Executive Summary

This report, "Climate Change and Biodiversity: Implications for Monitoring, Science and Adaptive Planning," identifies the research needed to fill information gaps that hinder effective modelling of the impact of climate change on Canada's biodiversity. Critical uncertainties remain about Canada's socio-economic, climatic and ecological systems, specifically how regional and local climate impacting biodiversity will change, and how species and ecological systems will respond to a changing climate. We are limited in our ability to measure or predict specific impacts, including the net result of various possible climate change impacts on multiple species or in given locations, as well as their rates of change. There is a pressing need for climate and climate change models to produce variables that facilitate ecological management and policy direction.

1. The Biodiversity/Climate Change Issue

The global decline in biodiversity is now recognized as one of the most serious environmental issues facing humanity. Despite its acknowledged importance, however, ecosystems are being degraded and species and genetic diversity are declining at an alarming rate. This is due to the impact of a number of forcing agents, including a changing climate, growing human populations and increasing resource consumption. A global goal has been defined: to reduce the rate of biodiversity loss by 2010.

Climate change has been described as one of the major challenges of the 21st century to conserving biodiversity. The threat it poses is compounded by the fact that humans have altered the structure of many of the world's ecosystems through habitat fragmentation, land degradation, pollution and other disturbances, making them more vulnerable to further changes.

Canada's climate is already changing: generally speaking, the country is getting warmer and wetter. Sub-regions of Canada are changing at a faster rate than other regions. In Ontario, for example, significantly wetter conditions have already been recorded in the lee of the Great Lakes in the shift of the "normal" climate from 1961-1990 to the most recent 30-year period, 1971-2000. Likewise, temperature changes are more rapid in some sub-regions, such as the Arctic, than in others. Overall, the adaptation deficit, as measured by insured and uninsured losses, has been increasing exponentially over the last 30 years, caused in large part by extreme weather conditions.

In Canada, climate change is one of multiple threats facing biodiversity. The fragmented landscape is creating islands of isolated habitats, which impedes the ability of biodiversity to adapt naturally to a changing climate. Many ecosystems have to simultaneously contend with invasive species, disease, acid rain, nitrogen loading, hunting and a host of other stressors. These impacts act synergistically to bring about even greater change.

Responses to deal with these threats will require improved scientific understanding of the linkages between the climate, biodiversity and the processes of desertification, along with an enhanced capability to predict potential biodiversity and land-use changes.

Some knowledge does exist through previous research of the sensitivity, fragility and adaptive capacity of certain species to a changing climate, but there is considerably less knowledge around the integrated impacts of the physical and chemical atmosphere on multi-taxa species. Such knowledge is crucial in the Canadian context. In a northern ecosystem, the conservation of a single species may be more critical to the way that ecosystems function than it would in a highly diverse tropical ecosystem, with its abundance of species and genetic variations. Canada can ill afford to lose even one species in a climate where species have expressly adapted to harsher conditions.

Because the climate of the future will eventually respond to all of the greenhouse gases (GHGs) accumulated in the atmosphere, ecosystems and communities would still need to adapt to change even if all anthropogenic emissions were to cease immediately. Although a wide range of adaptation activities has been designed or planned by Canada, few have been implemented to date. In many cases, adaptation actions have been delayed because the knowledge base and partnership processes required to support implementation do not exist or must be strengthened first.

2. The Status of Biodiversity Conservation in Canada

Canada is a signatory to both the Convention on Biological Diversity (CBD) and the Cartagena Protocol on Biosafety. It has further responded to the issue of biodiversity loss by ratifying the CBD in Parliament, establishing a Biodiversity Convention Office, producing a Science Assessment on Biodiversity and adopting the Canadian Biodiversity Strategy. In addition, Canada has endorsed the findings of the Millennium Ecosystem Assessment, which itemizes the various goods and services provided by ecosystems and emphasizes civilization's overwhelming reliance on them.

Likewise, Canada is a participant in the United Nations Framework Convention on Climate Change (UNFCCC), which seeks to stabilize GHG concentrations in the atmosphere at a level that will avoid dangerous human interference with the climate system. It has also helped to draft action programs to manage dryland ecosystems and arid regions as part of the United Nations Convention to Combat Desertification (UNCCD).

The integration of adaptation and mitigation actions within the context of climate extremes, biodiversity conservation and sustainable development all call for greater synergy in implementing the CBD and other relevant multilateral environmental agreements. Canada has recognized that the implementation of the CBD, UNFCCC, UNCCD and the Canadian Biodiversity Strategy will play a significant role in combating desertification, reducing loss of biodiversity and helping ecosystems adapt to climate change. Joint action on these international measures will moreover facilitate synergies in protecting biodiversity, such as the reduction of GHG emissions from deforestation.

This current series of white papers has been prepared to identify the knowledge gaps that hamper Canada's ability to move forward on its international and national commitments to biodiversity conservation. The lack of human and financial resources has been the greatest barrier to the implementation of the Canadian Biodiversity Strategy. In addition, a monitoring network support capacity is necessary to undertake coordinated climate change/biodiversity monitoring and research in Canada.

3. Gaps in Monitoring

3.1. Climate

The existing climate monitoring network in Canada is sparse, even in densely populated areas, such as southern Ontario and Quebec. This has led to large gaps in observations and subsequent analysis of long-term means, trends and extreme climatic conditions. Given the sparseness of the network and station closures, particularly in the northern regions of Canada, it is not possible at the present time to create a reliable "Atlas of the Climate of Canada."

The variety of observation stations, with their considerable diversity of technology – especially among electronic auto stations, which are owned and operated by a multitude of agencies – has led to analytical chaos. There are few regulations to govern observing standards, programming and quality control of the observed climatic data.

Confounding the expectations of scientists, long-term climate data are neither readily available nor easily integrated into research studies. Scientists have been disappointed to learn that it may take months of analytical processing to prepare useable climate datasets.

The lack of data is hindering climate model verification. To improve model verification, more complete observations must be obtained in certain regions and weather stations need to be established in diverse environments, particularly forests. All but one of the previous attempts to establish co-located climate monitoring towers in forest biodiversity observing sites have failed due to lack of technical knowledge within the bioscience community. More than half of Canada is forested, yet monitoring and understanding of our forests' buffering capacity in the face of the changing climate is virtually non-existent.

3.2. Biodiversity

Significant gaps exist in the Canadian observation network, impacting scientific reliability to evaluate past, present and future biodiversity. Current monitoring sites are, for the most part, sites of opportunity, owned, operated and managed by community groups without ongoing technical support.

Financial and institutional support is insufficient to keep current biodiversity monitoring sites active or to establish new ones. Continued support for periodic re-measurements of climate change/biodiversity monitoring sites is vital.

Outside of government, the only other major climate change/biodiversity monitoring project that remains to this day is the nationwide, community-supported network of biodiversity observing sites affiliated with the Smithsonian Institution. Despite financial constraints after the initial installation and measuring of sites and technical limitations with the climate stations, this network has played an important role in developing knowledge, information and biodiversity monitoring databases within Canada. It has helped to identify new species of forest canopy Lepidoptera (including a hybrid of pine and spruce budworm), signalled the first occurrence of gypsy moth in one area and documented the advancement of new fungus species detrimental to tree growth as a result of climate warming. Furthermore, it has helped to develop and test the adaptation baseline and given us important information on impacts to biodiversity. The standardized biodiversity monitoring plot design allows compatibility and comparable reliability in data collected at different sites around the world. The use of a one-hectare plot gives a relatively large sample and is robust enough to capture both the biodiversity of a site in the tropics and in the Carolinian zone of southern Ontario at its most biologically diverse.

Along with protected areas (IUCN) and Global Biosphere Reserves (UNESCO), the Smithsonian Institution Monitoring and Assessment for Biodiversity (SI/MAB) sites provide an essential starting point for creating an effective, community-based platform to monitor changes in ecosystem functioning and resilience. The development of a nationally coordinated monitoring program, including maintaining or reinvigorating current long-term climate change/biodiversity monitoring sites and establishing new ones, should be considered a priority. The program must have clearly defined goals and sampling designs that determine the variables to be monitored. Globally standardized biodiversity monitoring protocols, flexible and accommodating of different forest environments, need to be adopted as the national standard in place of the confusion that currently exists.

To meet the full range of monitoring requirements, permanent plot networks should be expanded to include sites subject to a broader range of climate extremes, human activities and impacts. It is critical to strategically establish biodiversity monitoring sites now, prior to extreme climatic events (e.g., ice storms, extreme wind and drought), allowing for direct comparisons of impacts. Additional sites need to be established nationwide across meaningful gradients to model key climate variables, such as temperature and drought frequency, within and between bioregions.

To be effective, the comprehensive monitoring program has to address the four main concerns under which most biodiversity monitoring activities can be categorized: monitoring based on species at risk; monitoring based on population trends; monitoring based on status and trends in habitat-based biodiversity; and monitoring based on threats to biodiversity (e.g., climate change).

A standardized methodology is required for applying multi-taxa designs. While there are protocols for monitoring multi-taxa, there is no integrated structure and governance to support such monitoring in Canada. The SI/MAB sites have already proven useful for multi-taxa monitoring. However, multi-taxa monitoring needs to be expanded to encompass more ecosystems across Canada; a few super sites will not suffice.

Community monitoring and measuring of climate change/biodiversity sites needs to be adopted as a key strategy for early detection of invasive species and the best use of available resources. Staff trained in biology and climatology are necessary to support community initiatives in climate change/biodiversity monitoring. At present, few people with highly specialized taxonomic training are available to lend expertise, nor can most community initiatives call upon people with highly specialized climate training and instrumentation.

4. Gaps in Science

4.1. Climate

The modelling of initial conditions, interactions and feedbacks in the climate system from large impact features, such as clouds, ice and large bodies of water (e.g., the Great Lakes), needs to be improved. Global Climate Model (GCM) resolution is coarse (typically no better than 2° longitude by 2° latitude) and must be enhanced by statistical or dynamical downscaling so that models can be verified and sensibly applied to biodiversity. This will require considerably more financial and computational resources, as computational demand increases exponentially with finer resolution.

Statistical downscaling input data have been developed for only a few Global Climate Models (GCMs) and emission scenarios. Some regional climate modelling has been done but not for all areas. The Canadian Climate Change Scenarios Network (CCCSN) is in a position to add other model/scenario predictor input data.

Global/Regional Climate Model resolution can also be improved by expanding the areas covered by regional climate modelling experiments and a greater representation of specific high-priority regions, such as the Great Lakes, the Arctic and Hudson Bay. Inadequate representation in these areas impedes climate change assessment and may, in some cases, underestimate actual climate trends.

Models need to be developed relating climate change scenarios to biodiversity. The prediction of climate change effects on key biodiversity drivers and likely biodiversity outcomes requires greater baseline information. Model output parameters should be expanded to include those important to biodiversity, such as freeze-thaw cycles, drought frequencies, wind intensities and snow-cover duration.

Climate models are needed to predict the probability of climate extreme events within climate change scenarios, along with their probable impacts. Improved forecasting of changes in the severity and frequency of an extreme event like flooding must be synthesized with models that predict the impacts of gradual changes, such as sea-level rise, saltwater intrusion and increased coastal erosion.

Methods to include estimates of climate extremes and climate variability, in addition to model averages, are essential. Since most outputs of climate models are means (i.e., mean annual temperatures), specific variables that will measure the extremes need to be developed. Extreme indices determined from the atmosphere must be coupled with extreme variables that are important to biodiversity, as it is often the extremes that reshape biodiversity. Besides the atmospheric extreme indices that have already been developed (five-day maximum precipitation, simple day intensity index of precipitation, heat wave duration and consecutive dry days), there is a need to develop other extreme indices that have a direct bearing on biodiversity, such as windstorms, wind intensity, snow cover, freezing rain, and soil temperatures. The results should be used in conjunction with other models that predict the impact of gradual changes in climate in order to gauge the unified effects of sudden and gradual change. Spatially resolved projections for water availability, water balance, river flows, increasing demand on river flow for human use and reduced flows, which will all affect water quality, are specifically required.

A forest climate monitoring program in highly altered landscapes needs to be co-located in the SI/MAB sites to understand the biometeorological exchanges and processes that influence biodiversity. Results from one forest biodiversity monitoring site indicated that forests can potentially have a profound buffering impact on changes in climate. This buffering capacity protects animals from overly rapid temperature increases and mitigates the effects of climate change on resident populations by providing an oasis with a cooler climate.

4.2. Biodiversity

Committed scientific research based on climate change/biodiversity monitoring sites is necessary. Research programs on climate change/biodiversity monitoring need to be implemented, using a paired plot design to measure managed versus unmanaged impacts for forest management, ecotourism and agriculture.

SI/MAB sites can help to facilitate forest management comparisons, including evaluation of harvest and silviculture techniques. For example, research conducted on one of these sites has indicated a potential maladaptation process in forests and a subsequent need for human intervention, such as planting to enhance diversity and increase forest adaptivity.

The consequences that climate change and climate extremes will have on biodiversity need to be more fully understood. The focus should be on identifying and redefining the demarcating thresholds in duration, intensity and severity of extremes below which ecological resilience and adaptive capacity declines. Again, the SI/MAB sites have proven useful for assessing the impacts of climate extremes, such as the recovery and mortality of trees affected by severe ice storms. This research can provide valuable information for predicting mortality and recovery rates and possible outcomes of future drastic weather events precipitated by climate change.

To facilitate investigations into the cumulative impacts of global change on forest biodiversity, a transect of biodiversity observing sites across physical, chemical and ecological gradients is required. Research on these sites will increase understanding of forest dynamics and ecosystem processes to help improve assessments of the impact of disturbance and better predict change.

Long-term climate change/biodiversity monitoring datasets are critical for research on global climate change. Further research is required to establish biodiversity monitoring sites that specifically track climate change, something the scientific community currently lacks.

It is not known how extreme events shape the edges of some species distributions. Improved identification of risk thresholds of climate extremes for biodiversity is crucial to better support the next generation of models.

Data sharing among partners establishing biodiversity monitoring sites remains inadequate. A central agency to support climate change/biodiversity monitoring is essential to ensure sharing of data, research and information.

5. Gaps in Adaptation Approaches and Integrated Research for Planning/Policy

To develop sound adaptation options under climate change, transfer functions (concepts of how ecosystems function, which can be used in another context or for a problem other than the one for which they were originally developed) must be identified relating interactions between key ecosystem processes and climate change, climate variability and extreme events.

Basic scientific knowledge about biodiversity and biodiversity-climate interactions needs to improve. Environmental indicators at test sites that are potentially within the influence of local or regional anthropogenic stressors should be assessed. Research is also required to determine new critical thresholds of climate extremes for multi-species, as well as ecosystems.

Improved modelling is necessary to investigate and predict potential interactions between climate change, disturbances, interactions between species and other factors affecting species' ranges and distributions. Models using biodiversity and climate parameters for multiple species, processes and ecosystems must be developed. In addition, threats and stresses likely to affect biodiversity need to be identified, along with their potential interactions with climate change impacts. Based on this knowledge of stresses and interactions, bio-climate models can then be enhanced to predict future eco-region scenarios and their implications for different management actions and ecosystem functions.

Risk assessment models that can be applied directly to biodiversity should be developed across Canada, specifically to assess the risk of species loss and habitat degradation. Tools and guidance in the form of scientific predictions of ecological states – especially ones that are scale-dependent and take into account climate extremes and rapid rates of change for planning/policy purposes – are necessary to pinpoint priority ecosystems and to formulate climate change adaptation options. The next generation of climate models also needs to address the current uncertainty around socioeconomic futures related to climate change, including future population dynamics, the development of new "greener" energy sources and technological advances.

Baseline and long-term climate change/biodiversity monitoring data are needed to define manageable levels of change and to assess climate change impacts. At present, few abiotic and biotic observations have been collected over the long term at the same site. An adaptation baseline must first be established to document change over time. The family diversity-by-heat adaptation baseline, illustrated in this report, could be used as an effective diagnostic tool to identify areas where the biodiversity is not in equilibrium with the present climate and also as an environmental predictive tool for climate change.

Current and predicted rates of climate change make it incumbent upon us to expand beyond classical approaches to adaptation (e.g., building of corridors, section 4.2.1) to accelerate and improve the adaptive capacity of ecosystems by building resilience. Studies indicate that many additional species will be lost if adaptation- and resilience-building actions are delayed, while management options will become more limited and expensive and have a lower likelihood of success. We urgently need to develop future adaptive management actions now. SI/MAB sites can help in assessing proactive adaptation options, such as the planting of trees from more southerly regions, which may be better able to respond to warming temperatures. Scenarios for managing extremes must be developed and tested and creative solutions identified without delay.

6. Strategic Recommendations

Establish one agency in Canada with institutional support and responsibility for the integrated monitoring of climate change impacts, including those relevant to biodiversity: a Canadian Action Network for Climate Change/Biodiversity Monitoring.

Put in place a support mechanism for a Canadian Action Network for Climate Change/Biodiversity Monitoring that will allow Canada to meet its national and international biodiversity commitments.

Facilitate the establishment of a "World Biodiversity Organization" (WBO), parallel to the World Meteorological Organization (WMO), to design global standards and protocols for monitoring.

Ensure integrated linkages between the Canadian Action Network for Climate Change/Biodiversity Monitoring and the global climate change/biodiversity monitoring network of Smithsonian Institution Monitoring and Assessment for Biodiversity (SI/MAB) sites.

Provide support for climate change and biodiversity research at all levels. Previous well-formulated and integrated monitoring, science and planning projects addressing climate change issues for biodiversity have lacked the political, managerial and financial support to be sustainable.

Provide support for sound monitoring, science and adaptive planning. Due to catastrophic gaps in monitoring, science and planning, there is little or no knowledge to guide policy development at any level. As a result, most actions taken on biodiversity and climate change are largely ad hoc and responsive, not anticipatory and preventative.

Establish more SI/MAB plots across ecological, chemical and climate gradients in highly altered landscapes in Canada to detect change and develop adaptation responses, including paired plots in managed and unmanaged landscapes.

Use the biodiversity framework grid to identity key goals and priorities for establishing proper sampling designs for new climate biodiversity monitoring sites, such as integrated and targeted networks, and for science, including research on ecosystem processes, assessment of impacts and monitoring change.

Expand the coverage of the biodiversity global site networks, which evaluate climate extremes under increasing human impact, by connecting them through GIS and remote-sensing-type technologies.

Use the proposed Hazard Identification and Risk Assessment (HIRA) process to help communities across Canada identify critical levels of vulnerabilities at which a native ecosystem is less able to adapt to the impacts of climate change and climate extremes.