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FOREST AND RANGE EVALUATION PROGRAM

Monitoring Forest and Rangeland Species and Ecological Processes to Anticipate and Respond to Climate Change in British Columbia

Margie M. Eddington, John L. Innes,
Alyson E. McHugh, Alanya C. Smith

Camimred Falls
Photo: Phil Clifton

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MINISTRY OF FORESTS AND RANGE
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Management of forest and range resources is a complex process that often involves the balancing of ecological, social, and economic considerations. This evaluation report represents one facet of this process. Based on monitoring data and analysis, the author offers the following recommendations to those who develop and implement forest and range management policy, plans, and practices.

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EXECUTIVE SUMMARY

The British Columbia Ministry of Forests and Range engaged John Innes & Associates to conduct initial research, analysis and liaison work necessary to inform the development of a strategy for monitoring forest and rangeland species and ecosystem processes to anticipate and effectively respond to climate change impacts. The ultimate goal of the monitoring strategy is to provide the data to help inform key forest and range management decisions in light of climate change.

The specific goals of the project were to develop a set of recommended indicators for monitoring forest and range associated species and ecological processes in British Columbia and identify the potential data suppliers that are available for evaluating the indicators. This report presents these indicators and their data sources along with a summary of the liaison and research work that has been used to inform their development. This work includes an examination of frameworks that are being used to monitor climate change at the local, national and international level which can be found in Appendix 1.

In the report a total of sixteen indicators are recommended and presented under the criteria-level headers of ecosystem drivers (7 indicators), natural disturbance (4 indicators) and biodiversity (5 indicators). Almost thirty diverse data sources were identified as able to support these indicators. Despite this, preliminary investigation and liaison work revealed that 6 of the proposed indicators, including some considered of critical importance to the framework, could not be reasonably supported through these existing data collections.

Recommendations for further work include the need to examine these data gaps to determine where and how it may be necessary to increase monitoring to support the framework. In addition, the extent to which these data from the various sources can be integrated and interpreted as a whole must be assessed. Final recommendations also call for further direction and consideration to be given to how the framework may be implemented, including how it is reported on and the extent to which information is made available to the wider community.

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INTRODUCTION

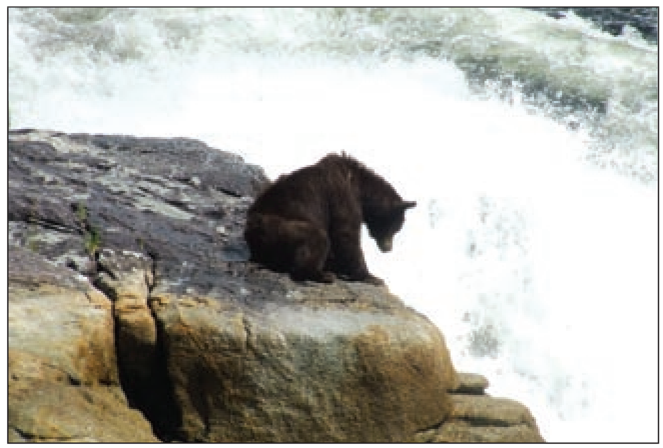
The Future Forest Ecosystems Initiative (FFEI) in partnership with the Forest and Range Evaluation Program (FREP), of the British Columbia Ministry of Forests and Range (MFR) engaged John Innes & Associates to advise on the identification of a set of indicators for monitoring forest and range associated species and ecological processes in order to anticipate and effectively respond to climate change impacts in British Columbia (B.C.).

The project is the first step towards achieving FFEI's objective to monitor the key species and ecological process indicators to detect changes over time and determine the agents of change. Detecting change will be a key thrust of the monitoring program, while determining agents of change will call upon research capability. Most crucially, the data collected and reported through the monitoring strategy must be designed to inform key forest and range management decisions in light of climate change. The ultimate goal of the project is to develop a climate change monitoring strategy for the Ministry of Forests and Range (MFR) based on the most cost-effective options, with the aim of increasing collaboration and efficiencies among existing programs where possible. The purpose of this Phase of the project was to conduct a significant portion of the initial research, analysis and liaison work necessary to inform the development of a strategy for monitoring forest and rangeland species and ecosystem processes in light of climate change.

In determining these indicators the project also identifies the existing monitoring and inventory programs that are potential data sources and data collection channels for evaluating the indicators. These include programs implemented by a range of different organizations including provincial, federal and international forest management and conservation agencies, universities and non-government organizations. Given current fiscal constraints, the integration of such programs will be an essential step in developing a provincial monitoring strategy.

The scope of the monitoring framework specifically relates to those key species and ecological processes in B.C.'s forests and rangelands. Thus, the species considered under the project are restricted to those that depend on B.C.'s forests and/or rangeland habitat for all or part of their lifecycle. Species both native and introduced to these areas are considered potential 'key species' for monitoring. Ecological processes, which include natural disturbances such as fire or wind throw, or ongoing processes such as the cycling of water and nutrients are more difficult to narrow down geographically. Changes to these processes occurring outside of forests and rangelands may have impacts on the ecosystems of interest (e.g., glaciers). As such, any ecological processes affecting B.C.'s forests or rangelands either directly or indirectly would potentially be the subject of monitoring under the framework.

The indicators presented in this report were selected based on a process of literature review and consultation with subject matter experts, and ultimately evaluated at an expert workshop against defined criteria. This can be considered a first approximation, with opportunity to add or change the indicators presented in this report in the future as new information and opportunities become available.



The Bear
Photo: Colin Nelson

BACKGROUND

Changes in climatic conditions and their effects on forest and range values

Warming of the Earth's climate is undeniable. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change gives observational evidence from all continents and most oceans showing that many natural systems are now being affected by regional climate changes, particularly temperature increases.[1] Forecasts of future climates under a range of different global development scenarios are available from numerous global climate models and there is high agreement and much evidence that even with current climate change mitigation policies and practices, global greenhouse gas emissions

1 IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland.

will continue to grow over the next few decades causing further temperature increases.

All reported temperature trends show that B.C. has warmed in recent decades.[2] Records suggest that the rate of change in temperature and precipitation in southern B.C. and much of the Pacific Northwest during the twentieth century exceeded global averages.[3] Although there is some regional disparity, most of the Province experienced warming in both mean and annual temperature during all seasons. Historical trends show that B.C. has become slightly wetter, with northern B.C. wetter in all four seasons.[4] There has also been on average a decrease in the snow to total precipitation ratio with more precipitation falling as rain and less falling as snow during the cold season.[5]

Models and emissions scenarios for B.C. predict that increases in winter and summer temperatures will continue. Warming is likely to be greater in northern B.C. than in southern B.C. and greater in winter than in summer. The winter minimum temperature in northern B.C. is likely to experience the greatest changes with models suggesting 4 – 9°C increases in minimum temperatures by the 2080s.[6] Scenarios of precipitation by season for B.C. suggest that conditions will be wetter over much of the Province in winter and spring but drier during summer in the south and on the coast.[7] These changes in precipitation may be significant with Spittlehouse,[8] for example, commenting that summer precipitation in southern and central B.C. is likely to decrease by the order of 10 – 40% and winter precipitation across B.C. likely to increase by 5 – 40%. He also notes that the depth of the snowpack is likely to diminish and the length of the snow season may decrease by up to a month.[9] Increased occurrences of extreme weather events are documented worldwide and climate models project a continuing rise in their frequency. As such, extreme weather and weather-related events are likely to become more commonplace in B.C. with increases in the frequency and intensity of precipitation events, windstorms, forest fires and landslides. The recent forest fires in the states of Victoria and New South Wales, Australia, with their associated tragic loss of life and property, provide evidence of the likely interactions between climate (a prolonged drought) and weather (extreme temperatures) and of how changes in these may result in existing adaptation strategies being greatly exceeded. The 2003 fire season in B.C. indicated that the Province could experience similar events to Victoria, and our knowledge of climate change indicates that the likelihood of such events is increasing.

Even if the most optimistic predictions are taken, these and other forecasted changes in climatic conditions are likely to affect the ecological processes in B.C.'s forests and rangelands significantly. Some changes have already been observed. Increases in average annual temperature, frost-free season length, and growing degree days along with earlier ice-free dates on lakes and rivers, accelerated glacial melting, and earlier spring freshet in rivers and streams have been reported.[10] Such changes have the potential to severely impact the core forest and range values identified under the *British Columbia Forest and Range Practices Act* (FRPA) that forest and range practitioners are required to manage for.[11] Recently, the most notable of these has been the alteration of the climatically suitable range for the mountain pine beetle, which has killed an estimated 620 million cubic metres of pine that would have been an important part of B.C.'s wood supply for decades. The mountain pine beetle epidemic has

2 Zhang, X., Vincent, L.A., Hogg, W.D. and Niitsoo, A. 2000: Temperature and precipitation trends in Canada during the 20th century; Atmosphere-Ocean, v. 38, no. 3, p.395–429; B.C. Ministry of Water, Land and Air Protection 2002: Indicators of climate change for British Columbia; B.C. Ministry of Water, Land and Air Protection, 50 p., http://www.env.gov.bc.ca/air/climate/indicat/pdf/indcc.pdf, [Accessed December 2008]; Whitfield, P.H., Bodtker, K. and Cannon, A.J. 2002: Recent variations in seasonality of temperature and precipitation in Canada, 1976–1995; International Journal of Climatology, v.22, p.1617–44.

3 Zhang at n. 2, Mote, P.W. 2003: Twentieth-century fluctuation and trends in temperature, precipitation, and mountain snowpack in the Georgia Basin–Puget Sound region; Canadian Water Resources Journal, v. 28, no. 4, p.567–85.

4 Zhang et. al. n 2.

5 Walker, I.J. and Sydneysmith, R. 2008: British Columbia; in From Impacts to Adaptation: Canada in a Changing Climate 2007, edited by D.S. Lemmen, F.J.Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, ON, p. 329–86.

6 Spittlehouse, D.L. 2008. Climate Change, impacts, and adaptation scenarios: climate change and forest and range management in British Columbia. B.C. Min. For. Range, Res. Br., Victoria, B.C. Tech. Rep. 045.http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr045.htm.

7 Walker and Sydneysmith n. 5.

8 Spittlehouse. n 6.

9 Spittlehouse, n. 6.

10 Gayton. D. 2008. Impacts of climate change on British Columbia's biodiversity: A literature review. Forrex Forest Research Extension Partnership, Kamloops, BC. Forrex Series 23. url: http://www.forrex.org/publications/forrexseries/fs23.pdf.

11 biodiversity, cultural heritage resources, fish/riparian, forage and associated plant communities, recreation resources, resource features, soils, timber, visual quality, water and wildlife [British Columbia *Forest and Range Practices Act* (FRPA) s. 149(1)].

also had a marked social impact on First Nations and others who use B.C.'s interior pine forests for traditional, spiritual and recreational purposes.[12]

Theoretical basis for monitoring

Due to the inertia of the Earth's climate system, even if global efforts to reduce carbon emissions were successful and greenhouse gas concentrations were stabilized immediately, not only would global average temperature continue to increase for the next two decades, but the effects of climate change on ecological processes and their associated species would be likely to continue for centuries.[13] As a result, it is necessary to encourage adaptation to changed and changing conditions by dealing with current and near-term impacts to the extent possible. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."[14] Fussel and Klein state that effective adaptation to climate change is contingent on the availability of two important prerequisites: information on what to adapt to and how to adapt; and resources to implement the adaptation measures.[15] The proposed monitoring framework aims to inform us on what changes are occurring as a result of climate change and how they are manifesting themselves in the forest and rangeland environment. The goal of monitoring and recording this information is to encourage and inform adaptation to changing conditions thus allowing the minimization of impacts on identified forest and range values.

Scope and nature of the monitoring framework

As detailed in the introductory section of this report, the framework provided in this report includes monitoring key species and ecological processes in B.C.'s forests and rangelands. As such, any species that depend on B.C.'s forest and/or rangeland habitat for all or part of their life cycle and any ecological processes that are either directly or indirectly affecting provincial forests and/or rangelands would potentially be eligible for inclusion in the monitoring framework. With this as a focus, the causes of climate change would not be monitored under this framework per se. Thus, factors that are clearly important for atmospheric concentrations of greenhouse gases, such as human-induced carbon emissions and carbon storage, are intentionally excluded from this particular monitoring framework at this time. Terrestrial carbon, in particular, is likely to be monitored under a number of different mitigation requirements whereas the proposed monitoring program is more concerned with adaptation. The authors do however emphasize that adaptation and mitigation are intimately linked and that any program to monitor carbon cycles in B.C. would need to be integrated with the monitoring program under discussion here.

It is not possible to measure all of the ecological processes or species associated with forests and rangelands, and we must therefore reduce what is an infinitely complex system into simpler parts for monitoring and management purposes. A parameter that characterizes these parts is termed an indicator. Originally conceived through the work of the International Tropical Timber Organization, the Forest Principles[16] and Chapter 11 of Agenda 21[17] of the Rio de Janeiro United Nations Conference on Environment and Development (UNCED), indicators have become a globally accepted norm in describing, reporting and monitoring progress towards ecologically sustainable development. Indicators are used to monitor factors such as: compliance with legal standards (compliance monitoring), whether planned activities were implemented (implementation monitoring), or whether implemented activities are achieving expected outcomes (effectiveness monitoring). This particular monitoring framework's focus is on status or trend monitoring. Under this type of monitoring components of the environment are measured and periodically reported to determine changes.

12 BC Ministry of Forests Website [Accessed December 2008].

13 Lemmen, DS. and Warren, F.J., 2008. Introduction: in from Impacts to Adaptation: Canada in a changing Climate 2007, edited by D.S Lemmen, F.J, Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, ON. p. 21-26.

14 IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, p. 869.

15 Fussel, H., and Klein, R. 2006. Climate change vulnerability assessments: an evolution of conceptual thinking, Climatic Change 75:301-329.

16 United Nations 1992, Non-Legally Binding Authoritative Statement Of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests, UN Conference on Environment and Development, June 1992. http://www.un.org/documents/ga/conf151/aconf15126-3annex3.htm.

17 United Nations 1992, Agenda 21 – Chapter 11, UN Conference on Environment and Development, June 1992. http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter11.htm.

Critical factors for indicator selection

In developing and selecting the indicators for inclusion in the monitoring framework we considered the attributes that individual indicators should possess in order to make them appropriate for inclusion. While it is necessary to choose indicators that are the most informative and act as the sentinels of the effects of climate change on forest values, other factors must also be considered. The terms of reference for the project provided guidance on this, requiring a focus on two linked factors:

- Cost of monitoring on a long-term basis (i.e. any indicators likely to represent a significant incremental ongoing fiscal cost are unlikely to be supported for an ongoing monitoring program).
- Priority for the use of existing data sources and currently supported collection processes (including sources outside the Ministry of Forests and Range).

From our research and experience in developing indicator frameworks, we considered that there would be a number of factors besides these that would also be important to consider when developing the indicators under the monitoring framework. Such attributes have been identified and described in the academic literature. However, as the critical selection factors for indicators are based on many variables, such as the funding available to implement the framework, current and future policy arrangements, geographic situation and what the framework is actually designed to monitor, the attributes critical to the selection of indicators for monitoring are likely to be unique to this particular framework.

In January 2009, a B.C. Climate Change Monitoring Strategy Indicator Development Workshop was held in Victoria, B.C. At this workshop B.C.'s forest and rangeland experts were requested to examine and draw out these 'important indicator characteristics' in more detail. Specifically, delegates were asked to identify the aspects that make a good indicator for monitoring changes occurring to B.C.'s species and ecosystem processes in light of climate change. The results of the exercise are summarized in Box 1 below.

Box 1: ATTRIBUTES IDENTIFIED AS IMPORTANT FOR INDICATORS TO BE INCLUDED IN THE MFR CLIMATE CHANGE MONITORING FRAMEWORK.

To the extent possible indicators should:

- Be cost effective
- Use existing data sources and collections (including previously untapped data sources such as volunteer and community based programs)
- Use existing trend data to the extent possible
- Be based on available or easily obtainable, scientifically valid, empirical measurements that can be consistently repeated over time to observe trends
- Be suitable to support and inform policy and land management decisions
- Focus on factors that are sensitive or closely aligned to changes in climate
- Be scalable spatially to be relevant at various levels of land management (regional, national and global)

IDENTIFICATION OF THE INDICATORS AND DATA SOURCES

Development of the indicators

The following Section sets out the recommended indicators for monitoring the impacts of climate change on forest and rangeland species and ecological processes in B.C. and the key potential data sources that have been identified to support analysis of them. The indicators have been selected based on:

- Liaisons with B.C. forest and range experts (including at the Indicator Development Workshop, January 15, 2009)
- Review and analysis of academic literature, organizational reports and websites

- Review of information from FFEI Vulnerability Assessment Teams
- Analysis of similar frameworks adopted at the local, national and international level
- Review of the available data to support indicator monitoring and analysis

We have attempted to design the indicators to allow for a considerable level of flexibility. This is partly because the effects of climate change are unknown and there needs to be sufficient flexibility to allow new sites, species or processes to be included in the framework. In addition, this flexibility is required as the framework will be largely reliant on data coming from external sources and should be able to incorporate new knowledge and data collections as they become available. To the extent possible a holistic ecosystem approach has been adopted in developing the recommended indicators for monitoring. We have focused on factors that are likely to be affected by changes in climate and that can be meaningfully measured over time.

Each of the indicators has been ranked with regard to their importance for measuring changes that affect key species and ecosystem processes, and for informing forest policy adjustments. This has been done primarily using the selection criteria developed at the workshop but also through our own expert assessment based on the research and liaison work undertaken during their development. This 'importance ranking' is described in more detail below in Table 1 and is reported against for each specific indicator in Table 3.

Table 1: ***Legend for indicator importance.***

	Importance
H	Highly important: This indicator is considered to be highly important if not critical for the monitoring framework
M	Moderately important: This indicator is considered to be moderately important for the monitoring framework

Data sources to support analysis of the indicators

Where possible we have developed the indicators to make use of existing and available data collections, inventory programs and studies. This is an important means to developing cost effective indicators. The only alternative to using this approach is to propose entirely new, full-scale monitoring and data collection programs; while this was not preferred, we would argue that the political importance of climate change in B.C. justifies some innovative approaches to the establishment of an adequate monitoring program.

There are some distinct areas we believe are highly relevant for monitoring that cannot adequately be supported using the existing data sources in their current state. In some cases there is considerable effort being made by various agencies to cover those gaps (for example Indicator 12, ecosystem distribution and composition).

We have made a preliminary ranking of each of the recommended indicators with regard to the extent to which their analysis and interpretation is able to be supported based on the brief assessment of the current data sources and liaison work conducted during this project. This ranking is based entirely on the existing status quo even though in some cases proposals for further work to bolster existing inventory and data collection programs are detailed. The ranking is meant only as a very basic guide and is not given with a high confidence rating. For all indicators further analysis of the adequacy of data sources is required. This analysis is due to be conducted during Phase 3 of the project (see Section 5 of this report for further information). The 'data ranking' is described in more detail below in Table 2 and is reported against each specific indicator in Table 3.

Table 2: ***Legend for the extent to which indicators are able to be supported by existing data sources.***

	Data
A	Adequate: Analysis and interpretation of this indicator is likely to be reasonably supported by existing data collections
M	Moderate: Analysis and interpretation of this indicator is able to be only partially supported by existing data collections. Data are not as detailed as required and/or are likely to be incomplete spatially or temporally.
L	Limited: Limited data currently available to support analysis and interpretation of this indicator.

RECOMMENDED INDICATORS

Table 3 Recommended indicators, importance ranking and preliminary assessment of data available to support their analysis

No.	Indicator title	Potential data sources	Importance	Data
ECOSYSTEM DRIVERS				
1	Precipitation	Environment Canada Climate Network for British Columbia and Yukon, B.C. Hydro's Regional Hydromet Data, Provincial Climate Related Monitoring Network Initiative, MOE River Forecast Centre	H	L
2	Snowpack	MOE River Forecast Centre	M	A
3	Streamflow	Environment Canada Water Survey, BC Hydro's Regional Hydromet Data	H	L
4	Water temperature	MOE Water Stewardship Division Sciences and Information Branch, BC Hydro's Regional Hydromet Data	H	L
5	Water quality	Forest and Range Evaluation Program, MOE Environmental Protection Division, MOE Water Stewardship Division Sciences and Information Branch	M	M
6	Glaciers	Canadian Glacier Information Centre, Canadian, Cryospheric Information Network, Western Canadian Cryospheric Network	M	A
7	Unseasonable or unexpected weather conditions	Environment Canada Climate Network for British Columbia and Yukon, Environment Canada's Meteorological Service of Canada, MFR Protection Branch, Pacific Climate Institute for Climate Studies	M	A
NATURAL DISTURBANCES				
8	Insects and diseases	MFR Forest Practices Branch (Forest Health)	H	M
9	Wind throw	MFR Forest Practices Branch, MFR Forest and Range Evaluation Program	M	A
10	Fire	MFR Wildfire Management Branch	M	A
11	Mass movements	Forest and Range Evaluation Program	H	L
BIODIVERSITY				
12	Ecosystem distribution and composition	MFR Research Branch, MFR Forest Analysis and Inventory Branch, Forest Ecosystem Research Network of Sites, British Columbia Conservation Data Centre, Nature Conservancy of Canada	H	L
13	Ecosystem productivity	MFR Forest Analysis and Inventory Branch, Forest Ecosystem Research Network of Sites,	H	M
14	Species diversity	British Columbia Breeding Bird Atlas, British Columbia Conservation Data Centre, Canadian Community Monitoring Network, Environment Canada's Ecological Monitoring and Assessment Network, Forest and Range Evaluation Program, Invasive Alien Plant Program, Nature Conservancy of Canada, NatureCounts, NatureWatch, RESULTS	H	L
15	Genetic diversity	Centre for Forest Conservation Genetics, MFR Research Branch – Forest Genetics Section, MFR Tree Improvement Branch – Headquarters Unit	M	M
16	Ecosystem connectivity	Data sources listed for Indicators 1, 2 and 3, Habitat and Enhancement Branch of Fisheries and Oceans Canada, Parks Canada, Hectares B.C.	H	M

ECOSYSTEM DRIVERS

Indicator 1: Precipitation

Rationale

Precipitation rates, timing and form are anticipated to change as a result of climatic change. Predictions show a shift to warmer, wetter years, more frequent wet years, greater year-to-year variability, and more extreme precipitation events as well as a change in the form precipitation takes, with more precipitation falling as rain and less falling as snow during the cold season. Such changes will almost certainly have significant effects on forest and rangeland ecosystems. Monitoring these changes will be important for informing future forest and range management decisions.

Suggested approach to monitoring

This indicator should monitor precipitation rates, timing and forms within forest and rangeland catchments, reporting information Province wide (by region) using data from as many climate stations as practicable. To the extent possible monitoring of water related indicators should be coordinated within a complementary network (i.e. measurements for all should be taken from similar locations or catchments) in order to aid the interpretation of the results.

Potential data sources

Environment Canada Climate Network for British Columbia and Yukon operates a network of approximately 500 climate stations in B.C. and the Yukon and maintains an associated archive of historical weather information. At 350 of these stations daily measurements of temperature and precipitation are taken.

BC Hydro's Regional Hydromet Data networks collect near real-time hydrometeorological data at various automated data collection stations in or near their reservoir systems across the Province to support reservoir operations. Major types of hydrometeorological data collected include precipitation, air temperature, lake levels, stream levels/flows and snow water equivalents.

Provincial Climate Related Monitoring Network Initiative is a relatively new joint project to expand B.C.'s hydrometric and other climate-related networks to improve the Province's ability to monitor, predict and adapt to changing climatic conditions that pose new threats for human health, safety and property, such as risks of flooding, storm surges, wildfire and drought. In the first 2 years of the project the goal is to identify and evaluate the existing provincial Climate Related Networks (CRNs) operated by MoT MFR and MOE to ensure that core climate data are collected on a year round basis and to advise on needed upgrades.

MOE River Forecast Centre is the lead agency in the Province responsible for the collection, quality control, analysis and archiving of snow data. Manually sampled snow survey data are collected from almost 200 sites around the Province while remotely sensed snow and meteorological data from Automatic Snow Pillows, transmitted via satellite, are collected at over 50 sites around the Province.

Cost/benefit of monitoring

This indicator is regarded as highly important, if not critical, for monitoring in light of climate change. It also provides context for the interpretation of many of the other indicators identified. While a number of potentially valuable data sources have been listed for this indicator, the current network of monitoring sites has been publically recognised as having a strong bias towards lower and more populated latitudes and elevations. Forest and range experts have also indicated that these existing monitoring stations are unlikely to be in areas identified as being particularly sensitive to climate changes (including higher elevations and transient snow zones) and are unlikely to be able to capture information on the various forms of precipitation adequately. The Environment Canada Climate Network has also been reported as being in decline, the extent of this decline is not known.

Indicator 2: Snowpack

Rationale

Snow accumulation and its characteristics are the result of air temperature, precipitation, storm frequency, wind, and the amount of moisture in the atmosphere. Changes in these and other climate properties will therefore affect snowpack. Reduced snowpack is anticipated and the snowline in mountainous areas is forecasted to rise in elevation. Changes in the timing of the development and loss of the snowpack are rather uncertain but could have considerable effects on forest ecosystem processes, as has been shown for snowpack variations associated with the Pacific Decadal Oscillation.

Suggested approach to monitoring

Snowfall depth should be reported Province wide (by region) using data from as many climate stations as practicable. To the extent possible monitoring of water related indicators should be coordinated within a complementary network (i.e. measurements for all should be taken from similar locations or catchments) in order to aid the interpretation of the results.

Potential data sources

MOE River Forecast Centre is the lead agency in the Province responsible for the collection, quality control, analysis and archiving of snow data. Manually sampled snow survey data are collected from almost 200 sites around the Province while remotely sensed snow and meteorologic data from Automatic Snow Pillows, transmitted via satellite, are collected at over 50 sites around the Province.

Cost/benefit of monitoring

Extent of snowpack is currently seen as being of moderate importance to the monitoring framework. At the expert workshop, River Forecast Centre staff anticipated that the organization would be able to supply adequate data on snow depth to support a reasonable analysis and interpretation of the indicator.

Indicator 3: Streamflow

Liard
Photo: Bob Krahn

Rationale

Predicted lower flows in summer and later in the season may reduce the amount of water available to forest and range ecosystems. These lower flows are also associated with warmer water temperatures and declining water quality, both of which threaten the health of aquatic ecosystems (an issue which may be further exacerbated when water is drawn for human use). Increased storms and precipitation amounts predicted as a result of climate changes may result in higher-than-usual water volume and velocity for winter months in some regions, potentially leading to increased river turbulence, scouring, and reduced in-stream channel stability (although these effects will depend on the nature of the hydrological system such as whether it is rain or snowmelt dominated).

Suggested approach to monitoring

Streamflow should be reported Province wide (by region) using data from as many monitoring stations as practicable. To the extent possible monitoring of water related indicators should be coordinated within a complementary network (i.e. measurements for all should be taken from similar locations or catchments) in order to aid the interpretation of the results.

Potential data sources

Environment Canada Water Survey collects hydrometric data including water level and streamflow statistics for a variety of sites throughout the Province. This network is funded through a cost share program between the B.C. and Federal governments. The network was in decline for many years and by the late 1990s had been reduced by over 40 per cent.

In the last decade, substantial funding was committed to rebuilding the network (especially for climate change analysis purposes) although the current fiscal environment has made this commitment uncertain.

BC Hydro's Regional Hydromet Data networks collect near real-time hydrometeorological data at various automated data collection stations in or near their reservoir systems across the Province to support reservoir operations. Major types of hydrometeorological data collected include precipitation, air temperature, lake levels, stream levels/flows and snow water equivalents.

Cost/benefit of monitoring

This indicator is regarded as highly important for monitoring in light of climate change. Although further assessment is required, forest and range experts have indicated that the existing network of monitoring sites is inadequate and is likely to not only have a bias towards streams found in lower more populated latitudes and elevations but also towards larger rivers, leaving smaller streams, considered of critical importance to forest and range ecosystems, likely to be underrepresented in the network.

Indicator 4: Water temperature

Rationale

Increased water temperatures are predicted as a result of climate changes especially in northern areas. Warmer temperatures are expected to affect the fitness, survival, and reproductive success of certain fish and other aquatic species. Over the long term, higher temperatures may result in a shift in the distribution of cold-water species to higher latitudes and elevations. However, if other factors such as habitat discontinuities were to limit these range shifts, an overall reduction in the distribution of certain species would be the result. By contrast, river warming may have positive consequences for aquatic species that prefer (or can tolerate) warmer water temperatures. Native warm-water species may be able to expand their range into higher-altitude lakes and more northerly regions. Warmer temperatures may also allow invasive or exotic species to expand in range.

Suggested approach to monitoring

Water temperature should be reported Province wide (by region) using data from as many monitoring stations as practicable. To the extent possible monitoring of water related indicators should be coordinated within a complementary network (i.e. measurements for all should be taken from similar locations or catchments) in order to aid the interpretation of the results.

Potential data sources

MOE Water Stewardship Division Sciences and Information Branch is currently conducting research into how water temperature monitoring can be improved (specifically for climate change analysis) although it is not yet known if this program will receive funding to continue in the next financial year.

BC Hydro's Regional Hydromet Data networks collect near real-time hydrometeorological data at various automated data collection stations in or near our reservoir systems across the Province to support reservoir operations. Major types of hydrometeorological data collected include precipitation, air temperature, lake levels, stream levels/flows and snow water equivalents however water temperature is only measured at some locations.

Cost/benefit of monitoring

This indicator is regarded as highly important for monitoring in light of climate change. We were unable to find evidence of any systematic programs that contain the necessary data required for supporting the indicator, thus, it is likely that the existing monitoring network would need to be bolstered to support a reasonable analysis of this indicator.

Indicator 5: Water quality

Eulatazella Lake
Photo: Kathleen Hebb

Rationale

Climate driven changes to hydrological systems are likely to cause changes in the physical, chemical and biological characteristics of water in forest and rangeland streams and lakes. Such changes are likely to have significant impacts on freshwater and estuarine ecosystems and aquatic species found within forests and rangelands and may also have some impact on the quality of water available for human use.

Suggested approach to monitoring

MOE Water Stewardship Division Science and Information Branch is currently conducting a detailed literature review that may be used to further inform the development of an approach to monitoring water quality in light of climate change. Although further work is required, based on preliminary assessment it appears that monitoring levels of dissolved organic content (DOC) may have potential.

Potential data sources

Forest and Range Evaluation Program (FREP) has data on fine sediment generation potential for 540 sites around the Province, and growing annually. In 2008, evaluations were undertaken in watersheds with recognized fish values and/or community watersheds. This assessment also included an additional rating that considered the size of the stream.

MOE Environmental Protection Division reports on water quality in the Province although this reporting is biased to a view of water quality in developed areas, rather than for undeveloped watersheds where hydrological systems are in a more natural state.

MOE Water Stewardship Division Science and Information Branch: As mentioned above, this branch is currently conducting research into the effects of climate change on water quality. It is likely that this work will result in an assessment of the adequacy of the existing monitoring network leading to some further recommendations regarding water quality monitoring in light of climate change.

Cost/benefit of monitoring

This indicator is regarded as moderately important for monitoring in light of climate change. While further research (including that currently being conducted by MOE) is needed to assess the extent to which the indicator can be supported by existing data sources, forest and range experts have indicated that there are enough data being collected to support at least a partial examination of the indicator.

Indicator 6: Glaciers

Silverthrone Glacier
Photo: Andy Waines

Rationale

Glacier retreat may cause changes in the flow patterns and possibly the temperature of some forest and rangeland streams and rivers. These changes, along with other climate-driven changes to hydrological systems, are likely to have significant impacts on freshwater and estuarine ecosystems and aquatic species. In the short term, melting glaciers will likely discharge more water into some B.C. streams and rivers potentially increasing stream turbidity and damaging fish habitat and riparian areas. In the longer term, glacier retreat will likely mean reduced water volume in glacier-fed streams and rivers, especially during the summer months potentially, exacerbating changes in stream flow and temperature.

Suggested approach to monitoring

The spatial distribution of glaciers should be monitored using either aerial surveys or remotely sensed data to record changes over time. Information should be interpreted in the context of data coming from the water related indicators described above.

Potential data sources

Canadian Glacier Information Centre (CGIC) currently controls data and literature about Canadian glaciers. The principal collection element is the Canadian Glacier Inventory, a printed and electronic catalogue of Canada's glaciers, complemented by an air photo collection.

Canadian Cryospheric Information Network (CCIN) has been developed as a collaborative partnership between the Federal Government (Canadian Space Agency, Meteorological Service of Canada, Natural Resources Canada), University of Waterloo and the private sector (Noetix Research Inc.) to provide the data and information management infrastructure for the Canadian cryospheric community.

Western Canadian Cryospheric Network is a consortium of six Canadian universities, two American universities and government and private scientists who are examining the links between climatic change and glacier fluctuations in western Canada.

Cost/benefit of monitoring

This indicator is regarded as moderately important for monitoring in light of climate change. Data sources are likely to be able to support a reasonable analysis of the indicator. Costs of monitoring this indicator may be reduced through the adoption of remotely sensed data.

Indicator 7: Unseasonable or unexpected weather conditions

Fraser Gold Creek
Photo: Don Coombs

Rationale

During periods of climate adjustment there is a strong likelihood of unseasonable or unexpected weather. This may include late or early frosts, extreme snowfalls, ice storms, hail, droughts and other weather-related events. Many of these can have major impacts on forests and rangelands.

Suggested approach to monitoring

Reporting under this indicator should include an examination of the frequency and intensity of unseasonable or unexpected weather events over long time periods to see how the current decade compares with those of the past.

Potential data sources

Environment Canada Climate Network for British Columbia and Yukon operates a network of approximately 500 climate stations in B.C. and the Yukon and maintains an associated archive of historical weather information.

Environment Canada's Meteorological Service of Canada (MSC) monitors and collects data on severe weather conditions, such as hurricanes, tornadoes, severe thunderstorms, storm surges, strong winds, high heat or humidity, heavy rain or snow, blizzards, freezing rain and extreme cold.

MFR Wildfire Management Branch reports annually on specific events although is not set up to report on 'diffuse' events such as droughts.

Pacific Climate Impacts Consortium (PCIC) produces climate information to inform adaptation in both operational activities and long term planning in order to reduce vulnerability to climate variability, climate change, and extreme weather events. They produce a wide spectrum of key data about past, current and future climate and weather events that may be used to inform this indicator.

Cost/benefit of monitoring

This indicator is currently seen as being of moderate importance to the monitoring framework. It is anticipated that the data sources listed will be able to supply adequate data to support reasonable analysis and interpretation of the indicator. The costs of monitoring and analysis should thus be fairly low.

NATURAL DISTURBANCES

Indicator 8: Insects and diseases

Mountain pine beetle
Photo: Alanya Smith

Rationale

A large number and variety of sources predict that increases in the severity and frequency of disturbances caused by insects and pathogens will be one of the first observable signs of climate change. Insects have been identified as important for monitoring in light of climate change primarily because their short generation times, rapid abundant reproduction, and potentially high mobility make them able to adapt quickly to changing climatic conditions. Pathogens such as foliar disease have been identified as important for monitoring as the occurrence and impact of many are likely to increase where warmer and wetter environments are predicted. There are a number of examples from B.C. of insects and pathogens that are already affecting forest health as a result of the climatic changes that have taken place (for example, Mountain Pine Beetle and Dothistroma Needle Blight). It is likely that the impacts of these agents will increase as the climate continues to change. There is also a high likelihood that insects or diseases that are not currently considered pests will emerge rapidly to pose a serious threat to forest health.

Suggested approach to monitoring

This indicator would report on the scale and severity of insects and pathogens adversely affecting forest and rangeland health. If utilising only currently collected data, this indicator would be monitored using Province-wide aerial surveys. However, this method is only able to identify insect and pathogen outbreak occurrences at a medium to large scale and in order to be truly useful to management, finer scale monitoring is needed to collect data that will enable early warning of insect and pest outbreaks and allow for early and aggressive intervention to delay and possibly mitigate impacts. Such finer scale monitoring would include: surveys, trapping and local analysis of occurrences (to determine extent of damage/condition/changes in species complexes) and the use of reference sites to determine current conditions as a baseline.

Potential data sources

MFR Forest Practices Branch has surveyed the majority of the forested land in the Province using aerial survey since 1999 resulting in the production of an annual report summarizing forest health conditions and digitized maps and tables describing pest conditions by region and district.

Finer scale insect and pathogen monitoring is conducted in various areas throughout the Province although these studies are localized and the results are not routinely collated or standardized by the MFR.

Some historic data are available from the former Forest and Insects Disease Survey (FIDS) of the Canadian Forest Service, particularly in relation to its now discontinued ARNEWS plots. ARNEWS was primarily an eastern program so there were only 15 plots in B.C. Twelve of these were located on Vancouver Island, the Lower Mainland or close to the US border, with the remaining three being at Terrace, Prince George and Quesnel. While some insect and disease monitoring is still undertaken by the CFS, it is very limited and unlikely to be of much use (in its current form) to the proposed program.

Cost/benefit of monitoring

Monitoring the scale and impact of pests and diseases adversely affecting forest and rangeland health is seen as being highly important for the monitoring framework. While the cost of finer scale monitoring is potentially high there may be opportunities for creating synergies with proposed increases in field based monitoring programs reported under Indicator 12.

Indicator 9: Wind throw

Windthrow, root plate
Photo: John Innes

Rationale

Increases in the intensity, frequency and severity of stormy weather predicted as a result of climate change is likely to result in increased scale and severity of wind throw damage to forests. Northern Vancouver Island, areas of the Central B.C. coast and parts of the Queen Charlotte Islands are likely to be most susceptible to these disturbances. Forests may also become increasingly susceptible to wind damage if stressed by other climate change related factors such as destabilizing soils (occurring from increased precipitation) and pest incursions.

Suggested approach to monitoring

This indicator reports on the scale and severity of wind throw damage affecting forests. It should be monitored using Province wide aerial surveys to record medium to large scale damage resulting from wind throw. This information should be supplemented where possible with information collected on a regional basis especially for those areas expected to experience increases in the intensity, frequency and severity of storms or suffering from other stressors thought to be climate related.

Potential data sources

MFR Forest Practices Branch has surveyed the majority of the forested land in the Province using aerial survey since 1999 resulting in the production of an annual report summarizing forest health conditions and digitized maps and tables by region and district.

Forest and Range Evaluation Program (FREP) has a cutblock level wind throw monitoring protocol and a review is underway of all FREP protocols to see how best to integrate wind throw monitoring on sites visited for other resource value monitoring.

Cost/benefit of monitoring

This indicator is currently seen as being of moderate importance to the monitoring framework. It is likely that current aerial surveys conducted will be able to provide adequate information to support a reasonable analysis and interpretation of the indicator.

Indicator 10: Fire season

Tumbler Ridge fire
Photo: Dana Hicks

Rationale

Climate change models project an increase in the number of fires and area burnt by fires across western Canada. This includes an increase in the number of fires ignited by lightning and an extension to the fire season length. Southern and central parts of B.C. are expected to experience drier summers thereby potentially increasing the frequency, severity and intensity of fires. Northern areas, which are predicted to be wetter, may experience a decrease in fire disturbance. Alterations in the fire regime will affect ecosystem transitions, the assemblages of species and their productive capacity.

Suggested approach to monitoring

The annual length of the fire season should be reported Province wide by region using the date of the first and last reported fire. The seasonal severity of the fire should also be captured using the seasonal severity ratings determined by the MFR Wildfire Management Branch.

Potential data sources

MFR Wildfire Management Branch reports annually and collects data on the number of fires, areas affected by fire and the cause (lightening or humans) of fires. This Branch also calculates a seasonal severity rating based on information from the Canadian Forest Fire Danger Rating System.

Cost/benefit of monitoring

This indicator is currently seen as being of moderate importance to the monitoring framework and it is anticipated that the data sources listed will be able to supply adequate data to support reasonable analysis and interpretation of the indicator keeping the costs of monitoring and analysis fairly low.

Indicator 11: Mass movements

Mass Movement
Photo: John Innes

Rationale

The frequency and extent of rapid mass movements are influenced by precipitation amount and intensity; snow accumulation, melt rate, and distribution; and roads and other land uses. Alterations in these factors as a result of climate changes may result in variations in the magnitude and frequency of mass movements adversely affecting forest health. Vegetation also influences the likelihood of mass movements through the soil-stabilizing effects of root systems and the effects of vegetation structure and composition on hydrology. Hence changes in vegetation type and condition such as that caused by exacerbated pest or wind damage may further increase the frequency of mass movements and erosion events.

Suggested approach to monitoring

This indicator examines the scale and density of mass movements and erosion events (landslides, rockfalls, debris torrents, debris avalanches, debris flows, etc.). Province-wide aerial surveys or remotely sensed data should be used to record mass movements and erosion events over a certain size. This information should be supplemented where possible with information collected on a regional basis in order to aid interpretation and gain some understanding of mass movement events occurring under forest canopy.

Potential data sources

We were unable to find evidence of systematic programs directed at monitoring mass movement frequency and extent. Some studies have previously been done by the MOE in areas on Vancouver Island and the Queen Charlotte Islands.

Some transportation corridors maintain records of disruption although these have not been traditionally used for monitoring. For example, geotechnical investigations have been undertaken for the Sea-to-Sky Highway. Similar records may be available for the Trans-Canada Highway and for the various rail tracks crossing B.C.

Information on mass movement events that disrupt forest roads was a reporting requirement under the Forest Practices Code but is no longer required. Some Districts, and some licensees, continue to report such disturbances, but the information is not collected systematically across the Province.

Forest and Range Evaluation Program (FREP) is in the process of developing the methodology to examine the terrain stability at the landscape level. The approach offers considerable potential for supporting this indicator and is expected to begin within the next year.

Cost/benefit of monitoring

Mass movement was seen as highly important for monitoring in light of climate change although data to support monitoring of the indicator on anything but a small case study basis is not currently available, making its analysis potentially costly.

BIODIVERSITY

Indicator 12: Ecosystem distribution and composition

Ecosystems
Photo: John Innes

Rationale

As climatic envelopes within B.C. change, alterations in the composition, diversity and spatial distribution of ecosystems are predicted along with the development of novel assemblages of species resulting in the formation of new ecosystems. Models suggest that there will be shifts in ecosystem and species' ranges upwards in elevation and northward with certain identified ecosystems appearing to be particularly vulnerable to such shifts. However, we stress that such models are based on ecosystem-level changes: research is increasingly suggesting that the individual species that make up current ecosystems may be affected differently by climate change, resulting in changes in ecosystem composition rather than changes in ecosystem distribution. As well as providing a direct measure of ecosystem diversity and the extent to which it is being maintained, monitoring of this indicator provides context for interpretation of many of the other indicators put forward.

Suggested approach to monitoring

This indicator would seek to examine changes in the distribution and composition of forest and rangeland ecosystems over time. Due to the strong field requirement, successful monitoring under this indicator will be largely reliant on building strong links with the proposed climate change programs identified in the key potential data sources listed below. The changing distribution and composition of forest and rangeland ecosystems should be tracked using changes to the Biogeoclimatic Ecosystem Classification (BEC) System zones over time. This system has been used for the past thirty years in B.C. and contains valuable baseline data for monitoring at the ecosystem level. Changes in the spatial distribution of BEC zones would need to be monitored along with changes in the composition and eventually the development of new ecosystems over time. Modelling scenarios should be widely used to inform and target monitoring under this indicator and aid in the analysis and interpretation of trend data and the formation of recommendations for management.

Potential data sources

Key:

MFR Research Branch, Biogeoclimatic Ecosystem Classification (BEC): Some modeling of ecosystem change under various climate scenarios using BEC and BEC data is currently underway both inside and outside the MFR. The MFR Research Branch is currently assessing areas and ecosystems most sensitive to climate change with the intent of installing permanent plots for observing changes over time to BEC zones.

MFR Forest Analysis and Inventory Branch (FAIB): FAIB is currently in the process of exploring options to adapt the National Forest Inventory and the Vegetation Resources Inventory to support climate change monitoring. Proposed changes include a doubling of the number of National Forest Inventory ground plots to enhance biomass and understory data.

Supporting:

Forest Ecosystem Research Network of Sites (FERNS): FERNS research is focused largely around the forest harvesting options and ecosystem function although the program may offer some useful data to help target this analysis under the indicator.

British Columbia Conservation Data Centre (CDC) systematically collates and disseminates information on plants, animals and ecosystems (ecological communities) at risk in British Columbia. This information is compiled and maintained in a computerized database which provides a centralized and scientific source of information on the status, locations and level of protection of these organisms and ecosystems.

Nature Conservancy of Canada (NCC) is conducting spatial optimization analyses. The results can be used to show the priority conservation sites for a suite of conservation targets and goals. Inputs used in the assessment include terrestrial and aquatic ecosystems and species distributions. Currently the program is being applied to the B.C. interior.

Cost/benefit of monitoring

Monitoring the composition, distribution and productivity of existing, evolving and emerging ecosystems could be the single most important aspect of any MFR Climate Change monitoring program. While the cost of monitoring this indicator is considered to be high, costs could be lowered significantly by building synergies with proposed programs to be conducted by the key potential data sources identified.

Indicator 13: Ecosystem productivity

Rationale

Anticipated alterations in temperature and precipitation along with increased incidents of extreme weather events and disturbances caused by pests and diseases may result in changes in ecosystem productivity. Some regions and ecosystems may experience enhanced productivity while others may experience declines. Measuring these trends also relates to determining how climate change effects growth of species at the margins of their range. For example, some may be declining in growth and other species may see unexpected increases from the historic data. Carbon sequestration (sink versus source) is also of interest and also tied to changes in which components of the ecosystem respond in terms of growth (positively or negatively and rate of change). Monitoring these changes in light of climate change over the coming decades will improve our understanding of the resilience of ecosystems to ongoing environmental stressors and inform us of the nature of changes that are occurring.

Suggested approach to monitoring

The National Forest Inventory (NFI) uses air photo sampling and ground sampling that could be used to support reporting against this indicator. NFI uses a system of air photo samples (2km by 2km) which are generally 1:20,000 but could also be at other resolutions in future (either 1:30,000 to reduce costs, or at low level higher resolution depending on cost and benefits). Information from ground samples will include estimates of growth by species (forest cover height and volume and changes over time) as well as above ground biomass information on tree and non-tree species (eg range clippings, coarse woody debris). Estimates for tree heights and basal areas from the photo plots will be adjusted based on information from the ground plots. Some units also have ground plots which are not located on the grid but which could be statistically adjusted and included in the analyses: Change Monitoring Inventory (CMI), MPB funded full eco VRI Phase 2. Data supplied from these measurements can also be used to adjust growth and yield models in the future.

Satellite remote sensing also offers a number of increasingly practical options for monitoring ecosystem productivity (for example, using the Normalized Difference Vegetation Index (NDVI) obtained using Advanced Very High Resolution Radiometer (AVHRR) equipment on the NOAA satellites).

Potential data sources

MFR Forest Analysis and Inventory Branch (FAIB): FAIB is currently in the process of exploring options to adapt the National Forest Inventory and the Vegetation Resources Inventory to support climate change monitoring. Proposed changes include a doubling of the number of National Forest Inventory ground plots to enhance biomass and understory data.

Forest Ecosystem Research Network of Sites (FERNS): FERNS research is focused largely around the forest harvesting options and ecosystem function. The program may offer some useful data to help target analysis under the indicator.

Cost/benefit of monitoring

Monitoring the ecosystem productivity is considered to be highly important in light of climate change. While the cost of monitoring this indicator may potentially be high, costs could be lowered significantly by building synergies with primary data suppliers and adopting remote sensing techniques where appropriate.

Indicator 14: Species diversity

Butterfly
Photo: John Innes

Rationale

Climate change is anticipated to provide both opportunity and pressure for B.C.'s species. Opportunity may come in the form of increased potential habitats due to new climate regimes for some species that have restricted ranges. Pressure may come from factors such as reductions or alterations in ecosystems or habitats and invasive species moving into new ranges. Many different impacts and scenarios are possible, some of which may not yet be understood or realized. Impacts of climate change are also likely to be confounded by other anthropogenic processes such as land-use change and loss of habitat.

Suggested approach to monitoring

This indicator would examine trends in population, range and phenology information for species from a range of taxa and habitats. There is no single species or even group of species that will be an ideal indicator for determining the impacts of climate change on forests and rangelands. Consequently, we propose including information for the widest possible range of species in climate change monitoring and analysis. In some countries (for example the UK), the approach has been to monitor and analyze often fragmented data from large numbers of species and then look for overall patterns rather than rigidly adopting and monitoring a few specific 'indicator' species. Using such an approach to monitoring species in this framework would allow the flexibility to include new research and analyses as they become available. It would also allow us to more readily target this potentially costly area of climate change monitoring focused on species found within ecosystems or relying on habitats reported in time to be vulnerable. However, this approach requires a considerable level of expertise that may not be readily available.

Potential data sources

British Columbia Breeding Bird Atlas: Seven year project (launched in 2007) set up to measure distribution and relative abundance of birds in B.C.. The on-line breeding bird atlas database can be manipulated by the user to show trends in bird populations, ranges, and abundance, all of which could be used to monitor changes in bird distribution and abundance in B.C. Although a cause-and-effect relationship cannot be established with these data alone, the information can be tied with other data sources to further scientific understanding of the vulnerabilities of birds to climate changes.

British Columbia Conservation Data Centre systematically collates and disseminates information on plants, animals, fish and ecosystems (ecological communities) at risk in B.C. This information is compiled and maintained in a computerized database which provides a centralized source of information on the status, locations and level of protection of these organisms and ecosystems. This information is being used by MOE to prioritize species and ecosystems of conservation concern through the Provincial Conservation Framework. Due to the *Species at Risk Act*, listed species with recovery plans will likely receive higher priority for funding and monitoring with regard to population trends.

Canadian Community Monitoring Network (CCMN): Indicators include worms and organic matter decomposition for soil health, benthic diversity for water quality, lichens for air quality, tree crown condition and seedling regeneration for vegetation, frog and salamander species richness for forests and wetlands, lake and river ice formation and thaw and the flowering of plants for climate variability. As more resources are directed towards monitoring, CCMN plans to expand to parks and protected areas.

Environment Canada's Ecological Monitoring and Assessment Network (EMAN) is responsible for reporting on the status and trends of ecosystems across Canada. It has partnered with the International Long-term Ecological Research Network (ILTER) and facilitates collaboration of ecological monitoring efforts across governments, communities, academic establishments, non-governmental organizations, student groups, volunteer groups and anyone else involved in ecological monitoring. In 2001, EMAN partnered with Nature Canada to engage in the Canadian Community Monitoring Network (CCMN).

Forest and Range Evaluation Program (FREP) has a number of research and monitoring programs of relevance to this indicator. The most pertinent activities are those currently being conducted by the Wildlife Resource Value Team which addresses the conservation of wildlife habitat; and the stand-level Biodiversity Team which is evaluating if stand-level retention (wildlife free patches and riparian reserves) is providing the range of habitat with the structural attributes understood to maintain species diversity.

MOE Fisheries Inventory Data Queries (FIDQ) provides access to the Fisheries Data Warehouse which contains information on fish species and their habitats that is of importance to assessment of this indicator.

Invasive Alien Plant Program (IAPP) co-ordinates information generated by various agencies and non-government organizations involved in invasive plant management. They have a database containing information on invasive plants that may prove useful for analysis of this indicator.

The Nature Conservancy of Canada (NCC) is conducting spatial optimisation analyses. The results can be used to show the priority conservation sites for a suite of conservation targets and goals. Inputs used in the assessment include terrestrial and aquatic ecosystems and species distributions. Currently the program is being applied to the B.C. interior.

NatureCounts: This website and database managed by Bird Studies Canada collates natural inventory and monitoring data for birds, amphibians, reptiles and bats. Examples of bird programs feeding into the database include the Marsh Monitoring Program (MMP), B.C.-Yukon Nocturnal Owl Survey, and the Canadian Migration Monitoring Network.

Nature Watch: Citizen-science monitoring coordinated by EMAN and Nature Canada. Programs include FrogWatch, WormWatch, IceWatch and PlantWatch. Programs in the development stage include lichens, tree health and benthic macro-invertebrates.

National Forest Inventory B.C. (NFI-BC): The NFI-BC involves two separate sets of permanent plots: one a set of photo plots and the other a set of ground plots. It is anticipated that NFI-BC would be able to provide data on species from both of these plot types.

Provincial Conservation Framework developed by the MOE in collaboration with other scientists, conservation organizations, industry and government provides a set of science-based tools and actions for conserving species and ecosystems in B.C.

RESULTS (Reporting Silviculture Updates and Land status Tracking System) tracks silviculture information by managing the submission of openings, disturbances, silviculture activities and obligation declarations.

Species Inventory (SPI) is a provincial dataset comprised of wildlife inventory data collected during surveys undertaken to determine the presence or absence; relative abundance or absolute abundance of any wildlife species. In this dataset, wildlife species include all vertebrates except fish (i.e. mammals, birds, amphibians, and reptiles), some invertebrates (arthropods) and macrofungi found in B.C.. Some of the data contained in the dataset is sensitive and requires special permission to access.

Cost/benefit of monitoring

Monitoring trends in population, range and phenology information for forest and rangeland species is considered very important for the monitoring framework. The approach suggested offers a low cost way to monitor this indicator as it is based entirely on analyzing and interpreting data that is already collected rather than conducting additional field based research programs. Despite the number of data sources listed it is highly likely that there will be considerable difficulty reporting detailed trend information for the vast majority of species (including even those that are considered iconic to B.C.). At the expert workshop, it was emphasized by both MFR and MOE research staff that the monitoring of individual species would be seriously compromised by the inadequacy of current data sets in B.C.

Indicator 15: Genetic diversity

Douglas-fir
Photo: John Innes

Rationale

Species are prone to increased risk of extinction when a significant proportion of their genetic diversity is lost. Such loss usually results from factors such as habitat reduction and fragmentation, reduced population levels, pests and disease infestations, and restrictions and/or shifts in former range (all threats which will potentially increase with anticipated climatic changes). Populations and individual species that have been affected by these factors can lose some of their genetic diversity, which may in turn result in decreased resilience and ability to adapt to future environmental changes.

Suggested approach to monitoring

This indicator examines trends in the distribution, composition, and structure of forest and range genotypes (the internally coded inheriTable information carried by all living organisms). Monitoring under this indicator could start with the development of a list of forest and rangeland species and populations considered to be at risk from isolation and loss of genetic variation. To the extent practicable, this information would need to be supported using baseline data on genetic diversity (stand and landscape level), including genetic composition (spatio-temporal distribution); and quantitative information from direct measures of changes (e.g., rate/direction of loss) in genetic variation. Analysis may also include monitoring the application of formal measures to mitigate declines in genetic variation such as in situ and ex situ conservation programs and assisted migration (moving species/genetic provenances outside their range).

Potential data sources

Centre for Forest Conservation Genetics (CFCG): The CFCG has a mandate to (1) study population genetic structure of forest trees using existing or new data; (2) assess the current degree of gene conservation both in situ in existing reserves and ex situ in collections, and the need for additional protection (although this is moving to MFR in the future); and (3) evaluate the current degree of maintenance of genetic diversity in breeding and deployment populations of improved varieties to meet current and future environmental challenges.

MFR Research Branch, Forest Genetics Section undertakes both theoretical research (quantitative genetics, climate-based seed transfer systems) and the practical applications of forest tree genecology, tree breeding and genetic conservation activities.

MFR Tree Improvement Branch, Headquarters Unit undertakes policy development and analysis; risk, impact and vulnerability assessments; criteria and indicator sustainable forest management reporting (CCFM, State of the Forest); evaluation and monitoring; and decision support. This unit is also responsible for the support of genetic resource conservation and management (GRM) spatial and non-spatial data sets, map products and information management systems, including the Seed Planning and Registry system, SeedMap, and GRM linkages to other corporate information management systems (RESULTS, MapView). Responsibilities include the development and support of GRM baseline data for the evaluation and monitoring of genetic diversity indicators and measures including seed selection, use and deployment. Climate change performance measures are also being developed to support climate-based GRM policy and practices (seed transfer).

Cost/benefit of monitoring

While not considered to be as critical as Indicators 12 and 13, an assessment of genetic level diversity was deemed worthwhile for climate change analysis, especially if costs could be reduced by creating strong linkages with existing programs examining the state of genetic resources in B.C. We note that technologies in this field are advancing rapidly and the type of monitoring considered even five years ago as cost-prohibitive is now feasible.

Indicator 16: Ecosystem connectivity

Rationale

This indicator examines the level of connectivity between forest and range ecosystems, both terrestrial and aquatic. Connectivity comprises the dispersion pattern of patches within the landscape. Significant distances from one patch to the next have been clearly shown to interfere with pollination, seed dispersal, wildlife migration and breeding. Forecasts show that in order to adapt to climate change some species may need to migrate (northward and to higher altitudes), hence, ensuring the connectivity of both terrestrial and aquatic environments that allow for such migration may become increasingly important. We recommend that the fragmentation of freshwater ecosystems is also monitored under this indicator. Both natural and artificial barriers may inhibit fish passage and changes in streamflow and temperature associated with climate change may interact with such barriers to affect freshwater ecosystems. It may also become more important to monitor the effects of natural causes of changes in connectivity (e.g., fire and landslides) as the frequency of these events may increase as a result of climatic changes.

Suggested approach to monitoring

The *B.C. State of the Forests Report* reports on the fragmentation of forest ecosystems. Currently, this is done using road density information only. Full analysis of the indicator in light of climate change would need to expand on this approach to examine the loss of ecosystem connectivity resulting from other sources (e.g., seismic survey lines, utility corridors, heli-logging, power projects, natural and artificial water bodies). While a Province wide analysis of trends in ecosystem connectivity would be the goal for reporting under this indicator it may be prudent to develop and test methods for monitoring ecosystem connectivity on a regional, ecosystem or case study basis initially. Modelling scenarios and in time data collected under Indicators 1, 2 and 3 should be widely adopted to inform and target the areas or ecosystems for which this analysis is most appropriate (e.g., habitat for vulnerable species and ecosystems).

Potential data sources

Data sources listed for Indicators 12, 13 and 14 above would be used in the analysis and targeting of this indicator. In addition to these sources, data collected by the following organizations is also of potential relevance:

British Columbia Parks is responsible for the stewardship of crown-owned protected areas in B.C. including Provincial Parks, ecological reserves, and conservation lands. This information along with information from Parks Canada may be used to determine intact natural areas.

Forest and Range Evaluation Program (FREP): The FREP Biodiversity team is currently monitoring stand level biodiversity and is in the process of developing an approach for landscape level biodiversity monitoring. The FREP Fish/Riparian team is examining the extent to which interconnectivity of aquatic ecosystems and fish habitats within drainage basins is being maintained.

Fisheries and Oceans Canada: Habitat and Enhancement Branch produces regular reports dealing with species regions (e.g., the lower mainland). They in turn rely on information derived from a range of sources, including their own staff, MOE, municipal staff and private organizations (such as Streamkeepers' associations, fish and game clubs, river management societies, etc.). Some local groups are particularly well organized and could be drawn on for detailed information: examples include the Alouette River Management Society and the Pitt River & Area Watershed Network.

Parks Canada, the agency responsible for the stewardship of national parks, collects a range of data related to the ecological integrity of these areas which may prove useful for supporting analysis of this indicator.

Hectares B.C. is a collaborative project created under the Biodiversity B.C. partnership. The purpose is to improve access to summarized, integrated, geospatial data about B.C. for the interest and information of any interested party. Available data is from a number of sources and is easy to query.

Cost/benefit of monitoring

This indicator is currently seen as being of high importance to the monitoring framework. Costs of monitoring could be reduced by conducting spatial analysis on existing information and data compiled under Indicator 1, by targeting analysis through the use of climate change models and through the adoption of remotely sensed data.

CONCLUSIONS

The specific goals of this project were to develop a set of recommended indicators for monitoring forest and range associated species and ecological processes sensitive to climate change and identify the potential data suppliers that are available for evaluating the indicators. Ultimately, a Monitoring Strategy will be developed to provide the data to help inform key forest and range management decisions in light of climate change.

Sixteen indicators are recommended and presented under the criteria-level headers of ecosystem drivers (7 indicators), natural disturbance (4 indicators) and biodiversity (5 indicators). Almost thirty diverse data sources are identified as able to support these indicators. Despite this, preliminary investigation and liaison work revealed that 6 of the proposed indicators (including some considered of critical importance to the framework) could not be reasonably supported through these existing data collections:

1) Precipitation
2) Streamflow
3) Water Temperature
4) Mass Movements
5) Ecosystem distribution and composition
6) Species Diversity

The results of this work reveal opportunities that exist now for collaboration among existing monitoring and data collection programs and reporting on some key indicators to inform forest management decisions. A preliminary review of data availability for analysis of some key indicators reveals important gaps that need to be addressed.
The authors urge monitoring and data collection programs to study these gaps and find cost effective approaches to filling them.

RECOMMENDATIONS FOR FURTHER WORK

The authors recommend that the next Phase of this project be completed as soon as possible. The objective of Phase 3 is to design a MFR Climate Change Monitoring Strategy with the aim of increasing collaboration and efficiencies among existing programs for cost efficiency. As designed, Phase 3 of the project effectively builds on the momentum and work of Phases 1 and 2. We have invested considerably in solidifying and building on FFEI's and FREP's multi-agency natures. Through this investment we have been effective in securing strong commitment and collaboration to develop the monitoring strategy from most key data providers and other agencies that are required to make Phase 3 successful.

In light of findings made through Phases 1 and 2 of the project we recommend that the following be conducted in completing these tasks:

1) A detailed spatial analysis of the existing monitoring sites that are currently collecting the data needed to support reporting and interpretation of the recommended indicators. This would include an assessment of the location of all known forest inventory, climate, and water monitoring stations in comparison to forest and rangeland ecosystems (most usefully by ecosystems identified in Indicator 1). It would be most beneficial if this spatial analysis also included some assessment of the diversity of 'other' landscape features represented. For example, further assessment is needed of the extent to which higher altitudes, smaller streams, snow-dominated and glacier augmented systems are represented within existing monitoring sites and the extent to which monitoring stations form a complementary network. This analysis would be used to identify the gaps that are occurring in the existing sites and where it may be necessary to increase monitoring, as well as the type of additional monitoring that is needed.

2) A detailed analysis of the accuracy and comprehensiveness of the data that are being collected by the sources identified and the extent to which those data can be integrated and interpreted as a whole. At its most basic this might include a brief assessment of data access and sharing abilities within and across the identified agencies. However, a more useful investigation would include a detailed assessment of the effect and suitability of differing scales of analysis, the various attributes that are monitored by each agency and the data collection standards that have been adopted. Phase 3 should also include some analysis of options for housing and updating the integrated data sets once they have been generated.

3) Direction and consideration should be given to how the recommended indicators are reported on and the extent to which information will be made available to the wider community. For instance, it is highly likely that there will be a need for information generated by the monitoring framework to be made available online in some form and it is important that any database or information housing options be considered in light of this. There is also significant potential to utilize existing sustainability reporting mechanisms currently in place at both the Provincial and Federal government level (such as the B.C. State of the Forest report and reporting conducted by the CCFM). Where necessary, linkages should be developed with these programs to ensure that data are able to be presented in a format that is useful to them.

APPENDIX 1 CLIMATE MONITORING – EXAMPLES OF LOCAL, NATIONAL AND GLOBAL EFFORTS

In 2007, the United Nations Food and Agriculture Organization affirmed ". . . the climate observing system in the Terrestrial Domain remains the least well-developed component of the global system, whilst at the same time there is increasing significance being placed on terrestrial data for climate forcing and understanding, as well as for impact and mitigation assessment." [18] The diversity in terrestrial ecosystems across the globe combined with the relatively high cost of terrestrial monitoring has inhibited the development of adequate long-term consistent, cohesive, and representative terrestrial surveillance programs. Not surprisingly, few full-fledged monitoring programs specifically designed for monitoring the effects of climate change on ecosystems have been implemented. Most of the monitoring systems currently being utilized were set up for other reasons; for example, many for forest health concerns such as air pollution. They were not designed to increase our understanding of the ecological implications of climate change. However, it is neither cost-effective nor feasible to develop completely new monitoring programs and therefore existing and especially long-term monitoring programs are being adapted to better inform policy decisions in light of climate change. Distinguishing causal effects of climate change on variables of interest may prove to be difficult from existing monitoring frameworks. Consequently, these systems may not detect subtle effects of climate change on ecosystem function, and predictive challenges within modeling may become evident.[19] Existing monitoring programs are the only starting point for developing reference conditions and identifying climate change impacts on forest and rangeland species and ecological processes.

Adapting current monitoring frameworks builds on data already collected and is the next step in the evolution of informative terrestrial observation systems. Due to gaps in knowledge and understanding of terrestrial ecosystems, existing monitoring programs need to be augmented and bolstered if they are to be used in a timely manner for climate change research and analyses. Non-forested ecosystems (e.g., alpine areas), forest ecosystems generally outside of commercial management, and wilderness areas illustrate just a few of the many knowledge gaps present in most contemporary terrestrial observational data.[20] Including such systems in monitoring programs, as well as adapting in other ways would facilitate an integrated analysis of the effects of climate change on all ecosystems and the services they provide.[21] Such an approach is required because of the complex interactions between ecosystems and the extent to which these interactions could be affected by climate change.

Climate change monitoring in British Columbia

Initiatives within B.C. have been monitoring environmental trends for years and provide some examples of the types of analyses that can be conducted with data currently or previously collected in the Province or region. The Indicators of Climate Change for B.C., 2002 [22] looks at the implications of a rapidly changing environment for human systems as well as terrestrial, marine and freshwater ecosystems. The report reviews indicators regionally and also explores the drivers of climate change. While this report represents one of B.C.'s earliest attempts to quantify and disseminate the effects of climate change on ecosystems and human communities, many other reports have been produced over the years that have evaluated changing environmental trends. The B.C. MOE *State of the Environment (SoE) Report: Environmental Trends in B.C. 2007* [23] has considerable synergies with FFEI monitoring objectives and is the latest in a series of SoE reports that have analyzed environmental trends over the last decade. This knowledge builds on reporting and monitoring frameworks used to develop four previous environmental trend reports for B.C. (i.e., in 1993, 1998,

18 FAO. 2008. Terrestrial Essential Climate Variables for Climate Change Assessment, Mitigation and Adaptation. GTOS, FAO, Rome, Italy.

19 CCSP, 2008: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P. Backlund, A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, R. Shaw. U.S. Department of Agriculture, Washington, DC., USA, 362 pp.

20 UK Forestry Commission website [Accessed December 2008].

21 CCSP, n.19.

22 BC Ministry of Water, Land and Air Protection 2002: Indicators of climate change for British Columbia; BC Ministry of Water, Land and Air Protection, 50 p., http://www.env.gov.bc.ca/air/climate/indicat/pdf/indcc.pdf [Accessed December 2008].

23 BC Ministry of Environment. 2007. Environmental trends in BC 2007. BC Ministry of Environment, 352 p., http://www.env.gov.bc.ca/soe/et07 [Accessed December 2008].

2000, and 2002). Substantial collaboration among federal and provincial agencies and many other organizations was necessary to produce these reports. Several chapters (e.g., climate change, ecosystems, fresh water, and species conservation) could be used to inform the FFEI monitoring program development process as well as complement its implementation. In a similar reporting framework, Environment Canada maintains a State of the Environment InfoBase,[24] which presents their work on state of the environment reporting and environmental indicators. Here ecosystems, wildlife species and other related indicators are used to assess environmental trends, but not specifically in relation to climate change.

The B.C. State of the Forests (SOF) Report[25] also offers potential for overlap with FFEI monitoring and reporting. Several indicators and data sources may be used to facilitate the development and adaptation of a FFEI climate change monitoring and reporting framework. The current SOF team has initiated discussions on incorporating climate change issues into the 2010 SOF Report and subsequent issues. This may provide an avenue for the public display of results from the FFEI monitoring framework.

The Pacific Climate Impacts Consortium (PCIC) is a research group designed to facilitate collaboration on climate change research and information dissemination aiding policy makers in informed and effective decision-making.[26] Many of the topic areas relevant to the FFEI monitoring initiative have been studied by the PCIC and several reports have been published that analyze the implications of climate variability and change on B.C.'s resources. It has created a Regional Analysis Tool, which allows the user to manipulate parameters of interest while focusing on local results from global climate model (GCM) data. It has also amalgamated Forest Health datasets; 17 different data sources were compiled as of March 2008, and most are available for research purposes.

Climate change monitoring in Canada

Almost a decade ago, the Government of Canada assessed its observations systems to determine whether the present monitoring systems could contribute data to the Canadian Global Climate Observing System (GCOS). In general, the atmospheric and oceanic components of the observing system in place were adequate to contribute data. However, most terrestrial monitoring programs and databases, without further enhancement, could not be used for the GCOS due to gaps in coverage, continuity and detail.[27] In some cases, specifically forestry databases, statistics were insufficient right from the start, inconsistent over time or space, or incomplete. Canada's ARNEWS (Acid Rain National Early Warning System) and the North American Maple Decline Project (NAMD) provide examples of monitoring programs which depict some of these problems. Both programs collected data for a number of years but were discontinued. Both programs were also largely based in Eastern Canada, with B.C. severely under-represented. The Forest Indicators of Global Change (FIGC) project continued monitoring utilizing both programs but this project was also discontinued. Although these programs no longer exist, the presence of historic data and a monitoring framework present opportunities for building existing infrastructure into adaptation options for B.C.'s monitoring systems.

Canada's National Environmental Indicator Series 2003[28] demonstrated the efficacy of building on existing frameworks to fill a knowledge gap. Public demand for information regarding the status of their environment provided the impetus for a national set of environmental indicators to be developed. The subsequent report covered numerous topics from ecosystem health to human well-being and all analyses were founded on existing information and monitoring systems. Natural Resources Canada recently released a report titled *From Impacts to Adaptation: Canada in a Changing Climate 2007.*[29] This report first presents an integrated analysis on a national scale, and is then broken down into regional assessments where overviews presenting regional challenges and adaptive opportunities for B.C. and other Provinces and Territories are given. General indicators (i.e., temperature, precipitation, extreme weather and weather related events, hydrology (river runoff, glaciers), sea level and ecosystems) are used to examine sectors such as forestry, agriculture, and terrestrial ecosystems for vulnerabilities to climate change as well as their adaptive capacity.

24 State of the Environment Infobase Website http://www.ec.gc.ca/soer-ree/ [Accessed March 2009].

25 BC Ministry of Forests and Range. 2006. The state of British Columbia's forests. BC Ministry of Forests and Range, 182 p., http://www.for.gov.bc.ca/hfp/sof/ [Accessed December 2008].

26 Pacific Climate Impacts Consortium (PCIC) website http://pacificclimate.org/ [Accessed December 2008].

27 Government of Canada. 1999. The Canadian National Report on Systematic Observations for Climate. The Canadian Global Climate Observing System (GCOS) Program http://www.ec.gc.ca/climate/CCAF-FACC/Science/nat2002/toc_e.htm.

28 Canada's National Environmental Indicator Series http://www.ec.gc.ca/soer-ree/English/Indicator_series/default.cfm#pic [Accessed December 2008].

29 Walker and Sydneysmith n. 5.

Environment Canada's Ecological Monitoring and Assessment Network[30] (EMAN) is responsible for reporting on the status and trends of ecosystems across Canada. It has partnered with the International Long-term Research Network (ILTER) and facilitates collaboration of ecological monitoring efforts across federal, provincial and municipal governments, communities, academic establishments, non-governmental organizations, student groups, volunteer groups and anyone else involved in ecological monitoring. In 2001, EMAN partnered with Nature Canada to engage in the Canadian Community Monitoring Network (CCMN). This is a network that engages communities across Canada in ecosystem monitoring. It strives to integrate Community Based Monitoring (CBM) data into policy decisions, and aspires to build local capacity for informed ecological decision-making within individual communities. Environmental indicators used in the pilot study included earthworms and organic matter decomposition for soil health, benthic diversity to indicate water quality, lichens for air quality, tree crown condition and seedling regeneration for vegetation information, frog and salamander species richness as indicators for forests and wetlands, and lake and river ice formation and thaw events in combination with the timing of phenological events (specifically plant flowering) for climate data. As additional resources become available for ecological monitoring, it plans to expand into parks and wilderness areas. Nature Watch, another program affiliated with EMAN, further coordinates citizen-monitoring programs and includes initiatives such as FrogWatch, IceWatch, PlantWatch, and WormWatch, all of which could be used to inform MFR.

Climate change and the implications for forest and rangeland ecosystems are mainly discussed in reference to the global carbon cycle at the national level. This is evident in the most recent Canadian State of the Forests Report, National Status 2005.[31] However, even here a lack of data precludes a full assessment of the carbon dynamics of Canadian forests. Climate change is only discussed in detail in Criterion 4, while it is merely mentioned in other indicator analyses. The CCFM recently released: *A Vision for Canada's Forests. 2008 and Beyond;*[32] this includes calls for consideration of climate variability in sustainable forest management. Goals include ensuring the survival and bolstering of the forest sector, and leading the world in researching, adapting to and mitigating against the effects of climate change on Canada's forests and forest communities. However, no specific details are described regarding the monitoring of forests for climate change. The Canadian Council of Ministers of the Environment (CCME) also assessed indicators of climate change in their report: *Climate, Nature, People: Indicators of Canada's Changing Climate.*[33] This report uses 12 indicators to assess the state of Canada's environment and at least two indicators are directly relevant to a terrestrial monitoring system: polar bears and plant development. Furthermore, the report introduces a program in Nova Scotia called the Thousand Eyes Project,[34] which engages students in monitoring natural events such as plant flowering timing, and arrival of butterflies and migratory birds. These data will be compared to statistics recorded using a similar student initiative 100 years ago.

In all the many initiatives and reports, it is evident that while there is some interest in monitoring and reporting the effects of climate change on Canada's forests, federal attempts to do so are constrained by the availability of sound and reliable field data. This reflects the uneven efforts put into monitoring across Canada, the short life of most 'long-term' monitoring projects, the difficulties involved in the compilation of data collected according to different provincial and territorial protocols and a number of other problems.

International Climate Change Monitoring

Despite the challenges with current land monitoring systems, several data sets and indicator frameworks have contributed to initiatives investigating and reporting the effects of climate change on ecological systems around the world. In the United States, studies have been conducted in light of climate change using current monitoring frameworks. The USDA Forest Service Forest Health Monitoring (FHM) Program[35] tracks the status and trends of forest health across the country by integrating ground and aerial inventories from disparate monitoring

30 EMAN (Ecological Monitoring and Assessment Network website. Environment Canada website http://www.eman-rese.ca/eman/ [Accessed December 2008].

31 CCFM, 2006. National Status 2005. Ottawa, ON, 154 p., http://www.ccfm.org/current/ccitf_e.php [Accessed December 2008].

32 CCFM. 2008. A vision for Canada's forests. 2008 and beyond. Ottawa, ON. 15 p. http://www.sfmcanada.org/CMFiles/PublicationLibrary/Vision_EN1OMQ-12112008-8724.pdf [Accessed December 2008].

33 CCME. 2003. Climate, Nature, People: Indicators of Canada's Changing Climate. CCME, Winnipeg, Manitoba http://www.ccme.ca/assets/pdf/cc_ind_full_doc_e.pdf [Accessed December 2008].

34 Thousand Eyes Project website http://www.thousandeyes.ca/english_en/index.php?lang=en [Accessed March 2009].

35 FIA Forest Health Monitoring Program website http://www.fhm.fs.fed.us/ [Accessed December 2008].

initiatives. They are currently developing indicators specifically for climate change and will continue to use and adapt existing monitoring frameworks for data. The US Long-term Ecological Research Network (LTER)[36] integrates long-term biological research and monitoring at sites across the US and has a Global Change Research Branch that uses monitoring data from its research sites to address knowledge gaps. The network has an international arm (the International Long-term Ecological Research Network [ILTER]), that includes long-term study sites in a number of countries, such as the Chinese Ecological Research Network (CERN).[37] However, none of these were set up specifically with climate change in mind, although efforts are currently underway in several to ensure that climate change impacts can be included.

The USDA Forest Service's Draft 2010 National Report on Sustainable Forests[38] reports on indicators (which are similar to the indicators of the Canadian Council of Forest Ministers [CCFM]), but incorporates climate change into its discussion. In addition, it includes an extra Section on climate change and discusses the possibility of developing a specific task force to analyze the particular indicators that are sensitive to a changing climate in a separate report. While it is important to build on previous provincial capacity and experience, it is also critical to engage other stakeholders, researchers or organizations, as new approaches for monitoring and adapting need to be developed.

The Heinz Center used an existing set of indicators to evaluate the effects of climate change on ecosystems in the US.[39] The US Environmental Protection Agency (EPA) conducts research on biological criteria (biocriteria) and indicators, specifically for water resources. A recent report examined the initial effects of climate change on indicator organisms and provided guidance to managers and monitoring programs on adaptation strategies. The study described and assessed the utility of potential indicators based on current literature, and suggested novel indicators and species traits that could be used in monitoring.[40] It further employed case studies to consider the temporal aspects of change detection and the ability of current monitoring programs to detect such effects. The US Climate Change Science Program recently conducted a comprehensive assessment of climate change effects on agriculture, land and water resources and biodiversity.[41] It identified several problems within US monitoring systems, and suggested that the National Ecological Observatory Network[42] (NEON), a new long-term monitoring program designed to survey both climate and ecological variability in a systematic and all-inclusive manner, may improve the ability of current monitoring systems to detect climate change impacts on natural resources.

Outside of North America, we were able to identify two key monitoring programs specifically designed to include climate change impacts. The first is the Terrestrial Effects Monitoring Program developed in the United Kingdom in the early 1990s. This developed a series of indicators and monitoring protocols for environmental change, with climate change very much in mind. Although monitoring protocols were developed, implementation of the program appears to have faltered, and while we have found a number of public statements highlighting the importance of the program, we have been unable to identify any reports.[43] The second program worth drawing attention to is the Langfristige Waldoköystem-Forschung (LWF) program of Switzerland. This program was established in the mid-1990s and involves a network of 15 forest sites throughout Switzerland. Its origins are complex, combining a desire to complement the European Commission's (EC) network of monitoring plots with a desire to accomplish something scientifically useful. As a result, while the indicators follow those advocated by the European Community and ICP Forest Program, they go much further. For example, while the EC program suggests the establishment of a meteorological station at the site, all the Swiss sites have two stations, one under the forest canopy and one in an open area. In addition, some of the sites have both below- and

36 US Long-term Ecological Research Network website http://www.lternet.edu/ [Accessed March 2009].

37 Chinese Ecological Research Network (CERN) http://www.cern.ac.cn:8080/news.jsp?id=328 [Accessed March 2009].

38 USDA Forest Service. 2008. Draft national report on sustainable forests. USDA, Forest Service 222p., http://www.fs.fed.us/research/sustain/2010SustainabilityReport / documents/draft2010sustainabilityreport.pdf [Accessed December 2008].

39 The H. John Heinz III Center for Science, Economics and the Environment. The State of the Nation's Ecosystems 2008. Measuring the Lands, Waters, and Living Resources of the United States. Washington D.C. http://www.heinzctr.org/ecosystems/ [Accessed December 2008].

40 U.S. EPA. Climate Change Effects on Stream and River Biological Indicators: A Preliminary Analysis (Final Report). EPA/600/R-07/085F. Global Change Research Program, National Center for Environmental Assessment, Washington, DC.

41 CCSP n. 19.

42 NEON (National Ecological Observatory Network) website http://www.neoninc.org/ [Accessed December 2008].

43 We are currently unable to provide references for further information about this program. Enquiries to the known program organizers (Jan 2008) have not been met with any responses.

above-canopy climate measurements and eddy correlation flux measurement capability.[44]

The LWF program is relevant to the MFR Climate Change Monitoring Project for a number of reasons. Firstly, it was a new monitoring program established in a time of fiscal constraint. There was considerable resistance from both the scientific community and the ministries with responsibilities for monitoring. Both were concerned that the costs of such a program would be drawn from existing budgets, resulting in cutbacks for existing programs. In reality, the program was presented to the Swiss Parliament and a special financial allocation was approved on the grounds that the proposed monitoring was critical and should not disrupt existing programs.

Secondly, the LWF program was established at a time when it was uncertain what the most important problems facing Swiss forests would be in the future. Air pollution, and acidic precipitation in particular, were considered by some to be major threats, but others considered climate change to be equally important. The program therefore was developed in such a way as to provide flexibility through a network of plots in different ecosystems throughout Switzerland. These included plots in areas believed to be sensitive to acidic deposition, areas believed to be sensitive to climate change and areas believed to be sensitive to ozone pollution. There were substantial expenditures in establishing base-line conditions in the research plots, particularly in terms of the trees, vegetation communities and the soil conditions. At the same time, some of the financial allocation was used to establish an experimental site which was subsequently used to generate a series of international publications on the impacts of ozone on plants. In the B.C. context, a potential equivalent would be to create an experiment that involved a warming of the climate. (Given the cost of such an experiment, an alternative would be to develop research in an area of naturally elevated high temperatures – such as Liard Hot Springs).

The key points of the Swiss LWF program are:

- **a.** It was established in response to a belief that environmental change, whether air pollution or climate change, would have an important effect on Swiss forests.
- **b.** It was established through special financing approved by the Swiss Parliament (at a cost of ca. $4 million annually). This funding was independent of existing departmental financial allocations.
- **c.** It combined monitoring with more traditional forms of research, thereby producing results of significance to policy makers earlier than a program only involving monitoring.
- **d.** Unlike many 'long-term' programs, it has successfully renewed its funding (now in a fourth 4-year funding cycle).

Other international monitoring networks are also being modified to broaden scientific understanding of climatic variability on ecosystems. In the United Kingdom, the British Trust for Ornithology (BTO) uses long-term data to evaluate the effects of climate change on birds and migratory species. Considerable effort is being put into research assessing indicators covering a range of taxa including birds, marine and terrestrial mammals, fish, turtles, and bats.[45] In Europe, the ICP Forests Programme[46] (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests) was originally designed to detect changes in forests due to air pollution, but emphasis is now being placed on detecting changes from both air pollution and climate change. The Food and Agricultural Organization (FAO) established the Global Terrestrial Observation System (GTOS) and fourteen Essential Climate Variables (ECVs) were developed that should be monitored as part of standard terrestrial monitoring systems.[47] Another example of a global monitoring program adapting to monitor for climate change is the UNESCO Biosphere Reserve Program, which will now directly support the UNESCO's Man and Biosphere Programme (MAB).[48] This program comprises UNESCO World Heritage sites, National Geoparks and Biosphere Reserves, and aims to integrate climate change observations and analysis throughout the global monitoring network. Numerous initiatives exist to adapt current monitoring systems throughout the world, however, most are still in an incipient stage of development.

44 Websites containing further information about the LWF program are: Langfristige Waldokősystem-Forschung website http://www.wsl.ch/lwf/index_EN [Accessed Feb 2008] and LWF Ozone Website http://www.ozone.wsl.ch/index-en.ehtml [Accessed February 2008].

45 Newson et al. 2008. Indicators of climate change on migratory species. Endangered Species Research. Pre-print Inter-Research.

46 ICP Forests website http://www.icp-forests.org/ [Accessed December 2008].

47 FAO n. 18.

48 UNESCO Task Force on Global Climate Change. 2008. UNESCO's strategy for action on global climate change. UNESCOUNESCO, Division of Ecological Sciences, Man and the Biosphere (MAB) Programme, Paris, France.

As monitoring programs continue to be developed and implemented, lessons can be learned and applied to the MFR Climate Change monitoring program in the initial stages of its development and throughout its lifespan. Paramount among these lessons is the need to continually foster and solidify ongoing political support that secures long term funding. This most important issue seems to have continually plagued the successful implementation of many status or trend monitoring programs globally and is the likely cause of the suspension or termination of some of the programs listed above. A brief description of all of the monitoring programs, frameworks and reporting mentioned above can be found in Table 4 below. Additional relevant examples are also included.

Table 4: *Local, national and international organizations and frameworks monitoring climate change and its effects*

Monitoring Framework or Program	Characteristics
British Columbia Ministry of Water, Land and Air Protection – Indicators of Climate Change for British Columbia 2002 http://www.env.gov.bc.ca/air/climate/indicat/	Assessment describes trends in indicators of environmental, economic and societal values that are considered sensitive to climate change. Broad topic areas of indicators include climate change drivers, climate change and freshwater ecosystems, marine ecosystems, terrestrial ecosystems and human communities. Many indicators assessed have considerable synergies with FFEI. Examples of indicators in the ecosystem Section include: the status of grassland habitats in southern interior B.C., area of protected grasslands in B.C., status of B.C. forests, and trend in the number of road crossings of streams in B.C., 2000 to 2005.
British Columbia State of the Forests Report http://www.for.gov.bc.ca/hfp/sof/2006/pdf/sof.pdf	The State of British Columbia's Forests is a provincial, sustainable forestry report that provides information about B.C.'s forests in three categories: environmental, economic and social, and governance and support. The 2006 report examined 24 indicators nationally and internationally recognized for assessing sustainable forest management. Several indicators and data sources could be used to supplement the FFEI monitoring program.
British Columbia Ministry of Environment (MOE) – State of the Environment Reporting: Environmental Trends in British Columbia: 2007 http://www.env.gov.bc.ca/soe/	The most recent MoE State of the Environment Report that assesses environmental changes in six topic areas, each with a distinct set of indicators. This information builds on reporting and monitoring frameworks used to develop four previous Environmental Trend reports for B.C.. Topic areas include population and economic activity, air quality, water quality, climate change, contaminants, ecosystems, and species conservation. Over 44 indicators and 25 supplementary measures were analyzed and adaptation is addressed in action plans for each topic area. Several indicators and data sources could supplement the FFEI monitoring program.
British Columbia Ministry of Environment State of the Environment Reporting – BC Coast and Marine Environment Project 2006 http://www.env.gov.bc.ca/soe/	Review of how climate change is impacting B.C.'s coastal and marine environment. Indicators include long-term trends in annual and seasonal air temperature, frost-free days, precipitation, coastal ocean temperature change and its effects along the B.C. coast, and rise in sea level and its effects on B.C. shore zones.
University of Victoria, Center for Global Studies – Pacific Climate Impacts Consortium (PCIC) http://www.pacificclimate.org	PCIC is a research group designed to encourage collaboration between government, academic institutions and industry while producing policy-relevant information to inform decision-making. It has created a Regional Analysis Tool which facilitates the comparison of past climate trends and future climate scenarios using GCM regional data. Water, biodiversity, hydro-climatology, and regions such as B.C.'s Southern Interior forests are among the research projects and impact assessments that have been conducted, and which could be relevant to the FFEI monitoring program. For example, the objective of the Preliminary Analysis of B.C. Climate Trends for Biodiversity project was to develop an index of climate change for biodiversity. A Forest Health Database has been compiled and most of the following data sets are available for research purposes: CRU climate data (TS2.1), CANGRID climate data, NCEP Reanalysis climate data, NARR climate data, PRISM climate normals, PRISM climate data timeseries, Historical gridded timeseries of Canada, VIC driving data: historical gridded daily timeseries of B.C., Yukon, and Alberta, Climate normals computed using ClimateB.C. software (CRU 1 degree data downscaled to 400 m), Canadian Digital Elevation Data (CDED) data, regridded for B.C., Climate timeseries computed using ClimateBC software (CRU 0.5 degree data downscaled to 400 m), Presence plot data, Vegetation resources inventory data, Forest inventory data, BEC zone projections computed using ClimateBC software, Forest inventory data and BIOSim pest outbreak simulation and historical climate data.

Monitoring Framework or Program	Characteristics
University of Victoria – Pacific Institute for Climate Solutions http://www.pics.uvic.ca/	Research group producing White Papers. To date, one focused on forestry: Carbon Sequestration in British Columbia's Forests and Management Options
Climate Impacts Group, University of Washington http://cses.washington.edu/cig/	Interdisciplinary research group studying implications of climate variability and change on four components of the Pacific Northwest environment: water resources, aquatic ecosystems, forests, and coasts. The Forest research group is currently focused on fire-climate relationships, climate impacts on Douglas-fir growth rates, insect outbreaks, tree species distributions, forest productivity and forest ecosystem carbon storage. Hydrology, salmon, agriculture and forests were among relevant topic areas recently assessed in a report titled "A Comprehensive Assessment of Climate Change on the State of Washington".
Forest Management in a Changing Climate: Building the environmental information base for Southwest Yukon http://yukon.taiga.net/swyukon/index.cfm	Climate-related indicators developed for the Southwest Yukon: temperature, precipitation, drought index, Frost free days, lightning, beetle infestation, forest fire occurrence, fire weather index, and potential forest fire behaviour.
EMAN (Ecological Monitoring and Assessment Network) Environment Canada http://www.eman-rese.ca/eman/	Ecological Monitoring network that coordinates collaboration between federal, provincial and municipals governments, communities, academic establishments, non-governmental organizations, student groups, volunteer groups and anyone else involved in ecological monitoring. It partners with the ILTER network (see below) and has facilitated the establishment of the CCMN and NatureWatch.
Canadian Community Monitoring Network (CCMN) http://www.ccmn.ca/english/	Indicators include worms and organic matter decomposition for soil health, benthic diversity for water quality, lichens for air quality, tree crown condition and seedling regeneration for vegetation, frog and salamander species richness for forests and wetlands, lake and river ice formation and thaw and the flowering of plants for climate variability. As more resources are directed towards monitoring, CCMN plans to expand to parks and protected areas.
Environment Canada, Pacific and Yukon Region Environmental Indicators http://ecoinfo.org/env_ind/indicators_e.cfm	Environment Canada's State of the Environment assessment for the Pacific and Yukon region includes a special Section for addressing climate change. Indicators include average temperature for regions of B.C. and the Yukon, change in the number of frost-free days, and trend in annual precipitation. Other indicators assessed in the report include shellfish closures, seabirds, toxic contaminants from biomagnification in birds and eggs, waterfowl species, several wildlife species, sensitive ecosystems, porcupine caribou, Fraser Valley smog, stratospheric ozone thickness, nitrate levels in ground water and waste water and use.
Environment Canada, State of the Environment Infobase – National Environmental Indicator Series – Climate Change http://www.ec.gc.ca/soer-ree/English/Indicator_series/default.cfm#pic	Indicators cover aspects from human well-being, health and activities, to natural resources and ecological life support systems. Forestry, agricultural soils, biodiversity, protected areas, acid rain, toxic substances, and climate change are general indicators and each is comprised of several supporting indicators. Examples of supporting indicators include CO2, greenhouse gases emissions, temperature and precipitation, weather related disasters, population status of forest bird species, number of forest fires in Canada, consecutive years of spruce budworm defoliation, trend in lake acidity, wet nitrate deposition, etc.
CCME (Canadian Council of Ministers for the Environment) – Climate, Nature, People: Indicators of Canada's Changing Climate http://www.ccme.ca/publications/list_publications.html#link3	Indicators were analyzed over two time periods (1950-2000, and 1900-2000) and regionally. Indicators include sea level rise, sea ice, river and lake ice, glaciers, polar bears, plant development, traditional ways of life, drought, Great-Lakes – St. Lawrence water levels, frost and frost-free season, heating and cooling, and extreme weather events.

Monitoring Framework or Program	Characteristics
Natural Resources Canada, From Impacts to Adaptation: Canada in a Changing Climate 2007 http://adaptation.nrcan.gc.ca/assess/2007/	A vulnerability and adaptation study focused on human and managed systems, first conducted at an integrated national level, followed by regional assessments. Indicators for B.C. include temperature, precipitation, extreme weather and related events, hydrology, sea level, and ecosystems. Indicators are assessed in several topic areas: water resource management, fisheries, forestry, agriculture, tourism and recreation, parks and protected areas, energy, critical infrastructure and health. Case studies are considered within the sectors and the specific indicators are dependent on the locality and driven by local variables.
Government of Canada Canadian Environmental Sustainability Indicators http://environmentandresources.gc.ca/	National assessment focused on health of Canadians. Indicators include air and freshwater quality indicators, as well as greenhouse gas emissions.
U.S. Climate Change Science Program/ U.S. Global Change Research Program – U.S. Climate Change Science Program (CCSP) http://www.climatescience.gov/	Integration of all federal research agencies studying climate change within the U.S. Comprehensive assessments and research are focused on the following topic areas: atmospheric composition, climate variability and change, the global water cycle, land-use and land-cover change, the global carbon cycle, ecosystems, decision-support resources, development and related research on human contributions and responses, observing and monitoring the climate system, communications, and finally international research and cooperation. The Synthesis and Assessment Products (SAPs) (e.g., Thresholds of Change in Ecosystems, or The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity) may provide guidance for the FFEI monitoring strategy.
United States Department of Agriculture (USDA) Forest Service – Forest Inventory and Analysis (FIA) Forest Health Monitoring (FHM) Program http://fhm.fs.fed.us	This program tracks the annual status, changes and trends in national indicators of forest health. The monitoring program integrates ground and aerial data from several programs and surveys, (including from local management inventories, the Forest Inventory and Analysis program, additional FHM, urban forest health monitoring, intensive site monitoring), and strives to cover all forestland regardless of tenure. The indicators currently used in the FHM program include tree growth, regeneration, tree crown condition, tree damage, tree mortality, lichen communities, ozone bioindicator plants, soil morphology and chemistry, downed woody debris, vegetation structure, and plant diversity. Additional parameters being monitored for climate change include the status, health, distribution and range of Whitebark Pine; drought impacts on forest health in the Southeast US, Southern California, and Alaska birch stands; modelling fire spread, intensity, fuel load and tree deterioration across beetle-affected landscapes; and invasive species response and ecological implications after fire.
US Environmental Protection Agency – Biological Assessment and Criteria Programs: Biological Indicators of Watershed Health http://cfpub.epa.gov/ncea/	The US Environmental Protection Agency (EPA) uses biomonitoring to detect climate change effects for streams and small rivers, lakes and reservoirs, estuaries and near coastal, wetlands, and coral reefs. A recent report evaluated the effects of climate change on stream and river biological indicators: Climate Change Effects on Stream and River Biological Indicators: A Preliminary Analysis.
The John Heinz Center III for Science, Economics and the Environment – The State of the Nation's Ecosystems 2008 http://heinzctr.org/ecosystems/	Reports on 108 indicators spanning forests, grasslands and shrublands, coasts and oceans, freshwaters and urban and suburban ecosystems and landscapes. The State of the Nation's Ecosystems 2008: Focus on Climate Change is a fact sheet that analyzed several of the 108 indicators separately, specifically in relation to climate change. Other fact sheets cover wildlife, contaminants and nitrogen.

Monitoring Framework or Program	Characteristics
National Science Foundation – National Ecological Observation Network (NEON) www.neoninc.org	Long-term continental research and monitoring network recently established to gather observations on environmental responses to land-use and climate change. Climate and canopy microclimate, air pollution and air quality, the carbon cycle, soil characteristics, water quality, soil and aquatic biochemistry, and patterns and changes in small mammals, insects, birds, fish, soil microbes, plants, and algae are all characteristics that will be studied at each site. Designed to provide GTOS and GSOS with terrestrial data.
National Science Foundation – Long Term Ecological Research Network (LTERN) www.lternet.edu http://www.lternet.edu/global_change/ Research Network (LTER)	A collaborative network of research sites spanning many ecosystems across the US. Monitoring core research areas over time and space that provide the basis for the LTERN. Core areas include primary production, population studies, movement of organic and inorganic matter, and disturbance patterns. The Global Change Research sector of LTER provides information on programs within the network that are researching climate change.
United States Department of Agriculture (USDA) Forest Service – DRAFT National Report on Sustainable Forests 2010 http://www.fs.fed.us/research/sustain/2010SustainabilityReport/	Reports on a monitoring framework with Criteria and Indicators (C&I) based on the Montreal Process (similar to CCFM National C&I). The report generally assesses sustainable forest management in the US but attempts to integrate climate change discussion into the analysis. The report also designates a Section to specifically, however briefly, reflect on the relationships of several C&I to climate change. Further analysis, including a distinct report with a climate change focus, is mentioned as an option that may be considered in the future.
ICP (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests) http://www.icp-forests.org/	European monitoring network originally designed to monitor for effects of air pollution on forests, but is now being adapted to monitor for both pollution and climate conditions. It is one of the largest bio-monitoring projects in the world, with two levels of monitoring which span several countries. Current monitoring indicators include local air quality and meteorology, atmospheric deposition, litterfall (biomass and chemistry), soil and soil chemistry (e.g., soil solution chemistry, dissolved organic carbon, plant available sulphur), foliar biomass and chemistry (i.e., foliar chemistry indicates nutritional status of tree) crown density and DBH (annually), phenology, ground vegetation composition (cover and species comp) and community structure (tree recruitment), deadwood (abundance and condition), biodiversity indices (e.g., bryophytes under coniferous tree species (i.e., lower plant groups) and higher plant groups), and above-ground carbon stock change.
Global Climate Observing Systems (GCOS) http://www.wmo.int/pages/prog/gcos/index.php	Internationally coordinated network of long-term surveillance systems designed to provide global, comprehensive, and continuous observational data regarding the state and variability of the entire global climate system. It plays a major role in ensuring that observation systems meet international requirements and can further provide much needed information for decision-making.
Food and Agriculture Organization (FAO) of the United Nations Global Terrestrial Observing System (GTOS) www.fao.org/gtos	International observation network developed to increase scientific understanding of climate change impacts on terrestrial ecosystems and ecological processes. GTOS Essential Climate Variables (ECV) for terrestrial monitoring include: albedo, biomass, fire disturbance, fraction of absorbed photosynthetically active radiation (FAPAR), glaciers and ice caps, groundwater, lake levels, land cover (including vegetation type), leaf area index (LAI), permafrost and seasonally-frozen ground, river discharge, snow cover, and water use.
International Long-term Ecological Research Network (ILTER) http://www.ilternet.edu/	Global network of LTER sites and researchers. The network focuses on long-term, ecological and socio-economic, site based research and encompasses numerous ecosystems around the globe, including 26 in the US.
United Nations Educational Scientific and Cultural Organization UNESCO Global Change Monitoring Programme	The UNESCO Man and Biosphere program was originally created as a Biosphere Reserve program and spans 94 countries. It is now being adapted to monitor global climate change in all of the major mountain regions in the world and will be the basis for the Global Change Monitoring Program.

Monitoring Framework or Program	Characteristics
British Trust for Ornithology: Climate Change Research http://www.bto.org/research/climatechange.htm	The BTO uses long-term data sets such as the Common Bird Census (CBC), National Ringing Scheme, and the Nest Record Scheme to monitor potential impacts of climate change on bird population sizes, ranges, and breeding events such as arrival on grounds, timing, survival and success. Other relevant research included testing a suite of indicators for bats, marine and terrestrial mammals, fish, turtles, and birds. Indicators used often span several species, rather than just one. Examples of indicators include the change in relative abundance of trans-Sarahan migrants, change in reproductive output of shorebirds, abundance of bats at underground hibernation sites
Center for Ecology & Hydrology – Environmental Monitoring at the Center for Ecology and Hydrology http://www.ceh.ac.uk/science/EnvironmentalMonitoring.html	A network of greater than 180 monitoring sites in Great Britain covering a broad range of ecosystems. Monitoring and research topic areas include animal taxa, soils, vegetation, water, air chemistry, and meteorology.
United Kingdom Environmental Change Network (ECN) http://www.ecn.ac.uk/environmental_indicators.htm http://www.ecn.ac.uk/ICCUK/	Long-term monitoring program designed to detect, monitor and interpret environmental change in the United Kingdom. Indicators include 34 climate change indicators and additional biodiversity and water quality indicators affected by climate change.
Climate Change and Freshwater http://www.climate-and-freshwater.info/	The project aims to define indicators and investigates the effects of climate change on European rivers, lakes and wetlands in both cold and temperate ecoregions. It first gives an overview of current indicators being used for monitoring frameworks, and then suggests indicators for climate change impacts. It goes on to assess how individual species are affected by climate change, and then finishes by describing case studies of how specific indicators are being used.
Hectares BC http://www.hectaresbc.org:22080/app/habc/HaBC.html	Collaborative partnership project aims to integrate data on natural resources, land use and the environment and provide an application for spatial analysis by the user.
Species Inventory (MOE) http://www.env.gov.bc.ca/wildlife/wsi/index.htm	The purpose of this project is to store and document all species inventory data in B.C. Wildlife species inventories include all surveys undertaken to determine the presence or abundance of any wildlife species.
Climate Related Monitoring Program (CRMP) http://www.env.gov.bc.ca/epd/wamr/crmp.htm	The Ministry of Environment, along with the Ministries of Transportation and Infrastructure, Forests and Range and Agriculture and Lands, are working together with BC Hydro to make long-term meteorological data available for professional users involved in climate change analysis and adaptation.

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B.C. Ministry Forests and Range, Victoria, B.C.

For more information about the Forest and Range Evaluation Program, visit our website: http://www.for.gov.bc.ca/hfp/frep

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