboriginal subsistence hunter groups (e.g. Young, 2006).

Risk perceptions are informed by individual observations, experiences, personal traits, social processes, and cultural orientations. The sharing of these experiences and information among and across scales of governance are important, especially when the interplay between the levels of knowledge and management regimes is one of dominance. Failure to learn results in the social construction of disasters, and manufactured vulnerabilities such as poverty, inequality, exclusion and conflict.

5.4 RECOMMENDATIONS TO OPTIMIZE DECISION MAKING

5.4.1 Chapter 2: Lessons from the disaster chronotope

Recommendation #1: *Where disaster impacts long outlive political election cycles and any policy changes, and where competing economic interests and scale assumptions hamper learning outcomes, participatory risk assessments, risk attribution (determining liability) and participatory scenarios planning may help reduce socially constructed vulnerabilities to disasters.*

Recommendation #2: *Bridging organizations—such as the Newtok Planning Group—have an important role in keeping issues on the agenda and promoting bilateral information flow.*

Five important factors create scale-dependent environmental resource regimes, as noted by Young (2006). The type of actors involved at the different jurisdictional levels create behavioral differences in what these groups are responsive to; how they factor future costs into present day calculations; what knowledge systems they use (experiential-longitudinal versus observational-methodological); and the policy instruments and compliance systems available for managing and monitoring resources. The different levels focus on level-specific spatial and temporal scales. Paying close attention to social regimes and systems aids in the cross-sectional analysis of disaster events and helps highlight issues of conflict, competition and inequality.

Chapter 2 outlined ways in which cross-scale interactions and scale-specific dependencies between the SES and disaster processes shaped learning and adaptive outcomes. The chapter discussed ways in which specific features of disasters contribute to these interactions. It also applied concepts from Fath *et al.* (2015) that described the role of the stages and phases of the adaptive cycle, and the readiness of the system to transition along, in a system's overall resilience. Decision making must consider scale-specific reflections not only to factor in cross-scale interactions and disaster types, but also the level-specific realities (progression and status of adaptive stages) of each SES. As a result, the extent to which improvisation and ad hoc groups, versus time-tested routines and institutions, should take prominence, can become clear. In the Philippines for example, the Provincial Government of Albay has integrated disaster risk reduction, environmental protection and development planning (reduction of social vulnerabilities) to reduce disaster risk. This is an example of a lower-level governing body acting to incorporate locally relevant considerations (e.g. poverty) in disaster planning. During the reorganization stage, modularity and access to stored capital are key features of success. This fact was highlighted in the events leading up to the Great Alaska Earthquake. A sizeable military personnel, equipment, and centralized disaster command in place made the recovery of Alaska communities possible.

During the growth stage, bilateral information flow, emergent leadership, and the ability to adapt and adjust (test and innovate) are most important. During times of stability in the K-stage, diversity and small-scale disturbances increase resilience and help avoid the rigidity trap. The Deepwater Horizon disaster was a result of *failure to learn* from small-scale events during times of stability.

During the collapse itself, cohesive leadership and maintaining vital functions are key to reducing fault cascade. The role of established rules and institutions in these functions is also essential, as is the extent to which they are capable of recognizing and accommodating emerging needs.

5.4.2 Chapters 3 and 4: Globally relevant lessons from the Arctic

Recommendation #3: *Deliberation of sustainable futures increases understanding between same-level groups of stakeholders; this speaks to the role of process in collaboration.*

Recommendation #4: *Differences in priorities and perceptions between levels highlight the importance of membership in decision processes.*

Global sustainability targets in times of extreme events resulting from climate change and water and food insecurity, demand multi-scalar collaboration. Resource development goals, however, often create high-stakes, low-consensus policy processes. Because knowledge is held and perceived differently at different levels, there is a political economy unique to the multi-stakeholder risk (cost/benefit) calculus in sustainable development, climate change adaptation and disaster resilience. Finding the baseline for these common goals and risks that threaten their success can work via anticipatory governance and deliberation. The two Alaska case studies illustrate the cross-scale linkages and rapid changes that drive competing interests in the public sphere in nested SES. Chapter 3 revealed success in increasing mutual understanding between same-level groups of stakeholders via deliberation of sustainable futures. This outcome speaks to the role of *process* in collaboration. Chapter 4 revealed that despite shared understanding of scientific information, important differences still exist in risk priorities and perceptions of adaptive capacity between levels of stakeholder groups, highlighting the importance of *membership* in decision processes.

Collective identity is critical to Indigenous cultural values (Barnhardt and Kawagley, 2005), while collective governance is an important component of fate control. The Arctic Human Development Report (Larsen *et al.*, 2010) (Larsen *et al.*, 2010) and Arctic Social Indicators (Larsen *et al.*, 2015) emphasized fate control as vital to northern people's sense of well-being and human development. It is therefore no surprise that North Slope tribal councils identified—in essence—a lack of political agency or control as the number one risk to their sustainable futures. On the other hand, the high degree of regional consensus over what are perceived as risks—confirmed in Chapter 3—suggest great potential for same-level groups (two northern Alaska boroughs in this case) to pool resources, better coordinate actions and use of political capital, to effect change.

In addition to observing spatial scales in the processes of decision making, temporal dimensions of issues may also impact consensus. Issues can become priority at different times, at different rates, bringing to focus one issue area over (Westley, 2002, p.358). Scenarios planning is a promising tool for bringing together distal temporal and spatial realities, and creating decision points where adaptive actions can be taken (Lindgren and Bandhold, 2009; Tschakert *et al.*, 2014). Adaptive actions can be anticipatory or reactive (based on timing), and strategic or tactical (based on duration) (Belliveau *et al.*, 2006). Scenarios support anticipatory-strategic adaptive actions by thinking ahead, increasing agreement, and reducing knowledge uncertainties. Ultimately, these steps keep decision making away from the edge of chaos (Stacey, 2007).

5.5 CONCLUSIONS: WHAT STEPS IMPROVE CROSS-SCALE ADAPTIVE LEARNING IN NESTED SES?

In these times of rapid change and transformation, increased inequity from climate change impacts, poverty and displacement, Arctic lessons on adaptation are ever important. Climate change is the issue with the greatest impact for the future both in terms of risks and in terms of opportunities. This understanding drives the need for the creation of a governance framework that can guide SES toward managing the unavoidable changes still to come. The governance of risks from natural disasters, climate change impacts, and resource development are complicated by issues of scale and perceptions. For example, the costs of climate risk mitigation are usually assumed by state and national governments, while its benefits are experienced globally (Parry, 2007). As another example, local adaptation action needs may depend on higher-level policy at the state or national level, where these needs must compete with the needs of the majority. Differences in perceptions also play a role in risk governance and adaptation strategies. For example, those residing near oil development sites may have vastly different views on the potential risks of the operation than others who live far away.

The very language of problem definition has an enormous impact on whether risk sources are acknowledged, and consequently, what type of learning, if any, takes place (Beck, 1992). There is a need for new governance arrangements that are transdisciplinary, and take on a social-ecological network approach in accounting for interdependencies between society and governed ecosystems (Bodin *et al.*, 2016).

Political context, the ability to bridge science and policy groups, and the salience, credibility, and legitimacy of knowledge are main factors in the success of learning processes (Cash *et al.*, 2003; Kunseler *et al.*, 2015). These attributes are traits of participatory learning, along with having inclusive membership and processes for bringing together informed actors.

These points underline the importance of membership and process in decision making.

There are many sources of adaptive capacity in the Arctic context (natural, social, human, financial, cultural capital; infrastructure and knowledge assets) that together can strengthen resilience in times of great uncertainty in decision making. Understanding these system dynamics is important in SES management. The Arctic is undergoing dramatic changes. Decision making spaces must be designed carefully to fit ecological and social processes to match spatial and temporal characteristics (Meek *et al.*, 2008; Robards and Lovecraft, 2010), while allowing for social and institutional learning as a way to increasing resilience (Chapin *et al.*, 2006).

The complex risks discussed in this dissertation highlight the questions that could drive further development of research policy in this region: what is the relationship between political capital (being at the table) and the capacity to deal with risks? Can inclusive risk management, based on a plurality of knowledge forms and stakeholder perspectives, increase adaptive capacity in a globalized, interconnected world where risks are interwoven?

Translating into practice the theoretical approaches to reducing uncertainties and building healthy, sustainable societies remains a challenge. Knowledge seeking and finding a common vision, on the one hand, are highly normative goals without some sort of standard in place, on the other hand standardized processes may not be attainable or even desirable as these activities are highly context and time specific. Risk framing, risk analysis and the evaluation of the acceptability of risks all contribute to a societal vision of the future, one that needs collective consideration. To move toward these goals, further research is needed to develop procedural recommendations for multi-stakeholder planning tools that facilitate horizontal and vertical scaling of shared understandings of risks and sustainability. For example, decision making may benefit from a consensus advisory process that is tailored to specific issue-areas, and can be employed by both ad hoc and permanent organizations. Research on the successes and failures of existing processes (such as the Danish Consensus Conference) can help specify the role of, and model the structure for, a consensus advisory panel. Iterative engagement of stakeholder groups and participatory scenarios planning may complement this process, and help to reduce conflicting viewpoints. Further research on the indicators that help gauge the perceived validity of membership, process and output in decision making, may be another important piece of the consensus-building puzzle. Together these indicators signal the sustainability of outcomes in competitive negotiations. Keeping in mind that perfect consensus is rarely possible, I believe that by strengthening and optimizing participatory processes and decreasing conflict, we better facilitate strategic futures thinking, reduce rates of issue renegotiation and increase consent over the outcomes.

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