Adaptation Strategies

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Vulnerability assessments frame management as adaptation to a changing climate. Sustainable forest management frames management as a means of providing ecosystem services desired by society over time. Both approaches must account for the impacts of both management and climate change on ecosystem services to develop realistic policies.

In the regional vulnerability assessments, many strategies were identified to achieve management objectives under climate change (Table 1), however, most, with the exception of assisted migration, are not novel, but rather are elements of ecosystem-based management that require broader application. Strategies can be grouped into two broad categories[1]:

1. **Reduce risks to forest ecosystems:**
    a. limit cumulative effects
        i. use a precautionary approach to development;
        ii. develop a regional cumulative effects assessment approach that limits total anthropogenic stress, accounting for climate change, in a region;
        iii. develop a BC-scale conservation strategy for adaptation and mitigation;
        iv. develop watershed-scale water conservation plans;
    b. promote resilience to change
        i. promote stand-scale species diversity (e.g. retain broadleaf and plant more species);
        ii. promote landscape-scale ecosystem diversity (e.g., age-classes, leading tree species, structure);
        iii. maintain favourable microclimates and site conditions (e.g., partial cut, buffers);
    c. guide ecological transformation
        i. retain connectivity among landscapes;
        ii. plant climatically-suited tree species (assisted migration);
        iii. develop a triage approach to deal with species at risk;
    d. combat detrimental change
        i. monitor and minimize excessive disturbance (e.g., beetles, fire);
        ii. monitor and control invasive species;

2. **Reduce risks to forestry-dependent communities:**
    a. increase monitoring and detection of undesirable change
    b. increase capacity of forestry community to respond to change
        i. increase emergency response capability (e.g., fire control, salvage harvesting);
        ii. increase diversity and flexibility of timber processing facilities;
    c. preferentially harvest susceptible timber (i.e., when facing imminent threat);
    d. increase capacity of infrastructure to withstand extreme events.

[1] Vulnerability assessments focused more on risks than opportunities.

The impacts of climate change can be viewed from various perspectives: undesirable changes in key ecological variables; undesirable impacts to the whole forest ecosystem; or undesirable impacts to ecosystem services. The Nadina, West Kootenay and Kamloops case studies emphasized each of these perspectives, respectively. In the end, all studies considered key ecological changes and recommended very similar management responses. Table 1 organizes potential adaptation responses identified in the case studies by management issue (responses are also consistent with the literature on adaptation in managed forests). Applying all potential management actions can only reduce impacts partially and some impacts cannot be lessened. Directly combating disturbance agents is likely a costly, losing battle given a fundamental shift in disturbance regimes within susceptible forests. Fire control will be necessary to protect important values, however.

Table 1. Management issues, resulting from ecological responses to climate change, and potential management responses. Chains of cause and effect have been greatly simplified.

Management issue (bold) due to ecological response (•) to climate change (○)	**Management response (adaptation)**

Loss or degradation of old forest ecosystems and focal species' habitat
• Increased stand-replacing and stand-opening disturbance
  ○ warmer mean temperatures increase pests and fire hazard
• Changing species assemblages (including shift to grassland)
  ○ altered microclimate and soil moisture affects some species more than others
• Uncertain changes in regional snowpack, snow condition and winter severity
  ○ warmer winters may increase or reduce snowfall
  ○ reduced forest cover will increase snow accumulation
  ○ altered freeze-thaw cycles will affect snow crusts
  ○ mean winter temperature will decrease but climatic variability will increase leading to uncertain winter severity
• Increased invasive species
  ○ warmer winters favour exotic and southern species
  ○ intense fires and salvage harvesting increase soil disturbance
	• Maintain a connected network of reserves, corridors, focal habitats and WTPs
	• Increase redundancy of reserves and habitat units
	• Allow flexibility to move habitat reserves
	• Reduce hunting and control predators of ungulates
	• Increase unroaded area to limit invasive species spread
	• Control invasive species

Potential extirpation of culturally important plants • Changing species assemblages (see above) • Reduced seed banks ○ intense disturbance can damage seed banks	• Avoid harvesting sensitive sites to maintain microclimate • Use silviculture to create site conditions that favour threatened plants

Variable and potentially reduced timber supply (growing stock and yield/ha)
• Increased stand-replacing and stand-opening disturbance (see above)
• Increased growth rate
  ○ longer, warmer growing seasons increase growth, subject to available moisture
  ○ increased CO_2 increases efficiency of water use and photosynthesis
• Reduction or expansion of the climatically suitable range for tree
	• Control insects, disease and fire, where possible
	• Preferentially harvest susceptible stands (i.e., imminent threat)
	• Shorten rotations to reduce risk of loss
	• Fertilize to reduce harvest age
	• Regenerate diverse stands of climatically-suited species/stock that resist insects and disease
	• Conduct provenance trials for assisted migration
	• Monitor of soil moisture conditions

Management issue (bold) due to ecological response (•) to climate change (○)	Management response (adaptation)
species (e.g., Douglas-fir and western redcedar expected to expand) ○ altered microclimate and soil moisture	
Loss of productive forest landbase to grassland (or weeds or human use) • Changing species assemblages (see above) • Warmer climate may lead to increased human habitation	• Avoid harvesting sensitive sites to maintain inertia • Partially-cut stands on dry sites to retain shelter • Promote rapid site recovery (e.g., reforest dry sites; retain deciduous trees on moist sites)
Increased plantation failures • Increased stand-replacing and stand-opening disturbance (see above) • Changing species assemblages (see above)	• Retain downed wood to store moisture on dry sites • Regenerate diverse, resilient stands of climatically-suited species/stock • Use stand tending to influence successional pathways
Reduced water quality • Increased peak flows, stream flashiness and scour and increased landslides and surface erosion ○ Increased spring, winter and fall precipitation ○ Increased winter rain/snow ratio and rain on snow events ○ Increased frequency and magnitude of storm events ○ Increased Equivalent Clearcut Area (ECA) due to disturbance reduces capacity of landscape to buffer rainfall events, leading to rapid (flashy) changes in streamflow	• Limit ECA to 30 to 50% of THLB; determine ECA for each watershed • Avoid locating roads and cutblocks on unstable terrain • Design roads and drainage structures to accommodate increased peak flow and bedload transport in areas likely to become wetter
Infrastructure damage • Increased peak flows, flashiness and scour and increased landslides and surface erosion (see above)	• As above
Degraded fish habitat • Increased peak flows, flashiness and increased landslides and surface erosion (see above), increases scour and sedimentation of spawning gravel • Reduced summer low flows (that can isolate fish) ○ warmer summer temperatures increase evapotranspiration ○ summer precipitation may decline (southern Kamloops, eastern Nadina, most of West Kootenay) ○ possible declining snowpacks lead to smaller and earlier recession, creating longer low flow period ○ possible declining snowpacks reduce late summer drainage feeding streams ○ glacier melt may increase summer flows for a period (Nadina) ○ compounded by human water use • Also see shift of stream ecosystem below (flow continuity affects habitat)	• As above • Limit human water use
Shift of stream ecosystem from perennial to intermittent or ephemeral	• Limit human water use

Management issue (bold) due to ecological response (•) to climate change (○)	Management response (adaptation)
(affects aquatic community and isolates fish) • Reduced summer low flows (see above)	• Limit ECA
Possible lethal temperatures for salmonids (low elevation streams) • Increased stream temperature ○ warmer annual temperature increases water temperature ○ reduced snowpacks provide less cool water ○ reduced summer flows (see above) are easier to heat ○ but glacial meltwater cools streams Note that cold high-elevation streams may become more productive (however many of these streams have isolated fish populations)	• Retain riparian cover • Manage warm water sources (e.g., ditches; deactivated roads) • Avoid harvesting sites with high water tables

Over the long term, promoting ecological resilience may be the best overall strategy. Changing resilience will be a slow process, because managers only influence a small proportion of total area each year and because forests grow and change over decades and centuries. Thus, adaptation by planting climatically-suited species will take time. Limiting harvesting to maintain landscape connectivity that supports natural adaptation and resilience can bring benefits in the short term, but such benefits are difficult to quantify. None of the case studies estimated the costs of adaptation measures.

Management actions must be supported by learning and planning. In general, climate change increases uncertainty about future ecosystem functioning and thus argues for greater monitoring and research to address several basic questions:

1. How is the climate changing in this region?
2. How are drivers of ecological change responding (insects, disease, fire, drought)?
3. How are ecosystems responding (seral stage, species composition, regeneration success)?
4. How effective are management interventions (connected landscapes, fuel management, reforestation)?

General trends in ecosystem services (i.e., usually a decline) and higher uncertainty related to climate change must be considered in planning and related analyses, otherwise we are basing management decisions on highly improbable scenarios of the future (i.e., continuation of current conditions).

Adaptation to climate change (management responses in Table 1) should be coordinated with efforts to mitigate climate change (carbon management). While vulnerability assessments focussed on adaptation to changing forest conditions, several potential management responses also contribute to mitigating carbon pollution.

The management issues identified in the vulnerability assessments point to significant consequences for BCs natural resource values including timber supply, water quality and fisheries, and infrastructure. Management responses are available to reduce negative impacts and capitalize on the opportunities that exist. Failure to address these risks and opportunities in a timely manner could have significant ramifications for BC’s resource values and communities.