Nadina Climate Change Vulnerability Assessment:

Summary of Technical Workshop 1. Impacts on biodiversity

Workshop held, Nov 8, 2010, Smithers, BC.
Summary prepared by Dave Daust, December 15, 2010.

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Workshop overview

Biodiversity is a valued ecosystem service and contributes to ecosystem resilience. Biodiversity is defined by the Biodiversity Guidebook (Province of BC 1995) as follows:

Biodiversity*: the diversity of plants, animals and other living organisms in all their forms and levels of organization, including genes, species, ecosystems, and the evolutionary and functional processes that link them.*

Dave Daust presented an overview of current climatic conditions and expected climate change in the Nadina. Workshop participants developed a high-level conceptual model describing how biodiversity will be affected by climate change.

Current conditions and expected change in the Nadina

Currently, mountain pine beetle damaged stands dominate the landscape. The high severity of the mountain pine beetle outbreak likely reflects an increased abundance of susceptible pine and climate change. Prior to the beetle outbreak, about half the forest was older than 140 years (Figure 1). Most pine in mature (and mid-seral) stands have been killed (Figure 2), leaving stands with reduced canopy closure.

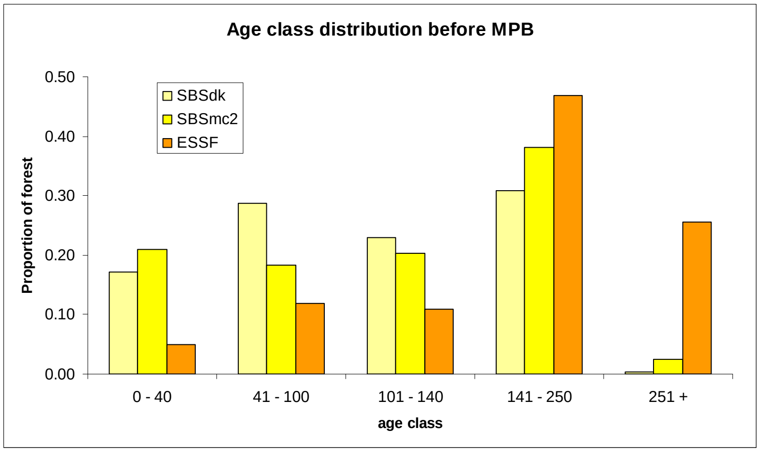

Figure 1. Proportion of forest by age class in the SBS and ESSF zones.

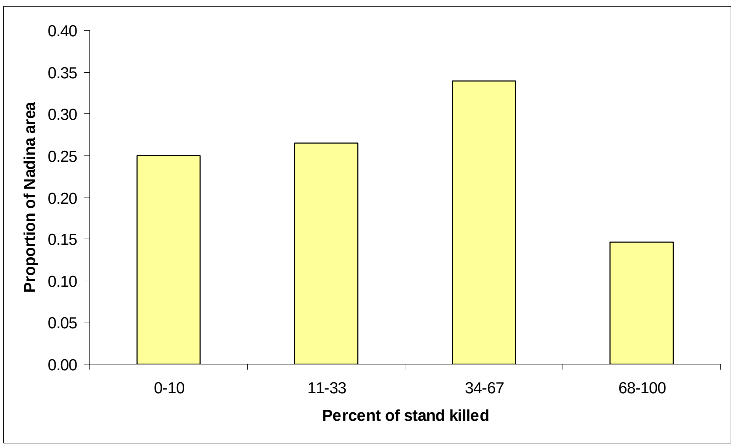

Figure 2. Proportion of forest versus mortality level (percent of stand volume killed).

Across the province, several BEC zones such as SBPS, AT, and SBS may lose historically typical climatic conditions over most of their extent by 2085 (Table 1). One of these zones, the SBS, makes up a large portion of the Nadina, currently.

Table 1. Percent of 1990 BEC zone area where historically-suitable climatic conditions may remain in 2085 (from Table 3, Hamman and Wang 2006) and percent area of each BEC zone in the Nadina.

BEC zone	Predicted area of zone climate envelope in 2085 (% of 1990 province-wide area)	Composition of Nadina excluding Tweedsmuir (% area circa 1990)
SBS:	15	70
ESSF:	73	21
AT:	3	4
CWH:	150	2
SBPS:	2	2
MH:	21	1

Three climate change projections have been prepared for the Nadina (Wang 2010). The projections reflect specific models and scenarios but still give a rough idea of how much change might be expected. The ESSF and SBS BEC zones currently dominate the Nadina. Projections suggest that the ESSF climate envelope (i.e., climatic conditions associated with the zone) will be mostly gone from the Nadina by 2050 and the SBS envelope will be mostly gone by 2080, but projections for the SBS are more variable (Figure 3, Figure 4).

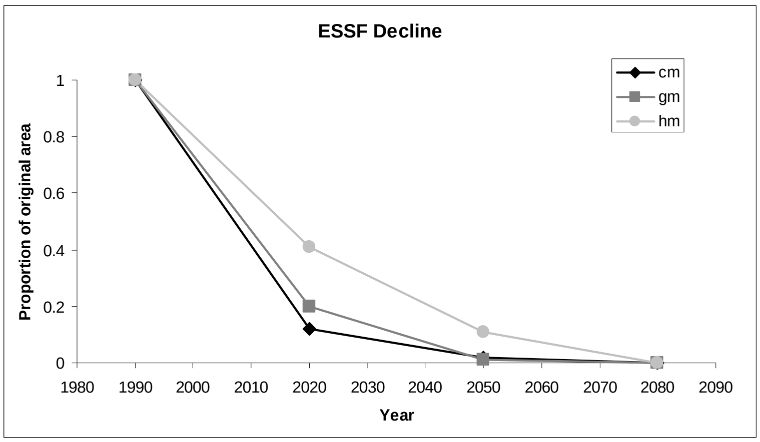

Figure 3. Decline in ESSF climate envelope over time predicted by three different model runs (cm, gm and hm).

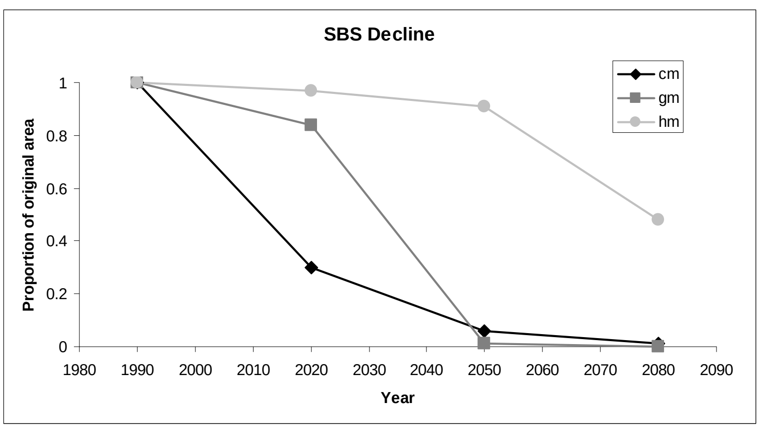

Figure 4. Decline in SBS climate envelope over time predicted by three different model runs (cm, gm and hm).

Impact of climate change on biodiversity

Sensitivity of different BEC zones

The Nadina should be divided into the western mountains region and the eastern plateau region for the purposes of considering climate change. Topography, climate, ecosystem types and development history differs by region. Mountainous terrain accommodates more climatic zones in a given area than gentle terrain, thus species may find suitable climatic conditions nearby, by moving upward in elevation, as the climate changes. The western mountains will likely become wetter, as well as warmer, whereas the plateau may not become much wetter. Projections show that the SBS may shift to ICH or CWH in the west and to IDF in the east.

Much of the ESSF zone is found on hilltops in the Nadina and therefore exists as a set of "islands" in a sea of (mostly) SBS. Climate change will shift BEC zones northward and upward. ESSF zones on isolated hilltops can only move upward and are limited by the elevation of the hill. The AT zone that lies above the ESSF may not easily allow colonization of trees within this century.

Similarly, the alpine tundra zone is found near the top of the higher mountains in the Nadina District and exists as a set of islands. The rock and ice, which lies above the AT may not be rapidly colonized.

Subalpine fir dominates the ESSF and is a sensitive species that may be more susceptible to climate change than other trees.

The SBS, particularly the SBSdk, has more ecological variety than the ESSF. It contains several dry and wet site series. Trees on dry sites face increased mortality risk due to drought as temperatures increase, providing rainfall does not increase substantially. Changes in hydrology that affect water tables will affect riparian sites. The many wetlands in the SBS may be quite sensitive to reduced summer low flows.

As well as considering coarse-filter biodiversity (ecosystems), important species in the Nadina should also be considered, including grizzly bear, Tweedsmuir caribou, northern goshawk, bull trout and salmon. In addition, some tree species are being threatened by climate change, including whitebark pine and willow (threatened by willow borer).

Relevant impacts to biodiversity are hard to define

Defining relevant impacts to biodiversity led to considerable debate. Under historic climatic conditions, extirpation of a species from a large landscape like the Nadina would typically be viewed with concern by ecologists. Climate change complicates matters because it has led to the general notion that species distributions will shift, to some degree, to track suitable climate conditions. Some species will head northward out of the Nadina and new species will arrive from the south. Extirpation of a species from the Nadina may reflect a "change" rather than a "loss" of biodiversity. Although migration may be the best option for many species to cope with climate change, successful migration and colonization are by no means guaranteed. Thus, Nadina-scale extirpation remains a potentially ecologically significant impact, although likely one that cannot be avoided.

Climate change has emphasized the importance of the concept of ecological resilience—the ability of an ecosystem to maintain its structure and function over time. Minor losses of biodiversity (e.g., reduced species ranges or a few extirpations) will not necessarily have a substantial effect on resilience. From this perspective, minor losses of biodiversity are seen as less important. Biodiversity is also a cultural value. People appreciate nature. For some, any loss of a species from the Nadina will not be acceptable.

Conceptual model

Figure 5 shows a rough conceptual model of factors affecting biodiversity, including climate change. Management influence is shown with grey boxes. We suggest that an overarching principle in developing adaptation strategies is to avoid management activities that aggravate the rate of climate change.

Predicted ecological changes are highly uncertain. As each species responds to climate change in its own way, relationships between species may become uncoupled. In particular, plants use environmental cues to time phenological changes such as spring growth and flowering.

The following sub-sections discuss some the boxes in Figure 5 (and related figures), focussing on the ones that directly affect biodiversity.

Biodiversity (Figure 5)

Across a range of taxa, species distributions tend to reflect two ecosystem-scale variables: seral stage (and/or successional stage) and site series (that reflect moisture and nutrient regimes). In addition, invasive species have the potential to substantially affect native biodiversity.

Biodiversity is threatened when certain seral stages and/or site series are in short supply. The late seral stage is most reduced by harvesting and natural disturbance and is usually seen as the most limiting for biodiversity conservation. Natural disturbance will increase as the climate warms. As climatic conditions associated with a BEC zone change, the moisture and nutrient regime of a given location will change—essentially the abiotic conditions supporting the plant community on the site will be lost.

Seral stage (Figure 5, Figure 6)

As stands age, they pass through characteristic structural stages. Most stands also follow successional pathways where one dominant species replaces another, which also affects structure.

Classic models of seral stage development begin with a stand-replacing disturbance, that leaves snags, downed wood and a few large live trees. Minor disturbance (e.g., windthrow of single tree or patch) is characteristic of late seral stages and does not greatly alter stand condition. Mountain pine beetles have created disturbances ranging from small-patch to stand–replacing. The seral stage of stands with intermediate disturbance is hard to classify and may best be treated as a new and different structural stage (e.g., Table 2). Mature and old stands often have advanced regeneration of varying height. Following disturbance, these young understory spruce, fir and sometimes pine trees, along with scattered old trees, form a multi-age stand.

Table 2. Reclassification of seral stages following different amounts of stand mortality due to mountain pine beetle.

Pre-MPB	**Percent live stems remaining**		
	< 15 or 20%	**20 to 50%**	**> 50%**
Pole	Young	?	Pole
Mature	Young	Multi-age (open-mature)	Mature
Late	Young	Multi-age (open-old)	Old

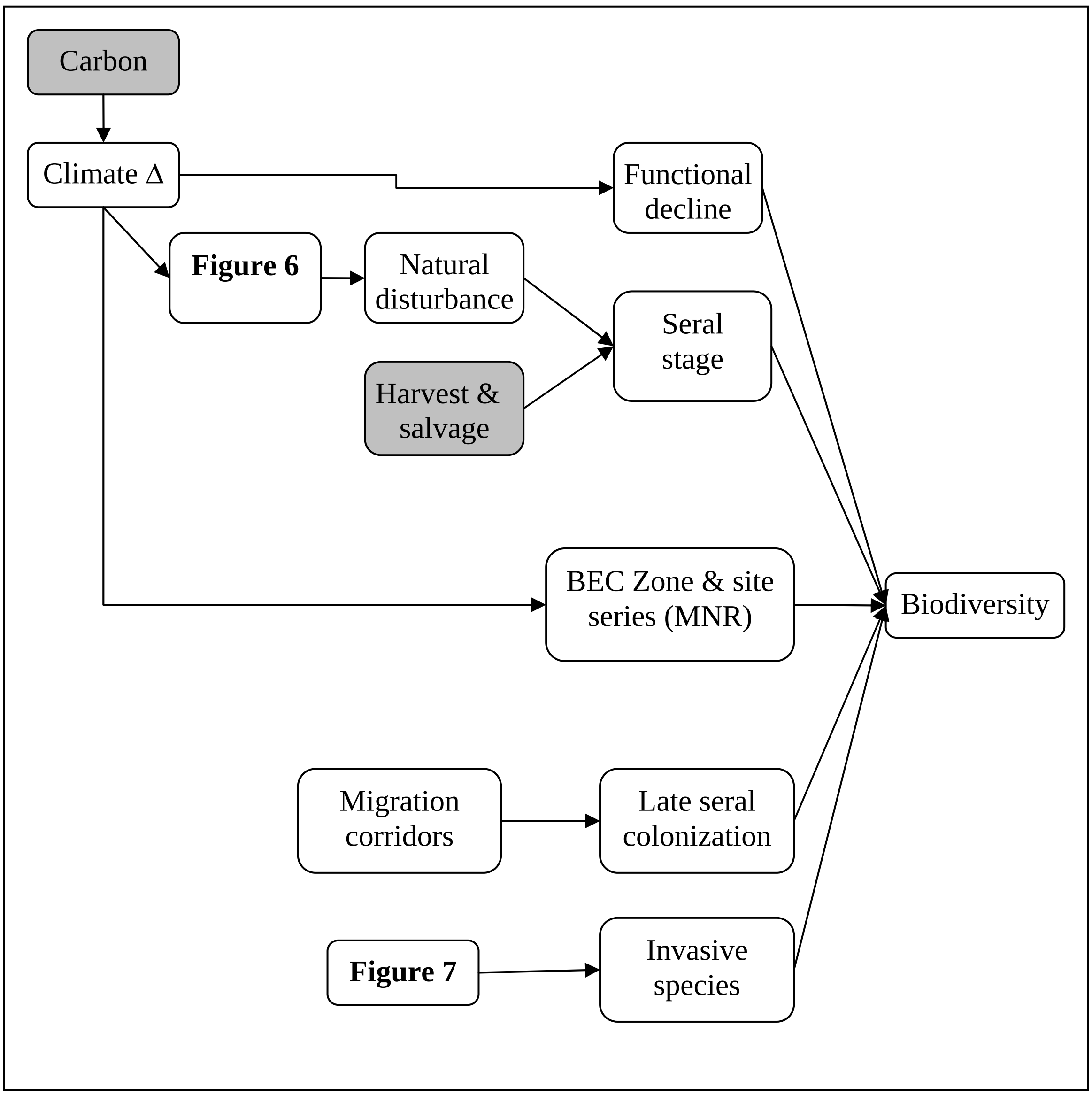

Figure 5. Factors influencing biodiversity in the Nadina. Grey boxes show management influence. MNR means moisture and nutrient regime.

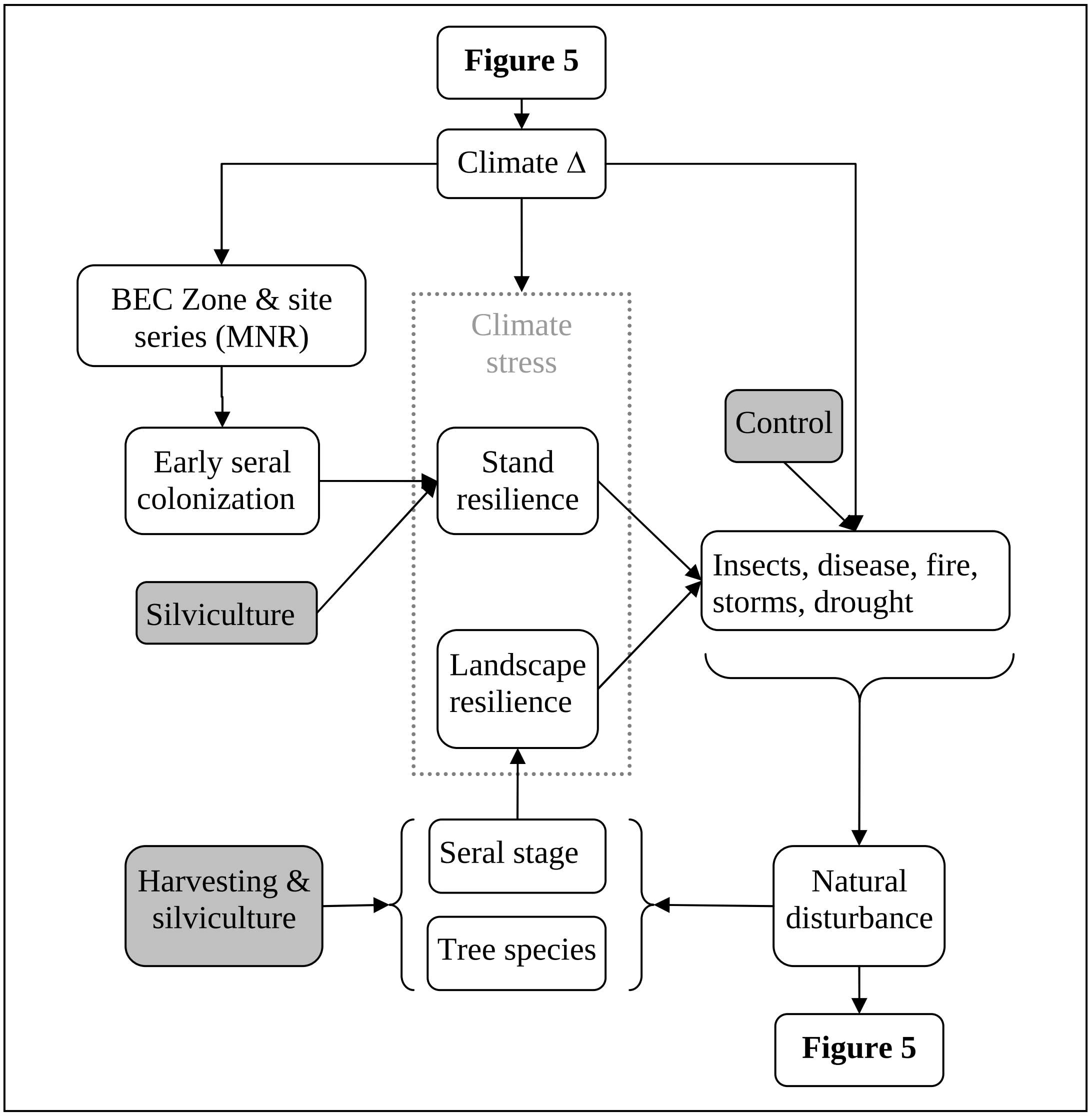

Figure 6. Factors influencing natural disturbance in the Nadina. Grey boxes show management influence.

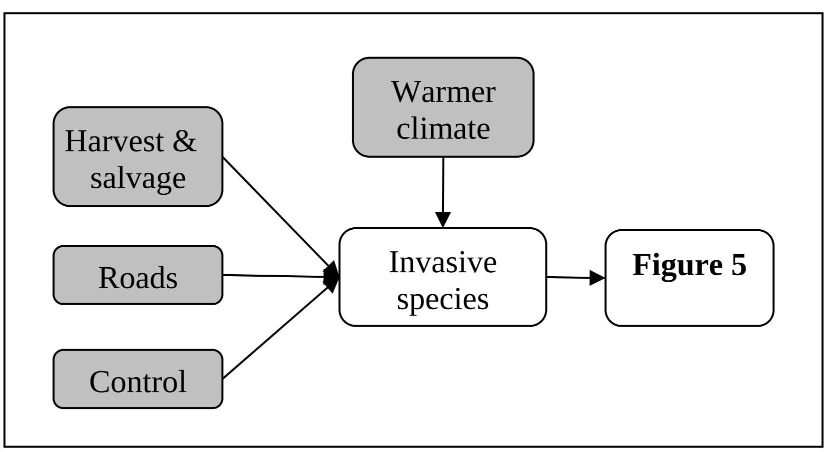

Figure 7. Factors influencing invasive species in the Nadina. Grey boxes show management influence.

Mature seral forest refers to forest where understory re-initiation has begun and late seral (climax) plant communities are established or starting to establish. This process begins in mature forest but communities are not usually well established until later.

As late seral forest declines, the probability of losing biodiversity increases (Figure 8). The late-seral graph is based on models used elsewhere (Price et al. 2007). In the context of climate change, more late seral forest may be required because the shifting climate may cause demographic depression in some species.

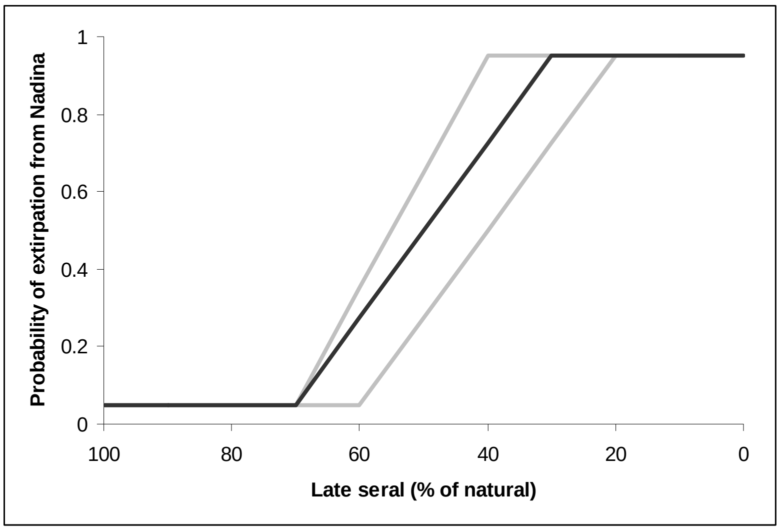

Figure 8. Probability of extirpation from the Nadina versus late seral forest. Late seral forest is expressed as a percent of the historic "natural" abundance (e.g., ~1/3 of SBSmc forest was older than 140 years historically). Risk also increases when the total area of late seral habitat falls below about 30% of the landscape, so this graph may be optimistic for landscapes with a naturally low amount of late seral forest. This graph assumes patches of later seral forest are randomly distributed and assumes that site series are represented in the late seral stage in proportion to their areal extent. Proportion of natural gives only one perspective on the sufficiency of the abundance of late seral forest. The x-axis could use other metrics such as percent of total area or actual area of habitat.

Site series and BEC envelope change (Figure 5, Figure 6)

BEC zones represent major forest types, each having a homogeneous macroclimate.

Climate models predict changes in temperature and precipitation, (and also other variables) at a large scale. They account for major changes in latitude and elevation, but do a poor job of accounting for regional topography. These climate change predictions can be applied to the regional scale (e.g., Nadina) by accounting for regional topography and by using weather station data. Changes in temperature and precipitation (amount and seasonal distribution) associated with climate change can be characterized as shifts in BEC zone and subzone climate envelopes (e.g., Hamman and Wang 2006).

Within the relatively uniform climate of a BEC subzone, variation in soil parent material and physiography lead to variation in moisture and nutrient regimes. Site series divide BEC subzones into units that have similar moisture and nutrient regimes and that consequently are capable of producing similar plant communities in late successional stages. As BEC envelopes change, moisture and then nutrient status will change.

SBS and ESSF climate envelopes will shift northward and upward over time, until the global climate stabilizes (if it does). The amount of original BEC area that remains with historically-characteristic climate conditions can be considered to be suitable habitat for the suite of species that occupy that BEC zone. Thus, the probability of extirpation is likely to increase as the original extent of the BEC zone that remains suitable declines (Figure 9 and Figure 10). The highest risk will occur if and when the climate stabilizes and the BEC zone reaches its smallest size. It may be possible to replace these expert-derived risk curves with a better-supported relationships derived from the species-area curve and considering colonization rates.

Several factors require consideration in conjunction with Figure 9 and Figure 10. First, the ecological difference between the original BEC zone and the new BEC zone will vary. If zones are relatively similar (have more species in common), then the original BEC vegetation may resist change for a longer time period, reducing the probability of extirpation within the original BEC zone and serving as a source for dispersal and colonization to suitable climate envelopes outside of the original zone.

Second, as the original extent of a BEC zone declines, its climate envelope will expand into nearby higher elevation or higher latitude forest. For example, as the IDF envelope replaces the original SBS envelope, the SBS envelope will move into the original ESSF envelope (Figure 9and Figure 10). In theory, BEC vegetation could follow its climate envelope, but the processes of dispersal and colonization that would allow this “tracking” are by no means guaranteed. The current rapid shift in climate outpaces dispersal ability by a factor of about ten times. Species with relatively poor dispersal and colonization abilities will be disadvantaged. Colonization of the new climatically suitable sites will be inhibited by existing vegetation. In addition climate change is expected to produce some novel climate conditions with no current analogue.

The degree of resistance of the existing vegetation to colonization is difficult to assess based on the ecological similarity of BEC zones. One argument suggests that colonization should be easier when BEC envelopes are ecologically similar (have more species in common). Another argument suggests that the established vegetation in a zone should resist change (including colonization from nearby) better when BEC envelopes are ecological similar. Perhaps community-level generalizations about colonization are inappropriate and species that are strongly correlated with specific BEC zones should be evaluated separately.

Even where original and replacement BEC envelopes have many species in common, the species in the original BEC zone will still need to move because moisture-nutrient regimes will shift. For example, species found on drier sites in cooler zones will shift to moister sites in warmer zones to obtain the same moisture and nutrient conditions. The distance of this shift will be small relative to zone-scale shifts, but colonization is still not guaranteed.

Alpine tundra follows the same general pattern as ESSF and SBS, but impacts begin when with more original zone remaining (Figure 10). Alpine species are more threatened because they have nowhere to go, however, the pace of ingress of trees into alpine areas is expected to be slow. Changes in the snowpack may alter alpine areas in unpredictable ways: for example, more snow could lead to heather-dominated ecosystems.

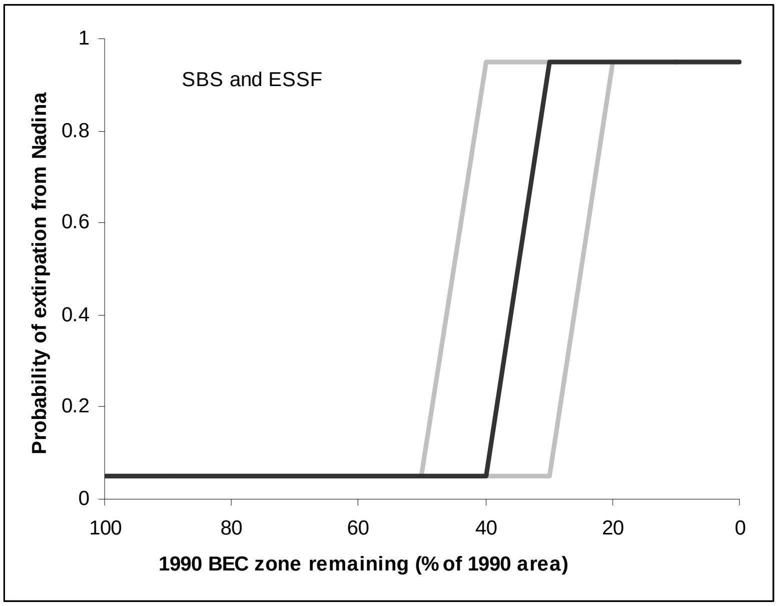

Figure 9. Probability of extirpation from the Nadina versus percent of the BEC zone with an unchanged climate envelope. Black line shows best estimate; grey lines show uncertainty.

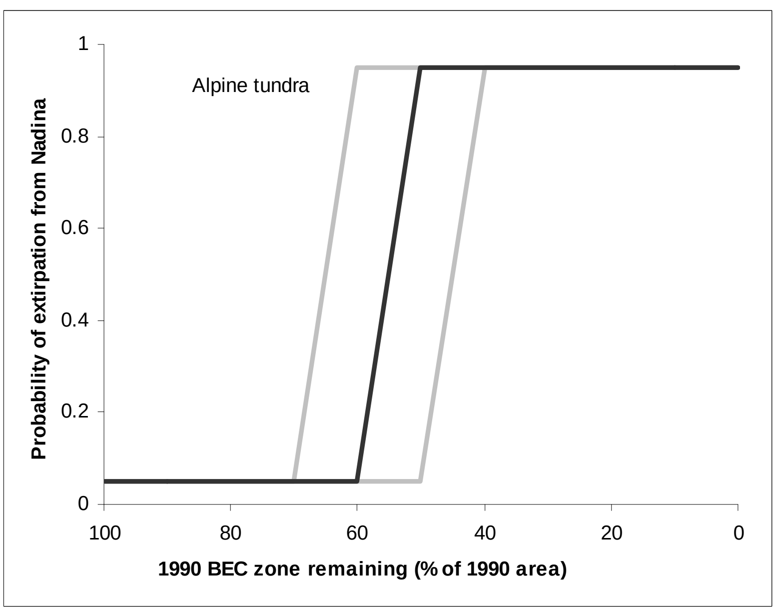

Figure 10. Probability of extirpation from the Nadina versus percent of the BEC zone with an unchanged climate envelope. Black line shows best estimate; grey lines show uncertainty.

Invasive species (Figure 7)
Invasive species move into an area, spread rapidly and outcompete and displace historic occupants. In the past, most invasive species have been exotic to Canada (e.g., coming from Europe or Asia). By spreading beyond their historic natural range, these species have left behind ecological relationships that control their population. Under climate change, species that occur naturally south of the Nadina may also become invasive here. In their historic range, native species are in balance with predators, competitors and pathogens. These relationships are expected to uncouple under climate change—ecological communities will not move in unison. Natural controls may re-establish after a period of chaotic reorganisation.

Exotic species will probably cause worse problems than species native to BC, because many of their natural limiting factors lie far away and have no probability of controlling the population.

Currently, the cold climate in the Nadina limits the invasion of many exotic species. Increasing temperatures and reduced continentality (e.g., less extreme summer versus winter temperatures) associated with climate change will favour exotic species.

Invasive species are expected to increase their occupancy of the Nadina as temperatures increase due to climate change and as soil disturbance increases. Fire and summer logging increase soil disturbance. Roads serve as major corridors of disturbed soil that facilitate spread (Figure 11). Range managers should be a good source of information about invasive species.

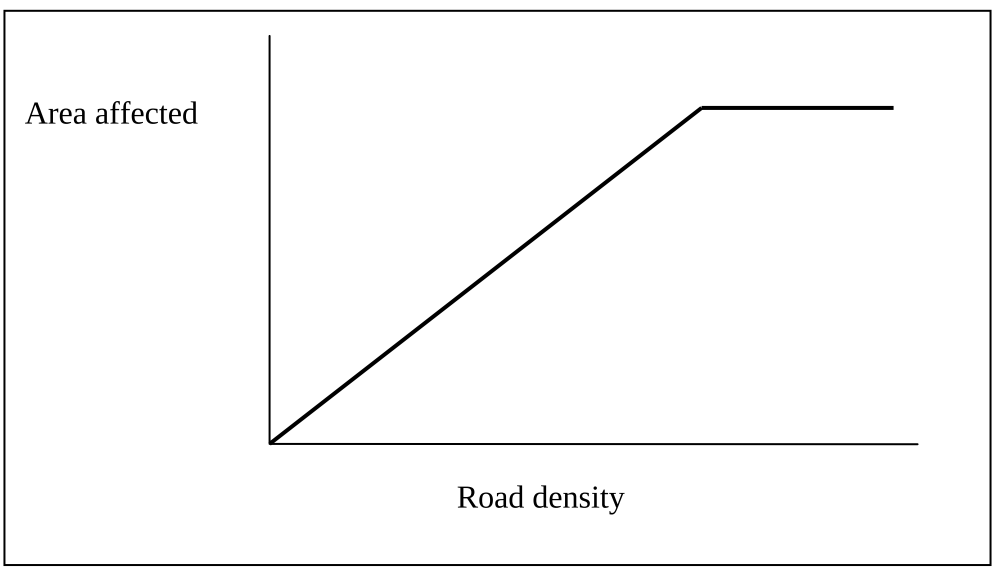

Figure 11. Approximate influence of road density on area affected by invasive species.

Stand and landscape resilience and resistance (Figure 6)
The resilience of a tract of forest to disturbance is a function of diversity at different scales (e.g., alpha and beta diversity). For example, young stands with diverse composition and structure are more resistant and resilient to insects and disease than homogenous stands. A landscape composed entirely of young diverse stands would be considered homogenous at the landscape scale, however. At the landscape scale, some stands dominated by a few species (including deciduous trees) would increase diversity, resistance and resilience as would a variety of seral stages. Mature and old seral forest is probably more resilient to climate change because mature trees mediate microclimate, buffering the direct effects of climate change.

Early seral colonization (Figure 6)
Open sites are more directly exposed to climate change. Thus, historically-common vegetation may no longer establish or thrive. Most colonizing species are generalists. Open sites may be colonized by species from warmer climates, including invasive species. Many colonizing species can disperse long distances. Soil disturbance will increase the chance of ex-situ species colonizing.

Late seral colonization (Figure 5)
Colonization of late seral forest by climatically-appropriate species requires landscapes with suitable amounts of late seral forest and migration tracts/corridors (with sufficient old seral, but not necessarily intact) to facilitate dispersal. Existing vegetation, established under historic climate conditions, may resist change. Late seral colonization may require that disturbance removes established vegetation and then that growth and succession create an appropriate microclimate.

Management forces (grey boxes in concept maps)
Forestry affects seral stage distribution and landscape pattern via harvesting, including salvage. Along with other development, forestry determines road density. Planting influences the species composition and genetic makeup of post-harvest sites.

Forestry can try to leave relatively unfragmented “corridors” that aim to facilitate migration. Corridors should support migration across latitudinal and elevational gradients. Riparian areas, including wetlands, are an ecologically diverse and productive component of the SBS plateau (and of the landscape in general) and form natural lineal features. They can serve as a backbone for migration corridors.

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