West Kootenay Case Study

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Study Region

The West Kootenay study area is located in southeastern British Columbia, composed of the Columbia 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, including 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. The study area includes the eastern flank of the southern Monashee Mountains, the central and southern Selkirk Mountains, and the western flank of the central and southern Purcell Mountains. These mountains form a portion of what is commonly referred to as the “Interior Wet Belt” or the “Interior Temperate Rainforest”.

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 on 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.

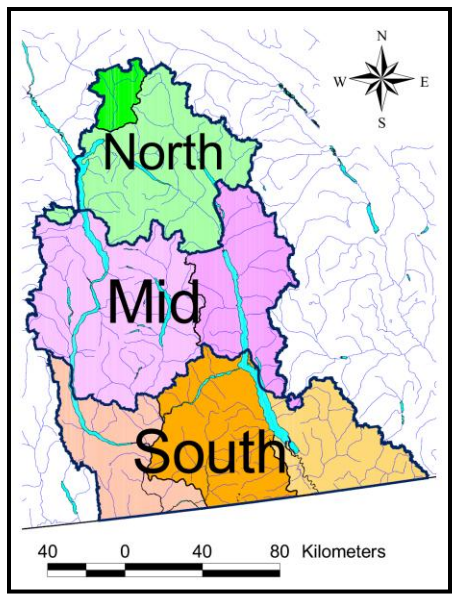


Figure 1. Study area subregions.

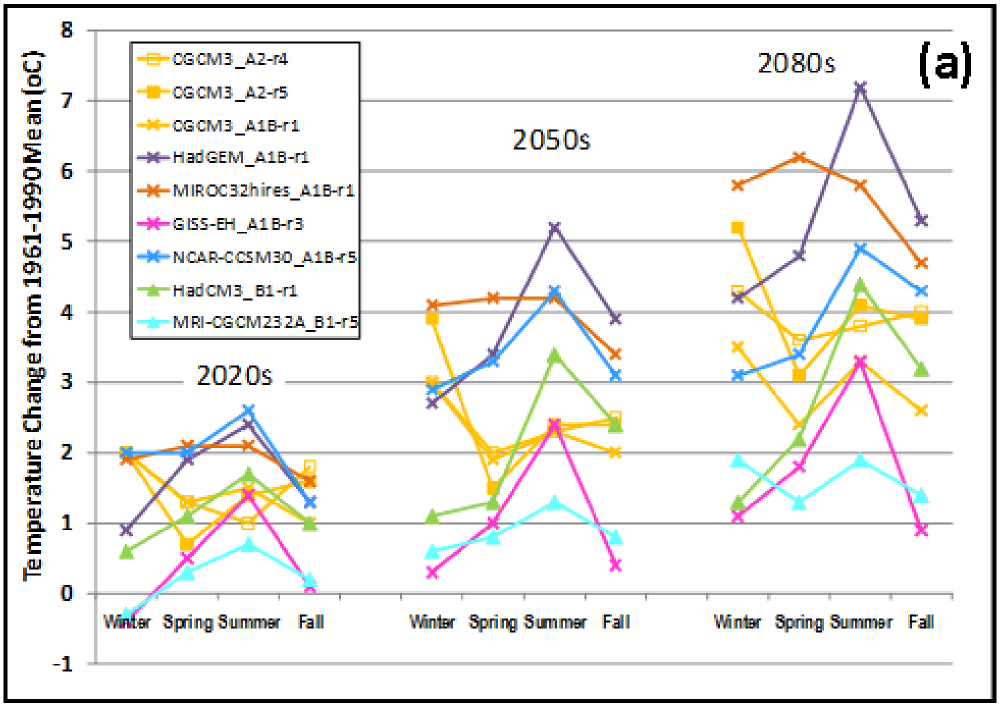
The West Kootenay study area was separated into north, mid and south geographic subregions representing “regional landscapes” with relatively homogenous regional climates (Figure 1). Traditionally in BC the logical unit for an ecological assessment would be a Biogeoclimatic Classification unit or an Ecosection. However, because both of those classification systems are based on an assumption of a relatively stable climate and species distribution, neither system will adequately portray the range of niches and biological diversity of the province as the impacts of climate change proceed over the coming decades.

Projected changes in climate and disturbance

Climate

To explore the range of climate projections for the study area, nine climate scenarios were selected, representing a cross-section of projected changes in annual temperature and precipitation. All of the models were reasonably capable of simulating seasonal patterns of temperature and precipitation for the study area during the baseline period (1961-90), with the exception that winter precipitation was significantly under-estimated by all of the global circulation models (GCM). Most of the models tested are potentially useful for projecting future temperatures and precipitation for the study area, with some concern for winter values.

Future projections for the study area estimate that by the 2080s, winter, spring and fall will be warmer by 2 to 5°C, and summer will be warmer by 3 to 7°C (Figure 2). Precipitation is projected to increase by 10-25% in the winter, spring and fall, and in the summer either remain unchanged, or decrease by up to 30%. The most obvious trend shown by the models is an increase in summer moisture stress.



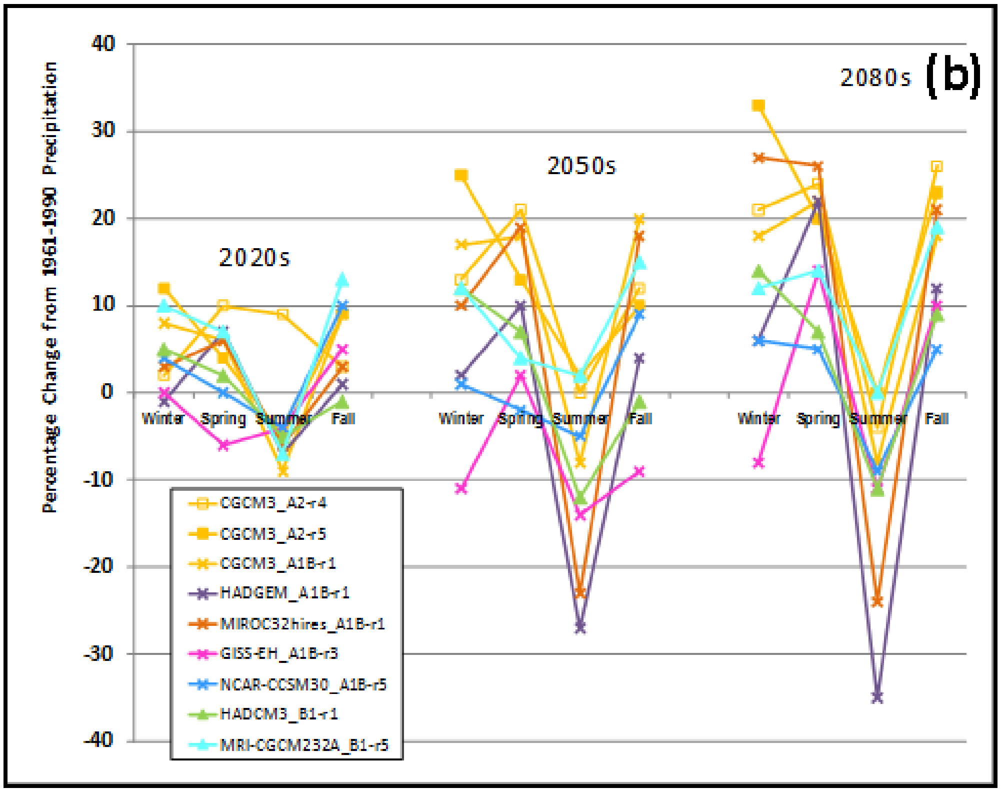


Figure 2. Comparison of projected mean seasonal temperature (a) and precipitation (b) for the study area as modeled by various GCMs for the 2020s, 2050s and 2080s (colours indicate individual GCMs, symbols indicate individual scenarios, open and closed symbols indicate differing runs).

Variability between different climate models exceeded variation due to differing assumptions about greenhouse gas emission, indicating that there is still significant uncertainty in our understanding of how the global climate system operates, and specifically how it will respond to increasing greenhouse gas concentrations.

Bioclimate Envelopes

Across all of the study area, three selected climate change scenarios (CGM3_A2_R1, HadCM3_B1_R1, HadGEM_A1B_R1) project bioclimate envelope shifts that reflect decreasing moisture availability at mid and lower elevations – with scenarios differing in the magnitude of change, but not the direction. At the lowest elevations in the South subregion, all of the scenarios project shifts from interior cedar- hemlock (ICH) bioclimate envelopes to grassland-steppe envelopes. At the upper elevations the results are more variable, with one scenario projecting an upward shift of existing ICH climate envelopes, another tending to more coastal transition ICH/CWH (coastal western hemlock), and the third showing a shift to semi-arid Ponderosa pine savanna envelopes, with very limited moist and coastal transition ICH/CWH envelopes at the highest elevations. **All of the scenarios project very large decreases in Engelmann Spruce-Subalpine Fir (ESSF) and parkland/woodland bioclimate envelopes – approaching complete elimination in most cases.**

Additional bioclimate modeling of common tree species' ranges also projects shifts in individual trees species envelopes that are consistent with the projected changes in ecosystem envelopes. Drought resistant and fire tolerant low elevation species' envelopes tend to expand and shift to the north and upslope. Changes in bioclimate envelopes for species currently occurring at upper elevations generally indicate a decrease in occurrence for those species.

Fire

Regression analysis was used to examine the historical interaction between annual area burned and climatic variables such as spring and summer maximum temperatures and summer precipitation. The resulting relationship was applied to projected changes in those variables from the three climate scenarios to estimate potential future changes in annual area burned. The regression models project steadily increasing area burned in all three subregions for all of the climate scenarios, although there is substantial uncertainty regarding the magnitude of the increases. **The minimum increases in average area burned for the 2050s (2041-2070) are 3 to 5 times greater than the area burned during the reference period (1961-90), with average increases of 15 to 300 times**. Current annual area burned ranges from almost zero to 12,000 ha in the north region, to between zero and 90,000 ha burned in the south region (range over the last century).

The West Kootenays is a diverse area – ranging from rolling topography and dry open forests in the lower elevations of the South, to steep sided valleys and wet interior cedar hemlock 'rainforest' in the North. This starting point clearly influences how changes in climate will affect future fire - with relatively little fire in the North historically, but with a high potential for drying and warming to increase this level. The increased importance of spring climatic variables in the North found in the regression analysis, is likely a reflection of the increased importance of spring snowmelt and its potential effect on the fire season in that high snowfall subregion. Early snowmelt can facilitate fires by increasing the length of the fire season and increasing fuel drying that leads to the build up of maximum drought codes. In contrast, in the South and Mid areas, summer high temperatures and drought seem to be the main factors. The projected changes in climatic variables correlated with area burned in the North appear to be changing at a faster rate than those in the South, leading to a steeper increase in estimated area burned. Available fuel will likely become a limiting factor before some of the area burned projections will be achieved, especially in the North subregion.

Forest Health

Climate change may affect forest health in many ways, some positive and some negative. Summer drought conditions can stress trees, thereby increasing susceptibility to a wider range of insects and diseases. Insects are primarily influenced by temperature, so increases in regional temperature will likely change the distribution, frequency and severity of population outbreaks. Timing of critical life stages of insects is also likely to change, resulting in both increases and decreases in insect levels In the West Kootenays. Pathogen populations however, are generally more influenced by precipitation, and so may respond differently than insect populations.

Evidence suggests that climate change may contribute to increased risk of outbreaks of Douglas-fir beetle, western balsam beetle, spruce beetle and western hemlock looper in mature stands. Spruce leader weevil, white pine blister rust, other stem rusts in lodgepole pine, foliar diseases of lodgepole pine and larch, and Armillaria root disease are routinely encountered in plantations, and some of these may increase with climate change. Lodgepole pine plantations in particular appear to be at risk to a wide range of insects and diseases. As climate changes, regeneration will also be subject to attack by insects and diseases found in existing plantations, and new insects and diseases that have only occurred historically in low numbers may reach outbreak levels in future plantations. In addition, diseases that in the past have only caused growth loss may now contribute to tree mortality as observed with larch needle cast and *Dothistroma*.

Vulnerabilities

Climate change is expected to impact or cause changes to many elements of ecological systems, and consequently to the goods and services that ecosystems provide. 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 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 likely to be significant at a particular 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. All levels of change – from species through to systems and processes—may affect the goods and services valued by people. In particular, transition to new regimes may be catastrophic and traumatic for various aspects of society.

To help in the interpretation of whether potential ecosystem shifts would result in significant 'vulnerabilities' or not, we considered the concepts central to 'resilience' theory, in particular, whether regime shifts and alternative successional pathways were likely. Our rationale for vulnerability is discussed for each subregion, below, and then summarized in Table 1.

North Subregion

Historically, ecosystems in the North subregion have been old-growth western redcedar/ western hemlock forests at low elevations and Engelmann spruce/subalpine fir forests at high elevations, with both experiencing gap replacement disturbances at long intervals. Seral species such as Douglas-fir, western larch and white pine are infrequent and generally restricted to dry, warm aspects. Moist conditions in these Interior Cedar-Hemlock (ICH) and Engelmann Spruce –Subalpine Fir (ESSF) ecosystems have for the most part kept fires small.

Climate change is predicted to cause warmer temperatures, higher annual total precipitation, but with drier conditions in the summer (Report #3, Utzig 2011). These changes along with more frequent extreme weather events are predicted to change stream flow regimes and likely reduce channel stability. Frequent large stand-replacing fires are projected to supplant gap replacement disturbances (Report #4, Utzig et al. 2011). Growing conditions on the warmest, low elevation sites are expected to be more supportive of grassland-steppe, grand fir and dry montane spruce (MS) ecosystem types (Report #5, Utzig 2012). The warmer and wettest sites may be more suitable for coastal western hemlock (CWH) ecosystem types. Conditions suitable for ICH species may move upslope into current ESSF ecosystems.

Mid Subregion

Historically, high elevation ecosystems in the Mid Subregion consisted of old-growth ESSF forests with gap replacement and infrequent stand replacing fires, interspersed with insect outbreaks, typically bark beetles. Mid to low elevation forests were a patchwork of old-growth western redcedar / western hemlock forests interspersed with diverse seral forests of Douglas-fir, western larch, lodgepole pine and western while pine, with minor amounts of western redcedar and western hemlock. The mid elevation forests developed through moderate to long return interval fire regimes, with some gap replacement disturbance, and in the lowest elevation forests, the disturbance regime was dominated by short to moderate return interval mixed fire regimes.

General climate change projections are the same as those described for the North Subregion and are expected to result in shorter fire return intervals, moving toward frequent stand initiating or maintaining fires (Report #4, Utzig et. al. 2011). **Growing conditions in the drier low and mid elevation forests will be more suitable for grassland-steppe, Ponderosa Pine (PP) or dry ICH ecosystem types** (Report #5, Utzig 2012). Moist aspects will become more suitable for dry montane spruce (MS) and transitional CWH ecosystem types. **The driest mid to upper elevations may provide growing conditions suitable for PP species while mesic to moist sites may resemble conditions found in ICH, ESSF, dry MS or transitional CWH ecosystems. Over time, it is expected there will be a gradual loss of Engelmann spruce.**

South Subregion

Historically, high elevation forests were often old-growth Engelmann spruce and subalpine fir with extensive areas of lodgepole pine. Gap replacement disturbances interspersed with long interval stand-replacing fires created this landscape mosaic. Seral forests consisting of Douglas-fir, western larch, lodgepole pine and western white pine with some western redcedar and western hemlock have been common at low to middle elevations, and were shaped by wildfires occurring at short to moderate fire return intervals. Some very dry sites and south aspects at low elevation had open stands of Ponderosa pine, Douglas-fir and western larch, and experienced frequent low intensity stand maintaining fires. Some scattered old-growth patches occurred at mid and low elevations.

General climate change projections are similar to those described for the North and Mid Subregions, and are expected to result in a more intense fire season with greater area burned. **Growing conditions**

at low elevations can be expected to become more suitable for grassland-steppe or PP ecosystem types. On moist low and middle elevation sites, growing conditions will become more suitable for grand fir, dry MS or Interior Douglas-fir (IDF) ecosystem types. Growing conditions in mesic upper elevations will move toward ICH conditions; whereas, moist sites may resemble transitional CWH ecosystems. Climate at very dry high elevation sites may be more suitable for IDF, PP or grassland-steppe ecosystems.

Table 1. Potential impacts and relative ratings of vulnerability for study area assessment units, including comments on contributing factors and potential regime shifts. Note that the results presented are uncertain, as the potential outcomes vary between the 3 scenarios considered. See original report for further information on exposure, sensitivity and adaptive capacity.

Assm't Unit	Potential Impacts[1]	Potential Vulnerability[2]	Comments	
			Key Contributing Factors[3]	Regime Shift (RS)
North <1000m	From M/W ICH to PP and/or GF/ MSD and/or GS	VH-H-VH	Magnitude and direction of NDT shift (2 and 1 to 4and/or 3), lack of local seed source for fire-resistant tree spp., fragmentation by reservoirs and harvesting, no downslope seed source availability	**RS very likely; likely catastrophic**
North 1000-1500m	From M/W ICH/ W ESSF to D/M/W ICH and/or Ctran/ MSD and/or PP/ GS	M-M-VH	Uncertainty of exposure/ impacts and possible magnitude of NDT shift (1 and 2 to 2 and 3 or 4), lack of local seed source for fire-resistant tree spp., moderate fragmentation	**RS likely to very likely; likely to be catastrophic**
North 1500-2000m	From W ESSF/ Atran to W ICH/ and/or CWH/Alp and/or PP/ D ICH	L-L-VH	Possible magnitude of NDT shift (unchanged, or 1 and 5 to 4 and/or 3), no local seed source for fire-resistant tree spp., minimal fragmentation	**RS unlikely, but if so, likely catastrophic**
North >2000m	From Atran/ Alp to W ICH/ W ESSF and/or Alp/ Atran and/or D/W ICH/ D ESSF	L-VL-L	Limited magnitude and direction of NDT shift (unchanged or 5 to 1 or 3 and 2), tree spp. seed source downslope, natural fragmentation	**RS about as likely as not; very unlikely to be catastrophic**

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[1] For a description of ecosystem types and more detail on the projected impacts see Report # 5 (http://www.kootenayresilience.org) (Utzig 2012).

[2] Vulnerability was rated for each of three climate projections: HadCM3_B1_R1; CGCM3_A2_R1; HadGEM_A1B_R1.

[3] NDT = Natural Disturbance Types, 1 = rare stand initiating events; 2 = infrequent stand initiating events; 3 = frequent stand initiating events 4 = frequent stand-maintaining fires; 5 = alpine and subalpine environments; changes from NDT 1 to 2 were considered moderate, 1 to 3 or 4 and 2 to 4 severe; from 3 to 4 moderate; and 5 to 2,3 or 4 low; estimated severity often varied between scenarios; for more information see: http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/biodiv/biotoc.htm

Assm't Unit	Potential Impacts[1]	Potential Vulnerability[2]	Comments	
			Key Contributing Factors[3]	Regime Shift (RS)
Mid <1000m	From D/M ICH to PP/ GS and/or GF/ MSD	M-M-M	Moderate NDT shift (3 and 2 to 4 and/or 3), some local fire resistant tree spp. seed sources, extensive fragmentation, no downslope seed source availability	**RS likely; unlikely to be catastrophic, significant invasive spp. risk**
Mid 1000-1500m	From M ICH/ W ESSF to PP/ D ICH and/or MSD/ GF/ Ctran and/or GS/ PP	H-H-VH	Magnitude and direction of NDT shift (2 and 1 to 3 and/or 4), some local and downslope seed sources, limited fragmentation	RS likely to very likely; about as likely as not to be catastrophic
Mid 1500-2000m	From W ESSF to D/M/W ICH and/or Ctran/ MSD and/or PP	H-H-VH	Uncertainty of exposure/ impacts and possible magnitude of NDT shift (1 to 2 and 3 and/or 4), lack of local tree spp. seed source, some but available downslope, limited fragmentation	RS likely to very likely, likely to be catastrophic
Mid >2000m	From Atran/ Alp to W ICH and/or Ctran/ Alp and/or PP/ D ICH/ D ESSF	L-VL-M	Limited magnitude and direction of NDT shift (unchanged or 5 to 3and 4), downslope seed sources, natural fragmentation	RS about as likely as not; very unlikely to be catastrophic
South <1000m	From D ICH/ GF to GS/ PP/ GF	L-L-M	Limited magnitude of NDT shift (3 and 4 to 4 and 3), local seed source for tree spp., extensive fragmentation, no downslope seed source availability	RS likely to very likely (localized); unlikely to be catastrophic, high invasive spp. risk
South 1000-1500m	From D/M ICH to PP/D ICH and/or GF/ MSD/ D IDF and/or GS	VL-VL-H	Limited magnitude of NDT shift (3 and 2 to 3 and 4), local and downslope seed source for tree spp., moderate fragmentation,	RS about as likely as not; about as likely as not to be catastrophic
South 1500-2000m	From D/W ESSF to D/W ICH and/or Ctran/ MSD and/or D/W IDF/ PP/ GS	L-L-M	Limited magnitude of NDT shift (3 and 1 to 3 and 2), downslope seed source for tree spp., low fragmentation	RS unlikely, but if so, about as likely as not to be catastrophic (localized risk)
South >2000m	From D/W ESSF/ Atran to W ICH and/or Ctran and/or D ICH/ W IDF/ PP	VL-VL-L	Limited magnitude of NDT shift (3,1 and 5 to 2 and/or 3), downslope seed sources, natural fragmentation	RS likely; very unlikely to be catastrophic

Consistency of vulnerability among climate projections varied by subregion:

<u>Consistent high vulnerability</u>: low elevation in the North Subregion; mid elevation in the Mid Subregion.

<u>Consistent low vulnerability</u>: highest elevation bands in the South, North and to a slightly lesser extent the Mid subregions

Inconsistent vulnerability: mid elevation band in the North and the South subregions.

For subregions with inconsistent ratings, choosing ecologically appropriate adaptation strategies that are robust to a range of future conditions will be particularly challenging. In addition, all three scenarios demonstrate the possibility of novel or non-analogue climate envelopes, which will add additional challenges for managers.

Recommended adaptations

Adaptation Issues by Subregion

Some of the specific issues that should be addressed in each subregion are summarized below:

North Subregion:

- significant ecosystem shifts projected – including both extensive mortality through disturbances, and decline syndrome type mortality, particularly at low elevation and on drier/ warmer sites;
- fragmentation below 1500m – harvesting, reservoirs, agriculture and settlement have fragmented elevations <1500m;
- lack of seed source for fire adapted species;
- mountainous terrain limits lateral connectivity/ movement; and,
- driest sites (low elevation/ warm aspects) and interface areas require attention first.

Mid Subregion

- significant ecosystem shifts projected – including both extensive mortality through disturbances, and decline syndrome type mortality, particularly at low/ mid elevation;
- fragmentation below 1000m – harvesting, reservoirs, agriculture and settlement have fragmented forest cover at these elevations;
- lack of downslope seed sources for elevations: <1000m and dry areas at 1500-2000m;
- risk of invasive plants at low/mid elevations (<1500m);
- mountainous terrain limits lateral connectivity/movement; and,
- coarse soils limit upward movement at mid to high elevations (>2000m).

South Subregion:

- significant tree mortality predicted (drought, fire and potentially through decline syndromes);
- extensive fragmentation below 1000m – harvesting, reservoirs, agriculture and settlement have severely fragmented lower elevations; moderate to high fragmentation at mid elevations due to harvesting;
- lack of downslope seed sources for elevations <1000m;
- high risk of invasive plants at low/mid elev (<1500m);

- fragmentation limits lateral species shifts at >1500m; Kootenay Lake and Arrow Reservoir limit lateral and northerly species shifts at low elevations; and,
- coarse soils limit upward movement at mid to high elevations (>2000m).

Adaptation actions applicable to all subregions

As an example of the types of direction presented in Report #9 (Pinnell et al. 2012), the section below provides a list of the adaptation actions that apply to all (most) elevations across all subregions.

Silvicultural systems:

- Select systems to maximize vigour and decrease susceptibility to insects and disease over the long-term.
- Increase partial cutting (shade in dry areas, structural diversity to discourage certain insects/diseases, wildlife habitat, increased future harvesting options).

Stand level biodiversity:

- Increase stand structure diversity (esp. species, age classes).
- Increase retention to focus on microclimate diversity (ravines, all representative aspects, etc.); protect climate refugia
- Increase coarse woody debris retention on drier sites,
- Increase wildlife tree patches to contribute to landscape connectivity,
- Increase riparian buffers for temperature sensitive streams.

Regeneration:

- Increase diversity (esp. species, genetics).
- Assisted migration.
- Underplant with other species/ genotypes where current regen (or forest) is at risk.

Stand Tending:

- Increase growth and vigour through stand tending to reduce rotation.
- Fertilize to enhance growth, reduce rotation and improve insect/disease resistance.
- Manage species composition, density, stand structure to improve diversity and increase growth.
- Vegetation control to reduce drought stress.

Alpine management

- Monitor forest ingrowth in alpine