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ASSESSING SOCIAL-ECOLOGICAL RESILIENCE AND ADAPTIVE CAPACITY
IN THE FACE OF CLIMATE CHANGE: AN EXAMINATION OF THREE
COMMUNITIES IN THE CROWN OF THE CONTINENT ECOSYSTEM

BY

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DISSERTATION

Submitted to the University of New Hampshire
in Partial Fulfillment of
the Requirements for the Degree of

Doctor of Philosophy
in
Natural Resources and Environmental Studies

December, 2011

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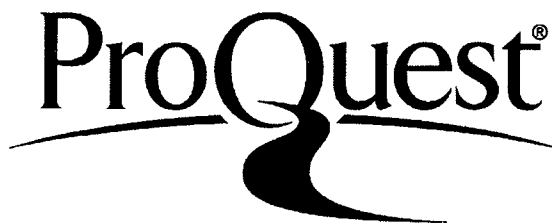
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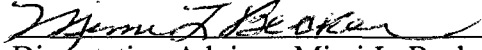
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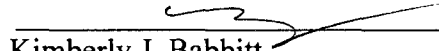
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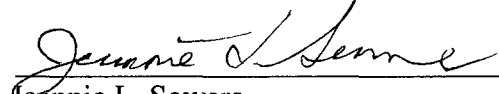
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DEDICATION

For my wife Trista, without your boundless devotion and encouragement this would never have been a successful endeavor.

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ABSTRACT

ASSESSING SOCIAL-ECOLOGICAL RESILIENCE AND ADAPTIVE CAPACITY IN THE FACE OF CLIMATE CHANGE: AN EXAMINATION OF THREE COMMUNITIES IN THE CROWN OF THE CONTINENT ECOSYSTEM

by

Bradley B. Johnson

University of New Hampshire, December, 2011

This research examines the social-ecological resilience and adaptive capacity of the Crown of the Continent Ecosystem through a suite of three case study communities and the impacts of climate change on the ecosystem's hydrologic regime. The Crown of the Continent Ecosystem spans the U.S.-Canadian border; case study communities composed of Kalispell and Choteau, Montana and Fernie, British Columbia fall on both sides of the border.

Primary data was gathered through a "bottom-up" qualitative approach utilizing an online survey followed by a semi-structured interview process with stakeholders in natural resource dependant industries and government at the local, state, and federal levels in the three case study communities.

Results produced a set of participant identified indicators specific to the direct and indirect impacts of climate change on the ecosystem's hydrologic regime. In addition to the indicators, participants identified social-ecological strategies and resources to address identified and foreseen ecological and economic impacts. Data further revealed a

multitude of impacts to social-ecological resilience and uneven adaptive capacity to the impacts of climate change on the hydrologic regime of the ecosystem. Finally, the data indicates that the Crown of the Continent Ecosystem possesses a robust multi-level set of natural resource management institutions capable of responding to ecological uncertainty if capacity building and collaboration are made a priority.

CHAPTER I

INTRODUCTION

The goal of the research encompassed in this dissertation is to understand how communities, industries, and agencies in a rural ecosystem develop strategies and resources to deal with the impacts of climate change. The research seeks to learn about the resilience and adaptive capacity of communities and their industries impacted by climate change by focusing on the changing hydrologic regime of the ecosystem. This research is driven by a desire to learn what climate change driven impacts are compelling communities and sectors in the Crown of the Continent Ecosystem (COCE) to respond and how those responses are shaped.

Concepts introduced here in the first chapter will be fully described in the following chapters. This introductory chapter begins by introducing the Crown of the Continent Ecosystem where the research took place, and describes how the ecosystem has already been impacted by climate change. Next, the two overarching theoretical concepts on which the research is based are introduced- these are resilience theory and adaptive capacity. The chapter concludes with a brief introduction to the qualitative methodology utilized in the study and is followed by the layout of the remainder of the dissertation.

The Crown of the Continent Ecosystem

The Crown of the Continent Ecosystem spans over 27,000 square miles (43,700 km²) (Prato & Fagre, 2007) and has been recognized for its cultural and natural resources through designation as a World Heritage Site and Biosphere Reserve, both of which are encompassed by Waterton -Glacier International Peace Park spanning the United States- Canadian border. This bi-national ecosystem is more than 80% publicly owned (Long, 2002) which influences both governance and access to natural resources.

The COCE is regarded as one of the least degraded, most ecologically intact, and highly contiguous ecosystems in the U.S. (Darrow et al 1990; Stanford & Ellis 2002 in Pedynowski 2003) . The ecosystem stretches across the spine of the Rockies from northwestern Montana, across the U.S.-Canadian border into southeast British Columbia, and southwest Alberta (Figures 1-1 and 1-2). Largely montane and heavily

forested, the ecosystem is influenced by two distinct climate patterns. Areas falling east of the Continental Divide are heavily influenced by continental climate patterns while areas falling to the west are more heavily influenced by Pacific maritime climate dynamics (Selkowitz, Fagre, & Reardon, 2002). The dueling influences of the two

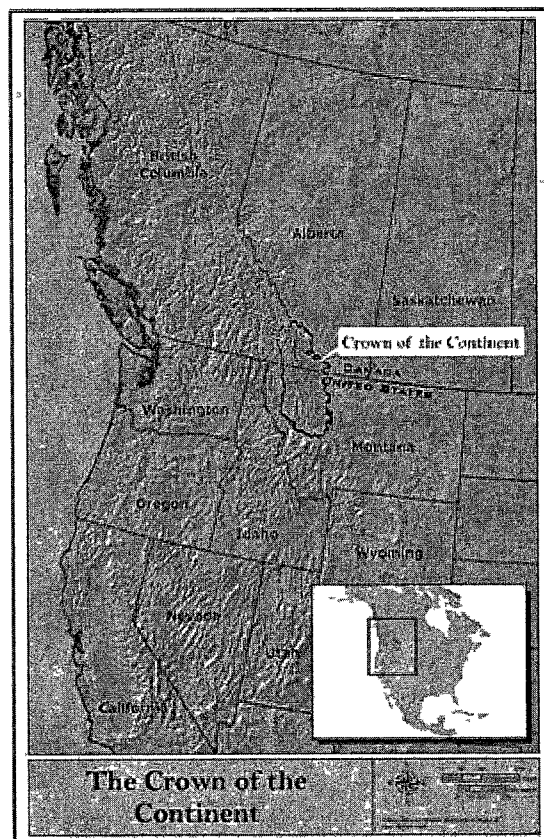


Figure 1-1: Crown of the Continent Location. Map is courtesy of the Crown of the Continent Roundtable's public domain maps.

climate patterns at such northern latitudes have historically produced long cold winters and short dry summers (Long, 2007).

Climate models for the Pacific Northwest predict an increase in both temperature and precipitation for the region. The National Assessment Synthesis Team, utilizing the Hadley and Canadian climate

models, predict a 1.5°C temperature increase by 2030, and a 3°C increase by 2050. The team presented a discrepancy between summer and winter predicted temperature increase, with a summer increase of 4-4.5°C and a winter increase of 4.5-6°C by 2090. In addition to increased temperatures the team predicts increased winter precipitation (ranging from single digits to 50% depending on the model) with little or no increase in summer precipitation- potentially

exacerbating seasonal water shortages (National Assessment Synthesis Team, 2001).

Three communities in the Crown of the Continent Ecosystem serve as case studies for this research: Kalispell, MT, Choteau, MT, and Fernie, BC. A number of conditions

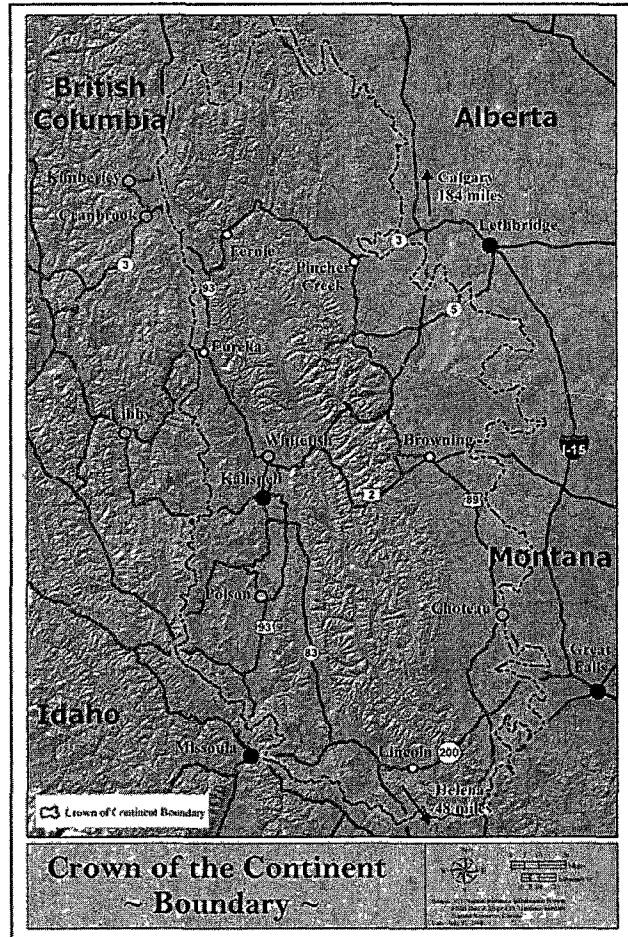


Figure 1-2: Crown of the Continent Ecosystem Boundary. Map is courtesy of the Crown of the Continent Roundtable's public domain maps.

were put forward for ideal community representation within the study area; these include communities that represent both urban and rural populations, fall on both sides of the Continental Divide, and fall on both sides of the United States- Canada border. Kalispell, with a population of 19,927 is the largest community in the COCE and serves as the closest representative of an urban community. Choteau is a rural community (approximate population 1,840 in 2009) and resides on the east side of the Continental Divide, opposite of Kalispell. Fernie, the only Canadian community in the study, having a population of 4,217 in 2006 is of an intermediate size and also falls on the west side of the Continental Divide.

Table 1-1: Case Study Community Overview.

	Choteau¹	Kalispell²	Fernie³
Population	1,840	19,927	4,217
Median Household Income	36,198	39,953	48,082
Poverty (percent)	13.3	16.9	14 ⁴
Post Secondary Education (percent)	23.5	25.2	12 ⁵

¹ Data from 2005-2009 U.S. Census Bureau American FactFinder estimates. ² Data from 2010 U.S. Census Bureau QuickFacts. ³ Data from Statistics Canada 2006 Community Profile. ⁴ Percentage from category titled “% in low income before tax- All persons”. ⁵ Percentage from category titled “University certificate, diploma, or degree” from the “Total population 15 years and over”.

Within each case study community a small set of natural resource dependant industries, non-profit groups, and natural resource management agencies served as the focus for the lens of climate change impacts in the COCE. This revealed that disturbance regimes are a critical means through which stakeholders in the region understood the impacts of climate change. The role of institutions plays a key role in understanding climate change in the region. For the purpose of this research, institutions embody two very different forms- the first is natural resource management and governance agencies,

policies, mandates, and capabilities; the second is the physical infrastructure specific to natural resource extractive industries. When considering the latter this includes such things as timber mills for the timber industry and reservoirs for irrigation based agriculture.

The Intermountain West, particularly the northern region, has long been recognized as a politically conservative region. The 2008 general election was characterized as a “wave” or “change” election that overwhelmingly supports and votes into office one party over another. In the case of the 2008 election this was the domination of the election by the Democratic Party. In the 2008 general election both Flathead County (in which Kalispell is located) and Teton County (in which Choteau resides) maintained their conservative mantle. Flathead County¹ voted, by a nearly 2-to-1 margin, for conservative candidates consisting of the presidential tickets of John McCain (Republican Party), Ron Paul (Constitution Party), and Bob Barr (Libertarian Party) receiving a combined total of approximately 62% of the vote. While Barack Obama (Democratic Party) and Ralph Nader (Independent) together received approximately 37% of the vote. In Teton County the vote was not nearly so disparate with approximately 58% of the vote going to the combined conservative vote and 40% of the vote for the two liberal candidates.

During the course of the research there, at times, existed a difficulty in undertaking climate change related research in the Crown of the Continent. These difficulties took the form of stakeholders and potential participants wishing to discuss the merits of climate change models, the politics of climate change, and a resistance to the

¹ Voting data was obtained from the Montana Secretary of State website- <http://sos.mt.gov/>. Vote percentages were calculated by adding together the grand total votes for “conservative” and “liberal” candidates cast then dividing by total votes cast in the county.

reality of man-made climate change. The situation required at times that the topic of climate change be dispensed with and the issue of “extended drought” instead be discussed. This difficulty was most prominent when engaging stakeholders from the agriculture and motorized recreation sectors. Natural resource managers who regularly engaged the public were the first to introduce me to the term “extended drought” and suggest that I use the concept as a means of addressing climate change without having to deal with the associated political baggage of the concept.

The effects of climate change have already begun to impact the COCE. Analysis of long-term climate data has revealed that extremely cold ($\leq -17.8^{\circ}\text{C}$) days, important for ecological processes such as insect lifecycles and stream temperature for aquatic biota, have declined (Pederson, Graumlich, Fagre, Kipfer, & Muhlfeld, 2010). Additionally, recent research in the COCE has determined that the ecosystem’s hydrologic regime has also already begun to be altered. Rood et al. (2005) describe declines in streamflow in the ecosystem over the last half century, while Mote et al. (2005) have documented a decline in snowpack throughout the mountainous regions of the western United States.

In their expansive work on climate change, the IPCC (2007) presented ecological, social, and economic repercussions resulting from the impacts of climate change. As the impacts of climate change become clearer, the need for adaptation, as a policy response, becomes more apparent (Pielke, 1998). Adaptation to climate change, as with any deliberate responses to environmental risk or vulnerability, cannot take place without conscious and collaborative effort. One means for anticipating what is required for

successful adaptation is by understanding and addressing the preconditions necessary to successfully adapt: more commonly this is recognized as adaptive capacity.

Social-ecological Resilience and Adaptive Capacity

Communities, to differing degrees, are dependent upon the ecosystem's in which they reside and from which they derive ecological goods and services. Recognition of the interdependent relationship of communities and ecosystems has led to the development of the concept of coupled social-ecological systems (B. Walker & Salt, 2006). Social-ecological systems are integrated through a community's direct and indirect reliance upon natural resources, degradation and allocation of those resources, and institutional policy responses to natural resource related concerns. Examples of social-ecological systems include Florida's Everglades (B. Walker & Salt, 2006) and the Great Lakes (Regier, Jones, Addis, & Donahue, 1999).

The study of social-ecological systems through a complex systems approach that recognizes the role of thresholds, tipping points, and non-linearity has been coined as "resilience theory" with the term being first applied to the work of Walker and Salt (2006). Origins of the theory lie in the work of C.S. "Buzz" Holling and his research on spruce-budworm outbreaks in the forests of Canada (1978) and his ecosystem modeling (1986). These efforts resulted in Holling's four-part heuristic known as the "adaptive cycle model" that recognized disturbance as part of an ecosystem rather than an exogenous force. What has come to be recognized as "resilience theory" stems from the original theoretical and empirical work by Holling (1986, 1978).

In his 1986 work, Holling defined ecological resilience as, "...the ability of a system to maintain its structure and patterns of behavior in the face of disturbance" (p.

296). The resilience of social systems is related to the ecological system in which they exist (W. Neil Adger, 2000) and therefore provides an important feedback between the two. Resilience is a concept that has been addressed extensively in the literature and has provided a framework in which to understand adaptive capacity. The integration of resilience theory into research on environmental vulnerability and adaptation has been succinctly undertaken by Nelson et al. (2007). In their work, Nelson and associates address social-ecological resilience and adaptation to drought in Kenya and Brazil and fishery and coral reef decline in the West Indies.

For the purpose of this research adaptive capacity is defined as, “the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements,” from (Nelson, et al., 2007, p. 397). In their third comprehensive study, the IPCC presented six determinants of adaptive capacity that served as a guide to research on the subject as will be demonstrated in the literature review in Chapter Two. The six determinants from the report include economic wealth, technology, information and skills, infrastructure, institutions, and equity (Smit et al., 2001).

It has been posited that the most effective way to recognize adaptive capacity and the role it has played in addressing the risks associated with environmental vulnerabilities is through concrete adaptation (Lemos, Boyd, Tompkins, Osbahr, & Liverman, 2007). This creates the conundrum of having to rely on a post-hoc review of outcomes to effectively assess adaptive capacity as concrete adaptations serve to identify the efficacy of adaptive capacity in the face of environmental risk. Scholarly literature has demonstrated that resilience theory can serve as a means of empirically studying adaptive

capacity without the need for a post-hoc review (Nelson, et al., 2007). It is for this reason that the two concepts are utilized for this study.

Research Overview

The driving research question behind this place-based research is how communities and sectors are responding to the impacts of climate change on the hydrologic regime of the Crown of the Continent Ecosystem. The approach taken to gather the relevant data to inform the study was a qualitative assessment of social-ecological resilience and adaptive capacity. Theoretical data were derived from the literature on ecological resilience and adaptive capacity. Empirical evidence for the research was gathered through two primary devices- a targeted online survey and a semi-structured interview process. For the purpose of this research the terms “participant” or “interviewee” is specific to those individuals who took part in the semi-structured interview process. The term “stakeholders” is utilized to broadly identify individuals associated with a specific sector (e.g. government, industry, non-profit, etc.). When discussing the targeted survey, individuals will still be referred to as stakeholders. The targeted survey was sent to stakeholders in each sector that was likely to be heavily impacted by or key to responding to the impacts of climate change. The sectors targeted in the survey include broadly natural resource extractive industries (timber, mining, agriculture), recreation (motorized and non-motorized), non-profits, and government (local, state, provincial, and federal). The purpose of the survey was to gather insight on what impacts of climate change are of most concern within a particular community and the specific sectors of each community. The survey was followed by phase two of the field research encompassed in the semi-structured interview process. The research presented in the following chapters seeks to

understand the impacts of climate change within the geographic context of the Crown of the Continent Ecosystem. This endeavor relies on the data gathered from the three case study communities as well as the social and economic context of the communities themselves in order to appreciate challenges associated with adapting to the impacts of climate change.

Chapter Two presents the results of the literature review that, in a step-wise fashion, develops the theoretical foundations for this research through the concepts of resilience theory and adaptive capacity. The review also provides the underpinnings for the empirical data gained from site specific field research. Chapter Three presents the methodology that was utilized for this research. Results of the fieldwork are presented in Chapter Four. A synthesis and discussion of the results is undertaken in Chapter Five that includes a discussion of ecological and social-ecological risk and vulnerabilities followed by the three case studies based on the communities of Kalispell, Choteau, and Fernie. The final chapter presents the conclusions and a set of recommendations from the research. These encompass recommendations for each case study community and recommendations that span the ecosystem.

CHAPTER II

RESILIENCE IN THE FACE OF CLIMATE CHANGE: ADDRESSING SOCIAL-ECOLOGICAL LINKAGES

Anthropogenic influences on the environment, from local to global impacts, have rarely been addressed in a comprehensive fashion. The result is that entire ecosystems have been influenced, collapsed, and simplified under anthropogenic stress. Given this outcome researchers have developed theories and frameworks to explore and address the complex linkages between ecosystems and human systems in an attempt to reduce environmental damage and increase sustainability.

An elegant ecological theory that views ecosystems as non-linear, hierarchical structures where change, rather than stability, is the norm is found in the adaptive cycle model originally developed by Holling (1986). The theory has been expanded to account for social-ecological and multi-scale systems termed ‘panarchies’ by Gunderson and Holling in 2002. Key to this robust theory is the concept of resilience. Resilience “is the ability of a system to maintain its structure and patterns of behavior in the face of disturbance” (Holling 1986, p.296), while stability “is the propensity of a system to attain or retain an equilibrium condition of steady state or stable oscillation” (Holling 1986 p. 296). The differences between the two concepts will become clear as the discussion on resilience progresses.

The concept of resilience is central to the adaptive cycle model and its four stage heuristic encapsulated within the model. Since its inception the theory has sought to

integrate humans into ecological systems noting the influences natural resource policy, in addition to other human impacts, bring to bear on ecosystems. Observing ecological, social, economic, and institutional systems through the adaptive cycle and its resilience focus has propelled researchers to apply the theory to coupled social-ecological systems, as will be demonstrated throughout this chapter. Ultimately underpinned by the concept of sustainability, the adaptive cycle model has been utilized to explore the adaptive capacity of various systems, as this literature review will demonstrate.

Resilience concepts have been incorporated in research related to environmental disturbance beginning with Holling's early work. Understanding related to the concept of adaptive capacity has gained tremendously from the adaptive cycle model and the resilience concepts. Integration of the two concepts, resilience and adaptive capacity, provide a robust theoretical foundation upon which to examine both the impacts of climate change on social-ecological systems and adaptations to environmental change. The following literature review will establish the theoretical foundation for this dissertation in a step-wise fashion.

The following chapter begins first with exploring the background of social-ecological systems. This is followed by an in-depth review of the adaptive cycle model beginning with its ecological roots, then addressing its expansion to social-ecological systems. Considerable emphasis is placed on the role of resilience within the theory and the concept's application to research. Next is a review of the concept of adaptive capacity, its relationship to environmental vulnerability, and a brief review of indicators that have been developed. Finally, the literature review draws to a close with a review of

the integrated application of resilience and adaptive capacity and its application to climate change.

Social-ecological Systems

There exists a drive among researchers and policy-makers to understand ecological processes through a lens of human influences and feedbacks. These efforts are tied to the development of an ecosystem-based management paradigm that integrates humans into an understanding of ecosystem processes (Christensen et al., 1996; Grumbine, 1994; McLeod, Lubchenco, Palumbi, & Rosenberg, 2005). As the move to understand the interrelations between social and ecological systems has continued and expanded, the term that has evolved to define such complexities is social-ecological systems (SES).

Relevant question about social-ecological systems paraphrases Westley et al., (2002) and asks why can we not simply call social-ecological systems either an ecosystem or a social system with influences of one upon the other? A short but nuanced answer stems from the dominance of humans on the environment and the manner in which humans, governance systems, and technology respond and interact with the environment (Westley, 2002). Additionally, concepts that apply to one do not necessarily apply to the other (Westley, et al., 2002). Being that we cannot simply label these systems as either ecosystems or social systems, it is pertinent to begin by defining what a social-ecological system is then move on to discuss system components, structures and stresses.

Working definitions of social-ecological systems reveal the integration of the two types of systems into a single conceptual structure. The wide-ranging Millennium Ecosystem Assessment (MEA) defines a social-ecological system as follows: “An

ecosystem, the management of this ecosystem by actors and organizations, and the rules, social norms, and conventions underlying this management,” (Chopra, Leemans, Kumar, & Simons, 2005, p. 603) One working definition utilized by researchers of SESs is “...an ecological system intricately linked with and affected by one or more social systems...” of which said system is composed of independent and interrelated subsystems (Anderies, Janssen, & Ostrom, 2004, p. 3).

Key to the two above definitions is the centrality of anthropogenic influences on the environment. While it can be argued that there no longer exists an ecosystem within the biosphere that is without some sort of anthropogenic influence, the social-ecological systems that are of interest to this work are those ecosystems that are readily observed as being influenced by human impacts. With this in mind Anderies and company (2007) have identified critical objectives associated with SESs. The objective of greatest importance is maintaining the flows of goods and services from SESs without degrading the system beyond a critical threshold. The MEA notes that policy responses must be underpinned by sustainability in order to maintain an SES, which includes the ecosystem goods and services upon which human societies depend.

Social-ecological systems are non-linear, hierarchical structures composed of nested subsystems (Anderies, et al., 2004; Janssen, Anderies, & Ostrom, 2007; Ostrom, 2007) that operate semi-independently of one another with influences from lower and upper level subsystems (Holling, Gunderson, & Peterson, 2002). Ostrom (2007) presents that these systems are partially decomposable, meaning the whole is greater than the sum of its parts and not entirely influenced by upper and lower scale influences, hence the semi-independent structure that has been applied to them by researchers. These multi-

level, multi-scale (sub)systems are open to influence and disturbance, both biophysical and anthropogenic, from a number of scales (Janssen, et al., 2007). The ability of SESs to cope with disturbance has led researchers to note that the systems themselves contain adaptive properties (Anderies, et al., 2004; Janssen, et al., 2007).

Institutional responses to disturbance within an SES are bounded by the governance and policy structures in place. Policy and decision-makers must make decisions under high levels of uncertainty about both the system and the impacts of natural resource policy on that system (B. Walker et al., 2002). The biogeophysical system state and physical infrastructure contained within social-ecological systems serve as parameters to policy responses. In certain instances these parameters may influence the scope and scale of disturbance when capacity of the socio-ecological system to absorb stress is exceeded. In order to cope with disturbance and to develop appropriate responses, institutional infrastructure must also be developed and maintained within the context of the SES in which they are located (Janssen, et al., 2007).

Social, political, institutional, economic, and policy responses are all underpinned by the governance structures of the system. Two specific components of governance structures are of interest herein, not because of their well structured and defined properties, but because of their continued application within governance structures with disregard for their lack of success- property rights and market pricing. Walker and company (2002) present in their research on the resilience of social-ecological systems that property rights and market pricing, when applied to natural resources, fall short of providing sustainable policy responses to disturbance in the face of uncertainty. The

challenges that surround the two policy mechanisms demonstrate a portion of the fundamental mismatch between governance structures and ecological systems.

Lack of institutional fit to natural resource problem-solving continues to plague the governance of social-ecological systems (Ekstrom & Young, 2009). The MEA presents a lack of local context and understanding as issues that hinder institutional responses to natural resource problems. In order to successfully address governance issues associated with social-ecological systems, institutions must be capable of structuring adequate responses to internal and external disturbances (Anderies, et al., 2004), critical thresholds (B. Walker, et al., 2002), and feedbacks within the system (Janssen, et al., 2007).

The preceding section provided a brief overview of social-ecological systems including differences between human and ecological systems, the hierarchical, nested structure of SESs, and institutional challenges related to responding to environmental disturbances. The challenge of constructing functional and relevant natural resource governance institutions continues to hinder movement toward sustainability. The Millennium Ecosystem Assessment notes that it will require a new worldview and the inclusion of diverse sources of knowledge to overcome this challenge.

Moving Beyond Linear Views of Nature

Holling's adaptive cycle model with its focus on resilience is a foundational concept for the theoretical framework of this research. In the following section ecological and social-ecological resilience are both reviewed. This is followed by an application of the concepts to social-ecological systems. Next, a review of the adaptive cycle model is

undertaken. The section concludes with a discussion on the role of adaptive management.

A Clementian² view of ecological succession³ proposes that communities move along a linear path towards an end point identified by a “climax state” whereby the dominant vegetation will continue to maintain dominance within the ecological community until influenced by an external force (Clements, 1936), has been long held in ecological thought and theory. During the same era of ecological thought and theory, a counter theory to Clements view of succession was offered by Gleason (1926). In this view of plant ecology the distribution of the individual plant serves as the basis for understanding the larger community and transitions between recognized plant associations. Individual plant distribution, under Gleason’s theory, is largely determined by migration and environmental conditions in the form of climate and soil conditions. Holling (1973) also challenged the Clementian view of ecology by focusing on the resilience and stability of an ecosystem. Undermining the climax state view of nature challenged management paradigms like maximum sustainable yield. Holling’s hypotheses, like Gleason’s, also challenged the theory that nature exists around a single equilibrium.

Equilibrium-centered theories of nature are supported through linear causation and an assumption of spatial homogeneity (Holling, 1986). Holling contends, alternatively, that many, if not most, ecosystems possess multiple stable states⁴ that are

² So termed after the eminent and influential early ecologist Frederic E. Clements.

³ Succession is defined as “directional change in ecosystem properties resulting in biologically driven changes in resource supply,” in F. Stuart Chapin, III, Gary P. Kofinas, and Carl Folke. (2009) Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer Science + Business Media, LLC. p. 352.

⁴ Multiple or alternative stable states are differing ecological assemblages and biophysical qualities that become dominant in an ecosystem when an ecosystem’s ability to absorb disturbance is overwhelmed.

influenced by the resilience and stability of the system itself (Holling, 1973, 1986). The two properties (resilience and stability) implicitly recognize the role of disturbance as an internal influence of the ecosystem.

Explicit to the concepts of resilience and stability is the role of human impacts on ecosystems by way of disturbance. In his 1973 work, Holling noted the impacts of human demands for ecosystem goods and services as well as pollutions sinks and endangered species as indicators that equilibrium-based theories of ecology are insufficient to account for ecosystem properties over time. Anthropogenic activities influence both the resilience and stability of an ecosystem and can move an ecosystem from one stable state to another when the capacity of the ecosystem to absorb disturbance is overwhelmed (Holling, 1986).

There exist qualitative differences in the impacts of anthropogenic influences on the resilience of an ecosystem. Disturbance normally absorbed by an ecosystem can act to overwhelm the system's resilience if anthropogenic influences have already reduced the ecosystem's resilience capacity; the result being a transition into a new stable state (Gunderson, 2000). Alternatively, anthropogenic influences coupled with the system's typical disturbance regime can again move the system between one or more stable states to include a previously unforeseen stable state. This often is accompanied by an ecological simplification of the system in addition to shifts in ecosystem structure and processes (Folke et al., 2004).

In his 1973 work, Holling presented then contemporary examples in the form of disturbances that had overwhelmed the Great Lakes. Eutrophication of individual lakes had fluctuated with human development and policy decisions; fish populations within the

lakes plummeted following changes in the nutrient levels and human exploitation of those populations. He goes on to present a terrestrial example in the form of rangelands of the western U.S. Overgrazing and the suppression of fire in the semi-arid rangelands allowed hardwood species to invade and become established to the detriment of native grasses and the larger ecological community.

As the role of ecological resilience and the heuristic of the adaptive cycle have been utilized as an ecological theory, additional cases have been presented of ecosystems transitioning from one stable state to another, often as the result of human influences. In addition to the Great Lakes- the Columbia River Basin, the Baltic Sea, the Everglades, and the Chesapeake Bay were case studies in a 1995 work demonstrating the effects of the loss of resilience at the ecosystem level (Gunderson, Holling, & Light, 1995).

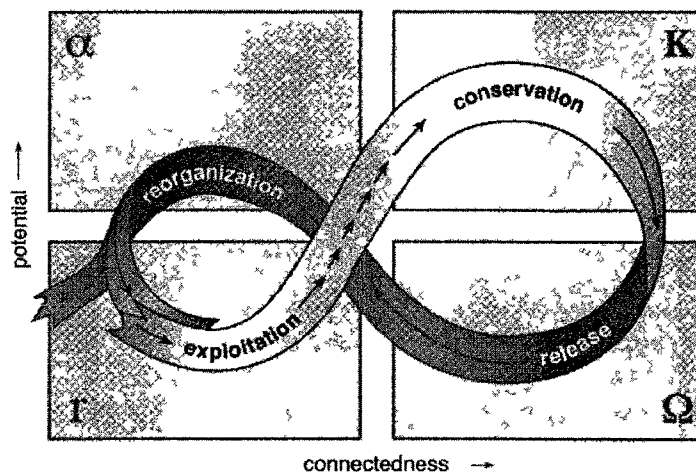


Figure 2-1: The Adaptive Cycle Model from Panarchy, edited by Lance H. Gunderson and C.S. Holling. Copyright (c) 2002 Island Press. Reproduced by permission of Island Press, Washington, D.C.

What is it that makes multiple stable states important? Ecologically they demonstrate the non-linear dynamics of ecosystems and their component subsystems. They also provide an empirical foundation upon which we can see the impacts of reduced

resilience. From the human standpoint multiple stable states serve as a means to validate or reject natural resource policy.

The concepts of resilience and stability and their application to ecosystems was formalized in Holling's 1986 work and the presentation of the adaptive cycle heuristic model (Figure 2-1). From a natural resource policy perspective, lack of knowledge of an ecosystem leads inexorably to surprise when disturbance overwhelms the resilience of a system and produces ecological outcomes unknown, foreseen, or unpredicted (Holling, 1986). Ecosystem resilience and societal surprise will both be further addressed in the following section.

The Adaptive Cycle Model

Ecosystem function can be understood through the four-part heuristic model of the adaptive cycle. The model is underpinned by a complex systems approach that recognizes non-linear interactions, feedback loops, thresholds, and tipping points associated with ecosystems. The model presents ecosystem function as a tradeoff between resilience and accumulated ecological capital⁵. Figure 2-1 presents the four functions of the ecosystem as exploitation (r), conservation (k), release⁶ (Ω), and renewal (α).

The four functions are based on two ecological strategies: r-strategies that reflect exploitation of a resource and k-strategies that reflect conservation of a resource (Holling, 1986; Holling & Gunderson, 2002). Assuming that the cycle begins in the exploitation phase (r) this is the point of time in which resources are readily available, uncertainty is

⁵ Ecological capital are resources specific to the ecosystem in questions and can be represented by examples such as plant succession, soil composition, nutrient accumulation, and so on.

⁶ Labeled as 'creative destruction' in the original version of the model from Holling (1986) after the moniker developed by Schumpeter's 1950 work on economic theory.

high, and resilience is high. As exploiters of the resource begin to dominate and accumulate the resource capital, connections between different parts of the system become established and hardened. This begins the transition from exploitation (r) to conservation (k). This process builds rigidity into the ecosystem lowering the resilience of the system as rigidity builds and ecological capital continues to be accumulated.

Ecosystem resilience is lowered as rigidity and connectedness increase. The slow accumulation and binding of resources increases the vulnerability of the ecosystem. Eventually resources are released following a disturbance that can no longer be absorbed by the system. Transitions such as these directly relate to the resilience of the system and its capacity to absorb the impacts of disturbance. This may be an event that could have previously been absorbed by the ecosystem when its resilience was still high or it could be an event that has no analog in the ecosystem's disturbance regime. The rapid release (Ω) of resources that follows the overwhelming of a system's resilience is followed by a period of renewal (α) again leading to a period of high uncertainty, but increased resilience.

Systemic outcomes resulting in the shift from release (Ω) to renewal (α) are difficult if not impossible to discern at this point. Uncertainty during this period is high and randomness can produce dramatic outcomes. Self-organization coupled with the availability of resources leads to the renewal (α) of the ecosystem but not necessarily in a previously recognized configuration.

The temporal scale at which an ecosystem moves through the four stages of the adaptive cycle vary between the different functions and between ecosystems. In his 1986 work Holling identified that cross-scale interactions of variables within an ecosystem

operate at three distinct scales related to rates of growth, generation time, and life spans of organisms. Holling hypothesized that there are a limited number of key variables that influence change in an ecosystem. The interaction of fast and slow variables against the background of reduced resilience in an ecosystem can produce the necessary circumstances for disturbance in the ecosystem. The key to this is understanding that while the three rates operate at different scales in time which overlap within an ecosystem, this takes place against a backdrop of resilience and disturbance that can move the ecosystem between the four different functions of the adaptive cycle. In their research on lake and agricultural resilience Carpenter and associates (2001) demonstrate how the interaction of slow and fast variables take place and proposed slow and fast variables for both systems. For a lake SES they proposed sediment phosphorus as the slow variable and water phosphorus as the fast. In the case of a rangeland SES dominated by wool production grazing they present grass root versus shoot biomass as the inverse variables in the system.

The four ecosystem functions of the adaptive cycle can be conceptualized as two separate but interactive loops (Holling & Gunderson, 2002; B. Walker & Salt, 2006). The first or 'fore loop' encompassing the r and K stages of the model is slow and dominated by stability and the accumulation of resources. The second or 'back loop' is quick moving and dominated by uncertainty encompassing the release of resources and reorganization of the ecosystem.

Up to this point the discussion of fast and slow variables and the earlier discussion of multiple stable states has been largely addressed in a scaleless fashion under the

generic term of ecosystem. A review of the adaptive cycle model would be incomplete without addressing the influences of scale.

Ecosystems and their subcomponents do not move through the adaptive cycle in a vacuum or at disassociated scales. Urban and company (1987) illustrated the role of scale in ecology through the use of hierarchy theory. Wanting to address the issue of scale, but without the conceptual baggage associated with a hierarchy (such as rigidity and lack of adaptability) Holling and Gunderson (2002) coined the term 'panarchy'. Encompassed within the term was the explicit relationship between scales, but with a hint of uncertainty and randomness that is ever-present in natural systems.

Panarchies are composed of interacting adaptive cycles that operate at their own spatial and temporal scales while possessing linkages with upper and lower level systems (Holling, et al., 2002) as demonstrated in Figure 2-2. The function of an ecosystem can be influenced by its subcomponents and in turn, can influence higher levels of organization if the fast and slow variables intersect with low resilience of a higher level of organization. The terms 'revolt' and 'remember' have been utilized by Holling, Gunderson, and Peterson (2002) to denote these inter-scale influences. 'Revolt' is associated with the 'back loop' of the adaptive cycle and represents the manner in which rapid change in one level of the system can influence another level. 'Remember' is associated with the 'fore loop' of the adaptive cycle and represents the manner in which the slow accumulation of resources can interact with the variables of different scales within the system.

Earlier in this chapter we explored why ecological systems and human systems cannot simply be viewed, studied, or understood by transferring the same concepts,

frameworks, tools, and paradigms from one system to the other. The adaptive cycle model provides a framework, through the multi-scaling of panarchies and resilience, that allows us to view linked social-ecological systems. Key to facilitating this within the theory is the role of sustainability.

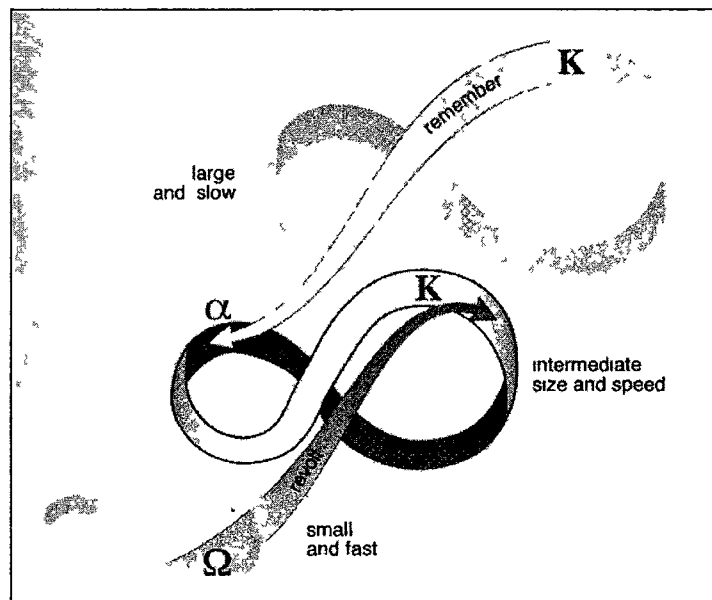


Figure 2-2: Multi-scale Panarchy Diagram from Panarchy, edited by Lance H. Gunderson and C.S. Holling. Copyright (c) 2002 Island Press. Reproduced by permission of Island Press, Washington, D.C.

Sustainability underpins the adaptive cycle model as the model continues to be refined and applied. Nested adaptive cycles contained within social-ecological panarchies produce feedbacks between the different levels of the system influenced by the resilience internal and external to multiple levels of the ecosystem (Holling, et al., 2002). Thus, the resilience of an ecosystem has been proposed as key to social-ecological sustainability (B. Walker & Salt, 2006).

While sustainability is a core underpinning of the adaptive cycle model and resilience, resilience is not always a desirable aspect. Maladaptation of a system can lead

to a loss of resilience (Holling & Gunderson, 2002) which, can in turn, lead to the collapse of the ecosystem itself (Holling, et al., 2002). If in the event of maladaptation the ecosystem is simplified or flipped into a new stable state that is undesirable, resilience in this new stable state may frustrate managers and facilitate reduced biodiversity to the detriment of the larger SES.

Weakening of an ecosystem's resilience can result in the application of engineered resilience to an ecosystem. Engineered resilience focuses on the speed at which a system returns to its equilibrium following disturbance (Holling & Gunderson, 2002). Walker and Salt (2006) criticize this view of resilience as one that seeks optimization of the system as though it were a human system rather than one that contains an ecological component. Of course, this is in broad contrast to ecological resilience that has been developed and applied by the adaptive cycle model.

The following section will review the application of the adaptive cycle model with an emphasis on resilience. Ecological systems will be covered first followed by application of the theory to social-ecological systems.

Ecological Resilience

The concept of ecological resilience has gained increasing traction among researchers and natural resource managers since first introduced in 1973 although it was not without its detractors (see Connell & Sousa, 1983; Sousa & Connell, 1985). The concept of resilience and the heuristic of the adaptive cycle model have been applied to a number of different ecosystems to explain their change in composition, structure, and function. The following section reviews the application of ecological resilience to a variety of ecosystems and scales.

Biodiversity plays a critical role in the function, composition, and integrity of an ecosystem (Folke, et al., 2004; Peterson, Allen, & Holling, 1998). Functional diversity⁷ has been posited as potentially being of greater significance to ecosystem composition and function than overall species numbers (Tilman et al., 1997). Furthermore, it has been hypothesized that functional diversity impacts ecosystem resilience (B. Walker & Salt, 2006).

Biodiversity thresholds influence the stability of ecosystems (Muradian, 2001) with implications for higher order systems (e.g. landscapes). Gunderson (2000) cites Peterson and associates (1998) in stating that biodiversity impacts cross-scale resilience within a system, adding cross-scale relevance to the role of biodiversity in an ecosystem. Biodiversity in the form of plant diversity has been demonstrated to allow for substitutionability between dominant and minor species that provides a buffer against disturbance (B. Walker, Kinzig, & Langridge, 1999) that may otherwise breach critical thresholds within an ecosystem.

The complexity of ecosystems has led to the realization that their structure, composition, and functions result in high levels of ecological uncertainty as a result of this complexity. Ecological uncertainty and the surprise for human society that stems from unanticipated change can be related to the existence of multiple stable states (Holling, 1986, 1996). An additional form of uncertainty is related to “brittleness” in the system (Gunderson, 1999; Ulanowicz, 2000) in the face of disturbance, which may be viewed as a function of the conservation phase of the adaptive cycle model. Brittleness may result in exceeding an ecosystem threshold, thereby producing additional ecological

⁷ Functional diversity is recognized as groups of species that represent a specific role in an ecosystem such as predators, decomposers, those that fix nitrogen and so on.

uncertainties (Muradian, 2001) that, as noted earlier, produces surprise for social and institutional systems.

The adaptive cycle heuristic, including the concepts related to resilience and the role of biodiversity, thresholds, disturbance, and uncertainty have been utilized by a variety of researchers. Some of the earliest examples are derived from Holling's work on the spruce budworm and its impacts on Canadian forests (Holling, 1978). Shifts in the Everglades between a saw-grass to a cattail dominated system as a result of large-scale hydrologic manipulation has been pointed to as an ecosystem exceeding a tipping point (Ogden, Mazzotti, Jewell, & Huchalla, 1999; B. Walker & Salt, 2006). A new equilibrium with regard to the water table in Australia's Goulburn-Broken Catchment has been identified by Walker and Salt (2006). Eutrophication and collapse of freshwater fisheries has led to an ecological reorganization of the Great Lakes as presented by Regier et al., (1999). Suding and company (2004) briefly reviewed disturbances that move prairie, rangeland, and coral ecosystems between stable states. Finally, a comprehensive review of ecosystems and alternative states has been compiled by Folke and company (2004).

The examples above of ecosystems that have been studied utilizing resilience theory as well as measurements of ecological resilience have a common thread- the role of anthropogenic disturbance. Resilience, thresholds, tipping points, and transition between multiple stable states all recognize the role of human impacts and demands on ecosystems. This directly addresses the fact that humans are tied to ecosystems and there exists feedbacks between the two systems. Therefore it is imperative to this research to

view social-ecological systems through the resilience paradigm. The following section pursues exactly that.

Social-Ecological Resilience

Including humans as part of an ecosystem has been considered a break from traditional views of ecology (Folke, 2006). Anthropogenic pressures continue to increase on ecosystems as do human demands for ecosystem goods and services. The complex systems approach encompassed by the adaptive cycle model and resilience theory can be expanded from understanding ecosystems to social-ecological systems. Researchers have identified nonlinearity, thresholds, and feedback loops in social-ecological systems (Liu et al., 2007) while noting resilience must be understood within the context of the ecosystem being studied (Carpenter, Walker, Anderies, & Abel, 2001).

In 1996 the Ecological Society of America produced a report on the scientific basis for ecosystem management. In that report the authors addressed the issue of including humans as part of the ecosystem and then tied ecosystem management to sustainability of natural resource management. Efforts such as this lay the foundation for applying resilience theory to social-ecological systems.

Just as social and ecological components of a social-ecological system are linked through feedbacks, the resilience of the two linked systems are also interconnected. Adger (2000, p. 361) defines social resilience “as the ability of communities to withstand external shock to their social infrastructure,” then goes on to note the importance of social resilience to natural resource dependent communities. In their work on building resilience in SESs, Olsson and company (2004) note that it is multi-scale structures and cross-scale arrangements that facilitate social resilience in the face of ecological

feedbacks. Additionally, functional diversity is extended to SESs through “functional actor groups” that provide for diverse interactions and responses (B. Walker et al., 2006). The following section explores resilience theory as applied to social-ecological systems. This is followed by a review of adaptive management, then sustainability of social-ecological systems. Finally, applications of resilience theory and adaptive management will be reviewed.

Resilience Theory

The term resilience theory has been credited to Walker and Salt and their 2006 work *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Their work presents applications of resilience theory to social-ecological systems with accompanying case studies to emphasize theoretical points. Research has shown that social-ecological systems are non-linear systems that contain multiple stable states (B. Walker, et al., 2006), are bounded by thresholds, and interconnected through feedback loops (Liu, et al., 2007; Nelson, et al., 2007).

Uncertainty is high in social-ecological systems as it is in ecological systems. Surprise in SESs are the function of uncertainty stemming from a lack of knowledge of ecological systems and has been identified as an emergent property (Nelson, et al., 2007). The interaction of slow and fast variables in the coupled system at multiple scales influence disturbance in social-ecological systems (Carpenter, et al., 2001), but given the high levels of uncertainty and multi-scale nature of SESs there is nonetheless self organization that takes place (Carpenter, et al., 2001) that can influence the system’s resilience. Examples of self organization from the above cited research include subsidies, natural resource policy, and property rights. Uncertainty in SESs can impact overall

system resilience with implications for environmental risk and further impacts on the social component of the system (Cutter, Mitchell, & Scott, 2000; Morrow, 1999).

Applications of Resilience Theory

Application of the adaptive cycle heuristic and resilience theory extend far beyond terrestrial ecosystems and grapples with both the social and ecological aspects of an ecosystem. Empirical observation has refined resilience theory as breaches in thresholds, shifts to new stable states, and feedbacks between environmental policy and institutional and societal surprise are identified and studied. The following section briefly reviews a suite of studies that applies resilience theory to a variety of ecosystems.

Beginning with a terrestrial example, rangelands, due to their widespread degradation, have become a germane ecosystem of study throughout the world. As noted earlier in this chapter, the Goulburn-Broken Catchment of Australia has been documented as reaching, if not surpassing, a critical ecosystem threshold with regard to salinity and the water table (B. Walker & Salt, 2006). Carpenter and associates (2001) also undertook the study of rangeland resilience in Australia and discerned a tipping point where the ecosystem transitioned from grassland dominated to a woody shrub dominated system as a result of livestock grazing policies and practices.

Socially important wetlands in Sweden and the transition of the Everglades from a sawgrass dominated to a cattail dominated ecosystem presented by Walker and Salt (2006) both serve as examples of the application of resilience theory to sensitive wetland ecosystems. An aquatic application of resilience theory, in the form of a freshwater lake ecosystem, is presented Carpenter et al. (2001), while a marine application is presented

by Hughes (1994) in the form of coral reef resilience in the face of overfishing and pollution.

One of the crowning strengths of resilience theory is the explicit placement of humans in the ecosystem. This is conceptualized as the social aspect of the social-ecological system. Resilience theory scholars squarely place human impacts within the context of the ecosystem whether it be livestock in the rangelands of Australia, the historical and cultural importance of wetlands in Sweden, or pollution and overfishing along Caribbean reefs.

Social science researchers have chosen to focus on social resilience when applying resilience theory as demonstrated by Donoghue and Sturtevant (2007) in their review of three ecosystem-wide natural resource regimes. The Forest Management Assessment Team, the Sierra Nevada Ecosystem Project, and the Interior Columbia Basin Ecosystem Management Project served as their case studies of social resilience influenced by natural resource policy and management. Natural resource policy was the lens through which Beier and associates (2009) studied the resilience of the Tongass National Forest in Alaska.

Regardless of ecosystem type, researchers, through the application of resilience theory, have demonstrated the linkage between the social and ecological components of an ecosystem. Ecosystem degradation as a result of human impacts threatens to overwhelm the ecological resilience of an ecosystem with a corresponding degradation of the social resilience of communities within the ecosystem. In his seminal text on the interactions of mankind with its environment, Levin (1999) demonstrates that ecosystems and indeed, social-ecological systems, develop emergent properties resulting

from internal self-organization, but these processes operate at disparate scales that prevent ecosystem and their components from adapting quickly enough to prevent human impacts from overwhelming ecological resilience. Managing human actions and activities within ecosystems is therefore critical to maintaining ecological resilience and social resilience for those communities and sectors directly dependant up an ecosystems goods and services. Adaptive management has been identified by researchers of resilience theory as a means of developing and implementing natural resource policy and management in a manner that supports ecological resilience while attempting to reduce and/or mitigate human impacts (Holling, et al., 2002).

Adaptive Management

Management of natural resources and ecosystems in a manner that allows for flexibility and adaptation to change has been promoted within resilience theory since Holling's original 1973 writing. Within that call for an adaptive management and policy paradigm is an indictment of traditional command-and-control natural resource management.

The failures of top-down natural resource management stem, in part, from views of ecology held within management institutions such as a belief in stable equilibriums, climax communities, and a focus on managing for a single commodity or species. Gunderson (2000) delivers an indictment that command-and-control management of natural resources assumes both a system near equilibrium and a constancy of relationships between components. Command-and-control natural resource paradigms can lead to a constraint of system variables that prevent adaptation within the system (Beier, Lovcraft, & Chapin III, 2009), which can result from spatial homogenization (Holling, 1986) and impair long-term sustainability.

Natural resource management agencies, while often successful early on, sow the seeds of their own failure. Initial success of management by constraining an ecosystem within determined boundaries and limited disturbance that reflect institutional goals lead to a focus on operational efficiency (Holling, 1986) and improvements in the form of optimization⁸ (B. Walker & Salt, 2006). The reduction in system variability through tighter controls can introduce rigidity that undermines long-term resilience and sustainability.

Maladaptation has been identified as an outcome of top-down management (Janssen, et al., 2007). Achievement of natural resource goals that increase engineered resilience while shrinking ecological resilience by reducing natural variability (Holling & Gunderson, 2002) are outcomes of traditional natural resource policy. Ecological resilience may be degraded through the achievement of social goals (B. Walker, et al., 2006) that in turn, possess the potential to produce maladaptive feedbacks.

Maladaptive social, policy, and institutional responses to ecological resilience lay the foundation for ecological surprise that negatively impacts social resilience. Nelson (2007) calls for a management paradigm that embraces change while authors of the report *On The Scientific Basis for Ecosystem Management* (Christensen, et al., 1996) acknowledge that management goals must address adaptability within and across ecosystems. An adaptive management paradigm begins to address the failures of command-and-control natural resource policy and maladaptation.

Uncertainty and the constancy of changes within ecosystems is an ongoing challenge for natural resource managers. Adaptive management views natural resource

⁸ As discussed by Walker and Salt (2006) optimization is related to increased efficiency within a narrow range of specified parameters. They identify optimization with natural resource management concepts such as maximum sustainable yield.

policy as hypotheses (Gunderson, 2000) that recognize regional contexts (Holling, 1986). A focus on resilience provides a framework to incorporate adaptive policy responses through a complex systems perspective (Nelson, et al., 2007); while adaptive management provides a means of managing for resilience (Gunderson, 2000). The inability to sustainably manage natural resources has led to loss of biodiversity, soil erosion, water quality degradation, desertification, and dewatering to name only a few. Direct results from these management failures include loss of direct and indirect revenue, famine, poverty, and disease (Chopra, et al., 2005). While negative impacts are scale and locality relevant, the historic inadequacy of natural resource management and stewardship has led to the advent and push for adaptive management.

Adaptive management recognizes uncertainty and “must allow for flexibility in times of disturbance,” (Nelson et al, 2007 p.399). Once an ecosystem’s resilience has been degraded to a point at which it can no longer absorb disturbance that would otherwise be considered within the range of natural variability it is likely that natural resource policy intended to serve as the management guidance paradigm has failed. Effective adaptive management must be underpinned by the goal of sustainability, which through a resilience paradigm, then applies natural resource hypotheses. This, in turn, is dependent upon a well designed monitoring system with the capacity to track change over time (e.g., system response to various interventions intended to redirect human behavior such that stresses are limited and system functional restoration is fostered). Accomplishing this requires natural resource managers to recognize themselves, their policies, and management actions as part of the ecosystem (B. Walker, et al., 2002).

Adaptive management seeks sustainable natural resource policy measures and outcomes. When considered within resilience theory “sustainability involves maintaining the functionality of a system when it is perturbed or maintaining the elements needed to renew or reorganize,” (Walker et al, 2002 abstract) as well as “the capacity to create, test, and maintain adaptive capacity,” (Holling 2001 p.399). The result has been that resilience theory has been utilized to identify unsustainable social-ecological systems (Beier, et al., 2009).

A major challenge to adaptive management and sustainability is development of institutional capacity to address the issue of sustainability in natural resource management in a flexible and adaptive manner. Interactions between natural resources users and public infrastructure have been identified by Anderies and company (2004) as a weak link in institutional support of sustainability. This builds on the well recognized failure of institutions to govern common pool resources in a sustainable fashion (Dietz, Ostrom, & Stern, 2003). Institutional failure to manage for, or even develop sustainable policies, contribute to the undermining of social-ecological resilience. As such, institutional reform is central to developing successful adaptive natural resource management.

Social-ecological resilience, environmental risk, and natural resource sustainability are linked concepts within resilience theory. There exists the need for a tool in order to embrace the complex adaptive dynamics of social-ecological systems in a manner that allows researchers and practitioners to bridge the concepts of resilience, sustainability, and risk. The concept of adaptive capacity serves as a conceptual bridge

between the three concepts. The following section will review the adaptive capacity literature, its relationship to resilience, and finally its application to climate change.

Adaptive Capacity

Climate change literature is replete with definitions and research related to adaptation and adaptive capacity. Literature on resilience theory and its applications have also utilized the term adaptive capacity. In his 2000 work Gunderson cites his earlier work with Holling, Pritchard, and Peterson (1996) in his definition of adaptive capacity (p.428) as “The property of an ecosystem that describes this change in stability landscapes and resilience...”. Holling (2001 p. 394) defines adaptive capacity as “...the resilience of the system, a measure of its vulnerability to unexpected or unpredictable shocks. This property can be thought of as opposite of the vulnerability of the system.” This definition appears to mirror the definition of resilience itself that has been operationalized throughout the development of resilience theory. The earlier definition provided by Gunderson, as expected, is based in resilience theory, but does not speak to the concept’s role with regards to vulnerability or adaptation. It should be noted that both definitions speak to ecological and social-ecological resilience and not climate change specifically.

There are a range of definitions of adaptive capacity, depending on both the author and the policy venue of concern. Brooks & Adger (2005 p. 168) see adaptive capacity as “... the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or magnitude of harmful outcomes resulting from climate-related hazards.” The ability of a system to cope with vulnerability is seen by Smit and Pilifosova (2003) as adaptive capacity in the face of climate change. While not speaking directly to climate

change Nelson et al. (2007, p. 397) define adaptive capacity, as quoted in Chapter One of this dissertation as, “the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements”. In their work, Nelson and associates (2007) note that resilience theory utilizes a systems perspective rather than an actor-based perspective when considering adaptation and adaptive capacity to environmental risk, to include climate change. They go on to note that as such adaptive capacity is a “core feature of resilient social-ecological systems” (p. 395). As Nelson and associates have demonstrated, application of resilience theory has advanced in such a way as to make it applicable to climate change and more specifically adaptation and adaptive capacity as it relates to the environmental risks related to climate change.

Researchers have developed and refined resilience theory and its relationship to environmental risk and vulnerability. Early on Gunderson (1999) proposed that “Resilience is defined by the adaptive capacity of the system...”; Smit & Wandel (2006) propose that resilience provides adaptive capacity, while components of adaptive capacity are related to disturbances that produce environmental vulnerability (Nelson, et al., 2007). Returning to the resilience theory links between resilience and adaptive capacity, Holling and Gunderson (2002) propose that adaptive capacity is multi-scale and as such related to multi-level, interrelated panarchies. Additionally, Folke (2006) posits that adaptive capacity is reflective of self-organizing and emergent processes .

Vulnerability has been mentioned multiple times in this section relative to adaptation, adaptive capacity, and resilience. Vulnerability is a core factor when speaking about adaptive capacity and its concrete endpoint of adaptation. When considering vulnerability in this fashion one must recognize that adaptive capacity

precedes adaptation (W Neil Adger, Brooks, Bentham, Agnew, & Eriksen, 2004). As such adaptive capacity “is a latent condition only observed through concrete adaptation,”(Lemos, et al., 2007, p. 1). Concrete adaptations, as the manifestation of adaptive capacity, provide a means of reducing vulnerability (Smit & Wandel, 2006). The capacity to cope with vulnerability is related to exposure to environmental risk (Smit & Wandel, 2006) whether the assemblage be an ecosystem, community, or social-ecological system. Brooks and Adger (2005) relate adaptive capacity to environmental hazards relative to a specific system.

Vulnerability can be decreased through improvements in adaptive capacity (Smit & Pilifosova, 2003). Realization of adaptive capacity through concrete adaptation, in the view of Adger et al. (2004) may reduce social vulnerability. Additionally, it is important to note that like resilience, adaptive capacity is dynamic in nature (Smit & Wandel, 2006). Nevertheless, it is possible for the realization of adaptive capacity to be undermined by external barriers such as regulations (Brooks & Adger, 2005). Collective action is necessary for the successful development of adaptive capacity (W Neil Adger, et al., 2004). One of the great challenges of addressing adaptive capacity is its relationship to vulnerability in that vulnerability cannot be directly measured (W Neil Adger, et al., 2004). It is possible however, to develop an adaptive capacity baseline (Brooks & Adger, 2005) in order to begin to address vulnerability to environmental risk.

One of the challenges associated with addressing the adaptive capacity of social-ecological systems to environmental risk is its measurement. While measurement of vulnerability is difficult, researchers have attempted to develop indicators in order to identify factors that influence adaptive capacity and its relationship to vulnerability and

environmental risk. Brooks and Adger (2005) propose health, literacy, governance, and economic development as national level indicators. A number of indices have been developed in order to address adaptive capacity at the national level (W Neil Adger, et al., 2004) that reflects a continuing challenge- developing sub-national, regional, and/or local indicators as well as multi-level indicators of adaptive capacity. A large challenge to developing sub-national indicators is the need for indicators to reflect the social-ecological context for which they must be developed, which precludes them from being “off the shelf” indicators that can simply be tailored to any context (Brooks & Adger, 2005). Nevertheless, a suite of determinants of adaptive capacity was advanced in the third IPCC report and has since been utilized by researchers. The determinants include economic resources, technology, information and skills, infrastructure, institutions, and equity (Smit, et al., 2001). Adding ecological resilience to this list is not beyond the scope of logic recognizing the interconnections between resilience and adaptive capacity that has evolved through the literature.

It is evident that indicators of adaptive capacity are heavily influenced by the original determinants presented in Smit (2001). But we must be clear that determinants are not indicators and the literature has evolved to reflect this. Even given the difficulty noted throughout the literature of downscaling indicators of adaptive capacity to sub-national levels, local level indicators have been developed and empirically applied as demonstrated by Vincent (2007) in Table 2-1.

The concepts of adaptive capacity and resilience address the issue of both vulnerability and environmental risk. The first through its relationship to concrete adaptation to environmental risk, the second through ecological surprise as a result of

failed or maladaptive natural resource policy. As noted at the conclusion of the previous section, adaptive capacity serves as a means of conceptually bridging the gap between social-ecological resilience, sustainability, and environmental risk.

Table 2-1: Determinants and Indicators of Adaptive Capacity.

Determinants of adaptive capacity¹	Factors of adaptive capacity³
Economic Resources	Health
Technology	literacy
Information & Skills	governance
Infrastructure	economic development
Institutions	National adaptive capacity index⁴
Equity	Economic well being & stability
	Demographic structure
Elements of adaptive capacity²	Global interconnectivity
Economic Well being	Institutional stability & well being
Demographic Structure	Natural resource dependence
Interconnectivity	Household adaptive capacity index⁴
Institutional well being	Economic well being & stability
Natural Resource dependence	Demographic structure
Knowledge & literacy	Interconnectivity in higher level processes
Technology level & availability	Natural resource dependence
	Housing quality

¹ Smit & Pilifosova 2001, ² Walcott & Wolfe 2008, ³ Brooks & Adger 2005, ⁴ Vincent 2007.

Although adaptive capacity as applied in climate change adaptation research differs somewhat from the concept's definition in resilience theory related work, many of the underlying concepts overlap such as vulnerability, stability, robustness, and flexibility (Smit & Pilifosova, 2003). Differences between application of the various concepts have been smoothed over by Nelson and company (2007). Discrepancies between definitions and applications become less problematic if utilizing resilience theory which, through

ecologic theory and research, provide robust and operationalized definitions of the aforementioned concepts.

Climate Change & Adaptive Capacity

In a world impacted by climate change the concept of adaptive capacity has become an issue of increasing concern throughout the globe. The adaptive capacity of social-ecological systems have been addressed in regions throughout the world to include Canada's forests (Williamson et al., 2009), prairies (D. Swanson, Hiley, Venema, & Grosshans, 2007), and provinces (Lemmen, Warren, Lacroix, & Bush, 2008) flood prone regions of Norway (Næss, Bang, Eriksen, & Vevatne, 2005), the desert southwest of the North America (Vasquez-Leon, West, & Finan, 2003), and the arctic (Ford & Smit, 2004). The wide ranging geographic locations of adaptive capacity research demonstrate that concerns related to climate change span ecosystem type and international boundaries.

The Canadian government has undertaken research to address both the direct and indirect impacts of climate change in the country. Prerequisites for adaptation in Canadian forests prescribed by Williamson et al, (2009) include increases in awareness of change over time, establishing objectives, monitoring for critical thresholds, and reducing vulnerability. Swanson and company (2007) developed a suite of indicators for adaptive capacity for Canada's prairie region utilizing GIS and census statistics. Researchers reviewed significant economic sectors within British Columbia and utilized case studies to illuminate potential adaptations and required adaptive capacity therein (I. J. Walker & Sydneysmith, 2008). In the latter report the authors note that both adaptive capacity and resilience vary throughout the province.

Norway, a country that has been noted as being particularly well positioned to cope with the effects of climate change (O'Brien, Sygna, & Haugen, 2004) has nonetheless undertaken research on climate change vulnerability. The country has been perceived as having a high adaptive capacity in the face of climate change (Næss, et al., 2005), but research has revealed that vulnerability to the impacts of climate change are unevenly distributed throughout the country with broad differences between regions, sectors, and social groups (O'Brien, et al., 2004).

In the desert southwest of North America researchers have demonstrated an uneven distribution of adaptive capacity and vulnerability to climate change. Social class and ethnicity influence access to resources that would reduce vulnerability to the impacts of climate change, particularly drought, in the region. Entitlements and lines of credit both serve as a means of adapting to drought in the region (Vasquez-Leon, et al., 2003). The authors go on to note the potential negative influences of buffering against climate change by increasing the perceived ability to adapt at the cost of the ability to actualize adaptation strategies. Successful adaptation to the environmental, economic, and social impacts of climate change on regional disturbance regimes have been posited by researchers from the examples in the two preceding paragraphs. In Norway successful adaptation to global warming related flooding is related to flexible and multi-scale institutional arrangement, local knowledge, and social learning (Næss, et al., 2005). Farmers and ranchers along the arid U.S.-Mexico border have established effective drought responses including maintaining native grasses on grazing land and investment in water efficient irrigation technologies (Vasquez-Leon, et al., 2003).

Researchers of communities in the Canadian arctic have taken a vulnerability approach to addressing climate rather than a scenario-based approach (Ford & Smit, 2004). In this approach both biophysical and social aspects are addressed thereby pulling together the social-ecological system and addressing its vulnerability. A proposed model of vulnerability is based on the interactions of vulnerability, exposure, and adaptive capacity of the community.

A common theme throughout research on climate change vulnerability and adaptive capacity is the role of institutions. In Norway responses to flooding at both the local and national level require institutional flexibility (Næss, et al., 2005), but local institutional capacity may be facilitated or constrained by higher levels of governance (O'Brien, et al., 2004). "...[L]anguage and literacy... influence access to institutional adaptations," as discerned by Vásquez-León, West, and Finan (2003 p. 169). Additionally, the United Nations Food and Agriculture Organization propose that agricultural adaptations to climate change will require increased ecological knowledge and local institutions (Food and Agriculture Organization, 2008). To see adaptation to climate change through successfully, the implicit issue is that institutions at all levels must have the internal capacity to discern and apply techniques, strategies, and resources in a manner that reflects disparate vulnerabilities to climate change.

Conclusion

Resilience theory accepts and internalizes change to social and ecological systems whether it be from natural or anthropogenic influences. In turn, this provides a foundation for understanding changes in social-ecological systems as well as the environmental change which human individuals, communities, and societies must adapt.

Table 2-2 summarizes the determinants of adaptive capacity, those factors that are essential to successful adaptation, components of resilience theory, and the four stage heuristic of the adaptive cycle model.

Table 2-2: Components of Adaptive Capacity and Resilience Theory.

Determinants of Adaptive Capacity	Elements of Social-Ecological Systems	Components of the Adaptive Cycle Model
Economic Resources	Non-linearity	exploitation(r)
Technology	Multiple Stable States	conservation (k)
Information & Skills	Thresholds	release (Ω)
Infrastructure	Feedback Loops	renewal (α)
Institutions	Tipping Points	
Equity	Multi-scale	
	Surprise	

The strength of addressing adaptive capacity is contained in resilience theory's complex system approach to addressing social-ecological systems. Non-linearity, the existence of multiple states, and the factors that address the stability of the system or create uncertainty and surprise serve as a potential guide to policy response to a changing environment (Nelson, et al., 2007). Resilience theory contains within it, not just the role of adaptive capacity, but also the determinants of adaptive capacity. This provides a sound theoretical foundation within which adaptive capacity can address environmental change as well as policy responses, adequate or inadequate. Given sufficient detail it may be possible to extend this understanding of adaptive capacity through reliance theory within the four-part heuristic of the adaptive cycle model if appropriate.

Integrating adaptive capacity into resilience theory provides a robust means of empirically studying responses to climate change at multiple levels. Interpreting identified determinants of adaptive capacity within a community through the lens of resilience theory can inform stakeholders and policy-makers within that community and

it's institutions. Finally, resilience theory explicitly addresses uncertainty within a social-ecological system which can, if undertaken correctly, serve as a gap analysis with regard to the determinants of adaptive capacity; assisting communities in determining where additional resource need to be developed or employed.

CHAPTER III

A CASE STUDY APPROACH TO SOCIAL-ECOLOGICAL RESILIENCE AND ADAPTIVE CAPACITY

Research methodologies are a reflection of the research questions to be addressed. As a result of the qualitative nature of this research, a case study approach has been applied herein. Qualitative research takes place in the setting in which the research is focused (Creswell, 2003) and relies on multiple sources of data (Creswell, 2003; Patton, 2002) that are contextually based. In turn, qualitative fieldwork can be approached without predetermined constraints or response categories relative to quantitative research (Patton, 2002). A critical element of qualitative research as seen by Creswell (2003) is the refinement of research questions through their utilization in the field. This dissertation is based on three qualitative case studies selected specifically for the purpose of providing data related to the impacts of climate change on social-ecological resilience and adaptive capacity in the Crown of the Continent Ecosystem.

A case study is a bounded system (Creswell, 1998) that is defined by the study and specific to the research questions being addressed. In his text on case study methodology, Yin (2009) includes in his two-part definition of case studies that they are empirical and investigate real-life phenomena in a contemporary context relying on multiple methods. This makes case studies well suited for addressing the impacts of climate change in social-ecological systems. Case study research can consist of either a

single case study or multiple cases depending on the goals of the research. Case studies rely on explanatory power to address the ‘how’ and ‘why’ of research questions (Yin, 2009), while multiple case studies additionally lend themselves to cross-scale analysis (Creswell, 1998).

Like all research methodologies, case study research development and fieldwork is influenced by a methodology’s strengths and limitations. George & Bennett (2005) see the strengths of case studies as developing conceptual validity, deriving new hypotheses, and exploring causal mechanisms. These mechanisms may include, as the two researchers note, both tipping points and feedback loops. Yin (2009 p.13) proposes that case study methods are best suited to address research questions related to “contemporary events...over which the investigators has little or no control”. Gathering data on a contextually specific phenomena introduces numerous avenues for bias in the research. Triangulation of data sources and methods can serve as a means of addressing these concerns. When applied to data sources, triangulation is the gathering of data from multiple types and sources to find common themes and consistencies. The purpose of triangulation is not to bolster a researcher’s results from one source to another, but to discover relationships, nuance, and context, that in turn, can either support or refute results thereby developing validity and reliability (Patton, 2002).

Limitations of case study research, as seen by George and Bennett (2005), include case selection bias, lack of representativeness, and trade-offs in explanatory power and ability. George and Bennett contrast generalization of case studies from generalization as understood from quantitative methodologies that strive to produce sampling protocols representative of a larger population. The two researchers press the stark disparity

between the two forms of research, but the issue is more elegantly addressed by Yin (2009) who presents that generalization from case studies tend to add to and generalize theories as opposed to statistical generalization that seeks to extrapolate results across a larger population. Finally, when relying on a multiple case study methodology, the more cases that are included in the research the less detail that can be ascertained per case (Creswell, 1998).

Having briefly reviewed the strengths and weaknesses of qualitative methodology we now move on to the remainder of the chapter which is split into three sections. The first section introduces the research questions for this research. This is followed by a refined set of research questions based on empirical observation throughout the fieldwork. Section two presents the case study methodology with section three presenting how the methodology was applied throughout the research to provide the reader transparency with regards to conduct of the study. This is accomplished by presenting the research efforts as reflected by the activities undertaken during the four phases of the research plan that were set forth in the research proposal.

Research Questions

Research Scope

The use of a case study methodology was chosen in order to address the three research questions on which this dissertation is based. A multiple case study research design was selected in order to provide cross-case analysis between communities within the Crown of the Continent Ecosystem. At the broadest level the ecosystem is the unit of observation, but this is only true after cross-case comparison between the three case study communities in the Crown of the Continent Ecosystem.

As originally designed and proposed the community was the unit of analysis for this study. Fieldwork has revealed a weakness and inadequacy in this unit of analysis. As fieldwork progressed it became obvious that in order to include the necessary stakeholders, simply remaining in the “community” if envisioned as the physical or geographic town site, would be inadequate. It became necessary to operationalize “community” to a sub-regional perspective in order to be as inclusive as possible while still adhering to the research design and maintaining within allotted budgets and time.

Research Questions

The research questions that directly follow are verbatim from the original research proposal from which this study stems.

Research Question 1: How is climate change affecting the hydrologic regime in the Crown of the Continent Ecosystem?

Research Question 2: What policies and strategies have been developed to deal with identified and anticipated changes in the hydrologic regime of the COCE?

Research Question 3: Have the policies and strategies that have been employed by policy and decision-makers affected the adaptive capacity of communities in the COCE? If so, how and with what effects?

As noted in the discussion of qualitative research earlier in this chapter, qualitative methods lend themselves to refining research questions. The three above research questions are stated verbatim from the research proposal that preceded this research. Fieldwork within the three case study communities identified a need to refine the research questions in order to clarify theoretical and empirical linkages. The result

was a revision of research questions two and three to more accurately reflect the intent of the research as originally proposed.

Revised Research Question 2: What policies and strategies have been developed to deal with identified and anticipated direct and indirect impacts to the hydrologic regime of the COCE?

Revised research question two allows for a more inclusive discussion of strategies and policies being developed with relation to the impacts of climate change by explicitly addressing potential, projected, and anticipated impacts. The original version of the question limits the discussion to only those impacts that have already been identified and addressed.

Revised Research Question 3: Have policies and strategies that have been employed by stakeholders affected the adaptive capacity of communities and discrete sectors encompassed in this research? If so, how, and to what effect?

As originally proposed the research question was at odds with the intent of the research. The research has always intended to understand the impacts of climate change beyond the purview and perspective of policy-makers alone. The question has been rewritten to agree with the overall goal of the research by broadening the scope of the question to include stakeholders rather than just policy and decision-makers.

Case Study Protocol

Formal data collection for this research is encompassed in the case study protocol that will be described in detail in the following paragraphs. As originally conceived, the protocol was based on the “bottom-up” research design posited by Smit and Wandel (2006) specific to the research of climate change and adaptive capacity. Benefits of the

approach include focusing on communities and allowing participants in the research to define stressors, vulnerabilities, and measures to address each.

The case study protocol for this dissertation research relies on the “bottom-up” concept by commencing the research without preconceived variables. Although, boundaries were placed on the scope of the research through limiting the research to the impacts of climate change on the hydrologic regime. Table 3-1 outlines the steps in the case study protocol that is described below.

Table 3-1: Case Study Protocol.

- | |
|--|
| <ol style="list-style-type: none">1. Identification of key stakeholders in each critical sector.2. Expansion of contact list, application of contact methodology.<ul style="list-style-type: none">- Snowball Technique.- 3-contact methodology.3. Site visits and direct observation.4. Dissemination of the survey.5. Semi-structured interview process.6. Participation in conferences & workshops.7. Data Analysis. |
|--|

It is important to note that other than steps one and seven, the steps in the protocol from Table 3-1 often took place concurrently and in differing order as was necessary to obtain the required data for this research. The identification of key stakeholders was a critical first step in the research as it served as the preliminary list from which the contact list for the remainder of research would be developed. The initial list of key stakeholders was developed from names originally provided by participants in the Crown of the Continent Symposium.

The snowball technique was utilized to identify and broaden a list of potential participants for this research. Utilizing this technique, a small group of stakeholders were

identified through attendance at a symposium on the Crown of the Continent Ecosystem at the Flathead Valley Community College in February, 2008. Beginning with participants at the conference I introduced myself and my research proposal then asked for the names of individuals who would be important contacts and/or participants. As the list of names evolved and solidified for each sector the same technique was utilized. Those individuals identified by multiple people as a potential participant moved to the top of the list. As with any research a number of participants self-selected not to be involved and an additional number proved to be beyond contact after three attempts. Nevertheless, as a result of the snowballing technique I received recommendations for more participants than could be accommodated within the time and funding parameters of this research.

Throughout the field research process there was a distinct difficulty in obtaining data from the recreation sector. After approaching numerous stakeholders in both the mechanized and non-mechanized recreation industry I realized that I had overestimated the extent to which the general public, even those potentially impacted by climate change, were interested and/or capable of speaking to the issue. The result, after having informal discussions with five-to-six individuals in the industry (an equal amount opted out of inclusion altogether), was that only two individuals exhibited interest in continuing with the semi-structured interview process. Those two individuals represented the motorized and winter recreation industries of the recreation sector respectively. There was a resistance by many members of the recreation industry to participate even in informal discussions related to the research. This was further complicated when those few who did participate in informal discussions proved to be largely unable to speak to

the impacts of climate change on their sector. In most cases the discussions revolved around their beliefs related to climate change (which often times reflected skepticism of the issue) and the political nature of the debate.

Data from the case study communities has been gathered through two primary sources; the first being a targeted non-random survey to stakeholders. The survey was followed by semi-structured recorded interviews with a small number of stakeholders from each community. Site visits, direct observation, and observer participation also served as data gathering devices.

A contact methodology of three attempts was established for participation in the research and falls under step two of the case study protocol in Table 3-1. The contact methodology consisted of three attempts to contact a potential participant either through email or a combination of email and phone. If after three attempts at contact with no response, the potential participant was dropped from the list.

Table 3-2: Participant Identification and Contact Protocol.

- | |
|--|
| <ol style="list-style-type: none">1. Identify sectors critical to the research2. Identify relevant stakeholders for each sector3. Make initial contact with potential key informants4. Solicit additional contacts from key informants5. Initiate three attempt contact methodology for all other potential participants |
|--|

Initial selection of individuals were based on two broad criteria 1) involvement in one of the sectors identified as central to this study and 2) the potential of an individual to provide further contacts in their own and related sectors. These two criteria were further refined as the potential participant list was developed. Individuals able and willing to discuss the impacts of climate change on their sector served as an additional criteria for

selection as development of the participant list progressed. As originally envisioned stakeholders from sectors likely to be impacted by the influences of climate change on the ecosystem’s hydrologic regime were selected.

Informal discussions specific to my research topic served as an excellent vehicle for building relationships, receiving initial feedback about climate change impacts and associated concerns, and further developing the contact list. Informal discussions began with the original scoping trip to Kalispell and ended approximately around the time of my attendance at the Crown Manager’s Partnership annual conference in April, 2010. The interview participant list also drew to a close at approximately the same period. Table 3-3 provides details on the number of informal discussions, survey responses, and semi-structured interviews that took place during the course of this research.

Through the contact protocol (see Table 3-2) a list of stakeholders was developed for both the targeted survey and the semi-structured interview process. It is important to note here that partaking in the targeted survey did not automatically mean inclusion in the semi-structured interview process. Nor did all the interviewees participate in the survey as some were identified following the conclusion of the survey portion of the research.

Table 3-3: Case Study Community Interactions.

Community	Survey	Interview	Informal Discussions
Kalispell	21	12	39
Choteau	9	7	22
Fernie	6	4	6
Unknown	1	N/A	N/A
Total	37	23	67

While the three contact methodology was being applied, several trips to both Choteau (5 trips) and Fernie (4 trips) were made to initiate informal discussions with

potential participants and conduct the interview process, while living semi-permanently in Whitefish, MT near Kalispell. The purpose of semi-permanent relocation to the region was to allow for flexibility of travel to Choteau and Fernie with Kalispell, the economic center of the ecosystem, serving as the central hub from which I worked.

The number of informal discussions specifically related to the research topic are presented in Tables 3-3 & 3-4. The online survey was disseminated to stakeholders in all three case study communities while site visits and further development of the contact list were on-going.

Table 3-4: Participant Interaction by Sector.

Sector	Survey	Interview	Informal Discussions
Local Gov't	6	3	5
State/Provincial Gov't	8	4	12
Federal Gov't	2	6	10
Forestry	5	3	2
Agriculture	1	2	8
Recreation (all)	4	2	6
Non-Profit	4	3	9
Science/ Research	1	N/A	7
Interagency	2	N/A	3
Other	2	N/A	5
Unidentified	2	N/A	N/A
Total	37	23	67

Sectors in bold reflect those for which semi-structured interview participation was sought.

Site visits were an important component of the case study approach. Visits to Choteau led to stakeholders advocating visits (which were undertaken) to areas of local interest on the Rocky Mountain Front and Freezeout Lake Wildlife Management Area. In Fernie site visits led to short trips on the Elk and Kootenay Rivers, and the regionally iconic Crowsnest Pass. Full-time residence in Whitefish allowed for visits to the Northfork of the Flathead River whose headwaters lie in Canada. Additionally, several

trips were made to Waterton -Glacier International Peace Park . Each trip provided perspective and context related to the concepts and opinions voiced by participants.

The purpose of the targeted survey was to get a sense of stakeholders opinions related to the impacts of climate change at various scales (a copy of the survey is contained in Appendix A). Additionally, results from the survey helped to inform the semi-structured interview questionnaires. The interview questionnaires that developed following the targeted survey were not based on communities but on the sectors in bold in Table 3-4. Examples of the semi-structured interview questionnaires can be found in Appendix B. Results from the semi-structured interview process are presented in Chapter Four. Those results are combined with data and information from secondary sources in the synthesis and discussion contained in Chapter Five.

Table 3-5: Targeted Survey Demographic Data

Gender		Age Group		# Years Lived in Region	
Male	72.2%	18-20	0.0%	Less than 5 years	11.1%
Female	27.8%	21-30	0.0%	5-10 years	5.6%
Education Level		31-40	19.4%	11-20 years	25.0%
Less than high school diploma.	0.0%	41-50	30.6%	21-30 years	19.4%
High school diploma or equivalent	2.8%	51-60	33.3%	31-40 years	19.4%
Some College	5.6%	61-70	13.9%	41-50 years	8.3%
Baccalaureate Degree	27.8%	71-80	2.8%	Greater than 50 years	11.1%
Graduate Education	63.9%	80+	0.0%		

Often times when utilizing qualitative data like that from the targeted survey, it is helpful to provide context through the use of quantitative demographic information, when available. Table 3-5 provides a suite of demographic data provided by respondents of the

targeted survey. The table demonstrates that respondents were overwhelmingly male, highly educated, most likely to be middle-aged, and highly likely to have lived in the Crown of the Continent for more than ten years. Table 4-2 in Chapter Four presents additional data from the targeted survey in the form of respondents concerns related to the impacts of climate change on water resources.

Participation in two conferences allowed for participant-observation opportunities. The two opportunities are detailed in the fieldwork phase below. As noted above, there was a great deal of overlap in the application of the case study protocol steps in the field. Fieldwork in Fernie provides an example of this overlap as site visits took place during the same timeframe as dissemination of a limited number of surveys, as it took longer to develop a solid contact list for Fernie than either Kalispell or Choteau.

While the formal case study protocol were being borne out additional data in the form of local and regional newspapers and sector specific documents was collected. Newspaper articles germane to the research, whether it be the effects of climate change or the closing of a timber mill, for example, were collected for later triangulation among data sources. The same process was used for the collection of relevant peer-review and gray literature in the form of sector technical reports and publicly available government documents.

Phases of the Research

The original research proposal developed a four phased approach to carrying-out the dissertation project to completion. The four phase approach has been adhered to; the following subsections will present the activities and products that have resulted from that process. As originally presented the four phases of the research are encompassed in 1)

Scoping and proposal phase, 2) Fieldwork phase, 3) Data analysis phase, and 4) Dissertation writing and defense phase.

Scoping & Proposal Phase. The scoping phase of the research began upon completion of all required coursework at the University of New Hampshire. Initial thoughts on potential topics were undertaken along with discussions with UNH faculty members in a multitude of fields within the Natural Resources and the Environment Department. These discussions were coupled with a wide ranging review of contemporary topics in natural resource policy. The result was a narrowing of the geographic scope of the project to the Rocky Mountains and the topic to climate change. The topic was further refined by a continuing review of ecological and climate change literature.

During this period I learned of a symposium being held in Kalispell, Montana on the Crown of the Continent Ecosystem, a region identified in contemporary literature as being observantly influenced by climate change. The symposium took place 20-21 February, 2008. In order to attend the symposium I applied for and received travel funding through the NRESS Student Support Fund. The purpose of the symposium was not to specifically address the impacts of climate change on the region, although Dr. Dan Fagre of the U.S. Geological Survey did provide a presentation on the topic, but rather to serve as a means of solidifying the concept of the Crown of the Continent as a regional identity and to develop an ecosystem-wide research initiative encompassed by the University of Montana's "Crown of the Continent Initiative".

On the first evening of the conference I approached the Symposium's coordinators Dr. Rick Graetz and Dr. Gerald Fetz of the University of Montana and introduced myself and my nascent interest in conducting research on climate change

impacts in the region. Both gentleman were gracious enough to take my interest seriously and then introduce me to academics, researchers, and presenters throughout the remainder of the conference. It is from this initial introduction that my contact list was first developed and expanded. I have remained in contact with Dr. Grazt throughout the research.

The research proposal public defense was held in February, 2009 nearly a year after attendance at the COCE symposium. The defense was followed by required submission of materials to the Institutional Review Board for the protection of human subjects. These included sample survey and interview questions and formats. The project received IRB approval in April, 2009. A copy of the IRB approval letter can be found at the end of the dissertation following the appendices.

Between the proposal defense and final IRB approval I returned to Kalispell, MT for a series of short meetings with stakeholders in order to more fully develop a list of potential participants for the research as well as to refine the scope of the research itself. During this set of meetings my list of potential participants was greatly expanded, as was anticipated through the snowballing participation technique. Additionally of great importance, the second case study community that I had originally proposed – Browning, MT- was roundly discouraged by everyone I spoke with during this trip. The resounding theme with regards to abandoning this community was a perceived lack of capacity to address any of the research questions I had proposed. In nearly all cases individuals who suggested dropping Browning as a case study community suggested it be replaced with Choteau. I was informed that Choteau was located just south of Browning fulfilling my desire to have a case study community on the east side of the Continental Divide. I was

also told that Choteau had a rich history of engagement and involvement in natural resource related issues and was likely to be capable of addressing my research questions.

Fieldwork Phase. The fieldwork phase of the research commenced in earnest with my semi-permanent relocation from New Hampshire to Whitefish, MT in June of 2009.

Although, this phase of the research could be viewed as beginning with the development of the targeted survey while still at UNH in the Spring semester of 2009. Early versions of the survey were tested internally by a focus group of graduate students also working in Dr. Mimi Becker's Natural Resource Policy Lab. A total of three versions of the survey were completed before a version was disseminated to the dissertation committee for their comments. Upon receiving comments from the dissertation committee a final version of the survey was drafted and prepared for dissemination to identified participants.

At the conclusion of the survey a total of thirty-seven surveys were returned. The last request for a survey response was sent on May 15, 2010 and the last response received was on June 03, 2010 drawing to a close that portion of the research fieldwork. As noted in the research proposal and earlier in this work the purpose of the survey was to inform the semi-structured interview questionnaires.

The semi-structured interview process began in February, 2010 and concluded in September, 2010. During the period of June, 2009- January, 2010 I conducted multiple site visits to each case study community, undertook informal discussion with stakeholders with regard to the topic of my research, and continued to refine the final participant list for the semi-structured interview portion of the fieldwork. Additionally, I was invited to attend a joint sponsored workshop on climate change by Montana Fish Wildlife & Parks

and the National Wildlife Federation in Kalispell, Montana in December, 2009. I also attended the Crown Managers Partnership annual conference in Fernie, British Columbia in April, 2010.

During this phase of the research primary data were obtained through the targeted survey, the semi-structured interview process, informal conversations with stakeholders, and observer participation at workshops and conferences. Secondary data were gathered through an ongoing literature review of scientific and peer-reviewed literature, gray literature in the form of agency and industry technical documents, and local media news articles. Secondary data largely come in two forms, the first being peer-review literature that details research on climate change or its impacts in the region. The second is regional contemporary news articles and sector specific documents to include government publications that help to triangulate the findings of the research.

In order to conduct interviews with personnel in Glacier National Park I was required to apply for a National Park Service research permit. The application process required submission of a robust research proposal structured within a provided template. After submitting the proposal for review by Glacier National Park, approval was received on January 19, 2010. A copy of the research permit is contained in Appendix C. The permit was issued to Dr. Mimi Becker as primary investigator for this research.

Data Analysis Phase. This phase of the dissertation project began at the conclusion of the preceding phase with the completed transcription of all semi-structured interviews. The focus of this phase of the research was on coding the data gathered from the transcripts of the semi-structured interviews.

Semi-structured interview transcripts were transcribed utilizing voice recognition software- Dragon Naturally Speaking 10. Transcription began early on during the research and continued as additional interviews were taking place rather than waiting to transcribe all interviews until completion of the final interview. This method led to completion of the final transcript on October 14th, 2010.

Coding of the transcripts was undertaken with the use of NVIVO 9 coding software. The process begins with the uploading of the document transcript into the software in a folder that reflected the case study community name relative to the individual transcript (e.g. labeled Kalispell, Choteau, or Fernie). Next, the newly uploaded transcript was opened and the coding begun; Table 3-6 denotes the categories derived from the semi-structured interview process, the number of participants that commented on the category (Interview Sources) and the number of coded discrete references under a given category.

The coding of individual transcripts begins with a thorough reading of the transcript. Individual statements along with supporting context were coded by highlighting the desired passage, right clicking the mouse, then either selecting a previously identified category or theme or choosing a new category in which to code the statement. Passages can be coded to reflect multiple categories depending on the complexity and context in which the passage was spoken.

The initial coding of all transcripts produced a total of forty-one categories. These forty-one categories and the accompanying transcript passages were then reviewed with some being marked for recoding. This process was undertaken a second time with a total of seven categories recoded to the extent that they were removed entirely with their

transcript passages, where appropriate, recoded into other existing categories. Three major factors precipitated recoding. The first was miscoding of a passage in one or more categories. This was addressed by simply uncoding the passage in the software then recoding it appropriately. If the passage was not coded correctly to reflect the category in which it should fall (as noted earlier each passage can be simultaneously coded) then it was recoded appropriately.

Table 3-6: Semi-structured Interview Categories and Associated Data.

Categories	Interview Sources	Coded References
Strategy	21	195
Collaboration	18	85
Resources	16	70
Hydrologic Cycle	19	68
Capacity Building	14	67
Monitoring	16	59
Irrigation	6	57
Fire	12	45
Ecology	11	44
Endangered Species	7	42
Forest Insect Infestation	13	32
Water Law	10	30
Drought	12	25
Communication	10	25
Social-ecological	9	24
Conflict	5	18
Indicator (Participant Proposed)	7	17
Resilience	6	16
Wilderness	5	9
Forest Disease	4	8

The second major factor that precipitated recoding of transcript passages was due to the development of a category that closely reflected an additional category and simply divided like transcript passages in an arbitrary manner when passages from both

categories reflected the same concept. This was rectified by combining the two categories and their accompanying transcript passages into a single category.

The third and final factor that was cause for recoding was the coding of statements that contained transcript passages with less than three references⁹. This was important for the purpose of validity. It is unlikely that an independent category is either necessary or accurately reflects the context of coded passages when only one or two participants identified the concept during our discussions. There were a total of four categories that fell within this criteria. In each of these four categories there were a very limited number of transcript passages. Recoding was undertaken in order to fold these passages into other categories that still reflected the context of the statements and could then be reviewed later for inclusion and discussion of the results of the data.

At conclusion of the three recoding efforts a total of thirty-three categories were derived from the semi-structured interview transcripts. Of those thirty-three categories the data were reviewed once again and several categories were either combined or omitted as lacking sufficient detail and/or information central to the research questions. The result was twenty categories that were then divided into three broad themes which will serve as the basis for presentation of the results in Chapter Four.

Writing Phase. The writing phase of the dissertation project began concomitantly with the fieldwork phase of the research, carried on through the completion of the data analysis phase and concludes upon the successful defense of the dissertation and submission of the final version to the University of New Hampshire Graduate School.

⁹ In the Nvivo 9 software a reference is any type of media (transcript, picture, graph, etc) that has been coded within the software. For this study specifically, a reference in this context is a semi-structured interview transcript.

Conclusion

Applying the research methodology in the field revealed early on a glaring flaw in the methodology. The targeted survey as designed, was found to be a poor tool for data gathering. While the survey did serve its purpose of informing the semi-structured interview questionnaire by presenting those issues most prominent on the minds of respondents with relation to climate change, it nevertheless was fraught with difficulty that reflected a lack of focus within the survey. The take away from this is that the survey could have been much shorter and more focused with the same result.

Recommendations to rectify this situation in future research are presented in Chapter Six and rely heavily on the early planning of research efforts.

CHAPTER IV

CLIMATE CHANGE STRESSORS, RESPONSES, AND SYSTEM STATES

The following chapter presents the findings of the research based on the data gathered through the case study approach detailed in Chapter Three. The focus of this chapter is the primary data gathered through the semi-structured interview process although in some instances this is bolstered and/or augmented by informal discussions, participant observation, and in some instances literature related to the topic. The research data will be synthesized and discussed in the context of broader research and scholarly literature in Chapter Five.

Data from twenty-three semi-structured interviews are presented herein through the three themes and the categories that fall beneath them in Table 4-1 as they apply to each of the three research questions upon which this dissertation is premised.

The results from the semi-structured interview process revealed a number of interesting findings. First, participant identified stressors from climate change ran the gamut across ecological, social, and economic fronts. Next, many of the categories that were revealed by the research reflect determinants of adaptive capacity (see Smit, et al., 2001) such as the role of institutional capacity and economic diversity. Finally, social-ecological resilience was addressed in a number of categories resulting from the participant responses, particularly those related to resources and strategies for addressing the direct and indirect impacts of climate change on the hydrologic regime of the Crown of the Continent Ecosystem. Chapter Five will address those factors that appear to reach

beyond the site specific context of the individual case study communities of this research. Addressing the results in a broad fashion will serve to lay the groundwork for the conclusions and recommendations contained in Chapter Six.

Table 4-1 presents the themes and categories identified through the coding of the semi-structured interview data. From the coding process three overarching themes presented themselves that have been related to the three research questions on which this research is based. Those themes are participant identified climate related stressors, social-ecological responses, and system states and institutions. In the columns beneath each theme are specific categories related to that theme. The body of this chapter will present the concepts and context to each theme and the categories presented in the table directly below. In many cases there exists overlap between themes and categories; this is reflected in the text and is also noted where this takes place in order to reduce confusion.

Table 4-1: Themes and Categories Revealed Through Semi-structured Interview Coding.

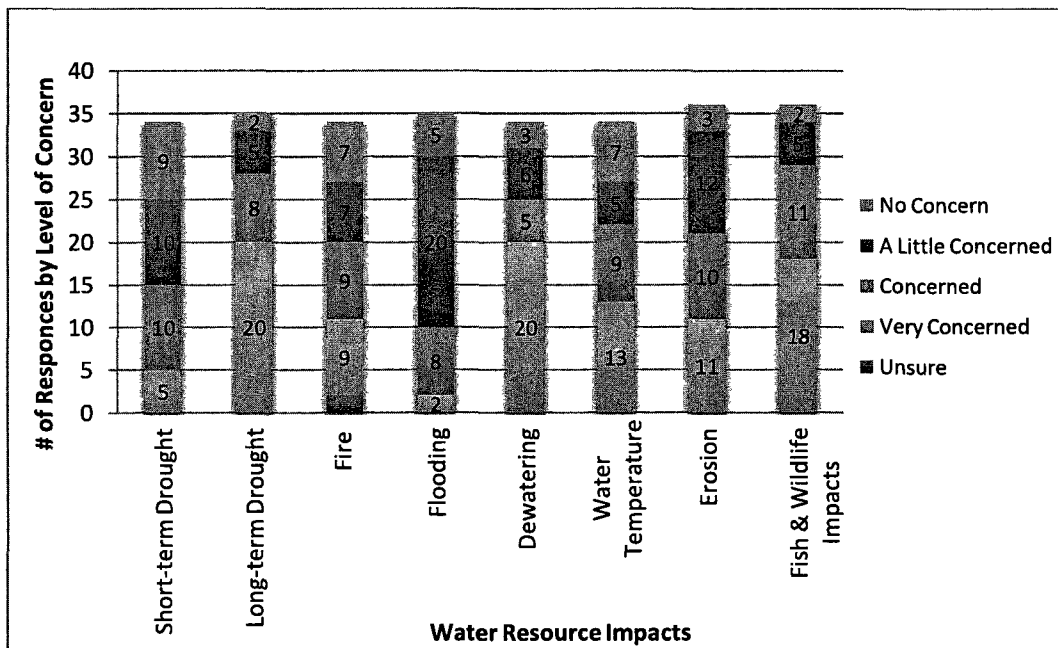
<u>Participant Identified Indicators of Climate Related Stress</u>¹	<u>Social-ecological Responses</u>²	<u>System States & Social Institutions</u>³
Hydrologic Cycle	Resources	Social-ecological
Drought	Monitoring	Western Water Law
Forest Infestation & Disease	Indicators	Wilderness
Fire	Capacity Building	
Ecology	Resilience	
Irrigation	Communication & Conflict	
	Collaboration	
	Strategies	

The three themes in bold reflect a specific research question; the research question associated with the themes are indicated by superscript numerals.

As noted in Chapter Three, the semi-structured interview questionnaire was informed by targeted survey responses in addition to informal discussions. Table 4-2

presents the levels of concern related to eight impacts on water resources. While short-term drought is of little concern, long-term drought is the most dominating issue for survey respondents. Of only slightly less concern is the issue of dewatering followed by fish and wildlife impacts. Each of the response categories was discussed by participants to differing degrees during the semi-structured interview process.

Table 4-2: Levels of Concern Related to Climate Change Impacts on Water Resources in the COCE.



Participant Identified Climate Change Related Stressors

The first theme presented here is directly related to the first research question of this dissertation. The categories that fall beneath the theme have been identified by participants in the Crown of the Continent Ecosystem as components of the ecosystem that are or will likely exhibit stress from the direct or indirect impacts of climate change on the hydrologic regime.

Description and context for each category will be presented in the following paragraphs. Specific concerns, threats, and stressors, as they are understood by stakeholders in the COCE, will be explored herein. This is accomplished through summarizing the data and presenting direct quotes from the semi-structured interview process to provide emphasis to critical elements arising from the data.

HYDROLOGIC CYCLE

The first category of climate change related stressors are those that stakeholders have noted are directly or indirectly encompassed within the hydrologic cycle itself. This is to say, those impacts that are broadly encompassed by the hydrologic cycle and either amplify, alter, or otherwise shift disturbance regimes or ecological processes.

Stressors within the hydrologic cycle which stakeholders identified as current or projected concerns include shifts in the timing of annual precipitation patterns and shifts in the amount and type of precipitation. The two aforementioned concerns are compounded by concern over secondary effects such as a shift in peak and average seasonal runoff with additional concerns for fish and wildlife, habitat, irrigation, and municipal water supplies.

Concerns over the availability of water in a changing system has been expressed as shifts in the 'water balance' of the ecosystem and the presence or absence of 'timely rains'. The former has been utilized primarily by resource managers and researchers while the latter tended to be most often expressed by extractive resource industry stakeholders. A timber industry participant had the following to say about the role of 'timely rains' with regard to fire and winter snowpack, "It's almost those timely rainstorms that are more important than what we get in the wintertime. However, if you

start the season out and everything is kind dry... [lack of timely rains] extend the [fire] season”. Agricultural producers in Choteau also spoke to the value of ‘timely rains’ within the context of the growing season and relative to irrigation.

The alteration of disturbance regimes has also been identified as a cause for concern with a prime example being flooding. Shifts in the timing of floods from spring to fall and winter was noted by numerous stakeholders as a change with potentially dramatic negative consequences. This change coincided for many participants with an increase in rain-on-snow events that in the past, at least anecdotally, were relatively rare. In addition to flooding, the loss of snowpack in a compressed timeline due to rain-on-snow events is worrisome for fire managers, wildlife managers, and agricultural producers.

DROUGHT

Drought was presented in all three communities as being a potential direct impact from climate change. It must be noted that discussions related to drought were often precipitated by interview questions that began the interview process with a discussion on drought rather than “climate change” in order to begin the conversation with stakeholders skeptical of climate change. This may have led to more than one interviewee misconstruing the intended question as one equating climate change to drought which was followed by a back-and-forth providing clarity to the question and ongoing responses by participants. It was a purposeful intention of the field researcher to seek and elicit responses to questions about drought rather than climate change early on in some cases to prevent discussions from sliding into politically charged debates over the merits of climate change and the research at hand.

Direct impacts of a potential increase in drought identified by stakeholders were increased frequency and intensity of ecosystem fire regimes, although it should be noted that some participants offered that this would be a temporary situation resulting partly from historical fire policy.

Indirect impacts on forests as a result of a potential increase in drought were identified as increased susceptibility of forest stands to insect infestation and forest disease. Thirteen participants noted the current outbreak of mountain pine beetle (*Denroctonus ponderosae*) and white pine blister rust (*Cronartium ribicola*) as empirical evidence of indirect impacts of drought. A stakeholder from the timber industry had this to say about the impacts of drought,

[f]irst obviously with drought, you start thinking about the fire season. It extends the fire season. It dries out earlier, you could have extended fire season. You know the other way it's been affecting us too is the trees are in a drought state, they're less bug resistant, weakened, so it opens our trees up to all kinds of other bugs, pathogens, whatever.

A secondary effect of vegetative stress related to drought were noted as shifts in ground and surface water with additional tertiary impacts on wildlife, habitat, community water supplies, and the availability of water for agriculture through irrigation and forage production. The impacts of drought on municipal water sources becomes clearer when discussing the issue of forest management and water resources with a timber industry stakeholder,

You start talking about water availability and timing of supply and that kind of stuff. We haven't quite gotten there yet in [the Flathead Valley], I don't think people are talking about that seriously. But without a doubt it's coming. Like Haskell Basin which is the water supply for the city of Whitefish, two thirds of that basin we own and manage. We have done that for a little over 100 years. So it's been going on, these forested watersheds are the source for all the water.

Participants have noted feedbacks and synergistic effects between climate change, drought, and a multitude of additional social and ecological effects on the Crown of the Continent's hydrologic regime. Given the interconnections between drought and other indicators of climate related stress, the issue of drought reoccurs in many of the discussions below.

FOREST INFESTATION AND DISEASE

While insect infestation and forest disease are distinct disturbance regimes, when timber resources were discussed by stakeholders the two were typically discussed in tandem. A common issue like the following was voiced by a Montana natural resource manager, "the other consequence is that when vegetation becomes drought stressed it's more susceptible to insect and disease". As noted in the previous paragraphs both disease and infestation have been identified as potentially increasing as a result of increased drought, a perceived outcome of climate change's impact on the hydrologic cycle of the ecosystem.

The current mountain pine beetle epidemic and its impacts were often discussed by stakeholders. Participants noted the impacts of other insects including the spruce budworm (*Choristoneura fumiferana*), the Douglas-fir beetle (*Dendroctonus pseudotsugae*), the spruce beetle (*Dendroctonus rufipennis*) and the Scolytus beetle, but all to a much lesser extent. Impacts resulting from increased infestation identified by participants include additional impacts on disease and fire regimes, changes in vegetative structure and ecological succession at the landscape level, and economic impacts with relation to direct revenue from timber harvest and indirect revenue from businesses related to timber harvest. At least one participant was concerned with reports that

mountain pine beetles were beginning to attack younger stands than had been previously observed.

White pine blister rust was most often cited by participants as the most troubling forest disease in the ecosystem. Loss of revenue from disease was noted by participants in the same manner as the preceding paragraph on insect infestation. Many participants noted that individual tree susceptibility to the disease may be exacerbated by drought stress. Economic impacts are related here by a Montana natural resource manager,

...there are certain habitat types that under drought stress become more susceptible to infestation by insect and disease. Which means they can have an increase in mortality, which then decreases our ability to maximize revenue from... the commodities we are trying to sell from those habitat types.

The same point was made on the opposite side of the Continental Divide by a public land manager in Choteau when discussing the cascading consequences of drought,

And then when it comes to recreation management I think there's some minute effects happening with our outfitter and guide industry¹⁰ that may have affects on clientele in terms of some of the effects of bug kill or the results of drought or the results of fires as a result of bug kill and drought. People come out expecting to see green forest and they don't anticipate changes that are natural and it affects some of their desire to continue a follow-up trip in another year or years down the road.

The increased mortality from both insect predation and disease was noted as a potentially exacerbating variable of the fire regime, although there was disagreement among participants on this point.

Of special concern was the impact of blister rust on whitebark pine (*Pinus albicaulis*), a species that is rapidly diminishing throughout the ecosystem and the landscape and has been proposed for listing under the Endangered Species Act. The U.S. Fish & Wildlife Service determined in July, 2010 that protection may be warranted and at

¹⁰ Outfitting encompasses activities related to sport hunting and fishing to include equipping, provisioning, and locating the sought after sport game species.

that time undertook a 12-month status review to determine whether listing of the species under the Act was necessary.

FIRE

After drought, impacts on the ecosystem's fire regime was the dominant topic of participants when discussing direct and indirect impacts of climate change on the COCE's hydrologic regime. In addition to the impacts noted earlier, projected and perceived increases in fire led participants to discuss secondary impacts in the form of lost revenue, reduced grazing opportunity on public lands, loss of property and in the case of the wildland-urban interface, potentially loss of life.

Participant responses to fire policy and management on a changing landscape took many different forms. Some participants saw the legacy of historical fire policy in the form of fire suppression as being repudiated, while others saw the loss of timber as "wasted resources" in addition to those resources required to fight the fire. Public land managers and timber industry stakeholders noted the increased difficulties inherent in adapting to a changing fire regime as well as observed increased variation in the size and intensity of fire from year to year. One public land manager explained his frustration with managing fire on a changing landscape the following way, "When it comes to fire management we've seen probably some hotter, drier conditions that have resulted in more intense fires and perhaps have grown quicker in size and have allowed us to be less effective in opportunities to manage them". The role of drought, insect and disease outbreak, and the manifestation of 'timely rains' were all noted during interviews with relation to fire.

The perceived impacts of fire on fish and wildlife and their habitat were diverse. Some participants projected only temporary impacts on species populations while others noted potentially dire consequences when the impacts were coupled with additional stresses on species. An example of the former thought is voiced here by a wildlife manager, “You know there’s some landscape changes that will affect some furbearer species potentially, again it’s a rotational issue though too. Are these permanent effects? Probably not”.

A general dividing line when discussing the impacts of fire on fish and wildlife appeared to be between game animals and endangered or threatened species. While the responses related to the threatened bull trout (*Salvelinus confluentus*) versus carnivores in the form of wolves (*Canis lupus*) and grizzly bears (*Ursus arctos horribilis*) were genuinely different, there was a characteristic undertone of increased concern relative to cumulative impacts on threatened and endangered species.

It was presented that changes to the hydrologic regime could potentially increase the utilization of fire as a management tool on the landscape. Shifts in vegetation cover, transition to new dominant vegetation types, and successional changes were all cited as potential challenges for the prospect. It was questioned by participants in both the public land management and the timber industry whether it is even feasible to consider fire in its historical role any longer? The issue was coupled with heightened concern about the spread of fire from public to private lands by many of the same participants and appears to contradict the idea of increasing the role of fire as a management tool.

ECOLOGIC STRESSORS

This section presents participants concerns with regard to impacts from climate change on the hydrologic cycle that may influence a population, species, or ecological community. This includes discussions on a subcategory regarding threatened and endangered species, which were singled out for discussion by participants. Barring the legal and policy implications of threatened, endangered, candidates for listing, or species of concern, the impacts to these species must be understood within the context of the larger ecosystem and will therefore be included herein.

Ten participants spoke specifically about the impacts of climate change on forest ecology, most but not all were in either public land management or the timber industry. A reoccurring theme among both public land and timber industry stakeholders were projected land cover changes in the form of shifts from forest to grasslands. Some tied this potential shift to changes in the fire regime with a land manager from Canada noting the following about Waterton National Park,

[O]ur big challenge here is for reintroducing fire because we used to have more grasslands than we have now and we've lost a lot of that to forest encroachment. If you look at the models fifty years from now it's showing actually that the forests should be receding. So we've had those discussions of, okay, how necessary is it if it's going to go the other way on its own anyway?

Concern related to the potential shift in vegetative species throughout the ecosystem was echoed across the border by a scientist with Glacier National Park when discussing the impacts of fire and other disturbances on the ecosystem, "You may see a total transformation of the forests that you have now. They may not come back as forests or they may come back as different species".

As noted in the preceding quote, shifts in plant community composition are a concern for some. Related concerns include shifts in phenology, increase and expansion of noxious weed species on the landscape, and uphill movement of species whose life cycles allow for rapid adjustment, as well as loss of species unable to migrate or adapt at lower elevations. Phenological and species diversity are points of concern in the following quote from the same land manager from Waterton National Park as the preceding quote,

The phenology of plants seems to be changing when we do surveys. There have been surveys for many years as a flower survey happens at a certain date every year and we go and see how many flowering species there are and the numbers are increasing. And that's not necessarily because the diversity is increasing its actually that more plants are flowering that time of year and earlier.

Uphill migration of animals were also noted as a possibility, although there was additional concern at the decreasing amount of habitat available as one moves uphill. Fragmentation of habitat, loss of connectivity as a result of shrinking and shifting habitat, and the loss of island populations were all cited by participants as cause for concern. The diminutive pika (*Ochotona princeps*) ([Figure 4-1](#)) has become a mascot for the aforementioned concerns, but mountain goats (*Oreamnos americanus*) and big horn sheep (*Ovis canadensis*) were also identified as species that may be severely impacted by such habitat changes.

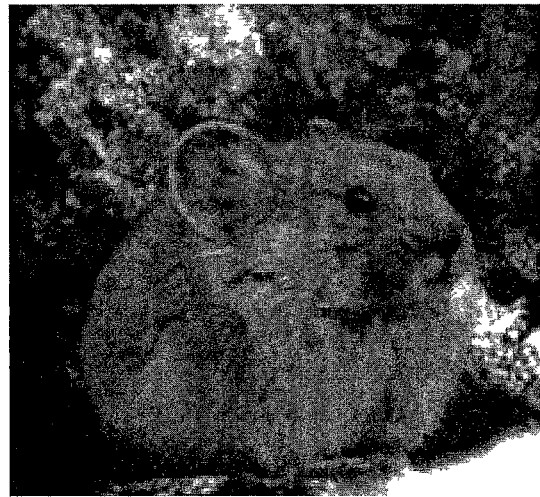


Figure 4-1: American Pika (*Ochotona princeps*). Picture is from Glacier National Park's website and can be found at- http://www.nps.gov/glac/parknews/blogs_olig_0908.htm

Aquatic species have an additional set of issues associated with potential changes in the hydrologic regime. Increased summer water temperatures, especially during periods of seasonal low flow, the loss of refugia during these times, and habitat fragmentation and loss, are all cumulative impacts on aquatic species.

Historical and continued stocking of non-native game species into the ecosystem's waters for recreation were discussed by many as a grave concern when trying to conserve and reestablish native fish populations. It was noted by participants that in many cases introduced non-natives already outcompete and displace native species. Some went on to say that increasing temperatures would further favor non-natives while increasing stress on native fish.

Historical and contemporary land and water use was discussed as an additional stress on both fish and wildlife. Irrigation practices, particularly on the east side of the ecosystem, was noted in this context. Increased habitat fragmentation resulting from climate change coupled with barriers to movement and migration were presented as additional impacts on species and populations. The need for connectivity between island populations was specifically cited by participants from state and federal natural resource management agencies as well as the timber industry.

Source-sink dynamics were also discussed, mainly in the context of predator species and the protections offered through legislative fiat via the Endangered Species Act (United States) or the Species at Risk Act (Canada) or policy related to public lands- specifically National Parks. Wolves (*Canis lupus*), grizzly bears (*Ursus arctos horribilis*), wolverines (*Gulo gulo*), and Canadian lynx (*Lynx canadensis*) were all noted as carnivore

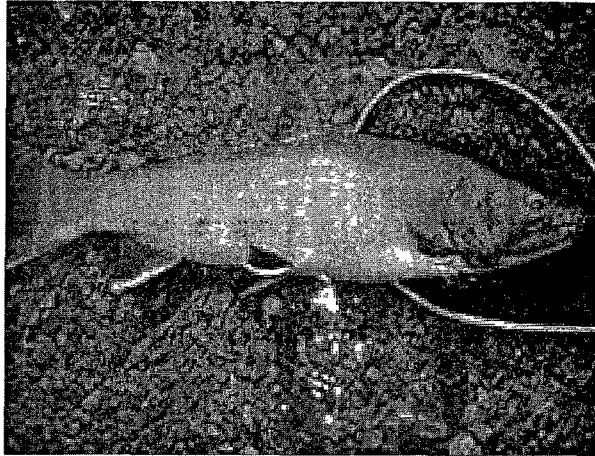


Figure 4-2: Bull trout (*Salvelinus confluentus*). Picture is from U.S. Fish and Wildlife Service's website and can be found at- <http://www.fws.gov/pacific/bulltrout/>

species with potentially unsustainable populations resulting from the source-sink dynamics in the ecosystem.

Aquatic threatened and endangered species, bull trout (*Salvelinus confluentus*) (U.S.) and the westslope cutthroat trout (*Oncorhynchus clarki lewisi*) (Canada) were discussed by stakeholders in public land management,

resource extractive industry, and the non-profit sector. In addition to the previously mentioned impacts to aquatic species it was noted by three scientists working in and around Waterton-Glacier National Park that flooding could disproportionately impact native spawners. Metapopulation dynamics were extensively discussed with regard to the warming of waters seasonally or longer, local extinctions, and recolonization by the two aforementioned threatened aquatic species and the potentially increased difficulty of maintaining a robust metapopulation. A specific fear is that the loss of local populations, compounded by negative impacts on habitat by climate change such as through habitat fragmentation, will prevent species from recolonizing an area and reestablishing locally extinct populations. A fishery biologist had the following to say about protecting and maintaining metapopulations of bull trout,

Maybe, through the course of doing some of that kind of work [translocation of species around a protective barrier¹¹] we'll be able to protect and conserve some of these genetic attributes that may otherwise be lost. But that's kind of small

¹¹ Permanent or semi-permanent barriers, natural or artificial, are commonly utilized to protect native fish species from invasion of their habitat by non-native species. While providing protection, such efforts make it increasingly difficult to establish connected populations that maintain genetic diversity.

potatoes because it doesn't address the big picture..... migratory, connected populations, that's a different deal.

The introduction of non-native species for sport recreation create an additional challenge for fish and wildlife managers. An example of this challenge in the COCE can be found in the management of both bull trout (Figure 4-2) and lake trout (*Salvelinus namaycush*). Lake trout are an introduced non-native species to the west side of the Continental Divide where stocking of the species for recreation has been widespread throughout the ecosystem, most famously in Flathead Lake. Numerous cascading consequences have resulted from competition between bull trout and the introduced lake trout, producing a dramatic decline of the bull trout population in the ecosystem (Martinez et al., 2009).

As was noted earlier not all impacts to populations, species, and ecological communities are necessarily negative. Timber industry stakeholders noted potential advantages of managing forests for species diversity and water management. In the words of one forest industry stakeholder diversity serves as a bulwark against fire, "We have diversity of stand types and structures so that allows more likely we're going to have a fire that's going to be on the ground with it more likely successfully attacked then". The idea being presented by the forest industry stakeholder in the preceding quote is that promoting and maintaining forest stand diversity allows for a fire regime that can be managed more easily through fire suppression. Providing support for the idea that there exists feedbacks between fire, disease, and insect outbreak the same stakeholder also noted, "that diversity also tends to reduce the severity of the outbreaks of insect and disease we have as well". Managing timber stands for the benefit of community water resources was presented by a timber industry professional in British Columbia,

secondarily, are things like water and if it affects water because we manage very carefully for domestic water supplies and community watersheds. We've got like specific regulations for harvesting in those areas and if water is drying up we have to think carefully about how that might affect what sort of forest management strategies we would apply within the drainage.

Some participants wondered whether public acceptance of non-native and invasive species favored by a warming climate would produce different types of benefits? Others speculated that for many species it is likely that if migration and adaptation can take place, negative impacts at the population, species, and community levels would likely be disparate and temporary. Although, it was questioned by two participants how to continue to utilize the historic range of variability in the management of species and habitat as well as how to define ecological health in the ecosystem in the face of climate change?

IRRIGATION

In the agricultural based community of Choteau, access to irrigation water is central to agricultural and therefore economic vitality. Although irrigation is a unique concern, within this research, to Choteau and was largely not reflected in the other two case study communities, this should not preclude irrigation from being reviewed.

By far the largest concern related to irrigation is the availability of water during the agricultural growing season. In turn, this has spawned a number of additional anxieties among interview participants and the larger body of stakeholders of the community alike. These anxieties include the amount of annual snowpack, release of said snowpack throughout the year, storage and transport of water, and availability of water for agricultural use. The role of 'timely rains' in reducing anxiety around these issues was noted throughout the interview process in Choteau. Oppositely, the fear of

rain-on-snow events and an uncontrollable and uncapturable pulse that would ultimately cause flooding and reduce water availability later in the year was also presented throughout the interview process. Stakeholders, largely from the agriculture industry, mentioned this phenomena, but were not alone, as public land managers also grappled with the challenges associated with rain-on-snow events.

Speaking specifically about the effects of a rain-on-snow event one agricultural participant had this to say, “It means if we get five inches of rain on top of our snow at the end of April and it all comes out at once we lose most of it down the river. It’s not a good deal. So we just gotta kinda wait-and-see what happens. We have no control over that”. A stakeholder with a public land management agency noted the following with regard to rain-on-snow events,

You know obviously we’re seeing some trends with changes in weather at different times. Flooding used to occur pretty regularly in the spring even when I first came here and now we’re seeing much more, we are seeing more flooding occurring in the fall with rains. So after we get some snowfall and then we get rain on top of that, some kind of level of warm fall flooding [follows].

Given the concern over access to the limited water resources on the Rocky Mountain Front where Choteau is located, competition for those resources has added an additional layer of turmoil. The competition over water for agricultural use, municipal use, and fishery habitat were each raised as points of conflict. This is coupled with the fact that the Teton and Sun rivers that flow from the Rocky Mountain Front are closed basins¹² and that a portion of the Teton river is currently undergoing Montana’s adjudication process with implications for water rights that potentially include increasing

¹² A closed basin is a waterway that has been declared fully or over appropriated. Such a declaration largely prevents additional water rights from being granted and developed on such a waterway.

the level of conflict and tension. This issue will be more completely discussed in the Western Water Law section of this chapter.

While agricultural uses dominated the discussion over irrigation related issues in Choteau, additional, but not unrelated concerns were also presented. These include the previously noted availability of water for fishery habitat, which was taken a step farther by some participants who voiced additional concerns related to recreational fishing and other activities that accompany it. Issues over water treatment due to yearly low flows and irrigation withdrawals was also discussed. Dewatering of Spring Creek, that runs through the town of Choteau, was a point of contention presented by several participants in the town. The role of irrigation practices on the dewatering, conflict over the veracity of this claim, and cooperation to prevent dewatering were all directly discussed. These issues will be more fully discussed in the Choteau case study in Chapter Five.

A final issue related to irrigation is one that has seemingly divided portions of the agricultural community and this is flood irrigation versus sprinkler irrigation. Proponents of both forms of irrigation presented the benefits of their chosen form of irrigation. Some noted the detriments of the other, but most were satisfied to instead discuss the benefits of one rather than demonize the other. Most stakeholders didn't choose a side but discussed the costs and benefits of each or simply the benefits of one or both. Recharge of the aquifer was the most cited benefit of flood irrigation while inefficiency of this form of irrigation was the most often presented detraction. The efficiency of sprinklers was the most often cited benefit of this form of irrigation, while the lack of aquifer recharge and the drying of wells were the most cited detriments.

Social-Ecological Responses

Throughout the interview process there were a number of overlapping responses with respect to strategies and resources for dealing with the direct and indirect impacts of climate change on the ecosystem's hydrologic regime. The categories that follow are the prominent answers that participants provided. Many were responses directly related to stressors discussed earlier in the interview process and reviewed above. Others are comments based on a more open discussion of problem-solving and not directly related to a specific stressor. Examples of both types of responses are contained in the categories below.

Resources

The importance of resource availability to the development of adaptive capacity was addressed in Chapter Two. Participants were asked about resource availability and development during the interview process and a set of common themes have emerged. Of course, the need for increased budgets and personnel to cope with the impacts of climate change on water resources in the COCE was a widely identified need, with 83% of participants discussing the issue. Unexpected issues that arose with regard to resources included the need to address infrastructure, a desire for increased research and monitoring, and the wasting of scarce natural and capital resources.

The issue of infrastructure was addressed from two very different viewpoints. The first was with regards specifically to addressing drinking water in Fernie as a result of increased turbidity from changes to the hydrologic cycle. The second venue was timber industry concerns in the Flathead Valley about the loss of infrastructure to the extent that options to utilize timber harvest as a response strategy may be precluded.

Timber industry concerns are exemplified by statements such as this, “[w]hat do you do with that [timber] when you lose the infrastructure? And if we get into a drought situation and we don’t have the mills or the infrastructure capacity to handle that wood and you have a bug epidemic like we talked about; then you can’t handle that bug epidemic”.

Turning to Choteau, infrastructure resources for the increased efficiency of water transport for irrigation were presented and discussed by participants.

Public land and resource management agencies, timber industry, and non-profit participants all noted the need for increased resources for research and monitoring. Specific examples included additional SNOTEL¹³ snowpack monitoring sites in the wilderness areas that drain to the Sun and Teton Rivers (addressed by the agriculture industry and local government), applied research for active timber management (presented by the timber industry), and long-term trend monitoring of species and abiotic resources (a concern for public land and wildlife managers, and non-profit participants). The latter was noted as a means of learning where to invest further resources on a changing landscape.

The issue of addressing wasted resources was raised by two participants from the non-profit sector. The application of fire fighting resources to fight fires in the wildland-urban interface was seen by these participants as a high cost subsidy borne by taxpayers with wealthy elites receiving the benefits. The following is an example of this thought,

it’s absolutely crazy that taxpayers in Montana, most of us that live in towns, are actually subsidizing generally wealthy people who are choosing to build homes-McMansions- out in the woods. You know they’ve got their acreage, they build their fancy homes in the woods, and we subsidize that in a variety of ways, but largely through firefighting, but also through providing other services.

¹³ SNOTEL (snow telemetry) sites are climate monitoring sites that include snow water content in their data gathering.

Fighting fire in the urban-wildland interface was a concern for a number of natural resource management agencies. One participant from these agencies noted the burden on his agency to take the same amount of fire fighting resources and make them available for longer and more intense fire seasons. Reallocation of available resources was one way that was presented as beginning to address the situation. Two additional areas of concern noted by participants is the disparity or lack of funding that reaches state and local levels to address climate change impacts and the need to develop resources for conflict resolution. Conflict resolution will be spoken to more fully in the communication and conflict subsection of this chapter.

Monitoring

A follow-up question after discussing whether or not adequate resources are available to implement current or proposed strategies was whether the current monitoring regime is sufficient for the needs of the participant and their agency/industry/constituency? There is a wide degree of disagreement on whether or not the current monitoring regime is capable of detecting changes or trends specific to the impacts that climate change is/may have on natural resources in the Crown of the Continent.

Within public land management agencies there was a wide disparity between perceptions of how well monitoring activities were performed. One agency official noted early on in an interview that the agency was very poor at monitoring, “let me start by saying we do a really poor job of monitoring,” but was contradicted by another member of the same organization in a later interview. When it was recognized that an agency did not have the internal capacity for monitoring they were quick to note their reliance on other organizations for monitoring. The U.S. Geological Survey and the Flathead Lake

Biological Station, and to a lesser extent the National Park Service were all singled out for providing monitoring data to other organizations. It is worth noting that there is concern within Glacier National Park about the efficacy and funding of their own long-term monitoring.

A concern for those agencies that believed they had or are capable of developing adequate monitoring regimes is the availability of funding to support such efforts. The lack of long-term funding to support monitoring had the impact of prioritizing what monitoring would take place. One Montana agency noted that they have the mandate and technical capacity to carry out more monitoring but lacked the funding to support such efforts.

Collaboration with regard to monitoring was presented as going beyond simply sharing data with other agencies and stakeholders. In Choteau the pooling of resources to support placement and upkeep of water and snowpack monitoring was discussed by many participants. The need for standardized data collection and a centralized repository with wide accessibility were presented as needed additions and areas for collaboration as well.

A small number of participants in public agencies and natural resource extractive industries made the distinction between the usefulness of formal monitoring protocols, such as those used for species and population monitoring, and informal monitoring. An example of informal monitoring comes from the timber industry, "The ground situation is our foresters are out there on the ground pretty much every day. So that's the kind of monitoring that we rely on is seeing it out on the ground". Several participants noted that their duties and the duties of others in the organization required extensive contact with natural resources and therefore sufficed for monitoring as such exposure provided

in-depth knowledge of the resource and changes affecting those resources. Timber industry participants noted this with regard to forest stand health, while public land officials noted the same thing with regard to range management as presented in the following quote.

How much monitoring do you need when you have a pretty good ocular observation [of] grazing? When you know the elk in this area are getting about 45 percent use we need to start looking at moving cattle. That's just an observation. So that could be considered monitoring.

There are a number of concerns that participants discussed specific to monitoring. In Choteau there is widespread concern with the lack of snowpack monitoring in wilderness headwater areas. Additionally, lack of groundwater monitoring and water quantity data were often raised, although some participants disagreed with the additional need for either. There was widespread belief among participants that monitoring of fish and wildlife was largely adequate, although increased monitoring with regard to non-game species would be an area for improvement. Monitoring of threatened or endangered species with low densities were also a concern; both the lynx and wolverine were specifically mentioned in this context. At times monitoring of species was discussed irrespective of the issue of climate change, but many times the implication of climate change begat the discussion related to the need for improved monitoring.

Indicators

When participants were asked what an indicator of success to grappling with climate change would be, the responses were widespread and varied with limited overlap. By far the most common answer was an uncertainty of what this type of indicator would look like. The below responses are mostly individual in nature and there is very little overlap. In instances where there was agreement between participants on indicators it is noted.

Skepticism of climate change and its cause was a major point of discussion with regard to an indicator. The acknowledgement of climate change and its impacts by the community and the larger region were presented as an indicator of success by one participant. Letters to the editor with regard to addressing the issue were presented as indicators of an increasing ability to grapple with the issue by another participant.

To multiple participants the ability to begin to address the symptoms of climate change's impacts on the hydrologic regime, such as drought and water availability, were an indicator of increasing success. Proactively addressing development issues in both floodplains and the wildland-urban interface were offered as another indicator. A non-profit stakeholder presented the following as an indicator related to successfully grappling with the challenges of climate change.

So a good indicator would be if the appropriate agencies say we have to recognize that the 500 year floodplain may be what becomes, maybe what we used to think of as a 500 year event, maybe that [becomes a] 50 year event. So we need to adjust our floodplain designations to discourage growth or prohibit growth in these active floodplains.

An indicator that was shared by many, but rarely in the same context was that of collaboration. The ability of diverse stakeholders and constituencies to come to the table to discuss climate change related issues was presented by participants in both the non-profit and local government sectors as a potential indicator. The critical level of involvement differed among participants with some saying simply getting people to the table in and of itself would be a success, while other stated that it would require proactive planning outcomes in order to qualify as an indicator of success. Additional indicators presented include the development of a community energy program and full access to needed water for irrigation.

Capacity Building

Building capacity in order to address the impacts of climate change was understood to be nascent in the region, but nonetheless recognized as a needed response to the issue.

Capacity building was largely addressed by participants through the lens of government activities, programs, and policies. While largely negative in their responses, interviewees did provide limited positive examples of capacity building.

The lack of capacity to address the impacts of climate change on water resources included blunt statements to that effect in addition to examples of shortcomings. “I mean they’ve had a couple of workshops in the state that [we] were invited to and that you know they did present some of the data and talk about [climate change]. But really, formally, as an agency we seem to be behind the ball on this”.

Lacking of staff and funding mechanisms were commonly noted, while others built on the lack of monitoring capacity of government agencies as evidence of limited capacity. “I would say that we’ve been fairly successful with research, fairly successful with experimental management but, what’s really of concern is the long-term ability to sustain those type of efforts and monitor their success”. The preceding quote was from a member of a public land management agency favorably looked on and regarded by other agencies with regard to their monitoring capacity.

Some participants noted that limited capacity to take in and analyze the increasing volumes of data were becoming a problem. A participant from a federal land management agency noted the following,

...there’s an expectation that we’re going to do all this and analyze all this information but the capacity isn’t there... if you’re wanting a fairly science-based response you need scientists! It just worries me, that the capacity at the field level is the thing I worry about.

Moving from data collection and decision-making to implementation of policies to deal with climate change impacts resulting in an “implementation gap” was seen as an area of concern which is evidenced in the following quote by a local government official from Choteau,

It’s kind of like the Crown Managers Partnership, those folks have a lot of conversations about what they do and yet I think they are stymied by the same problems. A lot of them will get together, they’ll analyze the situation, come up with a potential solution but that’s where it sort of seems to stop. The solutions don’t really seem to trickle down.

Uncertainty relative to directional changes associated with climate change was a source of confusion and difficulty for some organizations. A participant in public land management noted that lack of a “response toolbox” with regard to climate change impacts was a continuing frustration and source of uncertainty.

Non-profit participants, while noting the lack of capacity of government institutions to cope with the effects of climate change, offered that private organizations may be an avenue through which capacity building is addressed in the Crown of the Continent. Two non-profit sector participants presented private foundations as a means of receiving resources to develop capacity to deal with climate related impacts. It was unclear whether or not those resources would be retained in the private sector or furnished as a means of augmenting government agency resources.

While issues such as a lack of research capacity within an agency were causes for concern, not all agencies perceived themselves as being hindered by a lack of capacity to deal with climate change related issues specific to their mandate. Montana Fish, Wildlife, and Parks noted their ability and expertise in being able to address issues specific to fish, wildlife, and habitat management, although there was an admitted lack of

funding for increased personnel to capitalize on this ability. Nonetheless, there has been an internal reorganization of programs and staffing to address climate change related concerns within the department that was noted by participants.

A highlight of capacity building in the Crown of the Continent was a scenario planning workshop sponsored by Glacier National Park. Numerous participants noted either their attendance, intended attendance, or knowledge of the workshop. Interviewees provided details on webinars that took place prior to the workshop in order to facilitate an in-depth experience between participants who attended the workshop. There was disappointment from some participants at the lack of “buy in” by other agencies and organizations with regard to the program. Nevertheless, the workshop demonstrates a means of substantively increasing knowledge and capacity within and among participating organizations.

The final aspect of capacity building to be addressed is related to collaborative organizations. Two organizations came to the forefront as examples of collaboration between levels of government and stakeholders 1) the Flathead Lake Basin Commission¹⁴ and 2) the Crown Manager’s Partnership¹⁵. Each has issues respective to their mandate with regards to their capacity to address climate change as noted by participants. For the Basin Commission one interviewee detailed a failed attempt at conducting operational level activities. Now the organization serves as a facilitator of local entity capacity development. The Crown Manager’s Partnership is hindered by the lack of dedicated

¹⁴ The Flathead Basin Commission is a regional volunteer organization focused on addressing issues affecting the Flathead Lake and its tributaries. For more information see the organization’s website at <http://flatheadbasincommission.org/>.

¹⁵ The Crown Managers Partnership is a trans-boundary volunteer, collaborative organization of federal public land, state, and local government agencies focused on addressing transboundary natural resource issues in the COCE. For more information see the organization’s website at <http://www.crownmanagers.org/>.

personnel and the need to add additional duties related to Partnership activities to the workload of member agency personnel, severely limiting the capacity of the CMP to address climate change (or other natural resource related issues) at a broader scale and with greater efficacy.

Resilience

The concept of resilience was raised by participants in all three case study communities. The concept was discussed specific to ecology, economics, and the linkage between ecological processes and economic sustainability. The latter discussion was undertaken by participants in the timber and agriculture industries.

When discussing ecologic resilience the conversation tended to focus on an uncertainty of how to manage for resilience. Questions that arose from these conversations included what metrics exist to measure resilience? How can such metrics be applied to public land management? How do you monitor for resilience? Timber industry participants noted the benefit of managing stands for diversity which provides dividends in increased resilience. One public land manager wondered whether a shift to managing for resilience would replace a restoration management paradigm as well as what role historic variability would continue to play under such a management paradigm if such came to pass?

When discussing the linkages between ecological and economic resilience there was an apparent appreciation of how degraded ecological resilience could impact economic productivity in both the agriculture, timber, and tourism industries. With regard to the timber industry there was a feeling that the loss of industry infrastructure was reaching a tipping point with regard to the industry's responsiveness in the event of a

large-scale ecological disturbance. Quotes from two different participants in the industry demonstrate the interconnections between ecological phenomena and economics as well as the role of a declining infrastructure. The first quote speaks to the loss of a mill located in Frenchtown, Montana. "...now the forest products industry is at a tipping point, a critical point right now. The loss of Smurfit-Stone was a big blow to us", while another timber industry participant went on to say,

If you have no place to sell your logs and no place to make money and then you don't want to invest money into the land, then you couldn't take care of that epidemic caused by the drought. And we're at that point now where I think, at least in western Montana, where we are at that tipping point where if we lose another mill or two...

The interrelated issues of fire, forest disease, and insect outbreak were viewed as impacting the resilience of the sub-region and the larger ecosystem by participants across multiple sectors.

Communication & Conflict

Participants provided commentary across industry and agency boundaries regarding the need for effective communication in addressing the issues they chose to discuss in relation to climate change. Some participants spoke broadly about the role of communication in education and conflict resolution while other provided specific examples of (in)effective communications strategies, while many went on to provide suggestions for improvement. One suggestion for improvement came from a local elected official in Choteau, "we need some conflict resolution folks or somebody needs to say 'have you thought about what would happen if'... and hopefully people would start kind of thinking that one through".

Conflict can result from misperceptions as well as differing worldviews and values. While poor or faulty communication does not necessarily result in conflict, conflict is often a result of the discourse on natural resource issues. The role communication plays in addressing water resource impacts from climate change is not exempt from the already tense discussions that often accompany water related issues in the semi-arid region. In these areas conflict, as a response to climate change related impacts, is as important as any other aspect of communication and will be addressed directly following.

Beginning broadly, multiple participants discussed the subject of climate change within the broader public discourse. One participant noted that skepticism of climate change has grown inversely of increased scientific certainty on the subject. Another participant discussed how individual perspectives within their agency affects the manner in which the agency then deals with the public on the issue. The same participant continued by saying that the agency itself contained a broad spectrum of opinions on climate change.

Many participants spoke to the need for open dialogue that builds trust, while others noted that communication builds trust, but that communication over the issue had yet to rise to levels of trust building. Misperceptions were a key aspect of communication for many. In Choteau a participant expressed this attitude while going on to note that there is common ground to be found through communication, "...and so much of [the discussions] initially involved mistrust and misinformation and to some extent I think we're almost getting beyond that point now, where I mean I think I've

developed some pretty trusting relationships with some of the irrigators which is a great starting point”.

Numerous participants noted during interviews that they believed their organization did an adequate or very good job of communication, meanwhile other participants directly challenged these assertions. This type of disparity was most strongly associated with public land management agencies where staff believed they had done a good job of speaking to the public, but public perception as provided by participants of this study, were vocal in their disagreement. An example of this disparity comes first from a Forest Service employee, “And even in times of emergencies, like the fire events, we even have complaints from people sometimes because they get so much information they finally say, ‘you know, enough just call me once a week’ and we’ve got that reputation for doing that”. While during informal discussions numerous stakeholders in the community noted the lack of communication with the Forest Service in the region from which the above quote came from. A noted exception to this type of dynamic was the Park Service’s interpretive program that includes a discussion of climate change. Participants within the agency and beyond highly praised the program.

Misinformation and poor communication were both noted as poisoning relationships as well as fostering conflict. Agricultural stakeholders discussed misperceptions related to agriculture such as a belief that members of the agriculture community were rich, were welfare ranchers, and that family farms reflect a pastoral vision that no longer exists, if it ever did. Going along with these perceived misperceptions about agriculture was a belief that adequate education of American consumers about the realities of agriculture in this country, not just specifically the

region, would help to address not only misperceptions, but many of the difficulties associated with a career in agriculture.

A number of specific communication improvements were put forward by participants with regard to coping with climate change and its impacts. A participant in local government in the COCE noted with regard to the Crown Managers Partnership that, while supportive of the collaborative organization's activities, the organization needs to better communicate its goals, objectives, and activities to increase involvement at lower levels of government while building bridges with other sectors of society. Letters to the editor were proposed as a means of demonstrating both increased understanding of climate change and the ability to address the subject and the continuing skepticism over the topic that continues to foster conflict. One interviewee very candidly proposed that it is possible to speak to climate change without mentioning the term by seeking to address the symptoms that climate change produces. The key to this statement being that climate change is and can be a polarizing issue that in and of itself can hinder positive communication and outcomes.

When participants spoke about conflict there was a single issue which overshadowed all others - water. Water has served as the backdrop against which different user groups and stakeholders have divided themselves. The perception (or realized) scarcity of water is a catalyst for conflict. This has focused the discussion squarely among stakeholders I spoke with in Choteau, although stakeholders in the other two case study communities did note potential future scarcity along a number of lines and with differing impacts. The majority of stakeholders that chose to address the issue were focused in Choteau reflecting the region's water scarcity.

It was noted earlier in the irrigation section that water is scarce and competition for it furious. Conflict between agricultural users, recreational users, municipal users, and fish & wildlife advocates and managers were detailed by interviewees. Conflict over water resources and the use of water has led some to avoid conflict by dodging discussion of the subject in various forums. Two participants noted the need for conflict resolution resources to be brought to bear in order to address conflicts over water.

Given the current levels of conflict in the region with regard to water, participants presented additional concerns that could possibly increase the level of conflict. The drilling of water wells that are exempt under current Montana statute from regulation restrictions has raised the ire of participants from all sectors in Choteau. Additionally, these wells are seen as a means of infringing upon established water rights. Increased monitoring of snowpack, surface, and groundwater could potentially lead to increased conflict from two avenues. The first is the perception that increased monitoring could be used as leverage against particular users to the detriment of their water rights. The second is that data could identify trends challenging the status quo of water resource usage in the region.

Collaboration

The need to address natural resource related issues and more specifically the impacts of climate change on water resources through collaborative efforts, was a theme addressed by nearly all participants. Many participants volunteered observations on the need for collaboration on natural resource related efforts while others responded to a direct semi-structured interview question on the topic. No matter the method of opening the

discussion, participants noted the need in the Crown of the Continent for increased collaboration when dealing with climate change and its impacts.

A number of themes arose through the interview process with regard to collaboration: multi-level coordination, coordination on research, bringing people to the table, and utilizing existing collaborative efforts as vehicles for further collaboration were all common topics. Each of the four areas will be discussed in the paragraphs below.

Seventy-four percent of interviewees spoke to the need to collaborate in order to address large-scale impacts of climate change that will be either multi-agency and/or multi-sectoral with regard to jurisdiction and management. The multi-level governance arrangements of the Crown of the Continent will require that efforts to address impacts to water resources as a result of climate change, will be best addressed through a collaborative effort. It was noted during at least one interview that collaboration doesn't necessarily mean consensus and among participants there was uncertainty with regards to how decision-making should or would occur through collaborative efforts.

An effective avenue for collaboration in the eyes of many participants, especially public land and timber industry interviewees, was with regard to research. During the interview process participants volunteered accounts of successful collaboration on research, but nevertheless pressed the activity as an avenue through which collaboration would continue to bear fruit and could make gains if increased participation was undertaken. In addition to research, monitoring was seen as a means of providing broad benefits through collaboration. Stakeholders in Choteau pointed to the pooling of resources to maintain streamflow gauges as proof of positive outcomes from collaboration.

The need to conduct outreach and bring individuals and groups of stakeholders to the table was a common theme on the topic of collaboration. “So just plain sitting down to the table now instead of when matters get even worse is one item, one tool,” as was noted by a non-profit stakeholder active in Choteau. There was a sense among some participants that bringing people to the table would, at the least, reduce the level of conflict over natural resource management, although not all participants agreed with this assertion.

While there are a number forums on natural resource management in the COCE, there was a sense among many participants that critical stakeholders (some participants claiming themselves as evidence) were not being invited to the table. Additionally, there was a sense that a disparity exists with regard to engagement of stakeholders between the east and west side of the Continental Divide. This concern was raised by stakeholders on the east side of the Divide.

Given the number of groups and forums available for discussing, debating, and addressing natural resource management, to include the impacts of climate change, the success of many of the groups was noted throughout the interview process.

Organizations such as the Blackfoot Challenge, the Crown Roundtable, the Columbia Basin Trust, the Crown Managers Partnership, the Flathead Lake Basin Commission, local conservation districts, and watershed councils all served as participant examples through which successful results were produced. Utilizing the vehicles that already exist to further develop and refine collaboration were often proposed. Ideas such as developing memorandums of understanding to frame formal organizational requirements and duties were presented and discussed. Examples of successful collaborations included

fuel reductions in the wildland-urban interface and an ecosystem-wide invasive weed identification guide. One specific program that was raised time and again was the newly established Landscape Conservation Cooperative (LCC) lead by the U.S. Fish and Wildlife Service. LCCs are a public-private initiative that seek to span political boundaries. As currently conceived there are twenty-one LCCs; the Crown of the Continent falls within the Great Northern Landscape Conservation Cooperative. Of note is that in an effort to transcend political boundaries, the administrative boundaries of LCCs extend beyond even national borders both north and south of the U.S. Excitement mixed with uncertainty around the nascent program, its resources, capabilities, and mandate were expressed by numerous participants.

Specific examples of barriers to collaboration were raised by participants. The burden on government agencies was a widely cited concern. A local government official noted, "... I also believe that given a world with DEQ [Montana Department of Environmental Quality] or without DEQ, I would rather have DEQ. But I think sometimes those organizations are understaffed and their direction is not necessarily... [aligned with the needs of communities],” .

At the state and federal level, placing greater burdens on employees was cited as a cause for concern, while it was noted that most local government officials acted in their capacity as part-time government agents and attending conferences and meetings placed additional burdens on them. The same local government official in the preceding paragraph had this to say with regards to the challenges of being a part-time government official,

Because you find that the folks at the agencies or the organizations go to[all] the meetings but the local council people typically are, you know, we get paid 150

bucks a month, but its primarily a volunteer situation. Most everybody else has another job and they can't take the time off to go to those meetings.

Finally, a diverse set of participants from varied backgrounds expressed concern about the need for public land managers to be personally committed to collaborative efforts in order to produce positive outcomes. One public land manager in particular noted this and then went on to claim his disdain for such activities demonstrating the effectiveness of such a barrier.

Strategies

This final subsection of social-ecological response categories is a review of participant proposed strategies for dealing with the climate related stressors presented earlier in this chapter and highlighted in the first column of Table 4-1. Discussions of strategies were facilitated by a direct question posed to each semi-structured interview participant about the topic. The results are strategies in the context of the stressors discussed by specific interviewees. This has created a disparity with regard to the scope and depth of strategies by stressor.

The depth and breadth of the following discussions of strategies does not speak well to the level of concern related to each. In many cases, such as fire, long established, tested, and refined policies and management strategies as well as research has allowed participants to speak more broadly about the issue. Higher levels of uncertainty with regard to issues such as coping with changes to the hydrologic cycle, while of no less concern, do not have such broad understanding, adequate models, or predictions to allow for a more detailed discussion. Nevertheless, participants did provide thoughtful responses to the many stressors addressed in the interview process and proceeded to provide strategies where possible.

The remainder of this subsection will be broken down by participant identified indicators of climate related stressors. Strategies for the three subsections of fire, forest disease, and insect infestation were viewed as overlapping and interrelated just as the direct and indirect impacts of the three were often viewed as interrelated with their impacts on social and ecological components of the COCE. Given this interrelationship, the three are addressed under a single heading following drought and the hydrologic cycle. The case could of course be made, as it often was by participants, that fire, insect infestation, and forest disease were impacted by and produced feedbacks related to drought and the hydrologic cycle. The latter two categories while undoubtedly related to each of the aforementioned, was largely addressed separately by participants and thus allows for a useful if somewhat arbitrary division for the purposes of presenting the outcomes of this research.

Hydrologic Cycle- Strategies proposed for coping with changes to the hydrologic cycle encompassed dealing with both water quality and water quantity issues. Examples of strategies related to both issues are contained in the paragraphs that follow.

In order to address water quality issues the town of Fernie has undertaken development of a new municipal water supply as a result of increasing turbidity in their current water supply. Timber management for water quality was addressed by timber industry participants in both Kalispell and Fernie with ideas ranging from creating variable width riparian buffers to managing entire forest stands explicitly for community water supplies. Managing water quality through riparian protection and restoration, and the preclusion of dam building were proposed by a non-profit participant.

Addressing water consumption through changes to existing water law and the development of incentives for conservation and water sharing were strategies put forth by non-profit participants. Finally, to return to the idea of timber management for water resources, changes in the amount and type of timber harvest that could be used to manage for domestic water supplies and community watersheds was a strategy put forth by a timber industry participant who noted that such efforts had been ongoing for quite some time. An example of managing timber resources for water supplies was discussed by a participant from Fernie,

Secondarily, are things like water and if it affects water, because we manage very carefully for domestic water supplies and community watersheds. We've got like specific regulations for harvesting in those areas and if water is drying up we have to think carefully about how that might affect what sort of forest management strategies we would apply within the drainage. And it might change or limit the amount [of timber] that we could harvest.

Drought- Coping with the impacts of drought was the concern most widely discussed by participants on the Rocky Mountain Front, which encompasses the case study community of Choteau. Agricultural producers, as noted by a member of the industry, have long established strategies for coping with drought in the region that include rotating crops and rotating fields through a fallow period for dry land farming. Irrigation-based farming strategies include the rationing of irrigation water in times of over demand or low supply. This particular strategy was presented by agricultural producers and water managers alike. There appears to be a disparity between dry land and irrigated land producers and the potential impacts of drought on their productivity. This is an area that likely requires further exploration and may serve as a venue for additional research.

Putting in place a system that spreads the impacts of reduced water availability across a wide swath of the community was proposed by a non-profit interviewee in Choteau,

...there will be [water] short years. Coming to an agreement when a short year comes that we all find palatable [to include] solutions to sharing the loss, sharing in the severity of what's happening to us. So taking advantage of when we are flush with water and finding ways to deal with [the situation] from a positive way and also finding ways to be positive when we're short of water.

It is of interest to note that a presenter at the 2010 annual Crown Managers Partnership, Dr. Stewart Rood of the University of Lethbridge, detailed just such a proposal that was put into practice in 2001 on the St. Mary, Belly, and Waterton Rivers in Canada when it was determined that it was likely that the snowpack from that year would be unable to satisfy all water rights holders on those rivers. Dr. Rood detailed a program he referred to as "spreading the shortage" and presented a means through which the burden of lack of water availability was distributed widely as each water right holder received only 60% of their allotted share. He went on to note that the Canada Water Act allowed for this flexible policy approach.

Finally, with regard to the impacts of drought on timber management, participants from the timber industry noted that management for species and stand diversity as well as planting drought tolerant species were practices in place to cope, at least partially, with the impacts of drought.

Fire, Insect Infestation and Forest Disease- Managing fire on a changing landscape has produced diverse strategies, many steeped in past management policy and strategies, although there are nascent examples of adjustments to changing circumstances and uncertainty. Many of the strategies presented in the paragraphs that follow are part

of standard operating procedures associated with timber harvest. A germane question exists as to whether or not this rudimentary set of tools can be leveraged as viable future methods for addressing fire as climate change continues to reshape the landscape.

In the view of participants in public land management, timber industry, and the agriculture industry, reducing the occurrence of fire is a historical strategy that will continue to remain viable in the face of climate change. Ongoing strategies offered by these participants in order to limit fire and its impacts include conducting prescribed burns, slash management from timber harvest, pre-commercial timber thinning, maintaining an adequate road network for fire response, and timber harvest in promotion of fire reduction. The harvest of trees and stands impacted by forest disease and insect infestation were a priority for both public land managers and the timber industry. For public land managers timber removal reduced fire vulnerability and increased public safety while infected and infested trees serve as a ready source of marketable timber for the timber industry.

Strategies for dealing with an active fire on the landscape included maintaining a fire watch and invocation and enforcement of harvest and forest access restrictions. For the timber industry strategies for dealing with an active fire season included the stockpiling of timber inventories prior to the start of fire season. Fire season restrictions on the timber industry include reduce harvest activity and hoot owl restrictions, which are restrictions that limits timber harvest to cooler hours of the day with a large portion taking place during hours of darkness. A timber industry participant noted that hoot owl restrictions allowed for the freeing up of personnel and equipment for fire fighting. Voluntary restrictions have also been developed and implemented by timber companies

during particularly severe fire seasons resulting in voluntary shutdowns by timber companies. An excellent example of the implications of fire, voluntary restrictions, and reallocation of timber industry resources was described by a member of the timber industry,

Well when you go into hoot owl it kind of limits our production somewhat. We don't get as many logs into the mill so we try to build our inventories, our log inventories at our mills a little bit, so in case we go into hoot owl and there's limited production they can keep on running. The next thing that happens, is that [the Forest Service] could totally shut the woods down. And so they wouldn't want us working at all. A few years ago we voluntarily... shut ourselves down out of the woods. We did that for about four or five weeks. We just shut ourselves down, they didn't want us to do that, there's a lot of economic impact when we shut ourselves down. We shut ourselves down voluntarily because we felt the liability, the risk, was too high and it was just too dry out there. And what it did do, then too, it freed up a lot of those guys to go fight fire.

Reintroduction of fire to the landscape as well as the patchiness created by contemporary fire management provides land managers with a greater set of tools for fire management on a changing landscape. The use of prescribed fire as a management tool was noted by participants in all three communities. Salvage logging and the development of defensible and survivable space were also presented as additional strategies for coping with fire. The following quote comes from a member of the Forest Service describing an application of defensible space,

And so we are trying to take actions where we're trying to create what we are calling survivable space, defensible space right around the cabin that you can remove flammable material so that a fire's passage doesn't end up smoldering and burning down a cabin for example. We're trying to prevent, not prevent, we're try to create survivable space where we have a larger area that maybe would reduce the intensity of that fire coming through and then your defensible space would protect the cabin.

Insect infestation and forest disease are both understood as processes endemic to the forested regions of the Crown of the Continent Ecosystem. Nevertheless, managing

the two influences on fire are a concern for public land managers, the timber industry, and local government officials to name just a few, as a result of the interactions and feedbacks between fire, forest disease, and insect infestation. Strategies for the management of insect infestation in addition to detection and harvest include the use of chemical treatments, pheromone packets that mimic infestation of individual trees, and managing for individual tree and stand health. The underlying assumption of the latter strategy is that natural defense mechanisms are bolstered by actively managing for species and age class diversity. Finally, disease resistant strains of tree species are being developed such as blister rust resistant strains. One concern with this strategy is that there is a focus on commercial species and that species like the whitebark pine do not receive adequate attention for the development of disease resistant seedlings even though it has been identified as a keystone species¹⁶ in both the COCE and the Greater Yellowstone Ecosystem and may be in danger of extinction.

Ecological Stressors- Recognized, perceived, and projected impacts to ecological processes from climate change has led to the proposal of numerous strategies, with an explicit understanding among participants of the need for flexibility. Broad strategies for addressing ecological impacts included generic propositions such as the establishment of wilderness in areas that enhance natural resource protection as well as the more focused strategies that follow.

Maintaining corridors for the movement and migration of both wildlife and plants by addressing dispersal barriers and protecting intact corridors were presented by

¹⁶ Originally conceived as a predator species that increases community diversity as a result of predatory activity by Paine (1966), the concept of keystone species has been expanded to account for any species whose removal from the community would produce disproportionate disturbance and simplification of the community as a result.

participants both inside and outside public land management. A member of the British Columbia timber industry had the following to say about species migration and dispersal with regard to the industry's role,

You know in my perspective it's just making sure that we identify some of these key habitats, key passes for wildlife especially in the mountains to move through. And for plants, things like that, sort of move up elevation, that we've got areas that aren't crisscrossed with roads you know that might act as dispersal barriers.

Identifying key habitats both currently recognized and projected within landscape shifts is a challenge that needs to be addressed. Another key is not foreclosing options by undertaking activities on the landscape that ultimately limit future actions. Managing forests for water resource benefits and diversity were both addressed in earlier sections, but are worth noting here again as a strategy. Protecting headwater and riparian areas were proposed as a means of addressing the uncertain impacts of climate change on the landscape.

Strategies specific to endangered species were offered in addition to the more general strategies in the above paragraphs. Developing pre-endangered species listing protection for species in peril is something that some public land management agency participants noted would provide much needed flexibility before a species is placed on the Endangered Species List.

With regard to aquatic endangered species, existing strategies include removing and suppressing invasive species like the lake trout through gill netting that which takes place in Flathead Lake and other water bodies throughout the region where stocked species often outcompete natives. For the bull trout, listed as threatened under the Endangered Species Act, strategies include translocation around barriers and

reestablishing connectivity between population segments. These actions have been addressed through dam removal and the development of fish ladders. Establishing policies that manage for population migration and connectivity was one means presented of addressing uncertainty related to climate change and endangered species management. Of course, as noted earlier in the chapter, this requires research to determine where to apply resources to maintain and reconnect habitat. This becomes even more germane if climate change further fragments habitat. Like terrestrial species, managing harvest of aquatic endangered species either intentional or incidental, must be addressed. For the bull trout a punch card system has been established that allows anglers, on certain water in Montana, to catch and keep two bull trout a year. On Swan Lake anglers may take one bull trout per day. Given the usual restrictions on purposeful harvest of threatened and endangered species this is a fairly novel approach to management. The permitted taking is justified in Montana's bull trout fishing regulations as a means of increasing public support for habitat improvements and projects that expand the species range and overall numbers.

Irrigation- The central role of irrigation relative to the success of a large segment of agricultural producers in Choteau was noted in the discussion of irrigation under climate related stressors earlier in the chapter. Strategies to deal with the impacts climate change may have on water availability and therefore, on irrigation, are fairly narrow in scope. Improving water management by increasing the number of SNOTEL sites and placing them in wilderness areas has already been presented. Conservation and increasing efficiency through infrastructure improvements that include both canals and enlarging or building new reservoirs were discussed by participants.

In Fairfield, a neighbor of Choteau on the Rocky Mountain Front, agricultural producers are taxed for their access to irrigation water. These taxes provide access to 2-acre feet of water during the irrigation season- if enough water is available to provide for that amount. There is no prorating in the event that producers cannot receive their full allotment. Rationing in years when there is limited availability is a strategy that has been applied and by all appearances will continue. Rationing of water is described in the following quote by a participant involved in managing irrigation water on the Rocky Mountain Front,

It happens almost every year. Sometimes it might only be for a few days, some years it might be for a week or two if it's really hot and dry and everybody planted at the exact same time and they all want to irrigate at the exact same time we fill our canals as full as we can and if it doesn't meet the demand than we ration, we cut everybody down a little bit.

A final strategy is related to the over allocation of water resources through the adjudication of water rights in a basin-by-basin approach mandated by the state of Montana. Adjudication will be more fully discussed later in the chapter along with a discussion of Western Water Law.

System States and Social Institutions

The third and final theme is related to the third research question. It has become obvious that as stated and as addressed in Chapter Three that research question three is too broad to answer with the data gathering mechanisms in the timeframe envisioned for this research. Therefore it is imperative to address this shortcoming. A means to accomplishing this was through narrowing down the question by placing parameters on it that allow the question to then be engaged through the data collected and analyzed.

One means of understanding social-ecological change is through system states and institutions that influence, or are influenced by, natural resource policy and decision-making as was demonstrated in Chapter Two. The categories that follow are three system states and institutions that are found in the Crown of the Continent Ecosystem, as well as throughout the broader Intermountain West. Each category has been identified and discussed by semi-structured interview participants in a substantive manner that addresses how the state or institution impacts natural resources in the ecosystem.

Social-ecological Linkages

At first blush it may appear oxymoronic to have a category under a theme that holds the same title as a previous theme. The purpose of this category is a much more refined category that speaks, not broadly to social-ecological responses as the earlier sections of this chapter, but rather to focus on the interconnections between natural resource and social well-being identified by participants. This section will present social-ecological linkages as seen from the viewpoint of interviewees. This overall context lays the foundation for the system states and institutions to be discussed below.

Participants in all three communities identified social and economic health as being tied to natural resource management within the ecosystem. Among participants in the three communities, perspectives varied with overwhelming and not unexpected responses related to the agriculture and tourism sectors. In Choteau there was a highly developed and respected understanding among all interviewees that the agriculture sector supported the community and that the agriculture sector requires access to water in order to maintain itself. A local government official poignantly described the relationship like this,

So we've been living with [drought] and existing with it. And last year is probably the first year that the drought broke; not as far as severe as it had been eight or nine years previous. It impacts us a lot because we are an agricultural community and if we don't get rain, then the dry land crops don't produce. If the dry land crops don't produce then the farmers and ranchers that rely on those lands for a living don't make a living, they don't spend any money here and we all suffer. And so yeah, you know, the biggest part of our economy in a small town like this, in Choteau, is agriculture. And we're very dependent on them being successful for our success.

Snowpack, snow melt, spring runoff, timely rains, and irrigation season were common themes when interviewees were speaking to agriculture. The linkages between water availability and social and economic health are well entrenched and as noted earlier, serve as a source of conflict due to the limited nature of the resource. In Choteau, agricultural losses and the impacts on the larger community are still within social memory and likely serve as a benchmark for such considerations.

While agriculture exists in both Kalispell and Fernie, discussion about social-ecological linkages tended to focus more on the tourism and recreation sectors for these two communities. One participant posited that the economy of the Flathead Valley is directly tied to maintaining natural resources in a state that brings people to the region as demonstrated in the following quote,

We know we have something that's unique for the tourism industry. There is growing demand for places that haven't been spoiled, places that don't look like everywhere else. That is our competitive advantage. With climate change that's going to become even more true. And so conservation of our natural resources is going to be critical.

Given the bi-national nature of the ecosystem participants noted the need for international cooperation in addressing social-ecological linkages.

Notwithstanding the two expected responses to social-ecological linkages identified in the agriculture and tourism industry of the ecosystem, there were a number

of additional responses that merit discussion. The first is the extension of what has been termed the “shoulder season” or the expansion of mild weather during a year that facilitates activities that would have otherwise been precluded by inclement weather, typically in winter. Participants in each community saw opportunity in the form of an expended shoulder season whether it be in the form of longer ski seasons, considered in both Kalispell and Fernie; additional hunting & fishing recreation seasons and opportunities as explored by numerous participants in Choteau; or the improved harvest of crops either agricultural or timber, potentially offered by longer seasons posited by stakeholders in all three communities.

The role of forest management in community watershed quality and quantity was raised multiple times by timber industry participants. Included in these discussions were fears related to the loss of timber industry infrastructure with secondary impacts on the industry’s ability to respond to ecological disturbance through harvest. Global influences on the local demand and therefore supply of timber and the secondary and tertiary impacts on local economies were additionally noted by participants. This all leads back to uncertainty within the industry with regards to the industry’s ability to respond in the future to community concerns about water supplies.

A final social-ecological linkage that was addressed in both Kalispell and Choteau among participants from diverse sectors was fisheries. In Choteau increasing fishing and recreation opportunities related to fishing (to include camping, picnicking, etc.) were offered as a potentially viable means of diversifying the economy. In Kalispell the loss of bull trout in Flathead Lake and its tributaries to the non-native lake trout was also seen in economic terms, but not necessarily along the same lines. Participants questioned

whether revenue generated from sport fishing recreation for the non-native lake trout would outweigh the ecological and possible economic losses from local extinction of native bull trout. As this research was undertaken a debate was being played out in the Flathead Valley with regard to both bull trout and lake trout management as the U.S. Fish and Wildlife Service was revisiting the bull trout's critical habitat designation by court order. Concurrently the ten year Flathead Lake and Rivers management strategy between the state of Montana and the Confederated Salish and Kootenai Tribes was being reviewed and updated. The debate surrounding both were actively being played out in the local and state news media. Uncertainty with regard to the impacts of climate change on the bull trout's tenuous grip likely provides an additional difficulty in crafting long-term policy. Finally, climate change provides increasing uncertainty as to how both native and non-native species will respond to its impacts and whether the future management strategy will remain viable as climate change increases stress on the native species in Flathead Lake and its tributaries.

Western Water Law

Western Water Law is an institution as entrenched in myth as much as it is the annals of the legal system. The role of water rights, property in the form of water access, were addressed in Choteau and Kalispell, but to a much lesser extent in the latter. In Kalispell discussions about water rights were cursory at best. This may be the result of what one participant posited as the sub-region being "drought adverse" as a reflection of the large amount of water availability in the ecosystem west of the Continental Divide. The one extended discussion that was held in Kalispell on water rights was with respects to the restrictions water rights would likely place on snow-making for the local ski industry.

In Choteau the agriculture industry and a broad swath of the larger community view the world through a lens colored by the terminology and impacts of the institution of Western Water Law. At the very top of the vernacular was water rights and the role it played in serving as a constraint on agricultural and economic productivity that was perceived to trump that of physical water availability.

Participants saw water rights and the limits that they place on the taking or diversion of water from a natural water body as both an investment and a barrier. This dichotomy is demonstrated in the way in which numerous participants proposed expanding irrigation infrastructure through the construction of new or expansion of existing reservoirs, canals, or ditches, only to then exclaim how senior water right holders rights likely would prevent such activities. It is worth noting that with regard to the preceding sentence that participants were willing to speak to the subject off the record, but not during the formal interview process. Improvement activities were viewed as a means of enhancing the water rights of existing users. Oppositely, the protections of access to water available through water rights were used as a means to prevent other uses. Fishery habitat was a distinct point of contention in this context.

Four interviewees in Choteau spoke of Spring Creek, a small stream that runs through town, and its importance to the community as a place for recreation and social gathering. The same participants also noted that Spring Creek had often been dewatered, sometimes for many years, prior to when this research took place. Dewatering of Spring Creek had led to conflict between some town residents and some in the agriculture community. The legal recourse through which water right holders may dewater entire waterways in order to satisfy their held water rights was a shock to many and led to

conflict and misinformation. An additional point of contestation, as stated from multiple sources, was the connection through groundwater of Spring Creek and the Teton River. Interviewees acknowledged that an agreement was reached with regard to Spring Creek and maintaining water in it, at least temporarily.

The dewatering of waterways and the negative impacts on aquatic systems has produced two distinct responses within the Western Water Law institution for the study area. The first is a stream flow reservation by the state of Montana on the Teton River established in 1985. But as one interviewee noted, the water right is so junior¹⁷ that its greatest impact is providing a seat at the table for water rights discussions. Nonetheless, it was describe as precedent setting by the same participant. The second approach is water leasing¹⁸, a strategy tightly controlled by the Montana legislature.

The second word in the vernacular of Western Water Law that was most prominent throughout this research was “adjudication”. In Montana this is the process whereby water right claims and challenges are addressed on a watershed-by-watershed basis in the legal system. The end state produces an outcome known as a decree. A decree is issued by the Montana Water Court after the Montana Department of Natural Resource Conservation completes a review of all water rights in a basin. The adjudication process serves a two-fold function. The first is a means of bringing to resolution disputes over water rights. The second, is to quantify the total water rights

¹⁷ Water rights follow a “first in time, first in right” paradigm whereby the entity with the oldest water right may satisfy their entire claim before those who possess water rights later in time may begin to satisfy their claim. This becomes important in years of shortage when not all water rights can be honored and allows those with the oldest claims (senior) to receive their full share before those with more recent water right claims (junior).

¹⁸ Following on previous Montana legislatively established programs, water leasing provides the Department of Fish, Wildlife, and Parks a means of acquiring access to in-stream water for purposes other than extractive use. The water leasing program was established in 1989 and is detailed in Montana Code 85-2-141.

held in Montana that will serve as a bulwark against claims for water from other states, particularly those downstream. In order to lay claim to a water right, an entity must divert water from a natural water body and then put that water to “beneficial” use. This is to say utilized as an extractive resource for the purpose of agriculture, industry, or municipal use. Many streams and rivers have been fully or over-appropriated so this process no longer serves as a means of gaining access to new water rights.

If there is one word that this research can associate with the discourse surrounding adjudication its “fear”. In over-appropriated and closed basins such as the Sun and Teton rivers, the adjudication process, as voiced by many participants, will upset the status quo with regard to water rights and therefore the agricultural community. The adjudication process has gone on so long that in 2005 the Montana legislature passed House Bill 22 in order to draw the process to a close by the year 2020¹⁹. In the perspective of some participants, adjudication has intensified conflict in the community as well as among and between upstream and downstream users. As a final note, not all participants subscribed to the fear and conflict characterization so widely voiced. One participant believed that the adjudication process would result in greater equity and access to available water resources.

Currently the upper portion of the Teton River from its headwaters down to Choteau has been adjudicated. The local District Court is responsible for administering water rights located on the adjudicated section of the Teton River. Following adjudication, the court can (and has) appoint a Water Commissioner to serve as the day-to-day administer of water rights by opening and closing head gates, patrolling ditches

¹⁹ For a non-technical discussion of the issues and legislation related to water rights adjudication in Montana see the Department of Water Resources Division, Water Adjudication Bureau at- http://www.dnrc.mt.gov/wrd/water_rts/adjudication/default.asp.

and canals, and otherwise monitoring use by water rights holders to ensure rights are being serviced from senior to junior.

A very contentious issue associated with the adjudication process is tied to the economic impacts the process may have on Choteau. Numerous participants noted that irrigated acreage had expanded in the area and that this expansion requires additional water beyond the savings found by moving from a flood to sprinkler irrigation system. This was most often spoken of as an 'open secret'. It should be noted that while many stakeholders were willing to speak about this during informal discussions only one individual was willing to speak to the situation during a recorded interview.

Wilderness

As a concept in American natural resource policy the idea of wilderness has transformed through the years (Nash, 2001). When speaking about the impacts of climate change, like previous debates about the concept, wilderness designation is seen as both a bridge and a barrier. While discussions on the topic were limited to what was volunteered by participants through questions on other topics, it became evident that wilderness was an institution, largely related to public land management, through which policy related to climate change would be debated.

As a bridge to possible responses to the impacts of climate change, expanding wilderness was seen as a method of securing water availability and quality against appropriation and degradation. It was also viewed by some as a means of addressing the more widespread issue of biodiversity loss in the ecosystem.

As a barrier, the desire for increased SNOTEL snowpack monitoring sites in the headwaters of the Sun and Teton rivers were stymied due to their need to be located in

wilderness areas. Others viewed the current wilderness structure and proposal for expansions as precluding economic benefit from extraction through timber harvest. Public land managers, as a group, were inconsistent with regard to their perspective on wilderness. Some saw it as a hindrance to the management of fire, insect infestation, and forest disease, while others saw it as a challenge that with proper policy and management would provide benefits that outweigh the economic loss of timber production. Perceptions differed between managers even within the same agency on the former conclusion.

Conclusion

Results from the data gathering processes span a wide range to include ecological stressors, economic impacts, resilience, and adaptive capacity. While many of the themes encountered overlap between communities on each side of the Continental Divide as well as across the international border, each community possesses issue specific unto itself. These results will be synthesized through triangulation and integrated and discussed within the context of scholarly literature and broader research efforts in Chapter Five.

CHAPTER V

DISCUSSION AND SYNTHESIS: CLIMATE CHANGE VULNERABILITY, RESILIENCE, AND ADAPTIVE CAPACITY IN THE CROWN OF THE CONTINENT ECOSYSTEM

The chapter that follows builds on the results presented in Chapter Four by placing those results within the context of the larger scope of research and literature on climate change, resilience, and adaptive capacity. Discussion of the results will take place through a lens of climate change vulnerability. This approach builds on the theoretical foundations of resilience and adaptive capacity established in Chapter Two.

Addressing the impacts of climate change can be understood in much the same way as other environmental risks and vulnerabilities (Smit & Wandel, 2006). Exposure to environmental risk, in the case of this research those risks associated with climate change, is cause for addressing the adaptive capacity of the social-ecological system to that exposure. Resilience serves as the bridge in empirically addressing climate change vulnerability and risks through the application of resilience theory concepts.

Many of the results presented in Chapter Four are reflective of the determinants of adaptive capacity as set forth by Smit and associates (2001) and introduced in Chapter Two. Components of adaptive capacity, conceptualized as determinants and vulnerabilities, can be addressed through resilience theory (Nelson, et al., 2007). The synthesis and discussion in this chapter will undertake exactly that, thereby establishing a

broad understanding for the conclusions and recommendations that will be presented in Chapter Six.

The following chapter is split into two halves. The first is composed of a discussion of the results from Chapter Four that will be addressed in three subsections that reflect the three research questions of this research and the substantive issues each seek to address. The first subsection will cover vulnerabilities and risks associated with climate change in the Crown of the Continent Ecosystem. The second subsection will discuss strategies and responses to climate change impacts specific to the COCE within the scholarly literature. The third subsection will address the overarching ecosystem states and institutions presented in Chapter Four and the implications for both the COCE and the larger Intermountain region affected and impacted by the same institutions. The second half of the chapter is comprised of three case studies. The case studies will begin with relevant biophysical, social, institutional, and ecological information followed by a focused discussion of a select number of discrete climate change related impacts, strategies, and resources.

Ecological Vulnerability and Risk

The overarching theme for this research is the impact of climate change on the hydrologic regime of the Crown of the Continent Ecosystem. It's fitting that the discussion chapter begin with a narrative directly related to issues identified by participants related to the hydrologic cycle. This will be followed by a discussion on disturbance regimes. The final portion of this subsection will briefly discuss impacts to endangered species.

The hydrologic cycle of the COCE

A shift in the type, amount, and timing of precipitation received was a large concern for many participants. More specifically, a shift from historic snow-based precipitation to rainfall during a given year was at the heart of many discussions. The transition from snow to rain as a result of increasing average winter temperatures combined with a decline in extremely cold winter temperatures partially explains a demonstrable shift in the processes and functions within Montana's montane ecosystems (Pederson, et al., 2010). Research demonstrates that lower and mid-elevations appear to be more vulnerable to the shift from winter snow precipitation to rainfall throughout the Western U.S. (Knowles, Dettinger, & Cayan, 2006). The observed decline in mountain snowpack has the potential to accelerate (Mote, et al., 2005) and place increased demands on water resources.

Along with a shift in precipitation type, changes in the timing and amount of precipitation were additional concerns raised by participants. The region has seen a historical decline in stream flows (Rood, et al., 2005) that validate these fears, coupled with declines in snowpack (Mote, et al., 2005) and earlier spring runoff (Stewart, Cayan, & Dettinger, 2005). This provides context to participants' concern related to changes in hydrology via shifts in annual peak flows and annual low flows. Annual snowpack in the COCE is heavily influenced by the Pacific decadal oscillation and El Nino effect (Selkowitz, et al., 2002). The same authors also note that observed declines in glaciers are a continuing trend in the COCE. Mountain snowpack is the single largest water storage device in the West, eclipsing man-made reservoirs (Mote, et al., 2005). Warming temperatures will further decrease this natural storage capacity (Knowles, et al., 2006)

placing increased stress on ecological processes and industries dependant on water.

Given the importance of snowpack to economic sectors of this research, particularly agriculture, capture and storage of snow-water release is critical. The importance of capturing runoff for irrigation was evident in stakeholder discussions of water in Choteau, with the community's dependence on the agricultural sector. The ability to continue to capture runoff, as the timing of release changes, was an ongoing concern for many stakeholders in Choteau. This concern has proven to be justified as the following quote from research on runoff timing demonstrates, "a one-month advance in the timing of snowmelt runoff could threaten storage efficiencies for many reservoirs in the study area," (Stewart, Cayan, & Dettinger, 2004, p. 1154) which includes portions of the COCE. In follow-on research in 2005, Stewart and company note in their conclusions that shifts in stream flow timing will produce significant impacts on water management. Capturing earlier runoff with likely be difficult for man-made reservoirs even if new rules and management regimes are introduced and implemented as noted by Smith et al (2001) in their citation of Lettenmaier & Sheer (1991).

The paragraphs above have illuminated the importance of seasonal water availability to the communities in the Crown of the Continent. A major influence on water availability throughout the Intermountain West is drought. Drought, as noted by the IPCC in 2007, is becoming more frequent and intense in the Western U.S. Pederson and company (2006) studied historical long-duration drought in Glacier National Park and found that multi-decadal drought will place severe stress on ecosystem services and industries that rely on those services. While drought is a fact of life in the region an increase in the duration and/or intensity of drought as a result of climate change is not

certain. Nevertheless, given changes to the type and timing of precipitation and stream flow presented above, drought as discussed by Gedlof and company (2004) in their work on historical drought patterns in the Columbia River Basin, is likely to be exacerbated. The researchers go on to note that there is a lack of multi-year drought management capacity in the Columbia River Basin. This reflects participants concerns with regard to the lack of capacity to deal with increasing drought-related issues if they are indeed exacerbated by climate change. The influence of drought on disturbance regimes was the most prominent feature of discussions on the issue and will be addressed in the paragraphs that follow.

Disturbance Regimes

The IPCC (2007) identified that a warming climate coupled with associated disturbance regimes produces a likelihood that ecosystem resilience will be overwhelmed by 2100. Shifting disturbance regimes were a common thread of concern among participants of all three case study communities. The paragraphs that follow will discuss disturbance regimes in the form of fire, insect outbreak, forest disease, and flooding in the form of rain-on-snow events.

Fire is a vital component of the Crown of the Continent Ecosystem with multiple fire regimes highly influenced by elevation gradients (Keane & Key, 2007).

Management of fire in the ecosystem was discussed from a number of different perspectives that encompassed two broad ends of a spectrum. On one end was the management of fire as a natural part of the ecosystem where fire could be managed for ecological, social, and economic benefit. This is not without precedent in that vegetation and fire have been recognized by Sousa (1984) as a reciprocal relationship. The opposite

end of this spectrum was the belief by some participants that not only did fire constrain other management options, but it also reduced economic activity by reducing opportunities, particularly on public lands. Lost public land management opportunities presented by participants include the reduction or suspension of outfitting and rangeland grazing in addition to reduced or forgone timber harvest.

A specific challenge addressed by participants in the public land management sector was understanding what managing fire on the landscape would look like in the future. Of specific concern was whether or not utilizing the historical range of variability concept as a guidepost would continue to serve as a means of gauging the effectiveness of management goals in the future when there is a likelihood that changes in the system may not have a historical analog reflected in the existing data.

Results in Chapter Four spoke to the concern many participants had with regard to the feedbacks between fire, insect outbreak in the form of the mountain pine beetle (*Denroctonus ponderosae*), and forest disease in the form of white pine blister rust (*Cronartium ribicola*). Concern related to these feedbacks and ecosystem level changes is supported in the literature. Logan and Powell (2001) presented evidence in their work on the mountain pine beetles of an interconnection between beetle-based mortality and fire in western forests citing Schmidt 1988. There was considerable concern among timber industry and public land management participants with regard to the spread of infestation to previously unaffected areas. Research indicates that this is a well justified fear with evidence that outbreaks are shifting north and into higher elevations than historically documented (Régnière & Bentz, 2008).

It must be understood that the mountain pine beetle is endemic to the forests of the Crown of the Continent, and therefore a component of the natural disturbance regime. Historically, outbreaks would target and cause considerable mortality in stands of lodgepole pines of an even age class resulting from a past stand replacing fire (Logan & Powell, 2001). There is concern among participants and researchers that outbreaks of the mountain pine beetle are beginning to more heavily target alternative species such as whitebark pine (*Pinus albicaulis*). Logan and Powell (2001) note that it is not without precedent for individual trees of whitebark pine to be attacked and infested, but there is a growing concern that this keystone species has become more heavily preyed upon by mountain pine beetles. Therefore, the whitebark pine serves as a great case study to discuss fears related to the feedbacks between the disturbance regimes of insect infestation and disease.

Whitebark pine has the dubious distinction of being both a keystone species as well as a potentially endangered species. The tree has a symbiotic relationship with Clark's nutcracker (*Nucifraga colmbiana*) whereby the tree provides a food source in the form of its seeds and the bird disperses seeds by burying them in caches and promoting the species regeneration. Seeds from whitebark pine serve as a food source for up to 110 species, including grizzly bears (Keane & Key, 2007) that have been classified on and off as an endangered species in the last few years

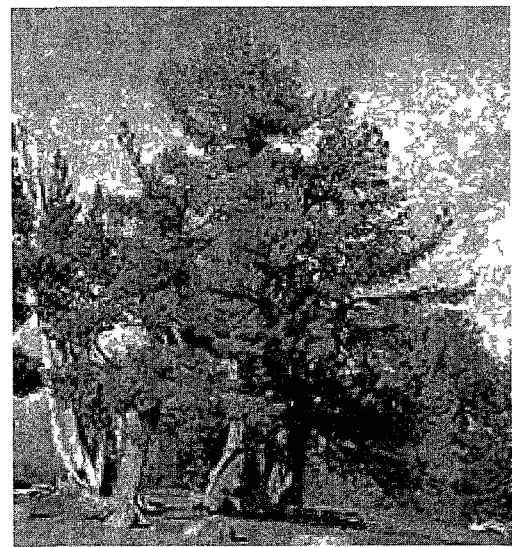


Figure 5-1: Whitebark pine (*Pinus albicaulis*). Picture is from the U.S. Fish and Wildlife Service's website and can be found at- <http://www.fws.gov/mountain-prairie/species/plants/whitebarkpine>.



Figure 5-2: Clark's nutcracker (*Nucifraga columbiana*). Clark's Nutcracker perched on a branch. Photograph taken by Michael Sulis, April 30th, 2006 at Crater Lake, Oregon. Found at - http://en.wikipedia.org/wiki/Clark's_Nutcracker.

in the Greater Yellowstone Ecosystem while their status continues to be 'threatened' in the COCE. Research provides indications that participant's fears relative to the synergistic relationships between disturbance regimes is well founded. In research in Montana, Daniels and company (2006) presented, citing Keane and Arno 1993, that there is a

likelihood that blister rust infection weakens whitebark pine resistance to attack by mountain pine beetle. Additionally, Keane

and Key (2007) present that fire suppression policy has partially led to the decline of whitebark pine through replacement of the species by sub-alpine fir (*Abies lasiocarpa*). However, this premise is directly challenged and rejected by Daniels and company (2006).

Departing from the synergistic and interrelated disturbances of fire, insect infestation, and forest disease, we begin the discussion of the final disturbance regime raised in this research, particularly but not solely in Choteau- flooding. In the Crown of the Continent there is a very specific context related to flooding as it was presented by participants in this research, in the form of flooding resulting from rain-on-snow events.

Flooding as a result of rain-on-snow, in addition to the destruction and social disruption typical of floods, produces additional concerns in the COCE relative to the ability to capture and store the water released in the event. This latter concern was

especially evident in Choteau with its need for the capture and storage of snowpack runoff in order to be utilized for irrigation throughout the growing season. Participants familiar with the storage capacity of reservoirs on the Rocky Mountain Front noted that as currently configured they are incapable of capturing and storing peak flow runoff and must “spill” water (allow it to pass through the dam) during these periods, which was considered a waste of the resource by some participants. Rain-on-snow events, especially in the winter and early spring, were of considerable concern in that participants who spoke to these events feared that water released early in the year would be unable to be captured and would compound water shortages later in the year with accompanying agricultural and in some cases aquatic habitat impacts.

Fears over the potential increase in rain-on-snow events and their impact on the agriculture sector was at least partially tied to concerns over a shift in the type of precipitation received and warming winter temperatures. Research indicates that rain-on-snow events may decline as a result of climate change as rising temperatures decrease snowpack and thereby the volume of stored water that could be released during a rain-on-snow event (McCabe, Clark, & Hay, 2007). In the event that such a scenario is borne out it will only exacerbate the drought concerns and the cascading consequences that accompany the situation.

Two system states provide context to forest related disturbance regimes in the Crown of the Continent Ecosystem. Wilderness and the wildland-urban interface lie at opposite ends of the system state spectrum. Wilderness management strives for minimizing and to a great extent excluding development activities in such designated areas. Conversely the wildland-urban interface are areas where development activities

are either creeping into previously undeveloped sites or an increasing human development presence is obvious. Fire, insect outbreak, and forest disease provide substantially different challenges for the management of the two different system states.

As briefly noted in the results of Chapter Four there was widespread anxiety among participants in the timber industry related to concerns of fire and insect outbreak leaving public lands and affecting private timber holdings. Public land management participants presented that in some cases containing the effects of disturbance regimes that originate and/or grow within wilderness areas present challenges to keeping the fire or insect outbreak contained within the wilderness. Being a good neighbor was a concern for all, but there is an admitted tension between managing some lands for conservation and other for extractive resources with an almost inevitable impact of disturbance crossing between the two. It should be noted that a number of public land managers spoke to the benefits of both wilderness and active disturbance regimes on the ecosystem. But, this was coupled with an apprehension about how climate change would reshape management of each.

The management of the impacts and effects of disturbance regimes, particularly fire and insect outbreak, was at the center of the discussions related to the wildland-urban interface. The context of these discussions were much different in that they focused upon public safety and the cost of fighting fire and containing and managing insect outbreaks. Land use planning was mentioned during discussions related to the wildland-urban interface as was, in some cases, a perceived economic disparity between those who made conscious decisions to live in the interface and the distribution of that risk across the local communities in the form of subsidizing the costs related to wildland fire fighting.

Disturbance regimes coupled with a warming climate will serve to influence land cover and the aquatic environment of the Crown of the Continent. The next section will place the reality of a changing landscape and participants concerns related to the issue in the context of climate change literature.

Terrestrial and Aquatic Environmental Impacts

The reality of a changing landscape was commonly appreciated among participants in all three communities. There were differing opinions about how quickly changes were and would take place especially as it related to forest cover in the COCE. There was widespread, but not necessarily unanimous, belief that shifts in the aquatic environment were already underway.

Evidence suggests that participant concern with a changing landscape is well founded. Changes in available snowpack will inevitably have impacts on the ecosystem's flood regime, which, in turn, will produce impacts on wetland and riparian species composition and abundance (Covich, 2003; Hauer et al., 1997). While it was noted that fire suppression had allowed for the invasion of trees into previously open meadowlands, there was nonetheless considerable concern about the loss of forest cover and a shift in species composition of forests impacted by climate change. In their report on potential climate change impacts in the Western U.S., Smith et al., (2001) posit that in a drier climate reduced forest cover is a possibility as is the loss of alpine tundra. The former is spoken to specifically within the context of Crown of the Continent by Malanson and company (2007) noting that the ecosystem's alpine tundra is extremely fragile. Concern related to the vulnerability of alpine tundra to the impacts of climate change is further discussed in a later chapter in the same edited volume by Fagre (2007).

In a few instances, discussion of terrestrial ecosystem response to climate change mirrored that of the literature with concerns over the northerly and upward migration of plant species. The former concern is supported by the predictions of Smith and company (2001) and the latter by observed changes in Canada's forests (Williamson, et al., 2009). Finally, there was widespread concern in all three communities about the spread of noxious weeds if a warming climate served to modify the environment and make it more conducive to their expansion. Loss of native diversity, homogenization of the landscape, and a reduction in viable rangeland are all related to concerns of noxious weed expansion.

When participants discussed the implications of climate change on the aquatic environment there were three reoccurring themes: increased water temperature, implications for lower stream flows, and the impacts of changes in runoff timing. In most cases all three were discussed in the context of the impacts of these changes on aquatic species. These will be covered more fully in the section immediately following. In addition to these concerns there is the possibility for degraded water quality as a result of changes to water chemistry (Covich, 2003; Hauer, et al., 1997) stemming from climate change. Also not to be overlooked are the impacts of receding glaciers and the function they serve such as maintaining stream flow and moderating stream temperature and the accompanying support of aquatic flora and fauna (Fagre, 2007; Pederson, et al., 2010).

Endangered Species

Impacts to terrestrial and aquatic environments, as noted in Chapter Four, was taken a step further, by a number of participants, to the impacts of climate change on ecological species, populations, and communities. The most poignant discussions revolved around

endangered species rather than more abstract interview discussion on 'ecology'.

Focusing on discussions related to species already on the brink of possible extinction also helps to provide needed perspective to more abstract discussions.

When discussing species extinction the IPCC (2007) notes that the process is multi-factoral including relationships between a specie's range, density, and preferred habitat. Going on, the panel presents that it is likely climate change will directly impact all three processes. When discussing endangered species, discussions with participants covered both terrestrial and aquatic species.

The recovery and management of the region's two carnivorous endangered species, the wolf and the grizzly bear, is highly contentious. Management of the two species, due to conflicts with traditional public land uses such as livestock grazing and hunting, has been highly conflictual. Wolf populations have recovered to the point of formal delisting processes having been undertaken and completed in Montana only to have the species be returned to the list via court order following a lawsuit by conservation organizations. In 2011, wolves in the Rocky Mountains were again delisted- this time through congressional action. The delisting of the grizzly population in the Greater Yellowstone Ecosystem (GYE) in 2007 has been challenged in the courts resulting in the species being again designated as 'threatened' under the Endangered Species Act.

In the Greater Yellowstone Ecosystem one reason stated by the litigants for their challenge to delisting the grizzly was the impact of climate change on the whitebark pine. Declines in an available food source, as whitebark pine abundance declines in the ecosystem resulting from blister rust infection and attack by mountain pine beetle, partially prompted the judge in the case to order the U.S. Fish and Wildlife Service to

reevaluate their decision to remove grizzly bear protections under the ESA. This legal and political process is taking place against a back drop of climate change and the impacts it is having or will potentially have on the ecosystem.

While there is concern over the decline of the grizzly bear as a result of climate change, research points to the possibility the wolves may serve as an ecological buffer against the impacts of climate change. Wilmers and Getz (2005) presents research that wolves in the GYE buffer the impacts of climate change for scavengers in the ecosystem by making late-winter carrion available during seasons that are becoming less harsh and therefore providing less winter kill.

The bull trout, listed as 'threatened' on the U.S. side of the ecosystem, was presented by participants as an example of an aquatic species likely to be impacted by climate change. Participants articulated concern about the loss of not just bull trout, but species habitat for all native salmonid as a result of climate change. In addition to the direct loss of habitat due to warming, there was discussion on the inability of native species to recolonize reaches of streams and rivers where a population has gone locally extinct as a result of warming water temperatures and dewatering from drought and withdrawals for agriculture.

Reiman and company (2007) demonstrate in their research that bull trout could see as much as 18-92% of their habitat lost as a result of warming temperatures. Habitat loss coupled with migration barriers in the form of physical man-made structures and unsuitable habit are further compounded by competition with non-native species.

Many species of non-native salmonids have been stocked in the lakes, streams, and rivers of the COCE and throughout the Intermountain West for sport recreation.

Many of these species already outcompete native species (Behnke, 1992). It is likely that many of these non-natives will be favored by a warming climate as they are able to tolerate the warmer temperatures and further colonize and compete with native species as additional habitat is made available as a result of warming. This ecological issue is further complicated by the ability of some species of natives and non-natives to interbreed and produce fertile offspring. Examples include the non-native rainbow trout (*Oncorhynchus mykiss*) interbreeding with COCE native Westslope cutthroat trout (*Oncorhynchus clarki lewisi*) (Behnke, 1992) and non-native brook trout (*Salvelinus fontinalis*) breeding with the threatened bull trout (*Salvelinus confluentus*) (Kanda, Leary, & Allendorf, 2002). Research in the COCE reveals that hybridization reduces the fitness of native species (Muhlfeld et al., 2009) and that introgression increases the risk of extinction (Muhlfeld, McMahon, Belcer, & Kershner, 2009).

Competition with the non-native lake trout is further complicated for the native bull trout by the introduction of mysid shrimp (*mysis relicta*), a non-native invertebrate introduced to the Flathead system in 1968. Introduction of the species has wreaked havoc on the food-web favoring lake trout over the native bull trout and upsetting the energy flow of the system (Martinez, et al., 2009) .

Ecological changes resulting from the impacts of climate change on the hydrologic cycle span terrestrial and aquatic environments affecting disturbance regimes and species, endangered or not. Many of the same impacts have direct and indirect effects on economic sectors important to the Crown of the Continent. The next section will discuss the impacts of climate change on the ecosystem's hydrologic cycle in the context of the forestry, agricultural, and tourism sectors.

Social-ecological Vulnerability and Risk

To a significant degree the forestry, agriculture, and tourism sectors of the COCE are directly related to the health and resilience of the ecosystem's natural resources. All three were discussed to varying degrees by participants in this research. Forestry and tourism were discussed during semi-structured interviews in all three case study communities while conversations related to agriculture were largely confined to Choteau.

Forestry Sector

The ongoing decline of the forestry sector in the Crown of the Continent served as a backdrop against which participants spoke to the vulnerabilities of the sector.

Participants from all three case study communities spoke to the situation with most commentary taking place in Kalispell. The impacts of climate change, largely, served to increase anxiety in the sector.

In Chapter Four, results revealed concern with regard to the remaining forestry infrastructure in and around the Flathead Valley. One participant from British Columbia noted that the opposite appears true in the province with too much infrastructure overburdening the sector. There was widespread concern, especially within the timber industry itself, but also among some public land managers, about whether timber harvest as a management strategy will be a viable policy option in the future.

In their review of the impacts of climate change on Canada's forests Williamson et al., (2009) present impacts on numerous fronts: impacts to forest management, forest operations, the timber market, and forest-based communities. There is little reason to believe that given the decline of the timber industry in western North America that the Crown of the Continent will not be impacted in a like manner. These looming issues

return us to the question of utilizing the timber industry as a management tool and policy response. Given the ecological changes and shifts in disturbance regimes currently impacting the forests of the COCE it is logical to question the industry's ability and capacity to serve as a response measure.

In addition to utilizing timber harvest as a policy and management tool there is increased anxiety in the industry about potential shifts in species composition, particularly those that are most valuable economically. Compounding this consternation is a fear of increased regulatory burden adding to the anxiety of the industry. Concern and anxiety in the industry translates to the larger community through socioeconomic linkages. The social and economic impacts on the forestry sector from climate change will at least partially be related to the speed at which ecological processes change (Williamson, et al., 2009). When viewed through this lens social-ecological linkages begin to come into focus.

Agriculture Sector

In Chapter Four it was noted that discussions related to agriculture largely took place in Choteau. But, it should be noted that agriculture exists to varying degrees in all three communities and the sub-regions in which they are located. While the majority of discussions on agriculture, given the topic of this research, focused largely on the role of irrigation, agriculture in the COCE also includes dry land farming and livestock grazing.

While decreases in snowpack will likely produce increased difficulties for crop irrigation in Choteau, not all impacts from climate change are necessarily negative. It appears that milder winters and extended "shoulder" seasons may potentially extend the growing season (Smith, et al., 2001). For irrigated crops it's likely that reductions in

snowpack will limit this advantage (I. J. Walker & Sydneysmith, 2008). Smith and company (2001) posit that climate change could benefit livestock producers by increasing forage availability. This could prove true on public lands in the COCE, but there are a number of interceding variables that include the ongoing transitions in community composition, shifts in disturbance regimes, management strategies (including the stocking rates of livestock), and of course decreasing snowpack. Research on agriculture in the Flathead Valley demonstrate that even with proactive climate change adaptation measures undertaken there is a likelihood that the sector will suffer negative economic consequences (Antle, Capalbo, Elliott, & Paustian, 2004).

Walker and Sydneysmith (2008) speak to agriculture providing stability to rural communities in British Columbia, but their logic extends to other regions and communities. The IPCC (2007) recognized that outmigration and increased uncertainty related to climate change will increase vulnerability of the agriculture sector. Many participants in Choteau addressed the issue of uncertainty and noted that agricultural producers constantly prepare for and deal with unforeseen circumstances. Of much greater concern was the generational shift taking place in the sector with the aging of the industry, out-migration, and financial barriers to those who would seek entry into the agricultural sector.

Tourism & Recreation Sector

The tourism and recreation sectors have become increasingly important to transitioning communities in the COCE. This appears to be especially true with Kalispell and the community's linkage to Glacier National Park as well as Fernie with its increasing winter recreation industry. Choteau is not to be left out, as numerous participants spoke to

increasing the exposure of the Rocky Mountain Front as a recreation destination along with promoting sport recreation in the form of hunting and fishing on the Front and nearby Freezeout Lake Wildlife Management Area.

A broad constituency of the COCE joined with the National Geographic Society to develop a geotourism guide and website for the Crown of the Continent. The website²⁰ and associated map focus on the local and regional character of the COCE in addition to promoting the ecological and cultural richness of the ecosystem. Economic benefits reaped from the joint venture are vulnerable to the impacts of drought, fire, mountain pine beetle outbreak, and other impacts from climate change (IPCC, 2007). A 2003 report by the National Parks Conservation Association detailed the economic benefits reaped by Flathead County as a result of its close proximity to Glacier National Park (L. D. Swanson, Nickerson, Lathrop, Archie, & Terry, 2003). The report directly associates economic benefits with non-extractive natural capital (e.g. tourism).

In addition to tourism, recreation takes many forms in the COCE including water sports, motorized recreation, winter sports, camping, hiking, hunting, and fishing. Each form of recreation will be vulnerable to both unique and overlapping climate change impacts. Research suggests that access to natural amenities such as forests and mountains are supporting a population boom in rural areas of the Rocky Mountains. While increased economic activity has accompanied this growth there is evidence that ecological degradation has also been the result of the increasing population (Hansen et al., 2002). Each of the three case study communities will potentially experience economic impacts resulting from the impact of climate change on their individual recreation industries. It is logical that economic impacts from ecological shifts resulting

²⁰ The interactive geotourism website is located at- <http://www.crownofthecontinent.net>.

from climate change will reflect the extent to which each of the three communities have diversified between major economic sectors and within the tourism and recreation sector.

Case Studies in Social-ecological Resilience and Adaptive Capacity

The second half of this chapter will be presented through the lens of resilience and adaptive capacity as it applies to the communities of Kalispell, Choteau, and Fernie.

Each case study will discuss resilience and adaptive capacity while integrating the results from Chapter Four. Discussions within each case study community will focus upon a limited number of discreet stressors, resources, and strategies that focus and exemplify the impacts of climate change on the hydrologic cycle as it relates to that particular community and the surrounding subregion.

Kalispell, Montana

The town of Kalispell is located in the Flathead Valley in northwest Montana. The valley is bordered by the Whitefish Mountain range to the east and the Salish Mountains to the west with namesake Flathead Lake lying south of Kalispell. Flathead Lake is fed by the three branches of the Flathead River, the North, Middle, and South forks.

Falling west of the Continental Divide, Kalispell's climate is moderated by the Pacific maritime climate pattern. The average minimum temperature in January is 29.1°F (1.61°C) while the average July maximum temperature is 50.2°F (10.11°C). Average annual precipitation is 15.27 inches with an average annual snowfall of fifty-three and a half inches (Western Regional Climate Center a).

The Flathead National Forest dominates land ownership along both mountain ranges surrounding Kalispell. Iconic Glacier National Park lies approximately thirty miles northeast of Kalispell. Glacier National Park is one half of the Waterton-Glacier

International Peace Park designated as such in 1995. Preceding that designation was Glacier's recognition as a Biosphere Reserve in 1976, followed by Waterton National Park in 1979 (Long 2002). Montana state lands are located in various size parcels throughout the Valley. Plum Creek Timber Company holds a sizeable portion of the private property in the Valley and the surrounding forested regions.

Kalispell is the largest community in the Crown of the Continent with a 2010 population of 19,927- a forty percent increase since the 2000 census. As a community within Flathead County, Kalispell falls within a non-metropolitan area as per the 2009 USDA Economic Research Service County Typology. The County Typology goes on to note that Flathead County is a service dependant county (USDA Economic Research Service). The 2009 American Community Survey census estimates place the service occupations at 18.2% of the economy, trailing sales and office occupations and management, professional and related occupations at 29.0% and 27.8% respectively. Natural resource extractive industries, as reflected in the ACS by the category of farming, fishing, and forestry occupations, are only 0.8% of the economy. This keeps in line with the continuing decline of the natural resource extractive industry in the larger Mountain West (Power & Barrett, 2001). Median household income in 2009 was \$39, 953 (U.S. Census Bureau).

Kalispell is the county seat of Flathead county. In addition to the typical state and local governance institutions, the Flathead Lake Basin Commission and the Flathead Lake Biological Station provide volunteer regional governance structure and scientific support. Public land and natural resource management are administered at both the federal and state levels in the COCE and the Flathead Valley. The Forest Service,

National Park Service, U.S. Fish and Wildlife Service, and Bureau of Reclamation administer natural resource at the federal level. Montana Fish, Wildlife, and Parks and the Department of Natural Resources and Conservation manage wildlife and state trust lands.

The impacts of climate change on Kalispell reflect the diverse nature of the city itself. Of the sectors addressed in this research Kalispell is likely to see impacts to the forest sector and the tourism and recreation sector. The most likely stressors to produce potential consequences on the two sectors are the synergistic impacts from fire, insect outbreak, and forest disease. Changes in the hydrologic regime resulting in shifts in both the terrestrial and aquatic ecology, as presented earlier, also have the potential to disrupt revenue streams related to economic sectors by potentially limiting harvest, reducing tourist and recreational interest in the area, and reducing management options.

Participants presented a number of strategies and resources that may potentially be brought to bear in order to address adaptive capacity as the community of Kalispell and the larger Flathead Valley encounter the impacts of climate change. Social-ecological resilience in Kalispell are intertwined between the forestry sector and the tourism and recreation sectors through montane forest land cover of the area, at least partially. Impacts to one sector stand to have potential impacts on the other, both of which are influenced by contemporary changes to the land cover itself. Issues associated with declining forestry infrastructure serve as a means of demonstrating the inter-related social-ecological linkages and a potential means of addressing resilience through adaptive capacity.

A mountain pine beetle outbreak has swept through the Crown of the Continent Ecosystem and synergies between the outbreak, fire, and forest disease have been recognized. From the tourism and recreation perspective one has to ask what impacts may befall the sector when nearly entire mountainsides and valleys are red from beetle kill rather than the expected green? This same question is often asked following fires such as those that gripped Yellowstone National Park in 1988. There is concern among participants that the feedbacks between beetle kill, fire, and forest disease may create its own cycle thereby maintaining a large portion of the landscape in a visual aspect that reduces desirability among tourists and recreationists. On the portions of the region that are managed, timber harvest has been presented as a tool to partially address the situation.

Both the forest industry and to some extent public land managers have indicated that in the Flathead Valley there may no longer exist timber sector infrastructure capable of supporting a strategy for dealing with these impacts. The capacity of the industry itself has been called into question by members of the timber industry. It was posited by one member of the forestry sector that the timber industry is or has surpassed a tipping point with regard to the sector's infrastructure,

...now the forest products industry is at a tipping point, a critical point right now. The loss of Smurfit-Stone was a big blow to us. You know we've, over the years, come to depend on managing all size classes of trees in our forest. Not everything makes a saw log or a log to make MDF [medium density fiberboard] panels you know. So having the outlet for the non-saw material, the pulpwood, whatever you want to call it, is extremely important to meeting our land management objectives. So that's a major problem, short-term problem. Long-term, to maintain the forest products infrastructure that we have in the state right now timber supply is still the number one issue. We've got 3.6 million acres of the Flathead National Forest out here and we see... I'm trying to remember how many mills we've lost in the last five years. We've lost well at least four that I'm aware of here in the Flathead Valley area and almost all those mill closures were due to lack of log supply, lack of demand for the lumber itself. You know, so that's a long-term issue. We've got all these Forest Service lands around us that have major insect and disease

problems and major fire issues and they don't seem to be doing enough to address those issues. At the same time we're losing the tools that five years from now when they say "oh we really need to do something more to conserve these forest lands," it's not going to be here.

The underlying assumption to this statement is that forestry may no longer be a viable tool in response to climate change and as such may not possess the capability to be a valuable piece of a larger response capacity to the impacts of climate change.

Harvest in and of itself is only one piece of the ability for the forest sector to respond to the impacts of climate change. Participants presented a number of additional resources and strategies for bolstering resilience to pine beetle outbreak, blister rust infection, and fire, but a timber industry participant offered the following with regard to the sector's ongoing challenges,

we need more diversity in our infrastructure at a local level. We need to find a local solution to the non-saw issue, find something so that we can utilize all the material that comes out of our woods. Because you don't just treat these acres once, we'll be back there over the next hundred years two times at least if not three [times].

Developing and planting disease resistant strains of native species, managing for species and stand diversity, and planting drought tolerant strains and native species are all additional components of a suite of timber industry response strategies that may influence resilience.

The dearth of timber industry infrastructure extends beyond potential impacts to the forestry sector to the tourism and recreation industry by an inability to harvest dead and dying stands. It is possible that managing timber resources in an area for the benefit of municipal water sources may be precluded adding an additional layer of impacts to the situation.

In December, 2009 it was announced that the mill owned by Smurfit-Stone Container Corporation in Frenchtown, Montana north of Missoula, Montana would be permanently closed. The closure serves to highlight the difficulties associated with timber industry infrastructure. Beyond the immediate impact of the loss of nearly 400 jobs from the mill closure, loss of the mill adds to an already difficult situation for the ecosystem's timber industry.

The above paragraphs produce an uncertain picture with regard to the social-ecological resilience of the timber, tourism, and recreation industries in Kalispell and the Flathead Valley. A question that has yet to be broached but may prove vital to the ecological resilience of the Flathead Valley and larger COCE in the face of climate change is "where does the system now lie if the current mountain pine beetle outbreak was to be mapped on the adaptive cycle"? Stepping back to apply a systems analysis to the situation may provide clarity as well as serve to further focus response efforts that bolster social-ecological resilience following the outbreak.

Choteau, Montana

The town of Choteau lies along the eastern edge of the Rocky Mountain Front, the rapid break between the Great Plains and the Rocky Mountains. Dramatic transitions surround the bucolic community with rolling hills and the Great Plains to the north, east, and south and the rugged forested Rocky Mountains to the west.

Falling in the rain shadow of the Rocky Mountains, Choteau is much drier than both Kalispell or Fernie and often buffeted by high winds from the west. Annual precipitation is slightly over eleven and a half inches with nearly forty inches of snow falling in an average year. The average minimum temperature for January is 10.5°F

(11.94°C) and the average maximum temperature for July is 82.3°F (27.94°C) (Western Regional Climate Center b).

Opposite of the Flathead Valley, the Front Range region surrounding Choteau is dominated by private property. A great deal of private land is held as agricultural production land, although there is a large amount of privately held conservation easements. The Nature Conservancy owns the Pine Butte Swamp Preserve, a biologically rich area that also serves as a vital migration route from the mountains into the plains for a number of species including the grizzly. Moving west from Choteau toward the Rockies, public land begins to prevail with a small amount of Bureau of Land Management (BLM) land giving way to the Lewis and Clark National Forest. The Bob Marshall Wilderness complex, as noted on the Flathead National Forest website, consists of the Bob Marshall, Scapegoat, and Great Bear Wilderness areas covering over one and a half million acres. The region serves as an undeveloped core spanning both sides of the Continental Divide.

The USDA Economic Research Service County Typology identified Teton County, the home of Choteau, as economically dependent on farm activity. A rural community, Choteau was estimated by the American Community Survey to have a population of only 1,684 in 2010 a slight decrease from 1,781 in 2000. While Teton County and Choteau are economically dependent on farm activity only 4.7% of the population are directly employed in the ACS occupational category that encompasses farming. Management, professional, and related occupations dominate the economy of Choteau employing 32.3% of the workforce followed by service occupations at 27.7% (U.S. Census Bureau). Undoubtedly a significant portion of these categories are directly

and indirectly related to agriculture such as through Farm Service Agency personnel, Montana State University Extension Services, etc. Median household income in Choteau is \$36,198, an annual difference of \$3,755 between it and Kalispell.

Like Kalispell, Choteau is the county seat. Local supporting institutions beyond those typically associated with local governance include institutional support reflective of an agricultural-based community. The Farm Service Agency, Natural Resource Conservation Service, and University of Montana Extension Services provide agricultural support to the area. Additional institutional support is also found in the private irrigation companies on the Teton River near Choteau and the federally managed Fairfield Irrigation District for the Sun River in Fairfield just south of Choteau. Freezeout Lake Wildlife Management Area is managed by Montana Fish, Wildlife, and Parks for waterfowl production and serves as a destination for hunting and bird-watching.

Shifts in the hydrologic cycle as a result of climate change stands to have far reaching consequences in the water reliant agricultural community. While the agriculture industry dominates the economy of Chouteau the sector is not the only competitor for the over appropriated water resources of the Teton River. Even though water rights have codified access to the limited water resource to “beneficial use” among a select set of stakeholders, competition and conflict over water is still prevalent.

Spring Creek, a tributary of the Teton River flows through the town of Choteau. The small stream serves a number of functions to the town and demonstrates how the impacts of climate change may influence both the social and ecological resilience of the community.

When viewed through a broad lens Spring Creek embodies competition over water between multiple sectors that include agriculture, recreation, and municipal uses. Participants from Choteau held considerable pride in the little stream that flows through town and provides citizens with numerous opportunities for relaxation and recreation. Opportunities such as picnicking and fishing were both associated with the stream. One participant noted with a little bit of joy that fishing regulations on the little stream bolsters youth introduction to the sport by not allowing anyone over the age of twelve to fish in the stream within the city limits.

Three interviewees, none of whom were in the agriculture sector, discussed Spring Creek. Each one noted how in the last decade the stream had been dewatered several times with one individual noting that the stream had been dry for possibly as much as seven or eight years prior to the year this research took place. Dewatering of the stream resonated with residents as one participant noted that people sent letters to the editor decrying the dry stream during Fourth of July celebrations. A local government official spoke of a letter he received from a previous resident dismayed at the dewatering of the stream and how it differed from his childhood memories.

I had a letter just, oh this fall, from a guy that used to live in Dutton if you know where that is? And he said he came to Choteau and he brought his grandson here to play in the creek and in the city park and just make a day of picnicking and that kind of stuff. He said when he got here there was no water in the creek and he says "I can never remember it not having water in it". So there is a reflection back on when he was a child where they used to come over from Dutton and come to the city park in Choteau and picnic so the kids can play there and fish in it.

The dewatering of Spring Creek and discontent that it engenders among different portions of Choteau's population are an indicator of the larger conflicts over the water resources on the Rocky Mountain Front. In addition to the social disruptions from

dewatering there are also the numerous ecological impacts to the aquatic environment and species resulting from the disruption. One participant noted the impacts from agricultural diversions, “ I mean we’re already almost at a critical point right now as far as our water use because we do not have really a healthy viable fishery, stream fishery on the Rocky Mountain Front. Not a single one because of irrigation withdrawals”. Without a healthy aquatic environment there is no recreational fishery in Spring Creek for children or otherwise and this is a reflection of some citizens discontent with the situation.

In the context of Spring Creek ecological resilience exists in two different states. The first is the aquatic environment as it is influenced by irrigation withdrawals, the second is the agricultural benefits resulting from irrigation. This begs the question of whether the health of one comes at the sacrifice of the other? In discussions with agriculture stakeholders and government officials at multiple levels in Choteau, there appears at the present to be a limited capacity to address ecological resilience or its social and economic impacts. Returning to Spring Creek, the little stream epitomizes the problem as a senior local official notes,

The town knows how valuable that water is to [farmers]. We don’t ever intend to fight those guys over water. We want enough to come down the river to keep that little stream filled. But if it has to do that at the expense of farmers getting water then we’ll forgo it. And we’ve done that for years. Those last eight years of drought we made no bones about anything still nobody did anything because we know that they weren’t getting it, they have to have it [water]. None of us survive unless they survive. So that’s vital.

Addressing efficiency issues related to irrigation were presented on a limited basis by study participants. Enlarging reservoirs, repairing irrigation canals and ditches, and utilizing pump systems were all ideas presented to partially address the situation.

Working within the constraints of Western Water Law has led to the development of limited options such as water reservations and water leasing to address aquatic habitat issues. Like the discussion in the Kalispell case study, management of forest land cover on the Rocky Mountain Front may present a possibility of enhancing social-ecological resilience. On this side of the Continental Divide these efforts are related to snowpack release and water utilization for both agriculture and aquatic habitat.

Its unclear whether Spring Creek was recharged in the most recent episode as a result of collaboration with agricultural producers or as the result of sufficient water resources being available to meet and surpass the needs of agricultural producers. Conflict over water resources under current conditions coupled with future uncertainty demonstrate the need to begin looking at the situation in a new light. As was presented early in this study, many participants noted that collaborating on the development of monitoring resources may serve as one means of beginning to develop additional technical and social capacities to address ecological and biophysical complexities. Although, it is worth noting once again that there exists a possibility for even this to become an emotionally charged issue and an additional point of contention. When discussing the connections between ground and surface water a state natural resource management official noted the following,

And two years ago when they [irrigators] actually did start letting some water run through in the wintertime and all of a sudden last February, Spring Creek started running ,oh boy! Did the town get excited! And the irrigators upstream were going “oh shit”. And I took a picture of Spring Creek running. [It] showed up in the Acantha [the local newspaper] on February 12th and on February 13th they opened the head gates that runs water to Eureka Reservoir and they quit. They stopped that water running down there...

Developing the means to adequately address this complex situation may provide a path to additional economic diversification, something multiple participants desired to see for the community. Additional hunting, fishing, and other recreational related opportunities were presented as a means of providing additional depth to the current economy thereby providing additional social and economic resilience.

Fernie, British Columbia

The town of Fernie lies in the Elk Valley of southeast British Columbia. The region falls within the boundaries of the Columbia River Basin. Fernie belongs to the East Kootenay Regional District; not necessarily analogous to county arrangements in the U.S., the regional district provides governance structure and services for rural residents of the region that fall outside municipal boundaries (Regional District of East Kootenay).

Established in 1898 and lost early in its history to fire twice (1904 & 1908), Fernie developed as a community based on natural resource extraction. Coal and timber served as the economic mainstay for the town. Fernie's contemporary economy has begun to diversify as the town has marketed itself as a recreation destination. This has led to winter sports recreation gradually increasing in economic importance to the community.

By any measure Fernie receives a great deal of precipitation. In his description of the Crown of the Continent's climate, Long (2002) presents that Fernie receives 46 inches of precipitation annually. Like Kalispell, Fernie has a moderate climate and is influenced by the Pacific maritime air mass.

Fernie and the surrounding region is supported by institutions at the local, regional district, and the provincial levels. A recent addition to the local institutional regime is the Columbia Basin Trust. The trust was formed in 1995 by residents in the

Columbia Basin negatively affected by the Columbia River Treaty that resulted in the construction of four dams on the river that caused significant environmental degradation and social and economic upheaval. Negotiations between local communities, First Nations, and the Province of British Columbia resulted in the establishment of the Columbia Basin Trust with a mission focused on building and increasing social and institutional capacity throughout the Columbia Basin. The Trust works directly with communities and funds projects that improve environmental, economic, and social components of the region. Examples of the Trust's broad support is evident in the projects funded in Fernie that include reducing bear and human conflicts, support for the Fernie Arts Council Administration, funding for preschool activities, and a support group for preschool age children through a women's support group to name only a very few based on the Trust's search engine of funded projects for the community²¹.

Canadian census statistics place the population of Fernie at 4,217 in 2005, an 8.5% decrease in population from 2001 (Statistics Canada, 2006). Although Fernie has a community history steeped in natural resource extractive industry, if that industry once dominated it no longer does. Statistics Canada places a combined category of agriculture and other resource-based industries at 16.4% of the economy for the town. The rather bland category of "other services" appears to encompass Fernie's burgeoning recreation industry (as well as other unidentified sectors and industries) and employs 27.7% of the population. Unfortunately, there is no way to discern what percent or absolute number of the population is employed in the increasing recreation sector. Nevertheless, Elk Valley Coal, Tembec forest products, and Fernie Alpine Resort are presented as leading

²¹ A search of 'Fernie' in the Columbia Basin Trust's funding page at the following website provided the above examples- <http://www.cbt.org/Funding/>.

employers in Fernie's community profile from the town's Chamber of Commerce website. Statistics Canada 2005 figures places median income for workers over fifteen years of age in Fernie at \$25,560 dollars Canadian.

As noted in Chapter Three there is a limited amount of data from Fernie. Nonetheless, a significant and relevant situation was presented during fieldwork. An interview with a senior local government official detailed how increased rain in place of snow appears to be impacting the local water supply. The official detailed how the influx of rain was negatively impacting Fernie's municipal water supply. The following quote provides insight into the situation, "The rain is having the impact on the aquifer so when we have runoff with the snow we don't seem to get the same kind of turbidity issues. We have lots of turbidity issues now because of the rain, the massive amounts of rain that we're getting".

Fernie has already begun the process of addressing the situation through the development of additional municipal water sources. The same senior local official noted the following during our discussion on the issue,

So what we've got is an aquifer that's in the mountains right, so we have no idea what it looks like. We know it's there and it's been there for 100 years, it's been our water source forever. But what we're finding is that in the last while we have more turbidity and much more stuff going on with that system. So something has happened within that aquifer, which is why [the city] council was pushing hard to get a second source. So that's when the James White well came up. That was one that the city had discovered some time ago but hadn't done anything with. They knew it was there, it has a pipe, it's been capped, it's just been there. But they've done the tests and found out that it is good clean usable water, what would actually make a great primary source.

Although overall data is limited the situation nevertheless illustrates an additional path through which the impacts of climate change on the hydrologic cycle has impacted the Crown of the Continent Ecosystem. While this situation addresses social and

economic components of the social-ecological system, it's likely that further research would reveal ecological impacts as a result of the situation, possibly related to land cover or aquatic habitat near the aquifer. It's hard to imagine that there are not additional consequences from turbidity on aquatic habitat and species that further impact the system's resilience.

Conclusion

Impacts of climate change on the Crown of the Continent Ecosystem's hydrologic regime is producing impacts that are in many aspects reflective of other regions as is supported by the broader research and literature. In the ecosystem itself there are a number of stressors that span the ecosystem, but in many cases those same influences impact the three case study communities in different ways and likely at different levels.

Governance and institutional support for natural resource management exists at multiple levels throughout the ecosystem. The Crown Manager's Partnership, the Flathead Basin Commission, and public land management agencies provide institutional and governance support to either the whole or a broad swath of the ecosystem. Local institutions like the Columbia Basin Trust and irrigation companies provide locally specific institutional support. The diversity of scale and capacity serve as a means through which both adaptive capacity and social-ecological resilience can be addressed in the COCE. The final chapter of this dissertation will present conclusions and recommendations as it relates to the impacts of climate change on the ecosystem's hydrologic regime and direct and indirect impacts on social-ecological resilience. Institutional support and capacity building will serve as a means to address these impacts.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The chapter that follows draws to a conclusion this dissertation. The first chapter introduced the reader to the purpose, goals, and setting of the research. Chapter Two established the theoretical foundation for this study. Chapter Three presented the methodology for the research; the application of those methods in the field were presented in the results of Chapter Four. Chapter Five synthesized the findings and placed them in the context of relevant research and scholarly literature before presenting a suite of three case studies. The three case study communities served as a means of further synthesizing and presenting the results. The following chapter will conclude the dissertation with a presentation of the conclusions and recommendations based on this research. The conclusions presented herein are based on each of the three research questions referenced throughout this study. Following the conclusions are a set of recommendations that address issues at both the local and ecosystem level. These are followed by a set of lessons learned that may prove insightful beyond the boundaries of the Crown of the Continent Ecosystem for researchers and practitioners addressing the implications of climate change.

Research Conclusions

Research Question 1

The results from Chapter Four, in addition to the literature reviewed in Chapter Two, provide clear evidence that climate change is impacting the hydrologic regime of the Crown of the Continent Ecosystem. The participant identified climate change indicators presented in Chapter Four provide evidence of the recognition of those impacts within the COCE.

Clearly there is appreciation of the direct effects of the impacts climate change is and will continue to have on the COCE's hydrologic regime. Additionally, there was considerable appreciation for the secondary and tertiary effects that have been or are likely to be produced, as evidenced by the quotes presented in earlier chapters, resulting from discussions on topics such as disturbance regimes, habitat impacts, and implications for industries.

Direct and indirect effects of changes to the ecosystem's hydrologic regime will continue to contribute to risks related to the forestry, agriculture, recreation, and tourism sectors. Vulnerability to these risks will in part be influenced by each individual sector's exposure and vulnerability (IPCC, 2007) to those indicators presented in this research as well as continually emerging threats. A means of continuing to develop the capacity to adapt to the impacts of climate change and its cascading consequences is through the development of strategies and resources to cope with these impacts. A number of the vulnerabilities identified through this research span community and sector boundaries setting the stage for development of robust responses that span political and professional boundaries. Of particular salience are the effects that shifts in disturbance regimes may

have throughout the ecosystem, on multiple sectors, and across numerous political boundaries.

A significant number of participants identified disturbance regimes as the lens through which they understood climate change's impacts on the hydrologic regime as the themes and categories of Chapter Four demonstrate. Ecosystem disturbance in the form of fire, mountain pine beetle outbreak, rain-on-snow events, etc. are also social-ecological disturbances through their impacts on economic sectors and as a driver of policy responses on a managed landscape. Within the context of disturbance regimes it must be recognized that there also exist social-ecological disturbances that provide feedbacks to the ecological system (Gunderson & Holling, 2002).

The closure of the Smurfit-Stone mill in Frenchtown, Montana is an excellent example of a social disturbance with potential ecological implications. In addition to the obvious direct impacts that stem from the loss of a major employer and the social and economic ripples that result throughout a community, in the case of Smurfit-Stone there is the potential for ecological consequences. Loss of yet another mill in the region further reduces policy options and management responses on a landscape in which considerable portion have been managed to differing degrees. In the short-term, loss of the mill appears to reduce the adaptive capacity of the timber industry with potential implications for public land management. In turn, this may result in a forgone policy response that could include fire management through timber reduction and/or habitat improvement, as limited examples.

Loss of Smurfit-Stone quantitatively reduces timber industry infrastructure. Smit and company (2001) recognizes the importance of infrastructure from the national to the

local level. Therefore it is rational, within the context of the COCE, to view loss of infrastructure from a regional, economic sector as an extension of that specific determinant of adaptive capacity. The situation additionally influences public land management and natural resource management institutions by potentially reducing policy response through timber treatment. The situation may also create an opening for future policy innovation and responses with regard to the impacts of climate change on the forests of the Flathead Valley by creating a need for innovation and creativity.

Management of areas impacted by mountain pine beetle provides an example of reduced policy responses to climate change as a loss of adaptive capacity. With a reduction in the ability to sell timber harvested as a treatment from areas infested by the beetle, natural resource and public land managers must now reconsider how they will respond to the disturbance, if at all.

Clearly, as demonstrated by Fernie's search for additional drinking water sources and Choteau's consternation over water availability for agriculture, climate change is producing direct and indirect impacts to all three communities in the COCE. How these impacts will be dealt with in the future are questions related to both adaptive capacity and the resilience of the social-ecological system. The second research question of this dissertation was intended to address these issues by asking what strategies and resource are being and have been developed to address the situation?

Research Question 2

Chapter Four presented an array of strategies for addressing the impacts of climate change on the COCE's hydrologic regime. There exist two overarching themes to the strategies that were presented and will be further discussed as both have implications for

affecting social-ecological resilience and adaptive capacity in the individual communities of this study and throughout the Crown of the Continent Ecosystem.

Strategies for coping with the impacts of climate change on the COCE's hydrologic regime presented in Chapter Four were held together by the common thread of a historical perspective. Most strategies were reflective of traditional activities related to natural resource management. Timber harvest to deal with fire, disease, and forest infestation; efficiency improvement and increased storage capacity to cope with changes in snowpack runoff are all deeply entrenched in traditional approaches to natural resource management in the timber and agriculture sectors when responding to variation within historical ranges. The danger of attempting to address the impacts of climate change through a historical perspective, for any sector, is the potential lack of a historical analog. Future uncertainty requires flexibility, leadership, and creativity in addressing unforeseen circumstances and outcomes- something that is difficult in most sectors even in a well understood operating environment. The difficulty with addressing the impacts of climate change is the possibility that impacts will fall outside the range of historical variability that individuals, sectors, and communities have experienced. This situation brings us to the second overarching theme related to the strategies presented- uncertainty.

Uncertainty relative to expected changes, the cascading consequences of current changes, and how to adequately or even proactively respond to these changes underpinned the responses from participants when speaking to strategies to cope with the impacts of climate change. Uncertainty is one of the most confounding issues when addressing social-ecological resilience (Holling, et al., 2002). Holling (1986) presents that uncertainty in ecological systems creates policy surprise as the ecosystem acts or

reacts in an unexpected manner. Ecological uncertainty as a result of climate change undoubtedly underpins the uncertainty in strategies presented to address the impacts of climate change in the Crown of the Continent. It is therefore logical, given this uncertainty surrounding the manner in which climate change has or will influence biophysical and ecological components of the COCE, that strategies are steeped in historical responses.

Given the high level of uncertainty in the Crown of the Continent, efforts have been undertaken to reduce uncertainty to some degree. Glacier National Park's scenario planning exercise reflects an established and recognized strategy to addressing the impacts of climate change (IPCC, 2007). Scenario planning allows participants to game out different projections and outcomes related to climate change. As note earlier in this dissertation Glacier National Park was recognized by participants on both sides of the international border as providing leadership in addressing climate change in the Crown of the Continent. The scenario planning workshop was only one strategy utilized by the Park to provide leadership while attempting to reduce uncertainty. Addressing climate change in the Park's interpretive program was a second avenue through which Glacier National Park was noted as providing leadership in addressing climate change.

A relevant question stemming from both the historical responses to climate change impacts and future uncertainty as a result of climate change is- are communities and sectors within the COCE developing strategies and resources to respond to climate change or to historical disturbances? Based on this research the answer is mixed. Clearly a number of historical responses to the impacts of climate change are being applied in the COCE. At the same time, Glacier National Park is clearly attempting to grapple with

climate change and its uncertainty through its scenario planning exercise. It is to be seen whether historical perspectives and responses will undermine resilience and adaptive capacity as the Crown of the Continent continues to be confronted by the impacts of climate change.

The second avenue through which adaptive capacity and social-ecological resilience was addressed in this research was through the application of resources. This research revealed two vectors in the COCE through which adaptive capacity is influenced. The first is through institutional capacity, the second is monitoring.

While public land and natural resource management agencies asserted differing views on their internal capacity to recognize and address the impacts of climate change on the hydrologic regime, there was overwhelming belief that there was a lack of capacity. As noted early on in the resources section of Chapter Four, many agencies noted the need for increased budget and personnel in order to adequately address the impacts of climate change. This was further supported by statements from non-profit and timber industry participants that noted public land and natural resource management agencies must already prioritize the issues they address leaving open the question of how the impacts of climate change would fall within the list of priorities.

Institutional capacity is one of the six determinants of adaptive capacity (Smit, et al., 2001) and therefore a lack of internal capacity among natural resource and public land management agencies is a reason for concern (lacking capacities may include poorly defined response policies, lack of clear mandates and jurisdictions, and the loss of institutional knowledge). Given the role that such institutions play in the social-ecological system between both the ecological and economic components, lack of

institutional capacity has direct impacts on the information and skills associated with developing future strategies and resources to cope with climate change, which are an additional determinant of adaptive capacity (see [Table 2-1](#)). An apt question related to this situation is whether or not the lack of capacity leads to or results in forgone opportunities?

A second concern related to resources raised numerous times by participants is the lack of a robust long-term monitoring program capable of detecting change as a result of climate change. Lack of long-term ecological and biophysical monitoring is not a new concern for natural resource and public land managers. Participants from the timber and agricultural industry also acknowledged the lack of a robust monitoring regime to meet their needs. The current monitoring regime supports continuing uncertainty and potential social-ecological surprise from missed ecological signals.

Although there is concern with regard to both strategies and resources related to addressing the impacts for climate change in the COCE, all is not bleak. Throughout the ecosystem there are an overlapping set of natural resource and public land management institutions. Institutions at the local, county, state/ provincial, tribal, and federal levels provide capacities that often overlap even if their geographic areas of responsibility do not. Management of game species overlap political boundaries as do responses to fire and flood. Institutions at different levels bring a different perspectives to the table, but in the realm of natural resource management can serve as a means of filling in holes in institutional capacity at different levels both above and below. These overlapping institutions provide increased response diversity (B. Walker, et al., 2006) increasing the ability to respond to unforeseen outcomes and if leveraged proactively, can also serve to

reduce ecological uncertainty by increasing institutional capacity between institutional levels.

Research Question 3

Determining the efficaciousness of adaptive capacity is largely based on concrete adaptations (Lemos, et al., 2007) in coping with natural resource related disturbance-climate change related or otherwise . As noted in Chapter Three this presents a number of difficulties with the third research question as originally written. While determining the efficacy of adaptive capacity in the COCE is beyond the ability of the data gathered in this study to address, as noted in Chapter Three, placing parameters on the question and refining it can provide focus through which the question can be partially answered. An effective means of addressing the third research question is by addressing it through the determinants of adaptive capacity (see Smit, et al., 2001). The section that follows will discuss the social-ecological systems within the COCE through the determinants of adaptive capacity.

Smit and company (2001) present that economic resources, at numerous levels from the national to the local, influence adaptive capacity. At the community level economic diversity appears to be the key when considering economic resources with regard to adaptive capacity. Kalispell and Fernie have both made strides in diversifying their economy. Leaders in Choteau recognize the need and benefit of economic diversification and most stakeholders recognize that Choteau's economy is largely dependent on agriculture in its current configuration. There also exists a concern that the town's identity may be lost if agriculture is reduced or replaced. This may present a significant barrier to developing future economic diversity.

Technological innovation and availability underpins many adaptation strategies. Leveraging technology in the Crown of the Continent as a means of addressing climate change is a mixed bag. Monitoring technology in the form of SNOTEL and other meteorological technologies obviously enhances data, but as noted throughout this dissertation there exists a belief that the current monitoring regime, meteorological, ecological, or biophysical, is not currently adequate.

The modernization and mechanization of both the timber and agricultural industries demonstrate definite technological advances. The question now is whether technologies for timber harvest and agriculture planting, fertilization, irrigation, and harvest will provide individuals, companies, and the sectors as a whole additional flexibility and the ability to leverage those technologies in innovative ways. When compared with the same industries in less economically developed countries there is no doubt that the timber and agricultural industries in the COCE possess considerable technological advantages. The challenge appears to stem from uncertainty in how to leverage those technologies in an uncertain future.

If there is a determinant of adaptive capacity in the Crown of the Continent Ecosystem that exemplifies the region's potential to see through concrete adaptations to climate change it is the information and skills determinant. The Crown of the Continent possess a robust multi-level natural resource management regime that has recognized the need to address the impacts of climate change. At the federal level, Glacier National Park has picked up the mantle of leadership and provided a scientific grounding for collaboration in addressing the impacts of climate change. While there is a high level of uncertainty surrounding how to respond to such a large and often amorphous issue,

Glacier National Park's scenario planning workshop demonstrates a commitment to bring stakeholders to the table to address the problem. Although, as noted throughout this dissertation there exists concern related to present and future monitoring capabilities, personnel, and resource availability.

The role of infrastructure has been addressed in this research through the narrow lens of timber industry infrastructure with only cursory discussion of social and public infrastructure. As presented by Smit and company (2001) infrastructure is related to physical structures that provide public benefit in the form of roads, power plants, storm drainage systems, etc. Nevertheless, infrastructure critical to vital economic sectors of a community and a region are equally important. It can be debated, given the small role the timber industry holds in the contemporary economy, whether infrastructure for this industry holds the same importance as that of other sectors in the Flathead Valley. But as Power and Barrett (2001) present, perceptions of economic importance play a powerful role in shaping the impacts an industry has in a community even when the dollar amount in the overall economy is relatively small. The take away from this discussion is that although the timber industry provides a small number of jobs and economic capital into the overall economy, decline in its infrastructure and further reduction in the industry can have an outsized impact when it comes to providing communities and the region tools to address adaptive capacity.

In addition to the adaptive capacity determinant of information and skills, institutions in the form of natural resource management in the Crown of the Continent Ecosystem are robust and provide a solid backbone for the development of adaptive capacity. Table 6-1 provides examples of the multi-level natural resource management

institutions in the COCE. Not to be overlooked are the scientific institutions at work in the ecosystem to include the Flathead Lake Biological Station and the U.S. Geological Survey with offices and on-going research in Glacier National Park. The Crown Manager's Partnership provides an international forum for natural resource management and has brought together stakeholders to specifically discuss the impacts of climate change in the ecosystem. There is considerable interest in maintaining the information and skills related to natural resources within institutions and finding a means of leveraging current and future knowledge in a manner that produces positive outcomes from the ecosystem's natural resource management. Competing management requirements and the disconnect between political boundaries and ecological realities will continue to plague natural resource managers. But even in this demanding environment natural resource institutions in the COCE provide a strong foundation for developing future tools, strategies, and resources to address the impacts of climate change on the ecosystem's hydrologic regime.

The final determinant of adaptive capacity identified by Smit and associates (2001) is equity. This research did not gather data in relation to the role of equity in the response to climate change. Thus, it would be inappropriate to attempt and extrapolate the data to speak to equity, as a result this determinant of adaptive capacity will go unaddressed. Nevertheless, this may offer an avenue for future research.

By narrowing the scope of the third research question to a discussion on the determinants of adaptive capacity it becomes possible to understand adaptive capacity in the Crown of the Continent Ecosystem without relying on a post-hoc review of concrete adaptations. As with research question two, the outcomes from this research point to

opportunities and difficulties in addressing the impacts of climate change on the ecosystem's hydrologic regime as well as cascading consequences for the larger social-ecological system.

Table 6-1: Examples of Multi-level Natural Resource Management in the Crown of the Continent Ecosystem.

Local	State/ Provincial	Federal
County Commissions	MT Fish, Wildlife, and Parks	Glacier National Park
Conservation Districts	MT Dept. of Natural Resource Conservation	Lewis & Clark National Forest
Irrigation Districts	MT Department of Environmental Quality	U.S. Fish and Wildlife Service
East Kootenay Regional District	BC Ministry of the Environment	Environment Canada

There are a final set of conclusions that stem from this research. These conclusions speak to the Crown of the Continent as a whole rather than the individual communities which served as the basis for data gathering and level of analysis for this research. The first is that while the Crown of the Continent is considered an ecological unit, it is not a single social-ecological system. As the three case study communities demonstrate each community is reliant on natural resources in a different manner and to differing levels. Additionally, communities unto themselves are not social-ecological systems. Rather it appears that the Crown of the Continent is composed of numerous social-ecological systems at the sub-regional scale (i.e. Flathead Valley or the Rocky Mountain Front). Finally, the role of public land management in organizing and influencing these social-ecological systems cannot be understated or underestimated. This research accounted for and included public land management agencies, but did not dwell on the social and political impacts that public lands produce in the Intermountain West or the Crown of the Continent. There can be no doubt that ecological resilience and

therefore social-ecological resilience will be heavily influenced by the policies, strategies, and resources developed and brought to bear by public land management agencies in addressing the impact of climate change in the COCE.

Recommendations

The section that follows draws this dissertation to a close with a series of recommendations based on the data and conclusions of this research and relevant literature. The following paragraphs will present a set of recommendations for the individual case study communities and the Crown of the Continent Ecosystem as a whole. Given that the purpose of the multiple case study focus of this research is on understanding the complex issues at the ecosystem level, local recommendations will be far more limited than ecosystem-wide recommendations.

Local Recommendations

As the largest community in the COCE, Kalispell possesses the most complex social and economic system in the ecosystem. The challenge for leadership and stakeholders in the Flathead Valley is to leverage the multi-level governance and natural resource management institutions that already exist to address the short-coming in capacity of any single institution or sector. This can only be accomplished through a willingness to collaborate on addressing the current and future impacts of climate change on the natural resource capital of the Valley. This will likely entail recognizing that there will be winners and losers in the outcomes related to climate change with regard to the allocation of limited resources toward addressing select impacts in specific sectors.

While Choteau's community and economy are smaller than that of Kalispell, the impacts of climate change are no less dire or contentious. This research reveals two

overarching recommendations for Choteau and the Rocky Mountain Front. The first is developing a willingness to address in an open and meaningful way the realities related to the limitations of water on the region and its cultural fabric- a task whose difficulty should not be underestimated. The second recommendation that accompanies the first is the development of resources to reduce conflict in a way that allows the conversation about water to move forward. Without conflict resolution and facilitation capacities being brought to bear the likelihood of achieving the first recommendation is highly unlikely.

As Fernie continues its economic transition the challenge for local government and industries is for future development not to undermine the ecological resilience of the Elk River Valley. Proactively integrating the impacts of future economic transition on the sub-region's natural capital will help to ensure the capacity to address ecological uncertainty is maintained.

The individual recommendations for each of the three case study communities hold the potential to address the ecological resilience of each sub-region and the adaptive capacity of each of the three communities. This sets the stage for a broader understanding of resilience and adaptive capacity at the ecosystem level.

Crown of the Continent Ecosystem Recommendations

The first Crown of the Continent-wide recommendation relates to all three communities as well as the larger ecosystem as a whole. A positive and proven means of beginning to address the uncertainty that surrounds climate change is through the development of a

vulnerability assessment (O'Brien, et al., 2004; Smit & Wandel, 2006). Such an assessment can be tailored to the needs of interested communities or expanded to encompass large geographic areas depending on the goals of the assessment. A very real danger associated with such an effort is the politization of the study purposefully or through a lack of early stakeholder engagement and community buy-in, which can result in increasing conflict and create barriers to accepting the findings or implementing strategies.

The second COCE-wide recommendation stems from an issue that was raised several times during the research by stakeholders in various sectors. When explaining the scope of the research many participants asked what metrics would be used to judge adaptive capacity in the research? Being a qualitative study I would explain that there were no measurable metrics that would be utilized to identify directional change. Thus, the second recommendation is to develop metrics, not for adaptive capacity, but also resilience, as we know that it's likely that adaptive capacity can be judged only following a disturbance and judged post-hoc (Lemos, et al., 2007). Therefore, the refined recommendation is to develop metrics that address social-ecological resilience and are capable of serving as an indicator of change. This brings us to the third recommendation.

It was not obvious at the outset of this research that the way through which many participants recognized and understood climate change would be through impacts and influences on the ecosystem's disturbance regimes. Addressing the impacts of climate change through disturbances can be accomplished through well established theory and measures related to environmental risk (Nelson, et al., 2007). Furthermore, utilizing disturbance regimes as the paradigm for addressing the impacts of climate change can be

accomplished by mapping the social-ecological system then determining thresholds and tipping points that reduce or generate resilience with regard to specific components of the ecosystem associated with related disturbance regimes. A ready example is determining the functional role of whitebark pine within the Crown of the Continent Ecosystem then determining critical thresholds with relation to the specie's abundance and distribution. A second metric would be a measure, within a set of parameters, if and when disturbance critical to whitebark pine, such as fire or the loss of its symbiotic companion Clark's nutcracker, impacted resilience of the larger ecosystem. An additional example would be to map the current mountain pine beetle outbreak, utilize the adaptive cycle heuristic, and ask the question of whether or not the ecosystem is poised to enter into the release or reorganization phase of the cycle? Generally understanding what phase the ecosystem currently resides in can provide clarity to developing future strategies for coping with climate change influenced disturbance and the application of scarce resources for planning and response to environmental change.

The fourth recommendation specific to the Crown of the Continent Ecosystem relates to the strong natural resource management and research institutional structures currently in place. The current multi-level overlapping natural resource, public land, and scientific institutional capacity can be utilized to develop scale specific indicators of social-ecological resilience, critical thresholds, and tipping points for both the ecological and social components of the ecosystem. This will require both personal and institutional leadership. Without the willingness of individuals to take the lead in developing the capacity for such an undertaking it's unlikely that such an outcome will be borne out.

Such an opportunity almost begs for the application of adaptive management as espoused in resilience theory.

The fifth recommendation that spans the ecosystem is to build on existing organizational and social structures to further develop collaborative approaches to dealing with the impacts of climate change. Organizations exist at multiple levels that can be adapted to undertake collaboration with regard to the impacts of climate change. At the local level the Sun and Teton River Watershed Groups can serve as the foundation for exploring the means to understanding and developing strategies to address the impacts of climate change across sectors in Choteau and the surrounding region. The Crown Managers Partnership currently serves as a trans-national means of collaborative information gathering on natural resource related issues, to include climate change. Nevertheless, there is an urgent need for substantive trans-national collaboration that addresses the impacts of climate change. In order to move from an information gathering and dissemination oriented organization to an organization that seeks goal-oriented responses, the Crown Managers Partnership and its constituent natural resource management and governance agencies must develop a mandate and foster the leadership to undertake such a transition.

The final recommendation specific to the Crown of the Continent comes from a participant in the research. Dramatic and unpredicted changes in a system often result from a lack of understanding related to the speed at which variables in a given system interact. The interaction of slow and fast variables in a system can move a seemingly stable system to collapse and reorganize (Holling, 1986). When observing the utilization and allocation of water on the Rocky Mountain Front it appears that Western Water Law

is the slow variable in the social-ecological system with change in that institution being outpaced by changes in the climate itself. If this proves true then there is a likelihood that variables operating at faster speeds may undermine the resilience of the system itself as the institution fails to keep pace with ecological and social change. While the outcome cannot be hypothesized at this point, the recommendation of a participant, in the following paragraph, may provide an additional bit of stability to the system.

During the course of multiple discussions one participant suggested bringing agricultural producers from a watershed that has already been through the adjudication process to Choteau to speak with local agricultural producers. The participant went on to note that this may alleviate some of the fear and uncertainty currently surrounding the process and that continues to create an atmosphere of tension and reduced collaboration. Implementing the participant's recommendation may well provide necessary perspective to the situation and its eventual outcome to allow for the beginning of proactive actions to address the impacts of climate change on the town's irrigation system.

The ecosystem-wide, and to a limited extent local recommendations, from this study can prove instructive for leadership in other regions experiencing the impacts of climate change throughout the United States. While many of the recommendations could apply to regions beyond the COCE experiencing the impacts of climate change on their hydrologic regime, there are nevertheless three specific lessons learned from this research that appear particularly applicable to different regions. The first is to identify the relevant level at which the social-ecological system can be understood and therefore institutional knowledge and capacity can then be appropriately applied. Second, map the disturbance regimes most likely or currently affected by climate change within the social-ecological

system and incorporate relevant upper and lower level components of the ecosystem. Finally, develop a monitoring regime capable of detecting changes in the disturbance regime at the level appropriate to the social-ecological system in question.

Conclusion

The Crown of the Continent Ecosystem is currently experiencing ecological and economic impacts resulting from climate change. As the impacts are coming into better focus the future remains murky and uncertain. There is an increased understanding across sectors in the COCE that the impacts of climate change on the hydrologic regime must be addressed at numerous levels.

The assessment of social-ecological resilience and adaptive capacity in this dissertation has revealed a limited set of vulnerabilities and stressors related to the impacts of climate change. Impacts associated with those vulnerabilities and stressors, in turn, produce cascading consequences with multi-level effects. The complexity of the situation has produced considerable uncertainty for the future. This research provides leaders at the local, state/provincial, and federal levels within the COCE a set of conclusions and recommendations to begin to address resilience and adaptive capacity related issues within their organizations. Leaders outside the COCE can also benefit noting the impacts, vulnerabilities, and capacities presented throughout this dissertation.

The focus throughout this dissertation has been to develop an understanding of the impacts of climate change on the hydrologic regime of a montane ecosystem and the social responses to those impacts. This was undertaken within the framework of three research questions. The data gathered provided substantive answers to the first two

research questions while the third was engaged when narrowed down to a manageable scope.

Adaptive capacity within the Crown of the Continent Ecosystem is uneven when viewed between the three case study communities and across sectors. Additional research on both adaptive capacity and social-ecological resilience at the sub-regional level can assist communities and sectors by providing much needed, scale specific clarity related to the impacts of climate change and responses to those impacts.

Throughout the course of this research resilience theory has moved from an abstract theory and organizational concept to a robust means of empirically understanding a changing environment and the social responses that accompany changes in natural resources. Ecological research, such as the identification of functional groups and their vulnerability to the impacts of climate change, can be further explored and understood through the lens of resilience theory . Addressing complexity and uncertainty in explicit terms and utilizing the tools provided by resilience theory (B. Walker & Salt, 2006), the adaptive cycle heuristic (Gunderson & Holling, 2002; Holling, 1986), and supported by the increasing literature, provides a sound basis for developing policy relevant, empirically based recommendations. Finally, resilience theory can be applied to empirical studies in such a way as to address the multi-level impacts of climate change on the biophysical, ecological, and social environments.

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APPENDICES

APPENDIX A

ONLINE SURVEY

1. Welcome to the Crown of the Continent Survey Research

You have been invited to participate in a research project that will study issues related to water resources within the Crown of the Continent. The purpose of this research is to develop an understanding of strategies developed and relied upon in the region to deal with water related issues, risks, and vulnerabilities.

It is projected that New England may experience future impacts related to water resources similar to those now being experienced and addressed by people and communities in the Crown of the Continent region. This research will seek to learn from your experience and the results used to inform future decision-making in New England.

This project is conducted by Brad Johnson, a doctoral student in the Department of Natural Resource & the Environment at the University of New Hampshire (UNH). The use of human participants in this project has been approved by the UNH Institutional Review Board (IRB) for the Protection of Human Subjects in Research. Please read the following statements. If you understand them and agree to participate, please click on the "next" button at the bottom to indicate your consent and go to the first question of the survey.

Information for participants

- you are being asked to participate in this research as you have been identified as a key participant. This is not a random survey.
- results from the survey may be reported in group format as part of a research or scientific publication.
- the survey is confidential and will take approximately 15 minutes. No individual identity will be determinable through demographic information such as age or gender.
- your participation is purely voluntary and you are free to withdraw your consent and discontinue participation at any time. Your responses to the survey will be kept confidential.
- finally, if at any time you have questions or concerns about any procedure in this project, you may e-mail the principal investigator at mimi.becker@unh.edu or speak with the principal investigator by calling Dr. Mimi Becker at (603)862-3950. If you have questions about your rights as a research participant, you may contact Julie Simpson in UNH Office of Sponsored Research, (603) 862-2003 or at julie.simpson@unh.edu.

2. Water Resource Use and Value

The purpose of the following questions is to get a sense of how individuals, organizations, and groups within the Crown of the Continent rely upon and value different water resources as well as identify concerns related to those resources

1. For what uses do you rely on local water resources? Please check all that apply.

- Drinking Water
- Sanitation (Septic System)
- Irrigation (Farming)
- Water Supply (Ranching)
- Business or Industry Need
- Recreation (including but not limited to summer winter and motorized)
- Fish & Wildlife Habitat Needs

Other (please specify)

2. For the uses noted in the previous question where does that water come from? Please check one.

- Ground Water
- Surface Water
- Both
- Unsure

3. In your opinion, what are the streams, rivers, lakes, and reservoirs that are most important to your needs? Please type the name of each in the boxes below.

Water Body 1

Water Body 2

Water Body 3

Water Body 4

Water Body 5

4. In your opinion, what are some of the most pressing concerns related to the water supply you depend upon? Please check all that apply.

- Water Quantity (do current and will future water availability serve your needs?)
- Water Quality (pollution)
- Public Access to Water Resources (recreation)
- Consumptive Access to Water Resources (agriculture irrigation)
- Consumptive Access to Water Resources (extractive industry)
- Habitat for Threatened, Endangered, or Species of Concern

Other (please specify)

5. In your opinion, what negative impacts to the water resource you rely upon concern you? Please mark your level of concern for each.

	No Concern	A Little Concerned	Concerned	Very Concerned	Unsure
Short-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dewatering (loss of stream flow)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Water Temperature	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Erosion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Influences on Fish and Game	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify other impacts and level of concern)

3. Water Resource Reliability

The following 3 questions are related to the reliability of local water resources for different periods of time.

1. On average over the course of 1 year how reliable are the surface water and ground water resources you rely upon? Please check one for both choices.

	Very Unreliable	Somewhat Unreliable	Reliable	Very Reliable	Unsure
Ground Water	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Surface Water	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. On average over the course of 5 years how reliable are the ground water and surface water resources you rely upon? Please check one for both choices.

	Very Unreliable	Somewhat Unreliable	Reliable	Very Reliable	Unsure
Ground Water	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Surface Water	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. Is there one or more seasons in which water reliability is a major concern for you? Please check all that apply.

	Ground Water	Surface Water
Spring	<input type="checkbox"/>	<input type="checkbox"/>
Summer	<input type="checkbox"/>	<input type="checkbox"/>
Fall	<input type="checkbox"/>	<input type="checkbox"/>
Winter	<input type="checkbox"/>	<input type="checkbox"/>
Unsure	<input type="checkbox"/>	<input type="checkbox"/>

4. Water Resource Issues on Local Public and Private Lands

The following 8 questions are related to the manner in which impacts to local water resources may negatively influence public and private lands.

1. Listed below are a number of influences and impacts related to local water resources. In your opinion, which, if any, produce negative impacts on public lands? Please check all that apply.

- Short-term Drought
- Long-term drought
- Fire
- Flooding
- Dewatering (loss of stream flow)
- Erosion
- Pollution (point source)
- Pollution (non-point source)

Other (please specify)

2. Please rate your level of concern related to each box you marked in the previous question.

	Unconcerned	Somewhat Concerned	Concerned	Very Concerned	Unsure
Short-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dewatering (loss of stream flow)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Erosion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (non-point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

3. In your opinion, how effective have efforts been in dealing with the impacts to local water resources on public lands? Please check one for each choice.

	Very Ineffective	Somewhat Effective	Effective	Very Effective	Unsure
Short-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dewatering (loss of stream flow)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Erosion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (non-point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="text"/>				

4. In your opinion, who is responsible for addressing negative impacts on public lands? Please check all that apply.

- Local Government
- State/ Provincial Government
- Tribal Government
- Federal Government
- Private Citizens

Other (please specify)

5. Listed below are a number of influences and impacts related to local water resources. In your opinion, which, if any, produce negative impacts on private lands? Please check all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Dewatering (loss of stream flow)
- Erosion
- Pollution (point source)
- Pollution (non-point source)

Other (please specify)

6. Please rate your level of concern related to each box you marked in the previous question.

	Unconcerned	Somewhat Concerned	Concerned	Very Concerned	Unsure
Short-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dewatering (loss of stream flow)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Erosion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (non-point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

7. In your opinion, how effective have efforts been in dealing with the impacts to local water resources on private lands? Please check one for each choice.

	Very Ineffective	Somewhat Ineffective	Effective	Very Effective	Unsure
Short-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dewatering (loss of stream flow)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Erosion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pollution (non-point source)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

8. In your opinion, who is responsible for addressing negative impacts on private lands? Please mark all that apply

- Local Government
- State/ Provincial Government
- Tribal Government
- Federal Government
- Private Citizens

Other (please specify)

5. Sector Questions

The following questions are intended to gain perspective into how specific groups rely on local water resources.

*** 1. Please indicate the sector in which you are most involved.**

- Agriculture (farming)
- Agriculture (ranching)
- Timber Industry
- Small Business
- Commercial Business
- Outfitter/ Guide
- Non-profit
- Local Government
- State/ Provincial Government
- Tribal Government
- Federal Government
- International Organization
- Other Industry (mining, oil & gas, etc.)

6. Agriculture Impacts

1. Approximately how many head of your cattle rely on the local water supply in an average year? Please place that number in the box below.

2. In an average year over how many acres of private land do you graze cattle? Please place the number in the box below.

3. In your opinion, what impacts to local waters impact private lands on which you graze cattle? Please mark all that apply.

- Short term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

4. Do you lease public lands for cattle grazing?

- Yes
- No

5. In your opinion, what impacts to local waters affect public lands on which you graze cattle? Please mark all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***6. Please place a check in the box below then press next to continue.**

Click here

7. Irrigation Impacts

**1. In an average year how many acres that you work must be irrigated to be productive?
Please place that number in the box below.**

**2. In your opinion, what impacts to local waters affect the waters you rely on for irrigation?
Please mark all that apply.**

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***3. Please place a check in the box below then press next to continue.**

- Click here

8. Outfitting & Guide Impacts

1. In your opinion, what impacts to local waters affect outfitting and guide business opportunities? Please mark all that apply.

- Public Access
- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***2. Please place a check in the box below then press next to continue.**

- Click here

9. Commercial Business Impacts

1. In your opinion, what impacts to local waters affect your commercial business? Please mark all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***2. Please place a check in the box below then press next to continue.**

Click here

10. Timber Industry Impacts

1. In your opinion, what impacts to local waters affect the timber industry? Please mark all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***2. Please place a check in the box below then press next to continue.**

- Click here

11. Small Business Impacts

1. In your opinion, what impacts to local waters affect your small business? Please mark all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***2. Please place a check in the box below then press next to continue.**

Click here

12. Agency Impacts

1. In your opinion, what impacts to local waters concern and/or affect the activities of your agency? Please mark all that apply.

- Short-term Drought
- Long-term drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

2. Is your agency involved in managing threatened, endangered, species of concern, or their habitat? If so, please place the common name(s) in the boxes below.

Species 1

Species 2

Species 3

Species 4

Species 5

3. In your opinion, what impacts to local waters impact species and their habitat that you manage for? Please check all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in box below)

Other (please specify)

***4. Please place a check in the box below then press next to continue.**

Click here

13. Non-profit Impacts

1. In your opinion, what impacts to local waters affect your non-profit organization? Please check all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***2. Please place a check in the box below then press next to continue.**

Click here

14. Industry Impacts

1. In your opinion, what impacts to local waters affect your industry? Please mark all that apply.

- Short-term Drought
- Long-term Drought
- Fire
- Flooding
- Erosion
- Dewatering (loss of stream flow)
- Pollution (point source)
- Pollution (non-point source)
- Water Availability (ground water)
- Water Availability (surface water)
- Recreational Activities (please provide the type in the box below)

Other (please specify)

***2. Please place a check in the box below then press next to continue.**

Click here

15. Water Issue Open Question

This is your opportunity to provide the researcher with any thoughts you may have on water issues and how they affect you, your livelihood, or your community. Please type text in the box below.

1. Please place your typed response here. Thank you.

16. Demographics

The purpose of these final questions is to learn a little more in depth information about the people and groups reliant on the local waters of the Crown of the Continent.

1. Place check the box that best represents your age group.

- 18-20
- 21-30
- 31-40
- 41-50
- 51-60
- 61-70
- 71-80
- 80+

2. Please indicate your sex.

- Male
- Female

3. Please check the box that best reflects your highest education level.

- Less than high school diploma.
- High school diploma or its equivalent
- Some College
- Baccalaureate Degree
- Graduate Education

4. Please indicate below the number of years you have lived in the region.

- Less than 5 years
- 5-10 years
- 11-20 years
- 21-30 years
- 31-40 years
- 41-50 years
- Greater than 50 years

5. If known, please indicate how many generations your family has lived in the region.

- 1 Generation
- 2 Generations
- 3 Generations
- 4 Generations
- 5+ Generations
- Unsure

17. Final Question

This last question is related to contact information and allows the researcher to track completion of the survey.

1. Please provide pertinent contact information in the boxes below. Thank you for taking the time to assist in this research by completing the survey.

Name:	<input type="text"/>
Organization:	<input type="text"/>
Address:	<input type="text"/>
Address 2:	<input type="text"/>
City/Town:	<input type="text"/>
State:	<input type="text"/>
ZIP/Postal Code:	<input type="text"/>
Country:	<input type="text"/>
Email Address:	<input type="text"/>
Phone Number:	<input type="text"/>

18. Thank You

Thank you for completing the survey! This page will further explain the purpose of the survey you have just participated in. After you are finished viewing this page and have submitted your answers by clicking on the button at the bottom of the page, it is recommended you exit or quit your Web browser to eliminate the possibility that your responses could be viewed by hitting the "back" button.

We would like to remind you that all the data you just provided will be kept confidential.

Because you have invested time in this study, you may have an interest in what we hope to find from your results. The purpose of this research is to develop an understanding of strategies developed and relied upon in the Crown of the Continent when dealing with issues related to water resources. Furthermore, it is the hope this research will help to inform decision-making related to many water resource related issues that are projected to impact New England that are currently experienced in the Crown of the Continent.

If you have questions about this survey, please email or call me using the information below. Thank you once again for your interest and participation. Now it's time to submit your answers.

If you would like results from the survey, please contact the principal investigator, Dr. Mimi Becker, at the number or address below.

CLICK Done if you have read this information and want to keep your responses to the survey.

CLICK Exit (located in the upper right hand corner) if you have read this information and want to remove your responses from the data file.

Principal Investigator: Dr. Mimi Becker
University of New Hampshire
Department of Natural Resources & the Environment
Nesmith Hall 310
46 College Road
Durham, NH 03824
Phone: (603) 862-3950
Fax: (603) 862-4978
Email: mimi.becker@unh.edu

APPENDIX B

SAMPLE SEMI-STRUCTURED INTERVIEW QUESTIONNAIRES

Agriculture Industry Questionnaire, Choteau

1. Drought has been identified as a significant impacts on water resources in the Choteau area. When thinking about drought in what ways in which it may be changed by climate change can I get your thoughts on that?
2. What strategies are utilized to help the industry cope with these impacts?
3. What resources (financial, political, and social) are available to help the industry cope with these impacts? Are there programs or incentives to cope available? Other activities?
4. In your opinion how effective have these resources been?
5. How can resource be improved? Increased availability? Increased scope?
6. If climate changes exacerbates drought in the Choteau area what, if anything will the agriculture industry need to do to successfully adapt to the circumstances?
7. Is there a need to develop new resources? In your opinion what these should look like or accomplish?
8. The Flathead Valley has a large number of organizations that seek to bring large-scale collaboration to natural resource policy & management such as the Flathead Lake Basin Commission and the Crown Manager's Partnership just to name two. Are there any organizations here in the Choteau area that look towards collaboration for landscape level natural resource management? Are you involved with any collaborative group(s)? If so, how?
9. Have organizations such as these added additional means of addressing issues related to drought in the Choteau area?
10. Given the impacts drought produce on industries such as agriculture and tourism, are there strategies that could improve the resilience of the community in the face of changing water resources (climate change)?
11. What type of monitoring data do you rely on to indicate that climate change may be impacting the agriculture industry? Is it adequate? How can it be improved?
12. In your opinion, what is or would be an effective indicator of the industry's ability to deal with the impacts of drought?

Additional questions based on time constraints.

13. There is a high level of concern related to the effects of changing water resources on fish and wildlife and their habitat. Has this produced impacts on the agriculture industry? If so, can you provide some examples?
14. Can you provide me a sense of the effectiveness of strategies and the applications of resources when dealing with fish and wildlife related concerns? How can they be improved if at all?

15. Dewatering was noted as an additional concern. This is surprising considering the amount of water here in the Choteau area. Do you have any thoughts dewatering?

Government Agency Questionnaire, Choteau

1. Drought has been identified as a significant impact on water resources in the Choteau area. What impacts does drought produce that most concern your agency?
2. Can you provide some background as to strategies used by the agency to deal with the impacts of drought?
3. When thinking about resources be it social such as collaboration, political such as the ability to implement new strategies or develop new resources, or economic such as the availability of financial incentives, how effective have resource been in dealing with the impacts of drought in the Choteau area?
4. How can resources be improved? Increased availability? Increased scope?
5. If climate changes exacerbates drought in the Choteau area what, if anything will the agency need to do to successfully adapt to the circumstances?
6. Is there a need to develop new resources? In your opinion what these should look like or accomplish?
7. The impacts of changing water resources on fish and wildlife have been noted. What impacts of drought has/may concern your agency?
8. The Flathead Valley has a large number of organizations that seek to bring large-scale collaboration to natural resource policy & management such as the Flathead Lake Basin Commission and the Crown Manager's Partnership just to name two. Are there any organizations here in the Choteau area that look towards collaboration for landscape level natural resource management? Are you involved with any collaborative group(s)? If so, how?
9. Have organization such as these added additional means of addressing issues related to drought in the region?
10. Given that the impacts drought produces on industries such as agriculture and tourism, are there strategies that could improve the resilience of the community in the face of changing water resource (climate change)?
11. What type of monitoring data do you rely on to indicate that climate change may be impacting water resources? Is it adequate? How can it be improved?
12. In your opinion, what is or would be an effective indicator of the agency's ability to deal with the impacts of drought?

Additional questions based on time constraints.

13. Can you provide me a sense of the effectiveness of strategies and the applications of resources when dealing with fish and wildlife related concerns? How can they be improved if at all?
14. Dewatering was noted as an additional concern. This is surprising considering the amount of water here in the Choteau area. Do you have any thoughts on dewatering?

Non-Profit Questionnaire, Kalispell

1. Drought has been identified as a significant impact on water resources in the Flathead Valley. Does drought impact your organization either directly or indirectly? If so, in what ways?
2. When thinking about resources be it social such as collaboration, political such as the ability to implement new strategies or develop new resources, or economic such as the availability of financial incentives, how effective have resource been in dealing with the impacts of drought in the Flathead Valley?
3. How can resource be improved? Increased availability? Increased scope?
4. If climate changes exacerbates drought in the Flathead Valley what, if anything will the you organization need to do to successfully adapt to the circumstances? What about the larger community?
5. Is there a need to develop new resources? In your opinion what these should look like or accomplish?
6. The Flathead Valley has a large number of organizations that seek to bring large-scale collaboration to natural resource policy & management such as the Flathead Lake Basin Commission and the Crown Manager's Partnership just to name two. Are you involved with any collaborative group(s)? If so, how?
7. Have organization such as these added additional means of addressing issues related to drought in the region?
8. Given the impacts drought produce on industries such as timber and tourism, are there strategies that could improve the resilience of the community in the face of changing water resource (climate change)?
9. What type of monitoring data do you rely on to indicate that climate change may be impacting water resources? Is it adequate? How can it be improved?
10. In your opinion, what is or would be an effective indicator of the communities' ability to deal with the impacts of drought?

Additional questions based on time constraints.

11. There is a lot of concern related to the effects of changing water resources on fish and wildlife habitat. Has this produced impacts on the timber industry? If so, can you provide some examples and how the industry and other organizations if there are any, have addressed the issue?
12. Can you provide me a sense of the effectiveness of strategies and the applications of resources when dealing with fish and wildlife related concerns? How can they be improved if at all?
13. Dewatering was noted as an additional concern. This is surprising considering the amount of water here in the Flathead Valley. Do you have any thoughts on dewatering?

Timber Industry Questionnaire, Kalispell


1. Drought has been identified as a significant impacts on water resources in the Flathead Valley. When thinking about drought how does it impact the timber industry?
2. What strategies are utilized to help the industry cope with these impacts?
3. What resources (financial, political, and social) are available to help the industry cope with these impacts? Are there programs or incentives to cope available? Other activities?
4. In your opinion how effective have these resources been?
5. How can resource be improved? Increased availability? Increased scope?
6. If climate changes exacerbates drought in the Flathead Valley what, if anything will the timber industry need to do to successfully adapt to the circumstances?
7. Is there a need to develop new resources? In your opinion what these should look like or accomplish?
8. The Flathead Valley has a large number of organizations that seek to bring large-scale collaboration to natural resource policy & management such as the Flathead Lake Basin Commission and the Crown Manager's Partnership just to name two. Are you involved with any collaborative group(s)? If so, how?
9. Have organizations such as these added additional means of addressing issues related to drought in the Flathead Valley?
10. Given the impacts drought produce on industries such as timber and tourism, are there strategies that could improve the resilience of the community in the face of changing water resources (climate change)?
11. What type of monitoring data do you rely on to indicate that climate change may be impacting the timber industry? Is it adequate? How can it be improved?
12. In your opinion, what is or would be an effective indicator of the industry's ability to deal with the impacts of drought?

Additional questions based on time constraints.

13. There is a high level of concern related to the effects of changing water resources on fish and wildlife and their habitat. Has this produced impacts on the timber industry? If so, can you provide some examples?
14. Can you provide me a sense of the effectiveness of strategies and the applications of resources when dealing with fish and wildlife related concerns? How can they be improved if at all?
15. Dewatering was noted as an additional concern. This is surprising considering the amount of water here in the Flathead Valley. Do you have any thoughts dewatering?

APPENDIX C

GLACIER NATIONAL PARK RESEARCH PERMIT

 <p>SCIENTIFIC RESEARCH AND COLLECTING PERMIT</p> <p>Grants permission in accordance with the attached general and special conditions</p> <p>United States Department of the Interior National Park Service</p> <p>Glacier NP</p>	<p>Study#: GLAC-00149 Permit#: GLAC-2010-SCI-0149 Start Date: Jan 15, 2010 Expiration Date: Dec 31, 2011 Coop Agreement#: n/a Optional Park Code: n/a</p>
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<p>Name of principal investigator: Name: Mimi Becker Phone: (603)862 3950 Email: mimi.becker@unh.edu</p>
<p>Name of institution represented: University of New Hampshire</p>
<p>Co-Investigators: Name: Brad Johnson Phone: (603)380-6339 Email: brad.johnson@unh.edu</p>
<p>Project title: Assessing Adaptive Capacity in the Face of Climate Change An Examination of Communities in a Rural Ecosystem</p>
<p>Purpose of study: The objectives of this research are to gain an understanding of 1) what perceived impacts of climate change on water resource people within the ecosystem are most concerned and 2) determine what resources are being developed and utilized in order to address perceived threats to water resources in the ecosystem from climate change</p>
<p>Subject/Discipline: Social Science</p>
<p>Locations authorized: The scope of the study area for this research is anticipated to be limited to NPS employee offices located at Glacier National Park</p>
<p>Transportation method to research site(s): Access to Glacier National Park offices will be conducted by using the established road network with a privately owned vehicle No other mode of travel is anticipated</p>
<p>Collection of the following specimens or materials, quantities, and any limitations on collecting: May interview park staff about climate change perceptions</p>
<p>Name of repository for specimens or sample materials if applicable: n/a</p>
<p>Specific conditions or restrictions (also see attached conditions): Please request permission and schedule appointments with interviewees ahead of time If your study allows, it is helpful to provide interview questions ahead of time so interviewee has time to consider them before the interview Some individuals may need to get clearance from their supervisor before participating</p>

Recommended by park staff(name and title):

John White, DIRECTOR CERIC

Reviewed by Collections Manager:

Yes No N/A

Approved by park official:

S.R. Davis

Date Approved:

1-19-10

Title:

Deputy Superintendent

I Agree To All Conditions And Restrictions Of this Permit As Specified
(Not valid unless signed and dated by the principal investigator)

[Signature]
(Principal investigator's signature)

1/19/10
(Date)

**THIS PERMIT AND ATTACHED CONDITIONS AND RESTRICTIONS MUST BE CARRIED AT ALL TIMES
WHILE CONDUCTING RESEARCH ACTIVITIES IN THE DESIGNATED PARK(S)**

INSTITUTIONAL REVIEW BOARD APPROVAL

University of New Hampshire

Research Integrity Services, Office of Sponsored Research
Service Building, 51 College Road, Durham, NH 03824-3585
Fax: 603-862-3564

28-Apr-2009

Johnson, Brad
NRESS, 326 Nesmith Hall
Durham, NH 03824

IRB #: 4526

Study: Assessing Adaptive Capacity in the Face of Climate Change: An Examination of
Communities in a Rural Ecosystem

Approval Date: 22-Apr-2009

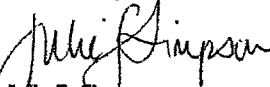
The Institutional Review Board for the Protection of Human Subjects in Research (IRB) has reviewed and approved the protocol for your study as Exempt as described in Title 45, Code of Federal Regulations (CFR), Part 46, Subsection 101(b). Approval is granted to conduct your study as described in your protocol.

Researchers who conduct studies involving human subjects have responsibilities as outlined in the attached document, *Responsibilities of Directors of Research Studies Involving Human Subjects*. (This document is also available at <http://www.unh.edu/osr/compliance/irb.html>.) Please read this document carefully before commencing your work involving human subjects.

Upon completion of your study, please complete the enclosed Exempt Study Final Report form and return it to this office along with a report of your findings.

If you have questions or concerns about your study or this approval, please feel free to contact me at 603-862-2003 or Julie.simpson@unh.edu. Please refer to the IRB # above in all correspondence related to this study. The IRB wishes you success with your research.

For the IRB,



Julie F. Simpson
Manager

cc: File
Becker, Mimi