Resilience and Climate Change: Adaptation Potential for Ecological Systems and Forest Management in the West Kootenays

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A two year integrated vulnerability assessment is underway in the West Kootenay region of British Columbia. The main goals of the assessment are to increase knowledge about climate change and ecological resilience, and enhance the capacity of forest managers to adapt to the challenges of climate change.

Technical Working Paper Draft

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An outline for the project, and more detailed workplans are available on our website: ***www.kootenayresilience.org***

1 Technical Paper: Working Draft.

Notes to the reader: This document has been distributed to participants of the West Kootenay Resilience Project - Technical Workshop #1. The purpose of making this paper available is to solicit comments and promote discussion.

This paper is WORKING DRAFT. It will be continually updated throughout the project. Expect an updated version sometime in January or February of 2011.

Any questions, comments, concerns email Rachel Holt (rholt@netidea.com), Greg Utzig (g13utzig@telus.net). We welcome comments / suggestions / feedback at all times on any aspects of this work!

2 Introduction

2.1 Background/context

Climate change is expected to dramatically affect ecosystems into the future and therefore will have implications for the values, goods and services they provide. The significance of climate change for the ecosystems themselves, and the human communities they support, will be determined by the scope and character of the change in climate, the rate at which it occurs, the sensitivity of the systems involved and the adaptive capacity of ecological and human systems. This project examines different aspects of this issue in the West Kootenays of British Columbia.

The project is funded by the British Columbia Future Forest Ecosystems Science Council (FFESC) to support the goal of adapting the forest and range management framework to climate change[1].

The project is lead by a team from the West Kootenays – Rachel Holt, Greg Utzig, Heather Pinnell , Cindy Pearce and Mike Stolte – and supported by regional and provincial academics and technical experts. The project is aimed to work with and for the diverse set of forest and land managers and stakeholders who are involved in forest management within the West Kootenay region.

Three main goals of the project are to:

- assess the vulnerability of West Kootenay ecosystems to climate change using a resilience approach,
- work with forest managers, technical / research scientists and other stakeholders to collaboratively learn about potential impacts and adaptation options and implications,
- advance the practice of resilience and vulnerability assessment, using a case study from British Columbia.

[1] http://www.for.gov.bc.ca/hts/future_forests/council/index.htm

This document is the first of a series that work towards meeting these goals.

2.2 Objectives of this draft paper and workshop

The project will hold a series of technical and manager-focused workshops. This paper is written to support the first technical workshop and is aimed at a technical and academic audience. It is intended to help provide some structure for moving forward on a complex topic, in order to achieve as much as possible in the limited time of a one-day workshop. But it is not intended to be either correct or complete, nor to constrain the process of group learning.

Within the draft, key questions are identified that we hope will engage participants in the workshop. Surrounding text is intended to provide ideas to facilitate discussion.

Undertaking a technical vulnerability or resilience assessment is not a quick task. In this work, we hope to engage with a broad range of academic and technical experts as efficiently as possible in order to ensure the widest range of ideas are included in this analysis. This first draft will be updated with results from this and subsequent workshops as the project progresses.

3 PROJECT FRAMEWORK

The core work of the project is to undertake a vulnerability assessment of West Kootenay systems applying ideas of resilience. Much literature and terminology has rapidly grown up around such assessments and often includes some confusion and overlap in ideas. Vulnerability has been linked to terms such as resilience, marginality, susceptibility, adaptability, fragility, risk, exposure, sensitivity, coping capacity and criticality (list from Liverman 1990 and Fussel and Klein 2007). We explain our use of terms below.

Many different pressures affect the vulnerability and resilience of systems. This project was inspired by the FFESC call for proposals that focuses on climate change, but other 'pressures' will also be included in the analysis.

3.1 Vulnerability assessments: An overview

Assessments of vulnerability to climate change are aimed at informing the development of policies to reduce the risks associated with climate change (Fussel and Klein 2007).

"Vulnerability" is defined differently in different fields and this has lead to confusion in some cases (see review in Fussel and Klein 2007 and Chapin et al. 2009). Here, we use the IPCC definition:

> ***Vulnerability****: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC 2007).*

In this project, we define 'sensitivity' at least in part by applying the concept of resilience to systems.

Vulnerability assessments have a variety of purposes: including providing evidence to encourage mitigation actions, to prioritise vulnerable regions or groups for action, and for recommending adaptation policies for a particular region or sector. Integrated vulnerability assessments involve a series of stages which usually are not all completed the first time through any piece of work due to the diverse expertise required and large complexity of such a project. A first step is often an impact assessment – how will climate change affect the system? And this is often focused on ecological aspects only, or on social aspects only – depending on who does the assessment. Subsequent stages tend to become more inter-disciplinary and include the effects of external stressors, and social or policy factors linking to adaptive capacity.

Impacts *– consequences of climate change on natural and human systems. Can be potential or residual impacts depending on whether adaptation is considered, or not.*

Moving from limited impact assessments into full integrated vulnerability assessments primarily includes concepts of potential and feasible adaptation options of different aspects of human society, and include the non-climatic societal factors affecting the system (in addition to those caused by climate change).

The goal of this project is to undertake a full integrated vulnerability assessment with respect to forest management in the West Kootenays.

3.1.1 When is a "vulnerability" significant?

In general, vulnerability is a relative term, rather than an absolute one. However, understanding the significance of potential vulnerabilities is obviously key to defining the extent of changes that may occur, and in determining the relative importance of adaptation actions. Within IPCC vulnerability assessments (2007), the significance of a particular degree of climate change for a particular variable is defined in a number of ways – impacts are linked to potential outcomes, and thresholds identified that note some level of 'tolerable risk'. Two types of thresholds are identified – systemic thresholds where effects can be measured (e.g. the temperature at which irreversible melting of an icesheet occurs), and impact thresholds which relate to non-linear responses of ecosystem components (Kenny 2000). Both of these result in crossing **'critical thresholds which lead to intolerable risks'**, which are then used to define the 'coping range' for a particular impact. The IPCC (WG2, AR4, Chapter 19) aims to identify 'key'[2] vulnerabilities, and defines them based on a combination of the following:

- Magnitude of impacts
- Timing of impacts
- Persistence and reversibility of impacts
- Likelihood and confidence in the estimates
- Potential for adaptation

[2] Although they have a list of factors, they note that defining something as key has both a science and a normative / value-based aspect.

- Distribution of the impacts
- Importance of the systems at risk

The concept of risk (probability of occurrence * magnitude of consequence) is then used to capture uncertainty within this structure.

Vulnerability assessments therefore use the concept of magnitude of impacts and thresholds to identify significance, but do not define them in a particular strict way.

3.2 Resilience Assessments: an overview

In common usage, resilience refers to the ability of a system or individuals to 'cope' with a stress and is often used in this general way in relation to climate change. The IPCC reports use resilience in this general way: (IPCC WGII AR4):

- *the resilience of ecosystems – (i.e. their capacity to adapt) is likely to be exceeded ….*
- *many arctic human communities are already adapting to climate change. Indigenous people have exhibited resilience to changes in their local environments for many thousands of years;*
- *non-climate stresses increase vulnerability to climate change by reducing resilience ….*

In ecological resilience literature, resilience has been defined more specifically as:

the ability to absorb disturbances, to be changed and then to re-organise and still have the same identity (to retain the same structure and ways of functioning). (Hollings; RA).

Or: the capacity of a social-ecological system to absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental function, structure, identity and feedbacks through either recovery or reorganization in a new context (from Chapin et al. 2009).

Resilience is often described using the ball and cup analogy – a resilience assessment is about understanding 'what basin the system is in', where in the basin it is (close to an edge / threshold), what direction is it moving in within the basin and how to alter the 'stability landscape', e.g. the ease of movement within the basin, and how to transform if that becomes the only useful option left. As resilience declines, the magnitude of the shock from which it cannot recover gets smaller. Identifying and avoiding factors that lead to increasing fragility is promoted so as to avoid enforced large-scale turbulent changes (the MPB epidemic is suggested as one such example).

The Resilience Alliance is "a multi-disciplinary group that explores the dynamics of complex systems" and have compiled a series of workbooks that outline an approach to assessing resilience. Their approach has a number of defining characteristics, including the need to assess the social-ecological system as a unit (rather than separating out the different elements and recombining them later). The hypothesis about systems focuses on loops of change through time when systems become more or less open to changing their fundamental structure, the importance of cross-scale interactions, and the importance of different drivers acting at different scales. True multi-disciplinary thinking and interaction is encouraged with the idea that little can be achieved unless everyone is slightly out of their comfort zone. The goal of resilience-based management is to manage for general system properties / processes rather than for narrowly defined production goals (e.g. timber supply, number of moose etc). AS a result, the define as significant an impact to 'processes', rather than just looking at general impacts.

We are using the Resilience Alliance workbooks as the foundation for our participatory learning with both scientists and managers.

3.3 The Integration of Vulnerability and Resilience Assessment Approaches

In our analysis, we are intending to combine a vulnerability assessment with a resilience approach.

Vulnerability and resilience approaches have many similarities in terms of their goals, the study unit (a social-ecological system) and general factors considered, and even perhaps have similar outcomes! But they use quite different ways to consider the focal system – and this comparison is one of the aspects of the project.

Our aim therefore, is to use the general vulnerability approach outlined by the IPCC and embraced at the federal level (Johnston and Williamson 2007), and to use the concepts of resilience as defined by the RA to assess the relative sensitivity and therefore vulnerability of different aspects of the ecological and social system. The RA workbooks provide a format for encouraging experts and managers to think outside their typical boxes, in an attempt to consider all relevant factors in the analysis. We do intend to consider both the ecological and social contexts, as promoted by the RA and within later stage vulnerability assessments (as defined by Fussel and Klein 2007).

Our rationale for combining vulnerability and resilience – rather than choosing one over the other - is because both concepts / terms are widely used in the context of forest management – at both the national level and within British Columbia. However, while the language of resilience has also been adopted BC MoFR and within academia (SFU now is a "resilience node" of the resilience alliance) specific application of the concept has not been tested in BC. So far, we do not see fundamental contradictions between the two sets of terminologies and ideas, however, part of the work is to identify any that arise. In addition, our aim is to identify what aspects of each may be most useful in a management context.

3.4 Our Approach

The intent of this analysis is to broadly assess the vulnerability and resilience of the West Kootenay social-ecological system, with a focus on forest ecosystems and forest management aspects of the social system. To accommodate the ecological variability across the region we have tentatively divided the region into seven "regional landscapes" which we will be assessing individually. With our focus on forest management, we are proposing to stratify our examination of the social system by the main types of forest tenure in the study area (e.g., area-based Tree Farm Licenses, volume-based licenses, woodlots). We will be examining the range of interactions between the diversity of ecosystems, the projected range of climate impacts and the unique policies and practices of each of the tenure types (more detail is provide in Section 4.1).

The first phase is to define the dominant drivers and processes for each of the regional landscapes, and relate these to the existing ecological and social systems, including the structure and composition of ecosystems and associated forest management systems. Examining the past and present interactions between forest management and ecosystem dynamics will be key to understanding how the overall system operates. A key element of examining the system dynamics will be the use of “participatory research”, where scientists, technicians, forest managers and other stakeholders are included in the assessment process. The culmination of this phase is the identification of potential sensitivities and the relative resilience of various components of the systems.

The second phase is to assess the potential impacts of projected climate change on key or ‘driving’ processes[3], and potential implications of those changes on the structure and composition of ecosystems and forest management systems for each of the regional landscapes. This step will also attempt to identify other direct impacts climate changes may have on aspects of existing ecological and social structure and composition (e.g., tree species whose drought tolerance that may be exceeded, reduction in winter harvesting opportunities, water shortages, changes in snow-free season affecting alpine woodland/parkland boundaries). The results of the individual regional landscape assessments will also be examined in the context of the region as a whole, and external factors that may have a bearing on local systems.

The third phase in the analysis is the assessment of adaptive capacity and vulnerability of West Kootenay ecosystems and forest management systems. As a complement to identifying vulnerabilities and adaptive capacity we will also be working with technical experts, forest managers and stakeholders to identify feasible adaptation options, and barriers which may limit the application of potentially viable adaptation options. These barriers could include a lack of information or uncertainty regarding ecosystem and socio-economic processes, a lack of resources, and/or management policies or regulatory frameworks which limit innovation.

[3] often considered to be “slow variables” in ecological systems and slow or fast variables in social systems

4 THE STUDY AREA: FOCAL ECOLOGICAL AND SOCIAL SYSTEMS

We have defined a study area for this project (Figure 1), but need to decide how to deal with the ecological and social variation within this area. This section provides some background, and a proposal for how to compartmentalise the west Kootenay study area.

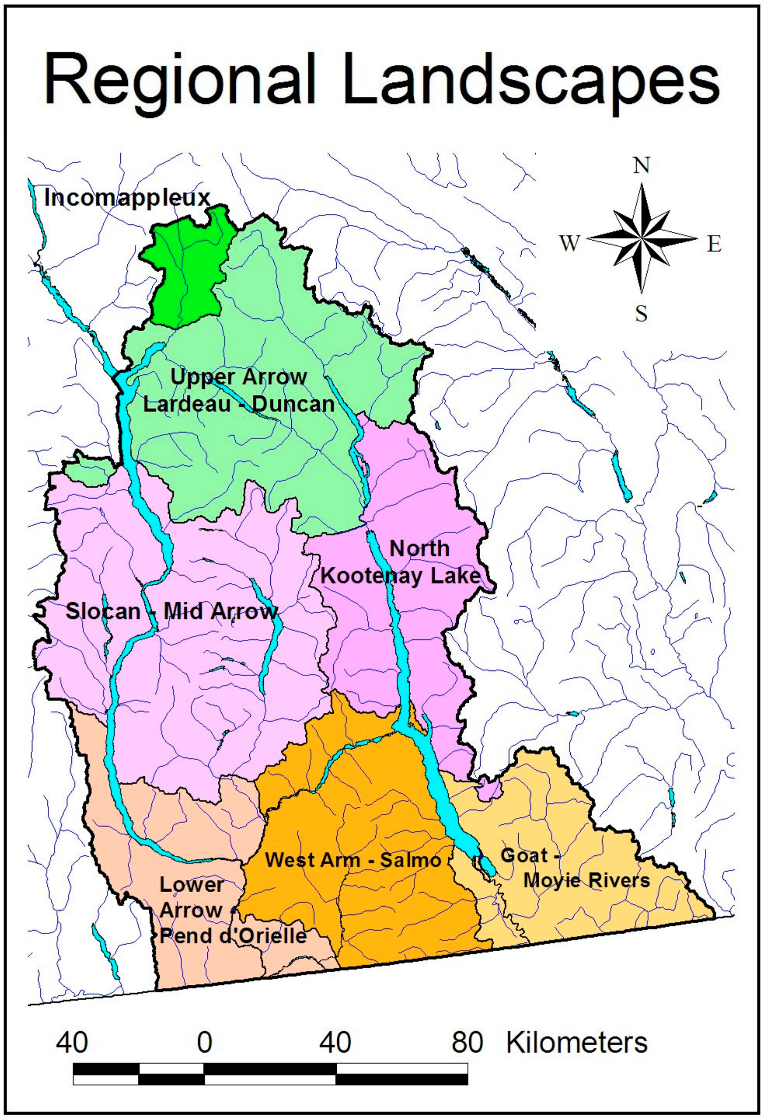

Figure 1. Project study area with proposed sub-units identified (see below).

The study area is primarily composed of the Columbia Valley River valley between Beaton Arm and the US border, and the Slocan, Kootenay, Lardeau and Duncan valleys. There are numerous small communities scattered throughout the study area. The communities include Nakusp and

Trout Lake in the north, Castlegar, Rossland and Trail in the southwest, Creston and Yahk in the southeast, and Kaslo, Nelson and New Denver in the center.

4.1 Ecological overview

The study area includes the eastern flank the southern Monashee Mountains, the central and southern Selkirk Mountains, and the western flank of the central and southern Purcell Mountains. This is a portion of what is commonly referred to as the “Interior Wet Belt” or the “Interior Temperate Rainforest”

The study area falls within two Ecoregions, the Northern Columbia Mountains and the Selkirk-Bitterroot Foothills and five Ecosections. It includes all of the Southern Columbia Mountains (SCM) and major portions of the Central Columbia Mountains (CCM), Northern Kootenay Mountains (NKM), Selkirk Foothills (SFH) and Southern Purcell Mountains (SPM) Ecosections.

The main valleys are generally north-south trending and U-shaped, with either gently sloping terraced valley bottoms, or are filled with natural lakes or reservoirs. Valley bottom elevations range from 420m in the Columbia, 530m in the Kootenay, and up to 720m at Trout Lake. In the northern portion of the area, mountain ranges are steep and highly dissected, with main ridgelines generally in excess of 2150m in elevation, and peaks reaching up to 3200m. In the southern portion, the mountain ranges are moderately dissected with generally rounded ridgetops varying from about 1650 to 1980m, with occasional peaks to over 2300m. The geology of the area is varied, including a range of folded and faulted sedimentary and metamorphic rocks, as well as significant intrusions of granitic plutons. The topography and terrain are typical of glacial source areas, with extensive colluvial materials and active glaciation at the upper elevations, morainal and colluvial materials over variable depths at mid elevations and extensive glaciofluvial and morainal materials in the valley bottoms. An extensive floodplain and delta occur where the Kootenay River empties into Kootenay Lake from the south. Soils are generally medium to coarse textured Podzols and Brunisols reflecting the glacial terrain and a moist climate.

The northern portion of the area is dominated by vegetation of the wetter subzones of the Interior Cedar Hemlock (ICH) and Engelmann Spruce – Subalpine Fir Zones (ESSF), typical of a moist to wet southern interior climate. The area also includes significant areas of parkland and Interior Mountain Alpine (IMA). Natural disturbance regimes are mainly long intervals of low intensity gap-replacement events, interrupted by infrequent stand-replacing events (mainly high intensity crown fires).

This grades to drier subzones of the ICH and moist to dry subzones of the ESSF in the southern portion of the study area. In the south, the subdued topography and drier climate eliminates the presence of IMA, although there are occurrences of upper elevation woodland and limited parkland. Natural disturbance regimes in the south range from relatively infrequent stand-replacing fire regimes at the upper elevations to frequent low intensity fire regimes at lower elevations on southern aspects.

Diversity of fish and other aquatic species is high, reflecting the wide range of lake, river and stream habitats present in the ecosection. Terrestrial and avian faunal diversity mainly reflects those species found in moderately to densely forested environments, with lesser occurrences of species found in drier habitats with mixed fire regimes or fire-maintained ecosystems in the south.

4.2 Socio-economic overview

The social system selected for analysis in this project includes people actively engaged in forest and land management including forest licensees, private land managers, government employees (federal, provincial, regional, municipal), water managers, Environmental Non-governmental Organizations (ENGOs), educators (college, university), fisheries and wildlife biologists and commercial recreation operators.

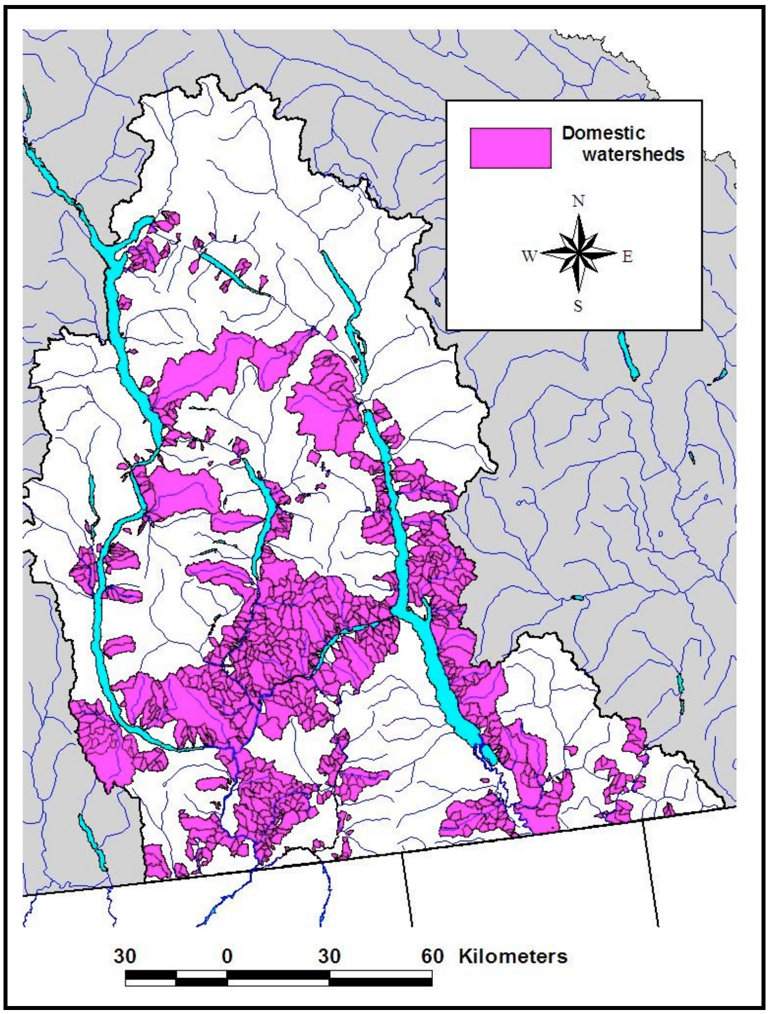

Figure 2. Domestic watersheds in the study area.

In addition to the obvious forest products of timber and fibre, the forest ecosystems of the study area are also important to other economic sectors in the region, including all-season commercial tourism, wildcrafting, hunting and backcountry guiding, and through their impact on the hydrologic cycle, water flows for electrical generation and agricultural irrigation. The forest ecosystems also provide numerous ecological services, including domestic and irrigation water supplies, erosion control, flood mitigation, recreation opportunities, as well as aesthetic and spiritual values.

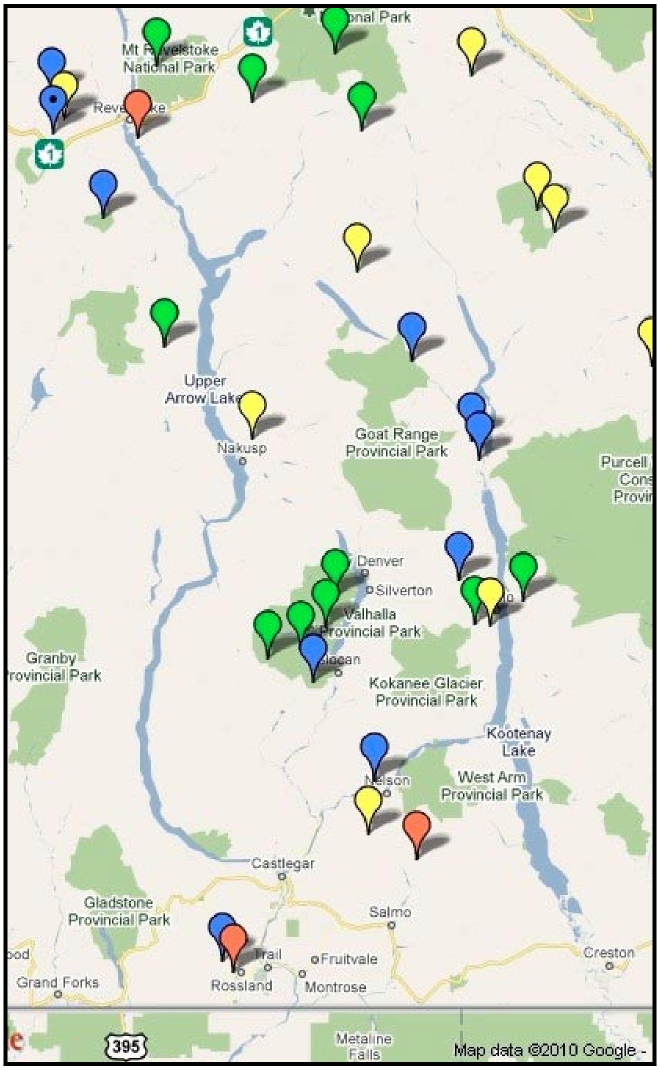

Figure 3. Winter commercial tourism locations. Red – alpine ski resorts; Green – backcountry ski operators; yellow – heli-skiing; blue – snow-cat skiing and pink- nordic ski areas.

Forest licensees form an important part of this social system due to the large proportion of Crown land they manage. The Kootenay Lake and Arrow Timber Supply Areas (TSAs) are diverse in terms of numbers and types of forest license holders, including 2 Tree Farm Licenses (TFLs), 12 volume-based Forest Licenses, extensive area of BC Timber Sales management, 29 woodlots and 5 Community Forests (also Section 4.1). The study area includes one pulp mill and 7 moderate-sized timber processing facilities. Wood is also trucked out of the study area to two large processing facilities located to the east and west.

Diversity in the basic economic sectors and Forest Vulnerability Indices (Horne 2009) describing the community's dependency on the forest sector were calculated for each forest district in BC (Table 1). Relative to other areas in the province, the economic diversity of communities in the Kootenay Lake and combined Arrow/Boundary TSAs were rated moderate to high, and high, respectively, for the period between 1991 and 2006. During this time span, both areas were considered to have a relatively low vulnerability to changes in the forest sector as compared to other districts in BC.

Table 1. Economic diversity and vulnerability to changes in the forest sector in the Kootenay Lake and Arrow/Boundary Forest Districts for the period between 1991 and 2006.

Forest District	Employment by sector	Dominant income	Economic Diversity Index	Forest Vulnerability Index
Kootenay Lake	Public sector – 37% Tourism – 17% Construction – 13% Forestry – 11%	Public sector – 27% Non-employment – 2% Transfer payments – 19% Forestry – 8%	Moderate to high	Low
Arrow/ Boundary[4]	Public sector – 31% Forestry – 19% Tourism – 14% Construction – 13%	Public sector – 22% Non-employment – 18% Transfer payments – 17% Forestry – 16%	High	Low to moderate

5 HOW CAN WE START TO THINK ABOUT THIS SOCIAL-ECOLOGICAL SYSTEM?

The Resilience Alliance (RA) workbooks ask participants to reflect on the broad study area, and identify how it functions and what external pressures have influenced in the past, now, and into the future. In the following sections, we ask a series of question that work through this general process.

The primary question in this work is 'how vulnerable or resilient are we to climate change?'. But what really does this mean? What defines 'we'? "We" can be defined by the natural world, or on

[4] Although only the Arrow TSA is part of the area of interest for the current project, the Arrow and Boundary TSAs were combined for the economic dependencies assessment.

the basis of a few indicators that we link to human wellbeing (e.g. timber supply, or average income or number of moose available).

The communities and local economies of the West Kootenays have traditionally been tied to, and continue to depend on the goods and services supplied by local ecosystems. This ranges from long-term subsistence use by First Nations, timber and pulp production, streamflow for community water supplies, and non-timber forest products, to a tourism industry based of wildlife and fisheries abundance and aesthetic qualities of the forests. Compared to many regions of the province, the dependence on a traditional forest industry is relatively weak.

In this project we are in general taking the broader approach – making the assumption that functioning of the natural world provides goods and ecosystem services that humans and everything else is dependent upon (Chan 2006). The scope will be limited to a high-level description of how each of the major forest use sectors may be impacted by the ecosystem changes, and will not include detailed economic assessment.

Within this whole system however, processes function at different scales and differently within different systems. We therefore still need to ask what we are measuring the resilience of, and at what scale.

5.1 Resilience of what? Proposed Study Units

Overview: in many resilience analyses, the study subject is an element of a broader system, for example a species of salmon, or an individual lake. In this work, we are interested in a complete ecological-social region, including all of the ecosystems and communities in the West Kootenays.

We propose to stratify the study area by both ecological and socio-economic/forest management criteria. The ecological stratification criteria are based on the present distribution of regional climate and how it is reflected in the distribution of vegetation (see Figure 1 for proposed subunits). Each assessment unit, or “regional landscape”, is defined by the occurrence of a single elevational sequence of biogeoclimatic subzones, and is assumed to have a relatively homogeneous subregional climate. It is assumed that the boundaries of the assessment units are primarily determined by the interaction between regional topographic features and weather systems. It is also theorized that as climate change proceeds, the specific climatic variables within each unit will change, but because the boundaries between the units are controlled by topography, the changes will likely be relatively uniform within each unit[5].

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[5] If there is a drastic change in the way Pacific and continental airmasses seasonally interact within the region, and/or the general directions that storms pass through the region, this assumption may not be valid.

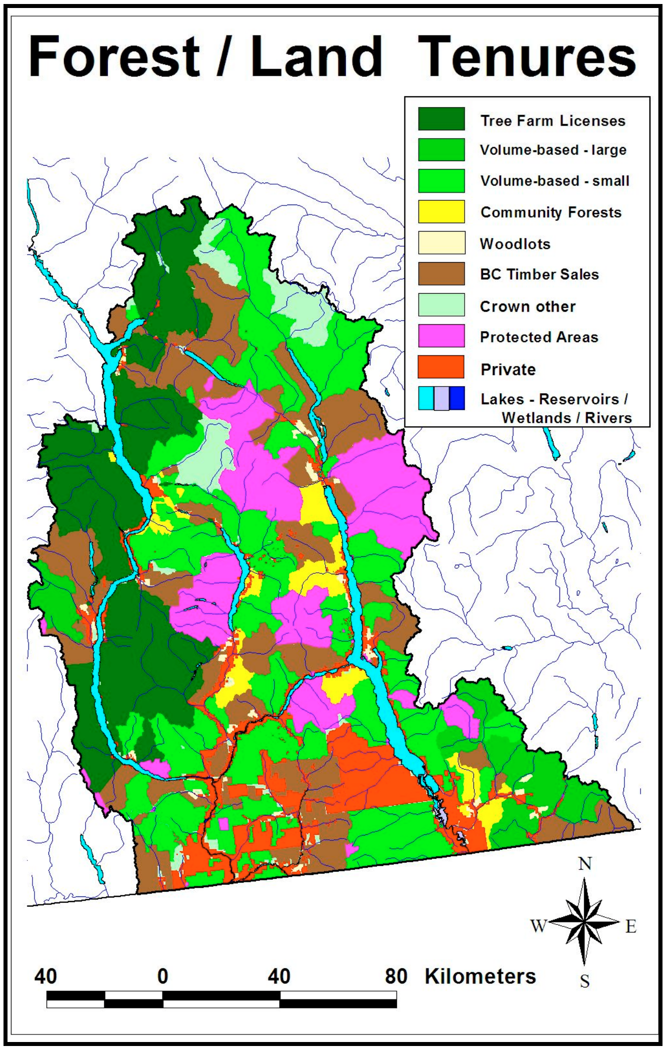

Figure 4. Forest tenures present within the study area.

The socio-economic/ forest management criteria chosen for stratification is the type of forest tenure (see Figure 4). At a broad level the study area can be divided into three classes based on primary use: timber extraction, conservation and intensive development (rural / urban and agricultural land). Timber extraction can be further divided based on tenure types: large area-based Tree Farm Licenses (TFLs), large and small volume-based tenures (Chart Areas), area-based Community Forest Licences, area-based Woodlots, and large parcels of private forest land (mostly Managed Forests). Conservation lands include Protected Areas and private lands managed primarily for conservation purposes. Other uses and values which are important to the ecological and socio-economic resilience of the region, such as critical wildlife habitat, commercial and non-commercial recreation, domestic and irrigation watersheds, and fisheries values also overlap these primary tenures to varying degrees.

<u>Question: is this a reasonable way to define 'resilience of what' under this broad range of values? Can resilience theory be applied to such a broad area and range of values? How does it link to the focal scale of interest identified below?</u>

5.2 Scales of analysis

A key feature of a resilience analysis is to examine and try to understand how different scales within the social-ecological system function and interact with one another. Cross-scale interactions have the potential to cause unexpected surprises and so are important, particularly across disciplines.

Question: Within these broad units, what scales do we need to consider in the analysis? What is the 'focal' scale, and what are the scales adjacent that are most relevant?

Forest management occurs primarily at stand scales (e.g., harvesting operations, silvicultural planning, forest health treatments) and landscape scales (e.g., zoning, harvest planning). Other scales are also relevant – for example, the AAC determination occurs at regional scale, planning for values can occur at the variant and site series scales.

Ecological processes occur at stand or individual tree scales (e.g., nutrient cycling, decomposition, succession, primary cavity excavation); watershed scales (e.g., stream flow, water storage), BEC variant scales (e.g., disturbance, succession) and global scales (e.g., global warming). Ecological processes also occur at the site series scale (soil weathering and decomposition, nutrient cycling, succession) and tree/tree group scale (e.g., competition among plants, soil biota; mycorrhizal symbiosis).

Economic processes occur at global scales (lumber pricing) and provincial scales (stumpage setting, provincial budgeting). Industry competition affects economies at a sub-regional scale.

Workshop Outcome: At the workshop we will examine which processes operate at what scales, and determine the appropriate scales for analysis.

6 HOW DOES THE WEST KOOTENAY SOCIAL-ECOLOGICAL SYSTEM WORK?

6.1 Ecological and Social Controlling Variables

Overview: compared with much of the rest of the world where resilience science has been applied, the southern interior is a relatively natural landscape. Identifying how the system functions naturally is therefore an important first step in understanding how to manage for resilience. Identifying the variables that control the system is the key way to understand how changes in these processes may affect the system into the future.

Question: What are the key ecological drivers or 'controlling variables' for the system. How do these vary for the subunits outlined above? Consider both ecological and social controlling variables if possible. Identify the scales at which they operate.

To start this discussion, we provide the following discussion:

At a regional landscape scale, in addition to regional climate, the primary process driver for stand structure, age class distribution and composition is a disturbance regime dominated by fire frequency. At present the frequency of stand-replacing fires decreases with increasing elevation and latitude across the regional landscapes. The dominant ecosystem structure throughout the study area is closed canopy conifer forests, with minor components of open canopy forests on warmer drier areas, and subalpine woodlands grading to krummholtz types at upper elevations.

Other disturbance agents such as landslides, wind, insects and disease, combined with human activities also play significant roles. At finer scales other processes such as hydrologic regimes and nutrient cycles are typically modified by topographic factors such as slope position and aspect. The role of various disturbance processes are mediated by successional processes, that also play a role in determining structure and composition.

Overlayed on the physical and ecological drivers are patterns of human activity reflecting the interplay between the ecological and social systems. The primary drivers for these activities are the basic human needs of local residents, and global and regional demands for products that can be extracted from the regional landscapes. The range and intensity of development in the study area is often determined at a provincial level through policies and land use decisions, but is often driven by market conditions at the national or even international scale.

The ecological and social systems interact with each other as the implementation of forest management policies and activities begin to affect changes to the structure and composition of ecosystems, and in some cases driving processes (e.g., fire management, dams and flooding). Conversely, ecological processes can influence the application of forest policies and management (e.g., mountain pine beetle infestations and AAC determinations).

Workshop outcomes: we will create a table that identifies the key controlling variables acting at various scales. In addition, we will identify, if possible, differences across the various regional subunits.

Understanding these interactions will be key to assessing adaptive capacity and the viability of potential adaptation options.

6.2 How have pressures worked historically?

Objective: to identify key elements of the social-ecological system that have changed over history, and that have left a lasting impression on today's system. In this step we look at how ***time*** has shaped the resilience of the system. This discussion is intended to help identify appropriate time periods for analysis, and to identify the key ecological and social factors that have influenced the system during these periods. It adds to the conversation about what have been the drivers of change in the system and what have been the effects of the subsequent interventions. This analysis paves the way for thinking about regime shifts that may already have occurred and how they may relate to current and future regime shifts.

Question: Within the study area, what are the events that have changed the management of the system? How did the system respond? What attributes made the system vulnerable to change? Separate these into ecological and policy / governance changes.

Are there differences across the subunits that can be identified?

Creating an historical timeline can be used to demonstrate the links between actions and system responses. Interpreting the timeline allows patterns to emerge that can help us to learn from the past. We will use an historical time line to link ecological responses to changing social interventions/attitudes over time (e.g. new policies or management systems), and to also examine social responses to ecological changes (e.g., changes in policies or management systems).

Table 2. Some examples of past human intervention that led to ecological changes in the forested landscape.

Policy or management system:	**Examples of ecological response:**	**Scale**
Early railroad development and mining exploration	Loss of forest cover due to increased fire ignitions	Landscape / stand
Building dams	Loss of low elevation cottonwood stands and wetlands; loss of salmon	Landscape/ watershed/ stream reach
Fire suppression	Change in age class distribution Increase in MPB susceptible stands	Landscape / watershed / regional
Over hunting and fishing	Caribou depletion; loss of fisheries	Landscape
Harvesting patterns	Old-growth depletion; creation of OGMAs	Landscape/ stand
Agriculture expansion	Habitat conversion; invasive plant introduction	Stand
TSR policy	Dependence on high AAC and reliance on enhanced silviculture	Regional / landscape / stand
“War in the woods”	Initiation of CORE, PAS, FPC, etc	Provincial trigger Affecting regional / landscapes / stand
Intensive recreation development/ motorized recreation	Golf courses displacing low elevation habitat; snowmobiles displacing caribou	Stand / landscape
Grazing tenures	Riparian degradation; modification of successional patterns; loss of predators; invasive species expansion; grassland degradation	Stand / landscape

Workshop Outcomes: We will build on this draft table of events to identify key historic factors shaping the West Kootenay social-ecological landscape. The goal is to highlight triggering events and to look for any connections between significant events or patterns that highlight vulnerabilities that led to change. We will aim to:

- Identify key ecological changes, their timing and their drivers.

- o Identify key social and economic changes and their timing. What institutions or groups were the primary actors in the system?
- o Identify key interactions between the ecological, social and economic changes. What values and perceptions have changed over time? What are the patterns, if any?
- o What are the defining time periods and what changes occurred to the system during these eras?

From this list we will add to the table of key drivers. Where possible 'triggering events' should be identified.

<u>Question: Which of these changes in the past may be most threatening to ecosystem resilience in the future?</u>

Workshop outcomes: this discussion should allow us to add social pressures to the drivers list. It also starts to build a list of pressures or threats which are part of defining the 'resilience to what?' question for the project.

6.3 People and governance

This section builds on the historical timeline work, and checks to see that key players are identified.

Objective: understand who affects the social-ecological system relating to forest management, and at what scales?

The central player with respect to land and forest management in the Kootenays has historically been the Ministry of Forests (now MoFR). Typically considered the most powerful of the 'dirt ministries MoFR has historically determined provincial level policies that determine rate and type of forest development. They also had significant say in relation to conservation strategies such as the location of protected areas and original implementation of 'soft' conservation tools such as old growth management areas.

Over the last decade, MSRM and then ILMB have had influence on these regional planning aspects, but are largely no longer operating within land management and planning at these scales. Ministry of Environment has had relatively little influence at the provincial scale, except through certain aspects of policies (e.g. UWR, or caribou GAR orders). Locally, influence is held through working relationships with the other ministries, though more recently the opportunity to engage in harvesting or planning issues has been significantly reduced.

First Nations have increasing influence provincially on land rights, and land management issues. Within the West Kootenays, First Nations have land management influence at different levels, typically in fairly localised areas.

Historically, the West Kootenay has had very active environmental groups. Local 'grassroots' groups input into processes like CORE and have had influence on parks, management strategies for old growth, cutblock planning and harvest planning in key areas (e.g. , domestic watersheds, caribou zones). It is unclear what extent these groups remain active within the forest management world; however, in some areas activity has continued to have significant influence through forest certification. Provincial level groups have also had significant influence in this region, particularly in relation to development of the FPC, and more recently the development of mountain caribou GAR orders.

Table 3. Suggested players and a preliminary suggestion of their influence through time.

Organisation	**Influence**	**Scales**	**Trend**
MoFR – Victoria	Policy	Regional to stand	Strong historic influence. Now decreasing influence provincially?
MoFR – local / regional offices	Implementation	Regional to stand	Strong historic influence ? influence declining?
MoE	Implementation of some elements of policy	Regional to stand	Low and decreasing
Environmental groups – provincial	Policy	Regional to stand	Low and decreasing, except in a few areas of the province
Environmental groups – local	Implementation	Stand (landscape)	?
First Nations	Policy	Regional	Increasing in many areas of province. Unsure of trends in West Kootenays
Large forest tenure holders	Policy to implementation	Policy / landscape / watershed / stand	Strong influence historically. Increasing influence through professional reliance?
Small forest tenure holders	Implementation?	Watershed / stand	Local influence on tenure areas
Private land managers	Land purchase	Watershed	Localised but increasing
Individual professionals	Implementation	Stand to watershed	Relatively little influence, though potentially increasing through professional reliance?
Individual Community members	Implementation	Stand?	Historically, some ability to influence, largely declined currently.

<u>Question: Where does the real power lie? Who has the power to influence the system, directly through policies, or indirectly (through voting/ lobbying etc).</u>

<u>How has power, relationships, informal groups of influence, key policies (variation between various tenures and management agencies [e.g. parks, MoFR, NGO, private]) (non-climatic factors) affected the system?</u>

Question: Which government agencies, private entities and public groups have affected the system? What are the types and significance of the influence they have had?

Workshop outcomes: pull together the sections on historic trends and people and governance section, and attempt to identify the underlying controlling variables (often those that change slowly) that caused changes in the natural system, the people, and in the interventions that people made.

Where are we at? **The work so far has attempted to reveal the main social or ecological change drivers, and how change has occurred (episodic, or slow linear) in the past. The intention is to help reveal longer term dynamics of the system. From this baseline, we can ask how resilient the system is today.**

And from this baseline starting point we can move on to assess how resilience may be impacted by future changes associated with climate change.

6.4 The newest pressure: Climate Change Exposure

6.4.1 Climate change projections

Overview: The discussion so far has been about the historic to current dynamics within the west kootenay social-ecological system. The effects of the changes that have already occurred will be ongoing into the future, and key drivers have been identified above. In addition, this project is focused on the potential future impacts of climate change (which we assume will be a major driver into the future). This section provides a very brief overview of the range of potential changes suggested to be reasonably likely into the future. This work is ongoing and over the next few months additional information will be available on the project website.

Projections of mean seasonal temperatures for the study area as determined by various Global Climate Models (GCM) for various scenarios at three future time periods are shown in Figure 5. All models and all scenarios project continuously increasing mean seasonal temperatures through all three time periods. The models differ with respect to which seasons show the greatest relative increases; however, summer and winter seasons are often the seasons with the greatest increases. For the 2050s and 2080s, some GCM/scenario combinations indicate rapidly increasing mean summer temperatures.

Projections of changes in mean seasonal precipitation for the study area as determined by various GCMs for various scenarios are shown in Figure 6. The various GCM/scenario combinations differ in magnitude with regard to projected changes in seasonal precipitation for winter, spring and fall, but generally show small to moderate increases over all three time periods for those seasons, with a some GCM/scenario combinations showing little change or very small decreases. In contrast, with one exception (CGCM3_A2-r4), all the GCM/ scenario combinations project small to moderate decreases in summer precipitation for all three time periods.

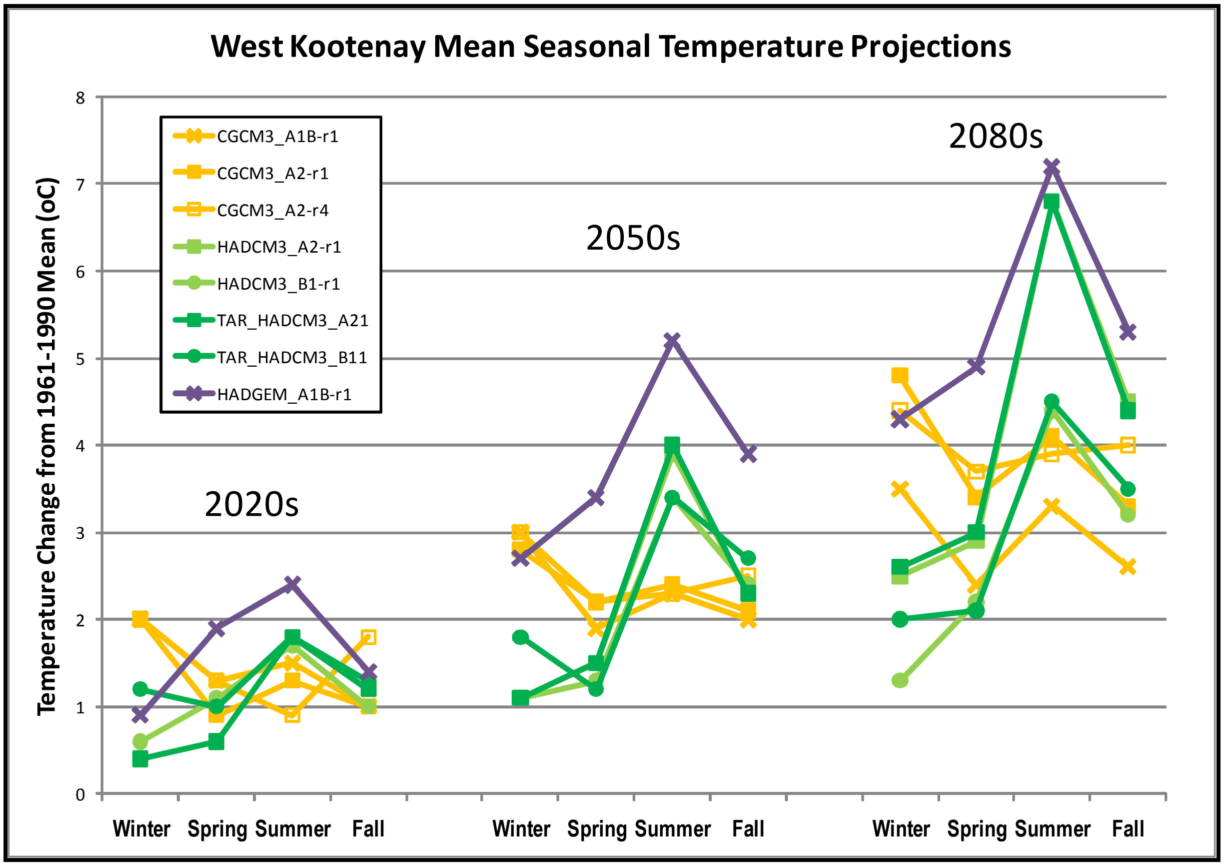

Figure 5. Comparison of projected mean seasonal temperatures for the study area as modeled by various GCMs for the 2020s, 2050s and 2080s (various colours indicate individual GCMs, various shades indicate separate IPCC reporting periods, various symbols indicate individual scenarios, open and closed symbols indicate differing runs) .

In general, all of the model/scenario combinations appear to reasonably represent the seasonal patterns of temperature for the study area during the baseline period, although they tend to systematically slightly under-estimate temperatures. The annual pattern of spring, summer and fall seasonal precipitation for the baseline period is reasonably well estimated by the GCMs, although slightly under-estimated on an absolute basis. Winter precipitation however, is significantly under-estimated by all of the GCMs.

The variability of projected seasonal temperature and precipitation changes based on different emission scenarios and a selection of GCMs demonstrates the level of uncertainty in what the climate of the study area will actually be in future decades. The systematic under estimation of winter precipitation by the GCMs for the baseline period also raises questions regarding the potential reliability of projections for winter precipitation for future time periods.

In addition to changes in seasonal temperature and precipitation patterns, a number of studies have also projected increases in the magnitude and frequency of extreme events (e.g., rain storms, heat waves). Further information should be available in the near future from another FFESC project that is completing analysis on this topic.

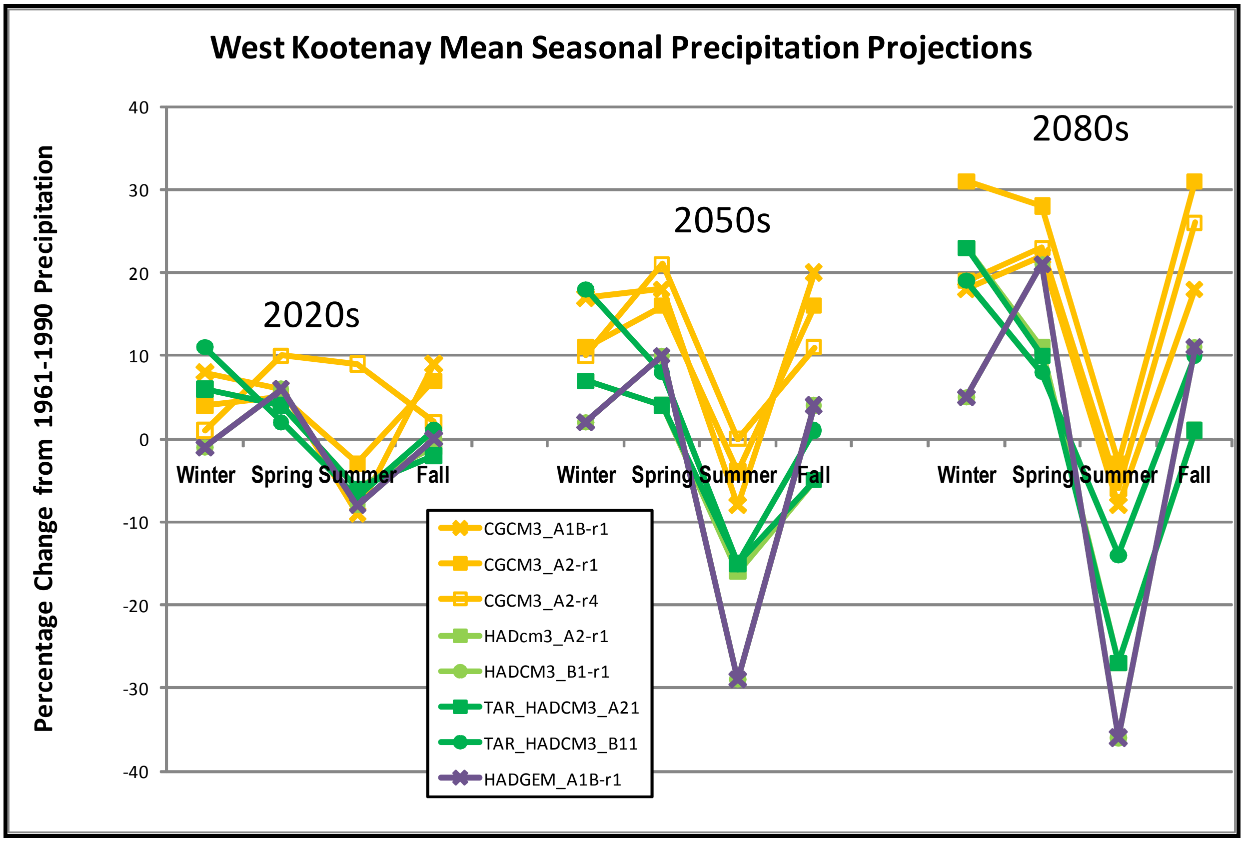

Figure 6. Comparison of projected mean seasonal precipitation for the study area as modeled by various GCMs for the 2020s, 2050s and 2080s (various colours indicate individual GCMs, various shades indicate separate IPCC reporting periods, various symbols indicate individual scenarios, open and closed symbols indicate differing runs).

6.4.2 Climate change impacts

Overview: This project is intending to interpret some of the climate change modeling using a variety of tools, including for tree species distributions (TACA) and modeling potential BEC envelopes. However, these provide only a very limited focus, and do not address many of the types of process changes at multiple scales that many occur.

Some general background on potential climate change impacts has been summarised for BC[6], but in this section we would like to accumulate the ideas of the experts on potential climate change impacts.

Climate change is expected to impact or cause changes to many elements of ecological systems. These include broad categories of impacts – direct and indirect impacts, and those affecting species, communities and broad ecosystems at different scales in both the aquatic and

[6] Utzig and Holt 2009. Available at: http://www.for.gov.bc.ca/ftp/hts/external/!publish/Web/FFEI/CC-EI_report_3-5-09_draft.doc

terrestrial realms. At the species level, food and habitat supply changes will alter population distributions across landscapes. Cumulatively, communities will alter as species come and go. The implications of such changes broadly will depend partly on the functional importance of individual species – shifts in keystone, engineer or foundation species may fundamentally alter how a system functions causing 'unexpected' changes in character and function. Changes to processes are often likely to be significant at some scale –changes in timing, severity and nature of disturbances may fundamentally shift whole systems. Fire impacts are the most obvious example for Kootenay ecosystems, though how fire frequency and severity may change is complex since temperature, moisture, fuel and fire management all interact to determine how fire will ultimately alter forest structure. Transition to new regimes may be catastrophic and traumatic for different aspects of society.

Question: what may be the primary impacts and secondary (indirect) impacts of climate change?

How may impacts differ by the study areas? And across scales?

Identify level of 'certainty' is associated with these potential impacts?

Workshop outcomes: Brainstorm impacts lists. Prioritise linking to key processes. Are some potentially key impacts missed using this resilience-based approach?

7 THRESHOLDS AND CHANGING STATES

Impacts will no doubt be many. Understanding which impacts are key for adaptation depends on many factors. Resilience theory focuses attention on changes that cause a threshold to be crossed at some scale that may be important in itself, or may cause cross-scale changes.

Question: Do we think the system has crossed any thresholds already?

Question: Consider what future possible states of the ecosystem may look like and how far away these are from current conditions?

Feedbacks – can we identify any in the system dynamics that may accelerate or decelerate the processes identified??

What characteristics of these systems may make them more or less vulnerable to climate change and crossing thresholds?

7.1 Implications

Overview: the work so far has identified a series of historic and future disturbances. We want to understand what are the potential implications with respect to ecosystem or 'forest' resiliency? The following questions refer to various aspects of this question and these (or other questions raised) will be discussed at the end of the workshop.

Vulnerability vs. Resilience: Do different impacts become important using the vulnerability criteria list that are not identified using the resilience terminology of 'crossing thresholds or moving towards an alternate state' terminology?

<u>Resilience Theory:</u> Does the system (at the focal scale of interest) appear to be a particular phase of the adaptive cycle? If so, how long has it been in that phase, and does it appear to be approaching a phase change? Refer back to the historical profile and examine it for a likely pattern involving the current system state. Does this help us make predictions?

<u>Cross-scales and Interactions:</u> Considering the issues identified through this process, what are the most significant cross-scale influences? What are the cross-cutting factors (social / ecological across scales)? How do events at one scale link to those (i.e. cause, or respond to), changes at other scales?

<u>Directional Change:</u> Climate change may result in a long-term directional movement for these ecosystems (i.e. no future stable state may occur for a long time) – does this create any issues with respect to applying resiliency theory to a climate change problem? Link this question to management implications in future workshops.

<u>Integrated Pressures:</u> What are the events/actions from the past that may have affected resilience of ecosystems in the study area such that these systems are now more or less vulnerable to climate change?

8 SUMMARISING LESSONS LEARNED

Recheck: Considering the above conversation, and the proposed sub-units for study (insert map) – are these areas an appropriate level for analysis? *(have we asked this above?)*

Recheck: are we focusing at the right scale?

Recheck: are we asking the right questions?

After Technical Workshop 1 this paper will be updated based on outcomes from the work, and the following sections will provided summaries that should lead to the next workshops that identify potential management levers.

8.1 The workings of the system itself

Identify key controlling factors in the natural system, and key pressures now and into the future.

<u>What are we capable of changing ? This is the opening conversation that will start the next stage of the work that hopes to identify options for management influence to increase resilience.</u>

8.2 Resilience of the system

Do we have suggestions that we have crossed thresholds already, or have some sense where they may be? If so, what are the implications of this?

8.3 Utility of resilience ideas

Has this process been useful (so far)??

8.4 Where to from here?

Consider how to move this theoretical basis on to a format accessible to managers, practitioners and stakeholders. How do we link to management options? Again, this is intended to be a starting conversation for the second phase of the project.

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