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Abstract

Assessing regional vulnerability by operationalizing the concept of adaptive capacity in the Pacific Northwest

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This thesis explores indicators for operationalizing social adaptive capacity in social-ecological systems in a testable manner. Adaptive capacity represents the potential to adapt, not the adaptation itself, and is an important component in assessing the vulnerability of a system. Adaptive capacity addresses system vulnerability to exogenous stresses like climate change. I survey a portion of the literature on vulnerability and adaptive capacity to acquire a definition applicable to the scope and scale for two locations in the Pacific Northwest. By doing so I engage the literature to initiate a regional vulnerability assessment. Such an assessment could serve as an important input in the process of developing plausible futures scenarios by incorporating environmental change and uncertainty present when addressing climate change. Through a better understanding of how adaptive capacity applies at these different spatial scales in the Pacific Northwest, it may be applied toward improved decision-making, particularly related to scenario planning.

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Section I: Introduction

Developing a method for assessing the trajectory of social and ecological systems from current policies to develop plausible futures in the context of climate change could prove useful for managers, scientists, and policymakers. Climate change in regions like the Pacific Northwest may serve as a tipping point for already attenuated ecological and social systems. Regional projections of a warming climate from the University of Washington Climate Impacts Group (CIG) indicate increases of 1.5 degrees Celsius by the 2020s and higher temperatures 50 and 100 years into the future. In general, projections indicate the Pacific Northwest will experience warmer wetter winters and drier hotter summers in the future.

Projected changes in the regional climate will affect ecological systems as well as the human systems dependent on them. The effects of climate change may vary but some of these changes include altered precipitation, more severe storms, higher temperatures, and rising sea levels. The effects of these changes could result in impacts such as altered river hydrographs, more winter and spring floods, decreased winter snow pack, higher probabilities of coastal erosion due to storms, coastal inundation, and changing tree composition and fire regimes within forests. Changes in natural systems such as these can then force wider impacts on salmon productivity and abundance, water availability for drinking, industry, hydropower, agriculture, and the maintenance of infrastructure.

Traditionally to address unforeseen shocks caused by natural phenomena—like climate change—managers work to define an often-complex problem through reducing the variables in question and reaching a simplified solution. Such problem solving assumes that the system is knowable and predictable as Holling (1993) terms this thinking "first stream" science. In critiquing first stream science, proponents of new management and scientific approaches called resilience science, or sustainability science, argue for improving the functions of natural systems so that they can absorb exogenous shocks to the system (Mantua and Francis 2004). This form of management, called "second stream" science, seeks to decrease the sensitivity of the system through retaining redundancies that are often attenuated by the simplification of systems through the predominant “first stream” approach (e.g. levees on rivers for flood control as opposed to improving the capacity of riparian areas and wetlands to absorb the abrupt changes and shocks that floods bring).

Given the increasing awareness that systems cannot be managed for an equilibrium state, the task of establishing effective management and planning strategies in dynamic systems where uncertainty is high presents challenges. How does one admit that uncertainty is present when oftentimes the manager or elected official’s job depends on making tough choices that should be ostensibly based on “real” and “hard” facts? Uncertainty then becomes something to be avoided by elected officials, managers, and planners. The perceived necessity to simplify management decisions in complex systems can result in a loss of redundancy in ecosystem support services. The prevalence of this management style creates a number of perverse outcomes that can ultimately reduce research and monitoring, as well as distract agencies from their goals (Lee 1993; Holling and Meffe 1996), thus increasing vulnerability.

A part of the Vulnerability Assessment

Research on understanding vulnerability in coupled human-environment systems is a central tenet of sustainability science (Turner, Kasperson et al. 2003). Assessing vulnerability in systems allows us to plan for a suite of risks when uncertainty is high. Vulnerability and how it affects a social system is made up of three components: exposure, sensitivity, and adaptive capacity. Resiliency—often seen as the inverse of vulnerability—represents the property of a system, or amount of stress or change that a system can endure while retaining its original functioning. O’Brien et al. (2004)

view vulnerability and resiliency as two ends of a continuum to social and ecosystem responses. How vulnerable the social system is becomes a function of its activities and reliance on the ecological system that it is coupled with.

Similarly useful in thinking about responses and the vulnerability of a social system is the concept of adaptation. Adaptation in social systems varies from adaptive capacity because it is the realized action or response that springs forth from adaptive capacity. Significant uncertainty exists within or measuring the potential for adaptation in social systems because it represents a very human quality where a choice to adapt or not exists. On the contrary, ecological systems lack the free will to actually choose adaptation—either the capacity exists which will lead to adaptation—or it does not. Knowing the system's potential for adaptation affects the vulnerability assessment and a proxy for adaptation is then adaptive capacity.

Why Adaptive Capacity?

"How does adaptive capacity fit in the Pacific Northwest?"

Adaptive capacity is in a state of pre-theoretical confusion. Because adaptive capacity as a concept interrelates to terms such as "adaptation," "adaptive management," "vulnerability," and "resilience," its dynamic nature needs clarification. Because of the transdisciplinary problem that it represents, climate change and surrounding research creates a confluence of divergent research traditions (Adger 2006). Walker et al. (2004) suggest that these concepts are simply imprecise by their nature. Like the concept of sustainability, which has multiple meanings and is differential within the various subgroups and disciplinary dialects that use it, terms like resilience and adaptive capacity are often obfuscated in a similar manner. The concept of adaptive capacity is used differently by authors who take the term's application to natural resource management and planning in divergent directions. For some (Adger 2006), often in ecological circles, it is used as a synonym for resilience, whereas in disaster planning and social sciences it is often used as a component of vulnerability (Eakin and Luers 2006). Defining the concept in a testable fashion and then applying indicators can help us understand the concept better. Acquiring a clearer theoretical understanding of adaptive capacity of local governments and how it shifts according to scales can then help us begin to ask the questions about the need and requirements for it in the context of scenario planning.

Toward Operational Definitions

A unified definition for adaptive capacity is likely untenable. Instead of creating a unified framework for adaptive capacity this thesis seeks to look at a particular region (the Pacific Northwest) and at two spatial scales (the Skagit river and the Columbia basin) to bound the concept of adaptive capacity within certain parameters of a framework developed by Eakin and Luers (2006). This filter then provides a structure of what I mean by vulnerability and adaptive capacity in the context of the two examples used in this project. From here one can begin to look at ways to operationalize the concept in order to clarify its application. I posit that a single definition or conceptualization through operationalizing it is not possible, but it provides one with a heuristic approach to understanding key components embedded within in the vulnerability assessment.

The Importance of Scale and Scope

Maddox (2000) notes that "the best environmental policy depends upon how you frame the question" (Ludwig, Mangel et al. 2001). Indeed, defining the problem and understanding the scale and scope of the problem are critical when addressing questions related to a differential concept like adaptive capacity. Developing integrated assessments of global climate change germane to decision making requires that it be scaled down to the levels where specific actions are taken. This means that downscaling to watersheds or regions is necessary (Wilbanks and Kates 1999). Downscaling concepts like vulnerability and adaptive capacity to a regional or local level provides context to the concepts wrestled within this paper.

The Map Forward

This is a place-based paper with a regional scope in a developed nation that aims to understand the nature of terms encompassing the vulnerability assessment. It explores indicators for operationalizing adaptive capacity in a testable manner in the context and spatial scales necessary for environmental planning in the Pacific Northwest. The second section will review literature on adaptive capacity and scale with attention paid to the scale and scope chosen. After that I will look at characteristics and traits of the two identified places. Finally it will operationalize a definition for adaptive capacity using indicators to analyze the two locations chosen.

Section II—Framing and Applying the Literature

Vulnerability and Its Origins

Vulnerability is not the central focus of this project, but it is a foundation and a jumping off point for an exploration of adaptive capacity. Adaptive capacity comprises a part of vulnerability (Turner, Kasperson et al. 2003; Adger and Vincent 2005; Smit and Wandel 2006). Vulnerability, according to the Intergovernmental Panel on Climate Change (IPCC), is a function of *exposure*, *sensitivity*, and *adaptive capacity* (Adger 2006). Like adaptive capacity, vulnerability as a concept can be ambiguous, which constrains its use in policy and science (Vogel and O'Brien 2004). Exploring the relationships between resilience, adaptive capacity, and vulnerability is in its nascent stages and needs to be addressed for consilience in the future (Adger 2006).

Vulnerability as a concept is not new (Vogel and O'Brien 2004). Its origins in risks, hazards, and food security literature spans back to the 1960s (Schröter, Polsky et al. 2005). Ecological resilience research extends back to C.S. Holling's theoretical ecology research in the 1970s. Global change vulnerability assessments differ from previous traditions of impact assessments. The risk/hazards research tradition focuses on the effects of one stress instead of multiple stresses. Food security literature focuses on the many stresses that lead to one effect (hunger). Global change vulnerability assessments now attempt to integrate many of these traditions into a synthesized whole. This integration uniquely makes for a space that involves climate change, future uncertainties, the amplification or attenuation of sensitivity to the system, and adaptation due to many stresses (Schröter, Polsky et al. 2005).

Eakin and Luers (2006) separate the origins of vulnerability into three distinct lineages: (1) risk/hazard; (2) political economy/political ecology; and (3) ecological resilience. The edges of these three lineages are blurry, but the utility in considering these three realms of the vulnerability discussion allows me to exclude certain elements before moving to a hybrid of my own. The lineages of vulnerability research described here help bound and exclude certain elements of the vulnerability debate not touched on in this paper.

Table 1. Three lineages of vulnerability compared (table from Eakin and Luers 2006)

Point of comparison	**Risk/Hazard**	**Political Economy/ Political Ecology**	**Ecological Resilience**
Focal questions	What are the hazards? What are the impacts? Where and when?	How are people and places affected differently? What explains differential capacities to cope and adapt? What are the causes and consequences of differential susceptibility?	Why and how do systems change? What is the capacity to respond to change? What are the underlying processes that control the ability to cope or adapt?
Key attributes	Exposure (physical threat, external to system), sensitivity	Capacity, sensitivity, exposure	Thresholds of change, reorganization, capacity (to learn and adapt)
Exposure unit	Places, sectors, activities, landscapes, regions	Individuals, households, social groups, communities, livelihoods	Ecosystems, coupled human-environment systems
Decision scale of assessment audience	Regional, global	Local, regional, global	Landscapes, ecoregions, multiple scales
Selected definitions	"…the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards place with the social profile of communities" (Cutter 1996) "…the idea of potential for negative consequences which are difficult to ameliorate through adaptive measures given the range of possible climate changes that might reasonably occur" (Reilly and Schilmmenlpfenning 1999)	"The characteristic of a person or persons in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Blaikie, Cannon et al. 1994) "Vulnerability comes at the confluence of underdevelopment, social and economic marginality, and the inability to garner sufficient resources to maintain the natural-resource base and to cope with the climatological instabilities of semi-arid zones." (Ribot, Najam et al. 1996)	"Vulnerability defined as the opposite of resilience, where resilience is "the capacity of a system to undergo disturbance and maintain its functions and controls"(Reilly and Schilmmenlpfenning 1999; Carpenter, Walker et al. 2001) "Resilience has the following characteristics: a) the amount of change a system can undergo; b) the degree to which the system is capable of self-organization; c) the degree to which the system can build the capacity to learn and adapt"(Carpenter, Walker et al. 2001)

The risk/hazard approach defines the level of risk extant in a system and measures vulnerability through a prism of exposure and sensitivity. The political economy/ political ecology approach involves incorporating the response to the said risk through the region's adaptive capacity. The latter approach is a response to a view of vulnerability that solely focuses on the "what" of system vulnerability instead of expanding to the "why" of how systems become vulnerable.

Vulnerability is often dependent not just on the exposure or sensitivity to the change, but also on the social and institutional factors that make up adaptive capacity, which then shape the response to the stress or shock (O'Brien, Sygna et al. 2004). Social systems can weaken ecological and social systems both from the bottom-up and top-down while terrestrial impacts from climate systems work from the top-down. While exogenous factors are often seen as being the main culprit in causing vulnerability, social and ecological systems can be stressed by endogenous factors within that system which can attenuate or amplify the stressor's effect on the system (Turner, Kasperson et al. 2003; Luers in press). Thus the political economy/ political ecology approach to vulnerability addresses more of the internal processes that create system vulnerability while simultaneously looking at the ways in which systems can adapt.

Ecological Resilience

Ecological resilience describes the state of a system and how much it can absorb before it shifts to another stability state (Holling 1973; Gunderson and Holling 2002). As vulnerability is considered to be important, resilience is often considered to be its counterpart (O'Brien et al. 2004). This is loosely accurate, but while overlap between the two concepts exists they may be better thought of as alternate perspectives to viewing systems (Adger 2006). Resilience here, and in Eakin and Luers (2006), describes the ability to absorb, to self-organize, and to learn whereas vulnerability represents the susceptibility of a system to be harmed (Adger 2006). Resilience in this management context denotes a process of retaining redundancy, function, and the complex adaptive nature that exists in both ecological and human systems, termed social-ecological systems (SESs reflect the idea that social systems are inseparable from nature and any distinction between the two is arbitrary), even when uncertainty is present.

Holling and Meffe (1996) describe two common types of resilience: equilibrium (engineering) resilience and ecosystem (ecological) resilience. The first represents an effort to simplify and maintain systems at a steady state where the measure of resilience is a function of the ability of the system to return to its equilibrium after a shock. The second definition, is what this paper refers to as ecological resilience, "the magnitude of disturbance that can be absorbed or accommodated before the system changes its structure by changing the variables and processes that control system behavior" (Holling and Meffe 1996). While resilience is often termed as something "good", this is not always the case. This is an important distinction from sustainability, which connotes a positive environmental and social direction (Carpenter, Walker et al. 2001). Resilience as a concept can describe an undesirable social or ecosystem stability regime. For example, the crash of Atlantic cod has led to an apparent shift to a new stability regime that appears resilient but not necessarily desirable from a social standpoint (Lebel, Anderies et al. 2006).

A clear understanding of ecological resilience is useful as a context for looking at how systems can shift from relative stability, to instability, to an entirely different state altogether. Ecological resilience represents a novel method for analysis in the social science domain. In the context of the social sciences, ecological resilience can be used to think about multiple system states and the stability states that they encompass. By looking at vulnerability we can think about how systems become attenuated and are able to shift between stability states as ecological resilience theory describes. In making the normative choices that underpin whether or not a system's current trajectory is agreeable, we must look at adaptive capacity to understand the potential to respond to future shocks whether or not they are exogenous or endogenous in their origins. When synthesizing these elements in environmental planning, managing for resilience is a critical component for pursuing sustainable development (Lebel, Anderies et al. 2006).

The Differential Nature of the Concepts

Part of the problem with finding a concise definition of vulnerability or adaptive capacity is that they are differential concepts. That is the concepts vary according to the context, scale and scope of where they are applied. Differential adaptive capacity can refer to the heterogeneous nature of populations and social groups within a given place (Schröter, Polsky et al. 2005). In this sense, certain segments of a population may be less prone to successfully adapt than others. Their limitation could be a result of income, education, or location-based inequalities present within a place. These social inequalities are relevant and important aspects when looking at differential adaptive capacity, but I choose to limit my project to spatial scale shifts that affect adaptive capacity. I do so in part to limit the scope of this research, and the range of discussion around spatial scale is rich enough to avoid a detailed review of temporal scale issues in adaptive capacity. These spatial scale changes in turn affect the sensitivity and adaptive capacity of a place.

Scale as a term can refer to a host of spatial, temporal, and analytical qualities, or dimensions, used by scientists and practitioners (Gibson, Ostrom et al. 2000). Within spatial scales, levels—the location of focus along a scale—are used to refer to the size of area analyzed. Extent and resolution also refer to key concepts within the discussion of scale, but for the purposes of this analysis their explicit definitions are not required. Hierarchies on the other hand, are important to think of especially in climate change studies. While analytical in nature, certain hierarchies—specifically constitutive hierarchies—play a large role in this process.

A constitutive hierarchy is a nested hierarchy where lower level units can combine to form new properties or organizations at higher levels, or spatial scales. The concept of emerging properties comes from this process whereby emergence is not simply additive, but instead as the scale or level of analysis increases, the properties can take entirely new forms (Gibson, Ostrom et al. 2000). At a social level, how a household interacts internally could be entirely different from how a group of households in an agricultural region may behave when faced with a social or environmental challenge. The response by a group of households from an ecological or social surprise or shock could result in an equally unexpected surprise due to the internal dynamics of the new larger organization.

Spatial scale is unique because it changes what vulnerability looks like. O'Brien et al. (2004) show how changes in spatial scale can drastically change the outcome of an assessment. As vulnerability shifts when the level of scale increases or decreases, adaptive capacity does as well. Social networks change substantially at different scales and one that appears to have capacity at one scale could be fractured at a smaller scale. Perhaps a certain social network exists in one small community organization, but not another. On a spatial scale comprising those same two communities, the adaptive capacity imbued in the community organization might not be visible, but at a smaller scale where one can parse out distinct and individual community traits, the adaptive capacity could be high in one and absent in another. The concept of emergent properties is especially important to note when considering adaptive capacity. Properties at lower scales might not indicate adaptive capacity until combined at a higher scale.

Taking results of analysis at one scale and extending it beyond that specific spatial scale is problematic. According to Holling (1992), upscaling or downscaling results cannot be compared easily and often focus on different phenomena. When considering scale in vulnerability assessments or looking at adaptive capacity alone, it is important not to extend the conclusions of the analysis at that scale to other scales altogether. If done this could result in mistakes related to the cause and effect of the phenomena in question (O'Brien, Sygna et al. 2004). Because the processes that cause variability differ at each scale of analysis, creating an aggregate assessment of vulnerability across scales lacks analytical merit (Adger and Vincent 2005). Aggregated statistics on a national level may show that adaptive capacity is high, but institutional, legal, or social hurdles at the local level can constrain local responses, thus limiting the adaptive capacity of a place. While a local or small-scale study is specific enough to be tractable, lessons from individual small-scale examples are not generalizable enough for widespread dissemination. In fact the variance is likely to be greater between geographic units if the spatial scales become smaller (Wilbanks and Kates 1999). Thus upscaling also poses problems.

Because spatial scale figures so prominently in affecting vulnerability assessments, it is valuable to consider multiple scales when conducting assessments. As with others, Lebel et al (2006) suggest that engagement at multiple scales is critical because of the top-down and bottom-up influences in the forms of regulations, funding, and environmental conditions that affect these different scales (Lebel, Anderies et al. 2006). When considering planning, being cognizant of multiple scales and how concepts can change or be differential adds to the depth of analysis when addressing the effects of climate change.

The Filter for Analysis

The focus on social adaptive capacity promotes a more directed approach as well as facilitating accuracy in my definitions. By creating bounds to the project focus, it excludes a number of confusions when assessing vulnerability and adaptive capacity between national and local levels and in nations with drastically different levels of development. Deriving a germane definition of adaptive capacity and vulnerability is more applicable when considering climate change and long-range planning for the Pacific Northwest.

For this essay, I use the same guiding identifiers that Eakin and Luers (2006) use in parsing out important points that define both vulnerability and adaptive capacity. As a way to bound these concepts I use Table 2 as an analytical reference point for culling the definitions that fall out of the analysis for vulnerability and adaptive capacity when described in this section. The shaded areas in the table are units that most closely align with the bounds of the project (listed in column 2). Certain comparisons overlap, and this represents the continuing hybridization that is occurring as the concepts within the vulnerability assessment continue to evolve.

Table 2. Three conceptual lineages compared with the project's bounds (Table adopted from Eakin and Luers 2006)

Comparison	**Bounds of this project**	**Risk/hazards**	**Political Economy /Political Ecology**	**Ecological Resilience**
Focal Question	How are different spatial scales of local governments in the Pacific Northwest affected by adaptive capacity?	What, where, and when of impacts and dangers	Differential questions of people, capacities, and effects to systems	Questions of change, response, and processes for coping
Key attribute	Adaptive capacity within a local system	Exposure, sensitivity	Capacity, sensitivity, exposure	Thresholds of change, reorganization, capacity to learn and adapt
Exposure unit	SES, but focused on the social system. Local (Skagit River watershed)/ regional (Columbia River basin)	Places, sectors, activities, landscapes, regions	Individuals, households, social groups, communities, livelihoods	Ecosystems, coupled human-environmental systems
Decision scale of assessment audience	Governments, communities, institutions at local to regional scale in a developed nation	Regional, global	Local, regional global	Landscapes, ecoregions, mult. scales

Similar to this paper, Eakin and Luers' (2006) political economy/ political ecology focal question is geared toward the differential elements of adaptive capacity. Because this paper does not address the "what?", "where?", and "when?" of impacts and dangers of a risk/ hazard vulnerability assessment, it aligns more closely to questions addressed in the political economy/ political ecology strain of vulnerability assessments. The paper does not direct its focus toward questions about changes to ecosystems because it is more focused on assessing the capacity to adapt within social systems. The focal question remains: how do systems' adaptive capacities change according to spatial scale? Similarly, attributes within this paper are focused on regional to local adaptive capacities. Unlike the impact-oriented risk/ hazards assessment, I see adaptation as a critical component of the vulnerability assessment because the responses to shocks of systems form an element of how systems act and react.

Exposure Unit

The exposure unit is the bounded system that is exposed to the given vulnerability in question. In the case of this thesis, we refer to exposure units as discrete SESs, but the real focus is on social vulnerability and social adaptive capacity. The adaptive capacity that is in the focus in this paper occurs in the social systems of either the Columbia or Skagit SES. It is useful to think about the SES as the playing field and the social system as the player, or actor that has the capacity to adapt. The ecological system is secondary and modified by the actions of the social system's adaptations. Adaptive capacity refers to the capacity of the human system to be able to then respond to the shocks to the system, or to change the sensitivity of the system. A changed sensitivity of the coupled human-environmental system, or SES, is the result.

Because of its differential nature, vulnerability assessments need to be "place-based." Strong variations of vulnerability by locations has led to the increased import of "place-based" studies and analysis when considering responses to environmental change (Turner, Kasperson et al. 2003). The scale of the assessment needs to occur at the same scale of the decision makers (decision scale of assessment) involved with a solid awareness of the importance of the nesting of scales in this process. Individualized place-based approaches do not undermine the development of general characterizations for vulnerable systems. As Turner et al. (2003) indicate, the multiplicity of these approaches requires generalizations through operationalized, general indicators, and other measures to help inform these placed-based approaches.

A significant portion of adaptive capacity literature refers to national scales (O'Brien, Sygna et al. 2004) in developed countries, or in developing countries (Adger and Vincent 2005). Other studies are directed toward small-scale communities that lack a governance structure similar to those in the Pacific Northwest and are typically located in developing nations (Tompkins and Adger 2004). These studies often provide useful information, but they do not sufficiently describe what adaptive capacity might mean at a regional scale in a developed nation, specifically the Pacific Northwest. The differences between developing and developed nations include the socioeconomic indicators of education and income, which add a great deal to the ability of individuals to absorb and respond to social, economic, and environmental shocks. In a developed country setting such as the Pacific Northwest, the impacts of climate change are more likely to affect natural resources such as water, salmon, and disruptions of economic livelihoods as opposed to creating or exacerbating mortality-related effects (Adger and Vincent 2005), poverty, or famine. Thus notable variations in adaptive capacity exist from a national level to the local level and between developed and developing nations.

Vulnerability and its Key Components

Vulnerability broadly represents the receptivity of a given geographic unit to a specific risk or driver that stresses that system. In the context of this study, the risk or driver is climate change and variability. What makes a system vulnerable then is not climate change, but *instead the state of the system that is impacted by the climate* (Brooks 2003; Adger, Arnell et al. 2005). Because this project focuses on social systems and their constructs, vulnerability used here refers to social vulnerability (referred to as vulnerability throughout this paper). The following descriptions of key components of vulnerability are described in a general fashion to illustrate the relationship that these terms have to one another. Later, the general description of Eakin and Luers (2006) help define the definitions in order to operationalize them.

Vulnerability is considered to be a function of *exposure, sensitivity, and adaptive capacity* (Schneider et al. 2001). It is the latter that applies directly to a system's response, but exposure and sensitivity are critical to determine the shape of vulnerability. In the conceptual bounding of the political economy/ political ecology framework that Eakin and Luers (2006) point out, these three components figure heavily as the key components of vulnerability as opposed to being limited to exposure and sensitivity without a response (risk/ hazards), or a focus more heavily on thresholds of system state changes along with the capacity for adaptation (ecological resilience).

Exposure

Exposure represents the possible impacts that could befall a system based upon its resources or natural factors that it is exposed to. For example, an agricultural system would be exposed to temperature, water, as well as punctuated weather events. While these forces do not intrinsically stress the system, certain characteristics such as their magnitude and frequency can result in stresses to the system (Luers 2005). Because exposure reflects the components of the given system, exposure is unique to both the system's scale and composition. Exposure is a differential concept (O'Brien et al. 2004). It depends on different factors in different situations, or more specifically, it is context specific.

Sensitivity

Sensitivity describes the quality of how the identified system would respond to the magnitude or frequencies of stresses put upon the exposures of that particular system. If a particular element of the system has a wide tolerance for the stress and its magnitude or frequency, it then has a low sensitivity and hence it is less vulnerable. Often sensitivity to a change in magnitude or frequency of a climatic event is perceived as bad. It is important to note that vulnerability to climatic change and its sensitivity is generally perceived as negative, but this is not necessarily the case. Certain arid agricultural systems may be sensitive to more rain, which could benefit crop yields or otherwise. Sensitivity can also disproportionately affect certain subgroups within a system. These more sensitive subgroups' vulnerability is often a function of their more limited tolerance for shifts in the system due to stresses. An agricultural example of a slow-changing variable would be the slow accumulation of salinity in soils that then ultimately affects crop yields and reduces the flexibility and thus increases the vulnerability of crops to the effects of climate change (Luers 2005). In environmental planning, it is important to pay attention not only to the fast variables, but also the slow-changing variables that can affect a system's sensitivity (Luers, Lobell et al. 2003).

Adaptive Capacity Generalized

Adaptive capacity describes the system's potential to respond, or adapt (Adger and Vincent 2005). Adaptive capacity comprises the elements that enable the ability of a system to adapt (Adger, 2003; Turton, 1999; Walker et al., 2002; Wilbanks and

Kates, 1999; Blaikie et al., 1994; Kasperson and Kasperson, 2001). Adaptive capacity represents a sort of bank account that is drawn upon when shocks occur. Adaptive capacity describes the resources that a system or society has at its disposal to respond to uncertain and novel futures that are likely as both human and climate impacts intensify. Unfortunately, the theory, nature, and determinants of what these resources are and how they interact with one another creates considerable uncertainty in their measurement (Adger and Vincent 2005).

Because adaptive capacity is disproportionately discussed throughout the paper, it is worthwhile to draw the distinction between adaptation and adaptive capacity. Adaptations are manifestations of adaptive capacity. Adaptive capacity does not encompass the components of the actual response. How a system directly responds is termed adaptation—a concept that due to its complexity is often fraught with even more uncertainties than is adaptive capacity (Adger and Vincent 2005). Adaptive capacity is a better proxy for making management and policy prescriptions than looking at adaptation prior to its occurrence. This is because adaptation requires additional steps by asking how the given actor *would* respond if it had the adaptive capacity to do so (Adger and Vincent 2005). Adaptive capacity represents the potential to implement adaptation, but not the actual adaptation by itself (Metzger, Leemans et al. 2005).

Adaptive capacity is important when considering the potential of a social system (within the context of a social-ecological system) to act in the face of unforeseen stresses such as those presented by climate change. Exposure describes the state of the system and the extent to which it could be susceptible to elements of climate change. The exposure of an agricultural area could be reduced entirely if agriculture was eliminated, but this is not considered feasible as a policy or planning option. Sensitivity provides an indication of how a system would respond to a change. The properties of adaptive capacity could ultimately affect the system's sensitivity, but it also can add to the ability of the system—however exposed or sensitive—to potentially adapt in the event of a fast- or slow-changing shock to the system. For planners assessing the vulnerability of a system, the adaptive capacity of the system provides the nearest proxy to being able to estimate the potential adaptation that could occur.

Adaptive capacity changes in the heterogeneous nature of different scales addressed as well as with the fact that funding, politics, and other factors play a large role in the nature of adaptive capacity (Schröter, Polsky et al. 2005). Because of its differential nature, it is important to avoid confusion about the direction and purpose of the adaptive capacity in question. As a result it important to define more clearly what is the system (adaptive capacity of whom) and adaptive capacity to what. In the case of this project the system is defined as the social system in the context of the two places described later. In short, the focus here is spatially oriented (place-based) and at the spatial scale bound to the place in question.

Adaptive Capacity in Context

Adaptive capacity as a working concept in the context of the climate change literature is obtuse. The scale or resolution of the concepts dealt with is often coarse or roughly defined. But they are constructive nonetheless. As the previous portions of this paper have identified, numerous definitions, lineages, and views about vulnerability and adaptive capacity exist. Because of the filter previously described, we employ the general precepts of adaptive capacity with knowledge of its differential nature toward a specific application in the Pacific Northwest.

Table 3. Selected Definitions of Adaptive Capacity

Author(s)	Definition	Commentary
(Folke, Carpenter et al. 2002)	Similar to resiliency and less to do with vulnerability. A term that encompasses social learning, structured scenarios, and active adaptive management in multi-jurisdictional institutions.	Too focused on the ecological resiliency strain of thought.
Adger 2006	"Adaptive capacity is the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope."	Close to this project in its focus on social systems within the context of an environmental system.
Smit and Wandel 2006	The elements that enable the ability of a system to adapt are the drivers of adaptive capacity. (Adger, 2003; Turton, 1999; Walker et al., 2002; Wilbanks and Kates, 1999; Blaikie et al., 1994; Kasperson and Kasperson, 2001).	Almost too open-ended. Fails to relate back to vulnerability in a comprehensive manner.
(Metzger, Leemans et al. 2005)	Adaptive capacity represents the potential to implement adaptation, but not the actual adaptation by itself. Factors that affect adaptive capacity include economic wealth, technology, infrastructure, information, knowledge, and skills, institutions, equity, and social capital.	Nice explanation of what the concept represents, but lacks sufficient context.
(Schröter, Polsky et al. 2005)	A component of vulnerability that describes the potential capacity to adapt to the effects of the sensitivity described in that component of vulnerability.	Good that it recognizes vulnerability and sensitivity; may be too specific to sensitivity.
(O'Brien, Sygna et al. 2004)	Describes a relative rather than an absolute state. Closely related to vulnerability and resiliency. How they interact together is not clearly known. Inherently differential in nature.	Too focused on ecological resiliency, but does emphasize the differential nature of the concept.
(Smit and Pilifosova 2001)	"[T]he potential or ability of a system, region, or community to adapt to the effects or impacts of climate change."	
(Luers in press)	Adaptive capacity refers to the potential actions that could reduce potential vulnerability. It does not refer to or reduce existing vulnerability. Thus, social adaptive capacity could be constrained by future unforeseen socio-economic, institutional, or technical constraints. In such a case, the system's ability to adapt would not occur and the system would be just as vulnerable as a system that had less adaptive capacity.	Too descriptive.

I take a different approach than do Eakin and Luers (2006) who have a focus for their analysis on developing nations, especially in the political economy/ political ecology description of vulnerability lineages. Instead of using one of the descriptions culled from their analysis, I choose to focus on another set of definitions shaded gray in Table 2. While, they are often tautological, their application is in their fit to the place in question. I choose to use Adger (2006) *"Adaptive capacity is the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope."* It fits with a place-based assessment, it can be regional to local and not just global, but it still retains an approach that isolates adaptive capacity and considers it more modifiable than the definitions that stress resilience because as (Schröter, Polsky et al. 2005) explain, resilience describes a state rather than a trait that can be actively managed or improved like adaptive capacity. The definition needs to be sufficiently flexible to account for the many changes and limitations of different assessments. Adger's definition is case-specific to the bounds I give it.

Vulnerability in Context

The type of vulnerability highlighted here includes the traditional impacts of the system to exposure and sensitivity, but it also includes the coping concept of adaptive capacity (Metzger, Leemans et al. 2005). Using Eakin and Luers (2006), I suggest that the political economy/ political ecology definitions provided best contain the use of adaptive capacity for this paper. Working along the lines of the three different vulnerability lineages, the questions sought after here relate to differentiality, capacity (in addition to exposure), as well as a spatial scale that can extend down to local levels.

Blankie et al. (1994) suggest vulnerability is "[t]he characteristic of a person or persons in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard." This definition could be expanded further to include not only persons, but also systems. Additionally, it requires less effort focusing on the exposure elements of vulnerability, but it is implied within the statement that the people (or in my use 'systems') are inherently exposed and made vulnerable. The risk/hazards definition by Cutter (1996), "…the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards place with the social profile of communities," emphasizes the need for exposure and also introduces the idea that the hazard's interaction with the actions of communities creates vulnerability. Internal, or endogenous, and not only external, or exogenous, processes can make a system more or less vulnerable.

Adaptive capacity plays a role in this modification of vulnerability, which profoundly shapes the nature of a system's vulnerability and the ability of a system to cope with shocks. With this coping consideration in mind, vulnerability as defined here is a combination of the Blankie et al. 1994) and Cutter (1996) definitions as: *The characteristic of a system in terms of its lack of capacity to anticipate, cope with and recover from the impact of a natural hazard as well as the internal stresses caused by the social processes of the system in question.*

Assessing the Adaptive Capacity of a Place

Yohe and Tol (2002) state that adaptive capacity holds the potential to serve as a point of departure for the construction of practical indices to compare the relative vulnerabilities of different systems. Because most indicators of adaptive capacity are indirect measurements they then serve as proxies of the adaptation that may or may not occur (Adger and Vincent 2005). Vulnerability indicators serve as important tools in monitoring and understanding the improvement or degradation of certain ecosystem services. They also can serve as not only measures of change, but also they can describe the landscape, or stability domain that the socio-ecological system exists in. Indicators that account for the differential nature of the concepts they are to measure, or those that are place-based are then necessary.

The practical applications of work incorporating indices to reduce vulnerability to people has not yet been established despite numerous studies using indicators (Smit and Wandel 2006). Most indicators developed for adaptive capacity have so far integrated the national scale processes. Sub-national indicators that describe adaptive capacity are less prevalent in the literature (Adger and Vincent 2005; Moss, et al. 2001; (Yohe and Tol 2002; Brooks, Adger et al. 2005). Indicators including clean water availability and educational attainment attempt to look at the aggregate well-being of society and its capacity to respond to shocks, but they still are lacking in measuring the adaptive capacity at finer spatial scales. O'Brien et al. (2004) have observed the differential nature of adaptive capacity and vulnerability in general when attempting to develop such metrics. Indicators for adaptive capacity have been conducted at larger scales, but the applicability for downscaling is less prevalent in the literature. The determinants of adaptive capacity appear to be very case specific as well as scale-dependent. That is different indicators work or may not be applicable at different scales (Adger and Vincent 2005).

A problem encountered in measurement through a review of case studies by Lebel et al. (2006) is that it is difficult to measure governance and how well social organizations can learn, adapt, and manage for resilience (Lebel, Anderies et al. 2006). Individual and institutional interactions pose problems for straightforward measurement. Given the inherent squishiness of such measurements how do we assess adaptive capacity when it distinctly relies on effective networks between organizations and people that are often complex and hard to measure? Proxy indicators may be an option.

Indicators to measure adaptive capacity face challenges because of a lack of specific data, or because they cannot be directly measured (Moss and Schneider 2006). Past research (Moss et al. 2001) used proxies to measure sensitivity, exposure, and adaptive capacity. These indicators, grouped roughly by economic capacity (GDP, Gini Index), human and civic resources (dependency ratio, literacy), and environmental capacity (population density, pollution measured by SO2, percent of land unmanaged) are more directed toward encompassing the concerns of national-scale indicators, as well as comparing the relative status of developed and developing nations (Moss, Brenkert et al. 2001). Ultimately these measurements are aggregated to form single sensitivity and adaptive capacity indicators and then finally distilled into one vulnerability-resilience indicator.

Beyond proxies, other studies using indicators compared regions or systems, instead of rating systems independently of others with indicators. Apart from being more national in focus, indicators used have been comparative in nature. Moss et al. (2001) establish a set of sensitivity and adaptive capacity indicators to compare these qualities for developed and developing nations. Yohe and Tol (2002) develop a more regional approach for employing indicators of adaptive capacity. Yohe and Tol's (2002) indicators are unit-less and again meant to provide a flexible and comparative approach to looking at the adaptive capacity of sub-national regions. A comparative approach may be sufficient in looking at the differences between spatial scales, but an approach where the individual adaptive capacity could be measured would be a valuable future research objective as well.

Numerical scoring in indicators for such a difficult and often cloudy concept as adaptive capacity may be constraining at times, but as Underdal (2001) notes, its unambiguous choice can both be demanding and more transparent, thus facilitating criticism and continued debate on a topic that needs more debate. In the current state of theoretical development of adaptive capacity, numerical scoring for indicators would provide more transparency and a healthier debate among the merits of an indicator or set of indicators. Defining adaptive capacity with quantitative measurements given the scope, scale, and contexts of the Pacific Northwest can begin to then help us use an operational definition to learn more about the concept and how it varies according to different scales.

The specific sensitivity and adaptive capacity indicators used by Moss et al. (2001) included in Table 4 illustrate one path for indices. Moss et al.'s (2001) indicators do not use a criterion similar to Schröter et al. (2004) where factors about climate change should be included in its indices development. According to Schröter et al. (2004), five criteria should be met to achieve the objective of "improved decision-making": (1) An interdisciplinary knowledge base; (2) Be place based; (3) Consider multiple stresses; (4) Examine differential adaptive capacity; and (5) Incorporate perspective and history as well. Other studies on the use of indicators have reaffirmed the concerns with uncertainties in indicators, and agree that there is analytical merit in continuing to develop indicators (Yohe and Tol 2002; Adger and Vincent 2005). Contrasting with Moss et al. (2001), other papers reviewed provided comparative rankings of vulnerability using unit less indicators to rank the relative capacities between social systems that have adaptive capacity (Yohe and Tol 2002; Adger and Vincent 2005).

Table 4. Proxy indicators to measure adaptive capacity (Moss et al. 2001)

Sensitivity or Adaptive Capacity Category	Proxy Variables	Proxy For	Functional Relationships
Economic capacity	GDP(market)/ capita Gini index	Distribution of access to markets, technology, and other resources useful for adaptation	Coping-adaptive capacity ↑ as GDP per capita ↑ At present Gini held constant
Human and civic resources	Dependency ratio Literacy	Social and economic resources available for adaptation after meeting other present needs. Human capital and adaptability of labor force.	Coping-adaptive capacity ↓ as dependency ↑ Coping-adaptive capacity ↑ as literacy ↑
Environmental capacity	Population density SO2/area % Land unmanaged	Population pressure and stresses on ecosystems Air quality and other stresses on ecosystems Landscape fragmentation and ease of ecosystem migration	Coping-adaptive capacity ↓ as population density ↑ Coping-adaptive capacity ↓ as SO2 ↑ Coping-adaptive capacity ↑ as % unmanaged land ↓↑

Some indicators in table 4 are not applicable for a regional to local assessment process. Some of the bounds already imposed on this project exclude some of these proxy indicators as listed, but they can likely be downscaled to provide a somewhat different, but still illustrative result. The semi-rural character of the systems of both the Skagit and Columbia mean that more urban-centric indicators such as air quality figure less prominently as proxies for stresses on ecosystems. Instead, other indicators for stresses on ecosystems could be used as a more practical proxy such as water quality, turbidity, or some of the other indicators already incorporated in the Moss et al. model such as percent of land managed/unmanaged. Likewise, population density, while potentially useful in certain places for assessments has less utility in assessing the adaptive capacity of the Skagit or Columbia.

Stakeholders and Assessing Adaptive Capacity for a System

Indicators, help inform us if adaptive capacity exists in a system at the spatial scale observed. Indicators depend on how you define the system. Because of the differential nature of vulnerability and adaptive capacity itself, refining indicators based on the place in question is valuable (Turner, Kasperson et al. 2003). In identifying vulnerability stakeholders in the system can use their knowledge and experience to help determine what indicators are applicable to the specific region in question. Indicators vetted by stakeholders are useful as a way to ground the literature and to provide a healthier debate for the future. By incorporating a criterion of how to assess adaptive capacity, and then by thinking about good indicators to use, we can improve the information and theory available. With a better picture of the sensitivity, exposure, and present adaptive capacity, users can then explore methods to shape and improve a system's adaptive capacity (Smit and Wandel 2006).

Perceived adaptive capacity has been shown to be a major determinant of whether or not adaptation will occur. (Grothmann and Reusswig 2004) Thus, place-based studies that look at the circumstances of vulnerability are important because they relate to populations and their specific concerns (Schroter, Metzger et al. 2004). Endemic qualities specific to that place or system make stakeholders important because they can assess the specific qualities of what adaptive capacity may look like in a given place (Smit and Wandel 2006). In these situations, stakeholders' on the ground expertise could be valuable to identify useful indicators for adaptive capacity. Additionally, stakeholders can identify indicators that fit the scope and scale of the system in question. Stakeholders can distill place-specific information into positive steps for managing for global change at a local level (Schroter, Metzger et al. 2004).

The Worth of Indicators

While caveats to indicators exist, they have utility. Indicators can struggle with poor data sources, proxy indicators by their very nature derail the ability to directly measure the quality in question; sketchy understandings of functional relationships between elements of adaptive capacity (Moss and Schneider 2006) and scaling mismatches can exist. On the other hand, indicators force hard views about the nature and substance of qualities that comprise adaptive capacity. Comparative approaches for indices have been used at a regional level and proxy indicators have allowed studies to compare the relative adaptive capacity between nations. A criterion for thinking about what indicators to apply in the context of climate change has worth (Schröter, Polsky et al. 2005). Additionally, incorporating the knowledge of stakeholders to create a case-specific set of indicators would provide more accuracy in data use and less potential for the scale mismatches described previously. Because of the nascent nature of indices development, drawbacks or questions about their utility should be incorporated, but those concerns should not discount the potential for learning about the nature of adaptive capacity through indices.

Two Examples to Apply Indicators

The two examples are chosen to provide an idea of how indicators could be used to operationalize adaptive capacity. The Columbia River Basin and Skagit River watershed are located in the Pacific Northwest and simultaneously share similar characteristics as well as differ, too. The two geographic units were chosen in large part because of the studies and focus that the CIG has put on them as case studies for climate change impacts and adaptations. Both regions are dependent and affected by the natural resource issues surrounding their rivers (hydropower, salmon, irrigation, flood control). Both geographic units also have significant conflicts surrounding resources and the rivers. The regions do differ in urban development pressures where the Skagit faces growth pressures from surrounding metropolitan areas and the

Columbia's growth is more diffuse in lacking the pressures of nearby metropolitan expansion. They also differ in their climate patterns where the Skagit receives more rainfall and the Columbia is more snowmelt driven in its hydrology (but the Skagit's winter snow pack is still very important). Ostensibly, both differ in geographic size, which should play a role in differentiating between the two areas.

The basin (Columbia River) and watershed (Skagit) levels of analysis differ in both spatial scales, which in turn results in differences in social and environmental complexity. Because spatial scale alters key components, it therefore would influence a differential concept like adaptive capacity. This section elucidates some key components of spatial scale toward the question of how the concept of vulnerability changes according to the scale of analysis (O'Brien and others 2004) and how that affects the operationalization of adaptive capacity.

Skagit River Watershed

Description

The Skagit River Watershed represents a complex geographic region with conflicting resource uses and goals. Located in northern Washington State (with a small segment in British Columbia) and emptying into the Puget Sound, the Skagit river consists of a third of the freshwater flow into the Puget Sound (Ecology 2004). Marked in the lower portion by private holdings that are agricultural and a growing service, residential, and light industrial component, numerous stakeholders hold differing positions on land use and environmental regulations. The upper portion of the watershed is forested and managed by federal, state, and hydropower interests. Apart from land use disputes, resource concerns in the watershed include agriculture, urban growth, fishing, logging, and recreation. Actors holding interests in the watershed include the agricultural community, tribal interests, a growing residential community drawn by the area's rural character and proximity to larger metropolitan areas, public utilities that manage the five dams on the Skagit River system, state and federal agencies that have mandated responsibilities that include land management and monitor compliance with laws (such as the Endangered Species Act), and local municipalities that rely on the Skagit for residential and industrial water supplies. Significant biological components of the system include runs of all five salmonid species, a major estuarine reserve, a listing as a national scenic river, a national park, and large amounts of forest resources.

Projected climate impacts

Impacts and vulnerability in the Skagit watershed are consistent with those in the Pacific Northwest. As a result it is both exposed and sensitive to the impacts of climate change and variability. The Skagit watershed has a large portion of farmland converted from deltaic or estuarine habitats. These low-lying areas are exposed to the risk of flooding if sea levels rise. Warmer winters and drier summers on the western slope of the Cascade Mountains, that the Skagit is a part of, will likely result in a higher probability of flooding as less precipitation will fall as snow and instead will either directly run off, or will create rain on snow events. Apart from the increased probability of winter floods, such changes will likely affect the stream hydrograph, which will force alterations in water resource management for activities such as hydropower generation, and it could have adverse affects on spawning, incubation, and migration for certain salmonid populations. In the case of hydropower generation, management could be sensitive to these impacts less because of the effects on storage, but more so because of the high sensitivity of the aforementioned salmonids to a changing stream hydrograph. In this case, the social-ecological system in the Skagit watershed is similarly exposed, but its sensitivity stems from a combination of both social and ecological phenomena.

Uncertainties appear to link closely with the vulnerabilities that the system appears both exposed and sensitive to in the future. The climate impacts—wetter winters and drier summers—appear to be highly probable, but the magnitude of both remains within a range of uncertainty. More uncertain are some of the endogenous changes to the system such as urban growth, and on the environmental side the abundance of salmonids. In both of these cases sensitivity to changes in the stream hydrograph and the increased winter stream flows due to more runoff could be amplified if increased urban development ensues and if salmonid stocks dwindle. Similarly, the coastal location of the watershed means that sea level rise could not only threaten current agriculture, but also salmon restoration activities in estuarine zones. Because of the contentious nature of these activities (and the perceived conflict between farms and fish) uncertainties like this might not only make certain activities more sensitive, but could increase political sensitivities in the watershed. Other uncertainties relate to the changes in composition and response of the forests to climate change and variability. Due to the high level of conflict present as well as exposure to probable events (sea level rise, changes in climate), the Skagit appears to be moderately vulnerable to climate change.

Columbia River Basin

Description

The Columbia River basin spans a multi-state area and extends across the border between the United States and Canada. Mostly snowmelt-driven, because of the large size of the system and the extent of its supporting river systems, flow does not result from weather systems per se, but instead through an averaging of climate patterns over the year. Major resource concerns within this basin that are dependent on the river include hydropower, irrigation (agriculture), municipal and industrial uses, recreation, trade (shipping), and salmon (both harvesting and regulatory concerns from the Endangered Species Act, and tribal rights to fishing). With over 100 hydroelectric projects and 250 reservoirs, the Columbia River basin has little capacity to add new storage as a way to accomodate freshwater uses, resulting in reduced flexibility for water allocation among the interests. Major interests that drive decision making include parties representing hydropower interests, farming, tribal groups, as well as governmental organizations such as the Bonneville Power Administration, state agencies such as the Department of Ecology, and smaller groups such as counties and local irrigation districts. *The lack of a coherent regional governing body and the lack of a shared perspective of the citizenry belonging to a greater basin beyond counties means that regional identity is lacking.*

Projected climate impacts

A large portion of research on the basin has been focused on water resources, which is a primary driver of the basin's economic activities. The CIG has conducted numerous modeling studies and interviews with managers and other stakeholders in the basin to look at impacts from climate change and climate variability (Miles, Snover et al. 2000). In terms of vulnerability, the system is exposed to the effects of climate patterns because of the system's need for precipitation (mostly snow and some rain) in a predominantly arid environment on the west side of the Cascade Mountains. The geography of the basin means that while the river system is driven by snowmelt, the upper basin relies more heavily on a moderating influence of glacial melt while the lower portion is affected by snow pack that varies on a seasonal basis. The system is also sensitive to climate change and variability, but this sensitivity is not uniform (Miles, Snover et al. 2000). The system's sensitivity is due to a combination of hydrological system responses as well as the political and regulatory environment that favors certain uses (Miles, Snover et al. 2000). Unlike the Skagit, the highly regulated Columbia will likely not be at risk of flooding adjacent areas.

Like the Skagit, many of the uncertainties in the Columbia are of endogenous sources. Demand for economic activities could change current water usages, thus affecting the projected water uses in the basin. In that eventuality, new conflicts could be generated from the reallocation of water where there is now a zero sum game between salmon and other uses, especially in some drier months. Uncertainties over the actions of a severe drought in the future could play a large role in resource conflicts throughout the Columbia. Similarly, the effect of climate on the composition of forests and on wildfire regimes remains relatively uncertain. How this will affect future development in wooded areas remains to be seen. In the end, how uncertainties from climate change will play out will have a large role in shaping resource conflicts in the Columbia River basin for years to come.

Applying Indicators to Operationalize Adaptive Capacity

As a way to compare and contrast the vulnerability of the Skagit and Columbia, we can look at their adaptive capacities. As way to learn more about adaptive capacity, indicators can operationalize the concept. Here, indicators are needed to determine the properties of the term in a testable form. Being testable, the operational definition should be able to be confirmed or falsified by the data used. Operational definitions can be used to define the concept of adaptive capacity, and could be defined by certain qualities or traits that it possesses, which could then be measured by the use of indicators suggested by Moss et al. (2001), Adger and Vincent (2005), or Yohe and Tol (2001). An example of an operational definition might be a psychologist who defines 'increased stress' as a rise in blood pressure. An environmental planning analogue might be a characterization of increased flood risk due to more impermeable surfaces and less forest cover in a watershed. For adaptive capacity, testing the definition to provide accountability creates the usability necessary for its application around uncertainty in natural resources planning.

Like Moss et al. (2001), I will look at indicators that are grouped into general categories of economic capacity, human and civic resources, as well as environmental capacity. I suggest only a few of the specific indicators of Moss et al. (2001) because some do not fit the contexts of the two systems described.

Table 5. Indicators Specific to Skagit and Columbia Systems

Sensitivity or Adaptive Capacity Category	Proxy Variables	Proxy For	Functional Relationships
Economic capacity	Local government budget	Represents the ability of governments to fund research, adaptive management, and restoration.	Adaptive capacity ↑ as local government budgets ↑
	Economic sectoral distribution	Proxy for economic well-being and the dependency residents have on sectors that are more exposed to environmental change	Large proportion of natural resource-dependent sectors may create conflict or resistance to change/adapt.
Human and civic resources	Local watershed organizations	Social and economic resources available for adaptation after meeting other present needs.	Adaptive capacity ↑ as dependency ↓
	Ecological literacy	Human capital and adaptability of residents to identify and support change.	Adaptive capacity ↑ as ecological literacy ↑
Environmental capacity	Impermeable surfaces	Population pressure and stresses on ecosystems	Adaptive capacity ↓ as population density ↑
	Water quality	Water quality and other stresses on ecosystems, which cause conflict	Adaptive capacity for aquatic dependents ↓ as water quality ↓
	% Land unmanaged	Landscape fragmentation and ease of ecosystem migration	Adaptive capacity ↑ as % unmanaged land ↑

The indicators listed in Table 5 are grouped into three general categories, but the first two are more oriented toward social capacity building and the latter serves as a proxy for environmental conflict between stakeholders and user groups, which could ultimately decrease adaptive capacity. The economic capacity category is split in two by the funding of local governments and the dependence of the local economy on natural resources through the measurement of economic sectoral distribution. This measurement of economic dependence, or distribution, is less about capacity building and highlights the reluctance of certain stakeholders to change policies or practices in order to adapt. The human and civic resources category would refer to local organizations such as watershed groups that seek to improve environmental management within areas. A corollary of organizations that seek to improve environmental awareness and education would be ecological literacy. Finally, the environmental capacity section would measure certain environmental characteristics as proxies for environmental conflict in a given region.

Economic Capacity as a grouping of indicators depicts local resources that could be devoted to funding research, response, or restoration to environmental change. Additionally, it also refers to the level of vested interests in protecting certain sectors of the economy. While grouped together, each indicator charts a significantly different aspect of a social system. Both can represent either progressive or regressive elements to the social system in the way they act. Thus both are good indicators at measuring the adaptive capacity for the economic capacity of a system. The former indicator may show signs of progressive elements with additional funding devoted to elements that can help test and monitor the resiliency of natural systems (adaptive management). The latter indicator, while notable in almost all economies, may exert a stronger signal in economic systems that are less complex (in this context they are less diverse and rely more on natural resources as a component rather than other industries that are less tied to the land like technology).

In the case of the Skagit, local government funding does not appear solely focused on funding more research on projects that could support adaptive management such as the Critical Areas Ordinance, as mandated under the Washington State Growth Management Act. Additionally, with a high economic composition of industries in natural resources (farming, logging), resistance to change would to restrict future adaptations and funding for programs such as the Critical Areas Ordinances. In the Columbia the numerous local governments do not work in concert on region-wide projects, and but larger institutions such as the Bonneville Power Administration or other hydropower projects (Army Corps of Engineers) serve to address these issues. As previously described, the dominance of resources tied to water usage from the Columbia (farming, industry, hydropower) limits system flexibility (Miles et al. 2000), which could result in high resistance toward changes or adaptations. For both, additional government funding by way of salmon restoration projects would theoretically benefit natural systems in both places.

The human and civic resources indicators depict the ability of decentralized groups or individuals to identify, act, or respond to changes or perceived needs within a social system. Mounting pressures through environmental change or urbanization appears to lead to responses by local groups, or sometimes more awareness of changes. How cohesiveness occurs, or how much conflict, exists between groups or actors, affects the quality of this measurement. Roughly approximating this assumption is that more local watershed groups and NGOs as well as more ecological literacy would promote higher adaptive capacity. Of the three larger groupings, this cohort of indicators may be the most imprecise as some local organizations could be counted but may not work for improving a system's ecological resiliency. Likewise, ecological literacy and an individual's awareness of environmental systems and processes could be muddled or counter to what is perceived as ultimately beneficial for restoring system complexity to a place. Perhaps, in this grouping of indicators, stakeholders could supply more context or more refined indices that would better characterize the human and civic resources necessary to foster adaptive capacity.

For the Skagit numerous watershed groups and other NGOs appear to be focused on working with (but sometimes in confrontation with) local landowners to restore natural habitat or to work on retaining farmlands or other open spaces in the face of urbanization pressures. Indicators, if one in measuring human and civil responses, could become harder to read in a larger spatial area where less common views could be held due to the larger geographic scale and the potential for more positions because of the larger population and economy. Similarly, emergent properties that appear could potentially affect the ability to generalize adaptive capacities between scales. Therefore, an integrated assessment across scales and between stakeholders would have to occur. Ecological literacy, a very tricky measurement because of its difficulty and lack of established metrics, might be better described as a proxy for ecological exposure. How to measure such a trait is less clear. In the case of the Columbia, disparate agencies and little overlap that bring the basin together may result in less coordination between groups that do not work on such a large spatial scale. Similarly, because of the close proximity to resource-based industries, measured ecological literacy in the Columbia may be comparable to the Skagit.

Environmental capacity in a social system setting best measures the ability for environmental conflict, which can restrain movements for change or adaptation to new changes, stresses, or shocks. While each of the three indicators in this grouping can also serve as predictors of environmental quality, in terms of measuring the future potential to adapt, environmental quality is not as germane. The first indicator—percentage of impermeable surfaces—is unique because it serves as a proxy for population increases, but also the patterns of development that new migrants bring to a region. It is the context and rural character of these two systems in question that make this indicator a proxy for conflict where different development patterns could result in animosity between various groups (those that wish to keep rural areas versus those that favor development).

Water quality, or the quality of riparian areas and coastlines in these systems, again could result in conflicts between different user groups. Low environmental quality could result in certain groups pushing for more stringent efforts of improvement, while other groups (farmers, developers) would likely resist such efforts. Conversely, high water quality would result in more harmonious relationships likely resulting in increased cooperation. As a terrestrial analog to aquatic environmental quality, the percentage of land unmanaged serves as a proxy for greater connectivity and ecological resilience resulting in the potential for more normal functioning of natural system processes and less conflicts resulting from the breakdown of the same processes.

An accurate assessment of the environmental indicators listed here is not feasible in this study (due to their breadth and the need to refine them in greater detail), but observations teased from previous work (Miles, Snover et al. 2000; Morlock 2005) identifies that in both regions conflict among resources and based on competing desires to use natural resources (farmland, water resources, and salmon) point to the restricted capacity to adapt due to social tensions related to environmental issues over land use, water allocation, and habitat preservation/restoration. While these tensions can be seen as wholly negative, creative solutions and partnerships to problems could produce favorable outcomes conducive to improving adaptive capacity of a place.

With all of these separate indicators to draw from, creating an aggregate indicator would then lead to a better understanding of what adaptive capacity represents. By using such indicators, we may be able to discern spatial scale differences. A larger geographic area like the Columbia may dampen the indicator signal, thus affecting the utility of certain measurements. Because the geographic scope of the Columbia is larger, it provides more chances to withstand localized shocks to the system. In this way, proxies that would seek to look at water availability, or salmon productivity—which both could serve as indicators for conflict between populations within a system (farmers/hydropower and tribes/fishermen) and may be dampened by the ability to withstand such a shock from the effects of climate change. As Lebel (2006) argues, multiscale assessments are necessary to counteract dampened signals from smaller spatial scales.

An aggregate assessment would also enable the development of measurements that are potentially more integrative across a range of the various indicators listed in Table 5. One such indicator would be a social cohesion/ fragmentation index. As previously discussed, the environmental capacity category services as a useful proxy for conflict, but elements of the economic sectoral distribution measurement could also serve as a rough proxy for income inequality, which in some cases could indicate a lack of social cohesion. In addition, depending on the context of the social system, a lack of interest groups, or local watershed organizations could serve as another proxy for the presence or lack of social cohesion. Taken together in the aggregate, one could piece together a picture of social cohesion using observations gleaned from these individual metrics.

Making an assumption of how networks interact between the two places addressed is difficult because of the differential nature of the concepts and how they work in these separate contexts. A comprehensive analysis of the Columbia would likely have to incorporate sub-scales and many more stakeholders due to its size. Does the larger and possibly more institutionally focused Columbia River basin change how or what vulnerabilities would be considered or defined? Would the complexity of a multiscale system then differentiate it from a smaller watershed like the Skagit? Does the increased complexity of scale in the Columbia constitute the largest difference?

Indicators begin to build substance around an operational definition of adaptive capacity at these two locations. High adaptive capacity using these metrics would be evident as a system that has adequate funding for governments, a balanced natural resource sector, one with sufficient organizations to manage environmental systems, a population that is relatively ecologically literate, and a system that has less environmental quality or scarcity problems that could result in environmental conflicts. To boil this down even more into something that is operational, one could say that *adaptive capacity is high when funding for environmental management exists, when civic involvement/interest promotes learning and involvement, and when environmental conflict is low*. Weighting the importance of the various metrics could be equally done, or there could be a greater import placed on those elements deemed more important given the context of the place in question.

Section III: Discussion and Conclusions

This thesis explored the concepts surrounding adaptive capacity as it applies to vulnerability in SESs located in the Pacific Northwest. As a crucial informational input and a proxy for adaptation, adaptive capacity can help inform the scenario planning process as a way to deal with future uncertainties. This is because adaptive capacity indicates potential for systems to cope with future change. Place-based assessments are increasingly important because of the differential nature of concepts like vulnerability. Being differential concepts, the concepts—like vulnerability and adaptive capacity—are highly dependent on their application and tailoring them to specific places could improve not only the assessment, but also the nature of the concept in that particular instance. Indicators can be operationalized, to gather information related to the institutional and social linkages to help establish an applied use for adaptive capacity. Conducting an assessment of adaptive capacity by operationalizing the term in testable form allows us to probe deeper into the qualities and components that comprise the subject in a place-based manner.

From a planning perspective, there is a need for more information in dealing with the uncertainties and complexity of climate change and long-range environmental planning. Information has only so much utility if not pointed in the right direction. Adaptive capacity provides an important input in the assessment process as a proxy for adaptation. It can help us consider system responses to vulnerabilities evident through the stresses of human use, as well as the exogenous stresses that climate change can bring.

When addressing vulnerability, it is important to ask “vulnerable to what?” In many ways, vulnerability is a societal construct and a result of the context that varies wildly within a spatiotemporal area (Vogel and O'Brien 2004). Vulnerability is dynamic and heavily influenced by multiple stresses as well as the context of which it occurs.

Developing a more coherent understanding of vulnerability adaptive capacity may help improve human system capacity to manage environmental change (Vogel and O'Brien 2004).

Conceptual definitions that can be operationalized through the use of indicators are most effective. Because of the differential nature of the concepts, they may be too dynamic and case-specific to refine the concepts past a coarse understanding of their meanings. In a limited way stakeholders, experts, or researchers of the system can then add value to the concepts in order to improve the development of indicators that can be used as inputs for developing potential future scenarios. More detailed research and a strict methodology of how to apply inputs into the metrics would be necessary to further vet the observations in the Skagit river and Columbia basin. This review attempts to provide an idea, process, or nascent methodology for considering some of the factors and for thinking about indicators that would be applied and how they would become place-appropriate in their use.

When looking to assess vulnerabilities and adaptation to climate impacts in the future, numerous uncertainties exist. Scenario planning for this reason appears to be a good way to analyze change over time (Adger and Vincent 2005). Information related to the capacity to adapt appears to be an important element in a scenario planning process. Scenario planning, a technique first employed in the business world in the 1960s to confront uncertain futures in the business landscape, seeks to address uncertainty in long-term planning. Scenario planning now appears to be gaining traction in the world of natural resource management and environmental planning as a method to reconcile the growing understanding that prediction is untenable and that complex systems bring with them highly uncertain situations in planning for the “long now” (Carpenter 2002). An extensive scenario planning exercise has been recently completed by the Millennium Ecosystem Assessment for a significant portion of its work to assess environmental change on human well being (Carpenter, Pingali et al. 2005).

Planning for climate change and for environmental change driven by human uses necessitates the appropriate use of context and scale specific to the system in question. When considering what information to use, it is important to understand the constraints and limited knowledge that we posses given the numerous uncertainties extant in long-range planning exercises. To avoid this, I posit that scale and scope in the context of assessing a system's adaptive capacity cannot be ignored if we wish to pursue a sustainable future where adaptation to change is better understood. To determine how well a system can respond to exogenous shocks, considering adaptive capacity as a proxy for adaptation is necessary.

Systems can change, but assessments can serve as a starting point to begin to understand how to plan for future change in the Pacific Northwest and beyond. Future work could stem from a selection of the following questions:

- Does it take a concerted planning effort to adapt or not? How does scale or complexity change this?
- How does one identify shifts in scales?
- What additional indicators could be used for future research?
- What is the role of place-based information in developing indices of adaptive capacity
- What are breaking points that define differences in spatial scales?

Ultimately, more studies and data gathering are necessary to parse out the nuances in spatial scale differences using indicators. For now we can begin to think about some of the possible outcomes resulting from differences between smaller more cohesive watersheds and larger aggregated systems that are less unified both culturally and institutionally. Perhaps it is these differences that will have the most profound differences when looking at indicators across different spatial scales. Acquiring data for some of these indicators, particularly data on ecological literacy could be tricky, but it provides a beginning to encouraging improved decision-making when planning for climate change.

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