

Impacts of climate change on British Columbia's biodiversity: A literature review

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Abstract

This Extended Abstract condenses a literature review that summarized research on the current and potential impacts of climate change on biodiversity in British Columbia. The review, which is preceded by a brief summary of observed and predicted climate changes, brings together the relevant information contained in those publications for the benefit of natural resource managers. Contemporary increases in atmospheric carbon dioxide concentration, average annual temperatures, and sea surface temperatures have been documented, and climatologists predict these increases will continue through this century. Research suggests that whole ecosystems and biogeoclimatic zones will not respond as a unit; rather, individual components of ecosystems will respond. Species will respond to these climate changes either by adapting in place, migrating, or going extinct. Examples of species responses have already been recorded in British Columbia.

Finally, the review summarizes research on how to mitigate climate change impacts on biodiversity. Mitigation will require implementing conservation principles, reducing non-climate stressors, providing latitudinal and elevational migration corridors, and instituting long-term monitoring to define causality between climate change and biotic responses. Perhaps the most important advice for natural resource and biodiversity managers is to implement, to the extent possible, good conservation practices.

KEYWORDS: *adaptation, biodiversity, British Columbia, climate change, ecosystems, species.*

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Editor's Note

This is a condensed summary of the full report, *Impacts of climate change on British Columbia's biodiversity: A literature review*, available on the FORREX website at: <http://www.forrex.org/publications/forrexseries/fs23.pdf>. References and figures are omitted in this abstract, but are available in the full report PDF.

Introduction

Climate change is rapidly becoming a dominant issue for land and resource managers charged with maintaining British Columbia's biodiversity. Recent publications, both from British Columbia and abroad, have focussed on actual biodiversity impacts and adaptation measures. The full literature review synopsized in this Extended Abstract summarizes the relevant information contained in those publications for the benefit of natural resource managers—citations for the observations and recommendations highlighted in the discussion below are provided in the full review.

Climate change goes beyond temperature; it affects precipitation, evaporation, relative humidity, and wind patterns. Embedded within changes to climate normals are changes in the variability of climate, and the frequency of extreme weather events. Climate change affects abiotic components such as glaciers, rivers, lakes, and oceans, which in turn drive changes in the biota that are linked to them. Manifesting differently from one region to another, climate change varies even within British Columbia's borders.

Observed Climate Change and Impacts on Biodiversity in British Columbia

In British Columbia, a number of climatic changes have been observed since the inception of record keeping, including increases in average annual temperature, sea surface temperature, frost-free season length, and growing degree days. Other changes observed are earlier ice-free dates on lakes and rivers, accelerated glacial melting, and earlier spring freshet in rivers and streams.

These climatic changes are already affecting species and ecosystems. The climatically suitable range of the mountain pine beetle has expanded over the last several decades, and the beetle has responded by moving into those newly habitable areas. A recent outbreak of needle blight in lodgepole pine can also be attributed to climate change.

Eight selected bird species in British Columbia have exhibited long-term trends toward earlier arrivals, later departures, and northward range extensions, with some species transitioning from migrants to year-round residents during the period studied.

In 2004, a hot, dry summer and low water levels resulted in Fraser River temperatures of 20–21°C, about four degrees warmer than normal. Such temperatures

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can be lethal to sockeye salmon, which prefer water temperatures of 15°C or cooler.

Projected Future Climate Change in British Columbia

Current analysis suggests British Columbia can expect the following climate changes:

- Average annual temperatures warming 1–4°C by 2100;
- Northern British Columbia warming faster than other parts of the province, and the Interior warming faster than the Coast;
- Winter temperatures warming faster than summer temperatures;
- Average annual precipitation increasing up to 20% by 2100;
- Winter precipitation continuing to increase, and a greater proportion of winter precipitation falling as rain;
- Declining snowpack in southern British Columbia at low and mid-elevations;
- Earlier spring freshet, resulting in increased flood risk, greater water turbulence, and related scouring;
- Declining summer streamflows on many snowmelt-dominated river systems, resulting in warmer water temperatures and lower water quality;
- Reduced summer soil moisture in some regions; and
- Substantial changes to hydrology, particularly to glacier-fed rivers.

Ecosystem and Biodiversity Responses to Climate Change

Changes in climate and related systems will drive changes in ecosystem structure (e.g., predominant vegetation, age class distribution, and species composition), function (e.g., productivity, decomposition, nutrient cycling, and water flows), and distribution within and across landscapes.

Projected climate change impacts on forested ecosystems include: disturbances related to extreme weather events, simplification of ecosystems, migration of species, stand age reduction, and extinctions or local extirpations.

Changes in species composition will either be *in situ*, with subdominants replacing dominants, or *ex situ*, with species migrating from other regions, or some combination of both.

Researchers have combined current ecosystem distribution with climate change predictions to model future changes to British Columbia's biogeoclimatic subzone distribution. They predict dramatic shifts in subzone extent and distribution (please consult the full review for more detail). Prevailing patterns of biotic disturbances, such as insect and disease outbreaks, are expected to increase with climate warming.

Patterns of abiotic disturbances will change as well. The length of our fire season, the amount of area burned, and fire severity are all predicted to increase. The occurrence of spring meltwater surges, flooding, debris flows, and high-intensity rainfall events are also projected to increase. Alterations in abiotic disturbance regimes will all have biotic consequences.

Ecosystem adjustments to climate change are most likely to be individualistic, taking place at the species rather than the community or ecosystem level. In other words, existing ecosystems will experience the loss of some species, changes in the dominance of others, and the arrival of new species. New arrivals will interact with persisting species, plus exotic arrivals, to create new ecosystems and biogeoclimatic subzones.

Projected climate change impacts on forested ecosystems include: disturbances related to extreme weather events, simplification of ecosystems, migration of species, stand age reduction, and extinctions or local extirpations. A number of factors may impede the establishment of forest trees in newly suitable climatic areas. The new sites may be too far from the species' previous range to allow for dispersal. Competing vegetation, unsuitable soil or hydrology, insect and disease outbreaks, and altered disturbance patterns may

also impede the establishment of tree species in newly suitable areas.

Climate change impacts living organisms, populations, and species by affecting: reproduction, fecundity, establishment, and dispersal; phenology and migration, growth rates, and mortality; length of growing or biologically active season; geographic distribution, population size, and response to disturbance. Simply stated, species can respond to altered climate in four different ways: they can adapt to the new conditions, evolve, migrate to areas of more suitable climate, or go extinct.

Changes to climate will also alter interactions between species, including patterns of competition, symbiosis, mutualism, predation, and dominance. Impacts will be incremental to other drivers, such as anthropogenic habitat degradation, habitat loss, pollution, and altered natural disturbance regimes. It is likely that negative synergy between climate change and these non-climate stressors will lead to dramatic and unpredictable species and ecosystem responses.

Species most vulnerable to extinction will be those with small populations, slow rates of dispersal, restrictive elevation, climate requirements, and those whose habitat is limited or occurs in patches. Migratory species face particular extinction risk, since they require multiple habitats in a particular seasonal order.

In summary, climate change is likely to induce:

- Large-scale biome, ecosystem, and species shifts;
- A breakdown and re-sorting of current plant communities, subzones, and ecosystems;
- A general expansion of species ranges northwards and upslope (note that for alpine and boreal species, this will mean range contractions);
- Loss of certain ecosystems, including some wetland and alpine areas;
- Changes in habitat quality and availability;

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- Increases in growing degree days;
- Changes in synchrony between species—for example, the timing of predator–prey or flower–pollinator interactions; and
- Differential range shifting—for example, when a pollinator insect experiences a range expansion, but its host plant does not.

Climate Change Adaptation and Management Implications

Adaptation to climate change can be broken down into three categories: the adaptation of human communities (not discussed here), the autonomous adaptation of species and ecosystems, and assisted adaptation (the work we do to help species and ecosystems adapt). Assisted adaptation measures can be further broken down into *reactive* (initiated after climate change occurs) or *anticipatory* (initiated in advance of change).

Biodiversity managers should attempt to provide opportunities for native species and ecosystems to respond to this climatic challenge to the limits of their natural capabilities, emphasizing anticipatory rather than reactive measures. Perhaps the most important advice for natural resource and biodiversity managers is to implement, to the extent possible, good conservation and ecosystem management practices.

Parks, protected areas, ecological reserves, and biodiversity corridors take on great significance in maintaining native biodiversity in a climate-altered future, so these areas should receive additional management attention. Effective dispersal corridors should be established now, as species range adjustments to climate change are occurring already. A good network of protected areas that are free of other stresses provides one of nature's best opportunities to adapt to climate change.

Given the current fragmented distribution of conservation lands, biodiversity management in “the matrix” (i.e., the areas in between conservation lands) becomes important. Unless there is some threshold level of conservation principles applied in the matrix, even the most conscientious management of parks and protected areas may not be sufficient to allow range change for many native species. This will be particularly true of north–south and upslope corridors, the most likely routes for range change in British Columbia.

Reducing or eliminating non-climate-related stressors to biodiversity will be of prime importance. One expert states that “the potential impacts of climate change will be an academic question in relation to

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ecosystems we are unable to save from current and immediate threats.”

Forest seed planning zones and recommendations will need to be revised to reflect the new realities of altered climate. Common gardens (the same sets of plant species or varieties planted in different geographic locations) and provenance trials assume a much greater importance in an era of climate change. Existing common gardens and provenance trials in British Columbia, particularly those containing forest trees, should be documented and monitored closely, and new ones should be established in strategic locations throughout the province. A priority should be testing species whose habitat is one or two subzones downslope or southward of the test location.

Although costly, some direct intervention may be required at the individual species level, through habitat restoration, recovery programs, assisted migration, and *ex situ* conservation techniques, such as captive breeding and nursery multiplication.

Conclusions and Recommendations

Our natural resource management culture has traditionally responded to major abiotic disturbances via the short-term crisis intervention paradigm, as in the case of floods or forest fires. We have little management experience in preparing for the protracted, global-scale disturbance that climate change represents. Meeting the challenge of climate change will demand the best of our abilities as resource managers, and the three-pronged strategy of climate change adaptation, carbon sequestration, and greenhouse gas emission reduction is the logical course to pursue.

Proactive and robust climate change adaptation strategies should become an integral part of all land use planning processes, both public and private. The following recommendations should be considered:

- The principles of good conservation and ecosystem management practice should be observed and implemented.
- Non-climate stressors, such as over-harvesting of natural resources, habitat fragmentation, excessive roading and soil disturbance, alien species introductions, etc., should be controlled and minimized wherever possible.
- Long-term, repeat monitoring of selected ecosystems, species, and ecosystem processes should be put in place, and formal connections made between monitoring results and management. Some portion of the monitoring effort should be of sufficient rigour to determine causality between climate change and biodiversity impacts.
- Modelling of climate impacts on ecosystems and individual species of interest should be continued and expanded. The modelling efforts should be linked to the monitoring work.
- Land management organizations, government ministries, and relevant professional societies should commit to assisting their employees and members to keep abreast of major developments in climate change science and biodiversity conservation, through some combination of providing extension materials, email lists, study groups, conferences, and workshops.
- Measures should be undertaken to enhance communication between agencies managing conservation lands, to ensure co-ordination of effort in developing and maintaining multi-jurisdictional migration corridors.

Land management organizations, government ministries, and relevant professional societies should commit to assisting their employees and members to keep abreast of major developments in climate change science and biodiversity conservation.

- Land management organizations should “put their own house in order” by reducing greenhouse gas emissions wherever possible (see <http://www.bcclimateexchange.ca/index.php>) and exploring opportunities for enhanced carbon sequestration.

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The full literature review, including references and figures, is available on the FORREX website at: <http://www.forrex.org/publications/forrexseries/fs23.pdf>
Hard copies are also available upon request.

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Test Your Knowledge . . .

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How well can you recall some of the main messages in the preceding Extended Abstract?

Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Species can respond to climate change in four different ways. List them.
2. What practice is the single most effective tool for enhancing the ability of species and ecosystems to adapt to climate change?
3. How do ecosystems respond to climate change?

ANSWERS

1. Evolution, adaptation, migration, extinction.
2. Good conservation practice.
3. Entire ecosystems will not expand or contract in response to climate change; the species making up those ecosystems will each respond individually to climate change.