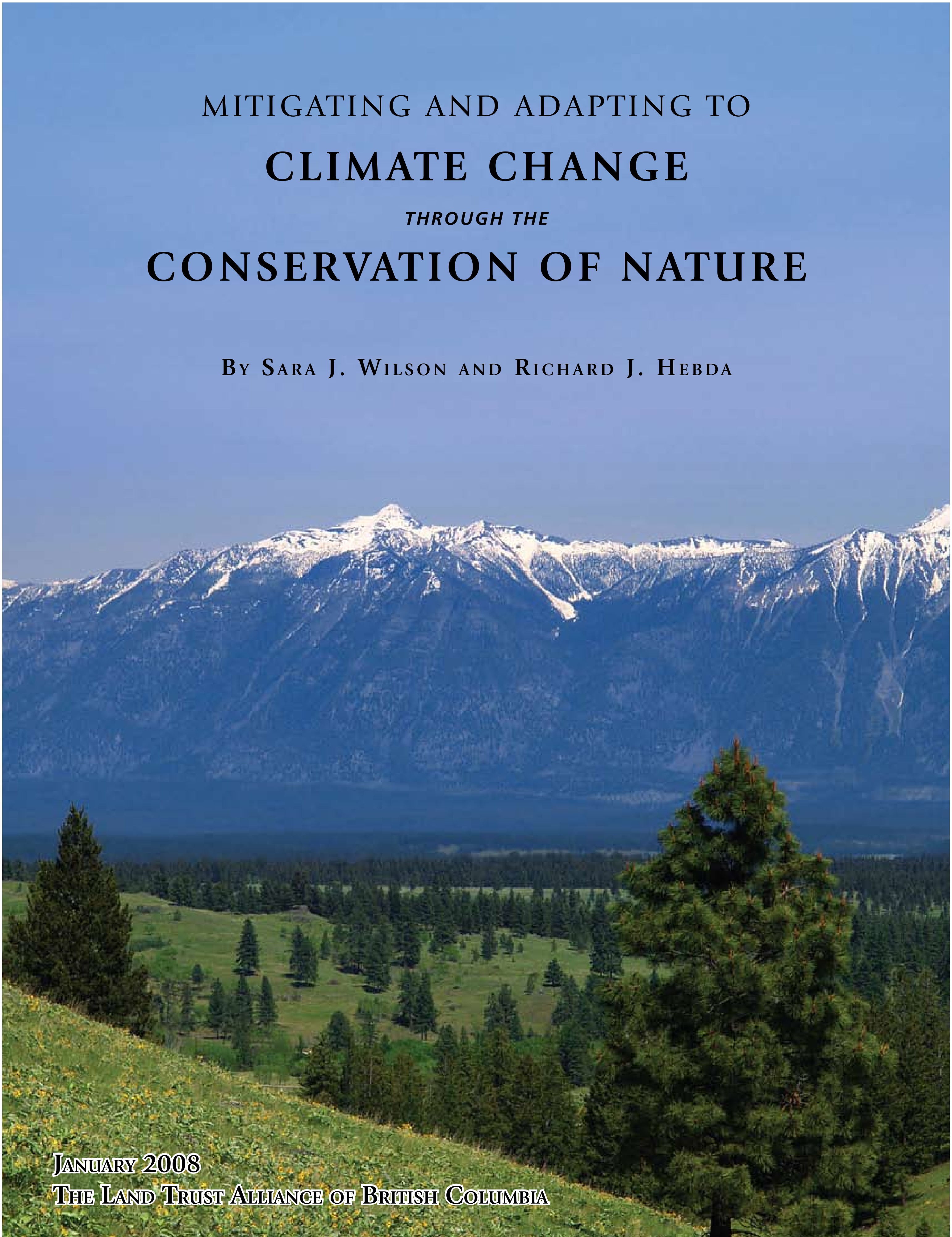


MITIGATING AND ADAPTING TO

CLIMATE CHANGE

THROUGH THE

CONSERVATION OF NATURE

By Sara J. Wilson and Richard J. Hebda

January 2008
The Land Trust Alliance of British Columbia

Acknowledgements

The Land Trust Alliance of British Columbia initiated this report in response to increasing concerns about climate change. We are grateful for the extensive economic review and expertise provided by Sara J. Wilson. Dr. Richard Hebda provided his authoritative research on climate change and added several original contributions to this report. We are thankful to them both, plus the many people whose names appear below who provided materials, review or assistance for this report.

Sheila Harrington, Land Trust Alliance of BC
Dan Buffet, Ducks Unlimited Canada
Jan Kirkby, Environment Canada
Shyanne Smith, Garry Oak Ecosystem Recovery Team
Pierre Lachetti, Nature Conservancy of Canada
Kathryn Martell, The Land Conservancy of BC
Tory Stevens, BC Ministry of Environment
Dr. Katherine Dunster, Land Trust Alliance of BC
Trevor Murdock, Pacific Climate Impacts Consortium
Werner Kurz, Canadian Forest Service

Editorial, graphic and promotional support:

Sheila Harrington, Valerie Huff, Patricia Walker
Dan van Stolk
David Suzuki Foundation
Todd Carnahan
Cover photo: Tim Ennis, Nature Conservancy of Canada
–View from Pine Butte Ranch

Many thanks to Mountain Equipment Coop and VanCity for their financial contributions toward the dissemination of this report.

We are especially thankful to the following for providing financial support:

The Bullitt Foundation

Ducks Unlimited Canada
Conserving Canada's Wetlands

THE REAL ESTATE FOUNDATION OF BRITISH COLUMBIA

Foreword

Climate change has brought increased awareness to our environment, resulting in public and political calls for action to address this significant challenge. Despite numerous conferences, lectures, educational material and scientific papers on the topic, little attention has been paid to the conservation of nature and its ecosystems as a substantial strategy to both mitigate and adapt to climate change.

The projected and real consequences of climate change are now being recognized, along with considerable demand for alternatives to the energy and transportation systems that have dominated the last half century. Public and political response has focused on mitigating human impacts to reduce emissions and expanding on technological solutions. However the protection of natural ecosystems that counter climate change is equally as important. This report analyses the role and values that natural ecosystems play to mitigate and adapt to climate change, the predicted impacts of climate change on ecosystems in British Columbia, and strategies to address climate change, especially for land conservation and ecosystem protection.

In 1997 the Land Trust Alliance of British Columbia (LTABC) became the first of four provincial alliances of land trusts now working across Canada. The LTABC board consists of representatives from land trusts across the province, plus associated land professionals. Our 2007 membership of more than 90 includes 32 land trusts, 26 associated organizations whose goals include land stewardship or management, plus another 32 individuals primarily working in the field of conservation. We provide education, research, communication and financial services to our members and the public to promote and support the stewardship and conservation of our natural and cultural heritage. Currently, the LTABC estimates that the combined amount of land protected by British Columbia's land trusts is 253,863 hectares or 627,041 acres – larger than the Metro Vancouver area. See Appendix 1 for a list of land trusts, their missions, regions, and lands protected.

Anna's Nest
Photo: Todd Carnahan

In 1994, the BC Land Title Act was changed to enable non-government organizations to hold conservation covenants on private lands. The Act opened the door to the formation of one province-wide and many new regional and local land trusts, adding to the two existing national and one provincial conservation organization that previously existed. As a result of this change, more than 30 local, provincial and national conservation organizations are now working across BC to protect private land for long-term public benefits - through direct acquisition, perpetual conservation covenants and by arranging temporary stewardship agreements or management agreements.

The Land Trust Alliance of BC has commissioned this report to raise awareness of the increasing need to protect the natural ecosystems of our Earth, habitats for wildlife and biodiversity, native plants and species on all landscapes, and wilderness and park areas for our own health, and the health of all life. We also hope that by providing substantive analysis of ecosystem values and projected climate change impacts in BC ecosystems, that conservation organizations, associated government agencies, land use professionals and land trusts will be better able to plan conservation, restoration and protection strategies considering the projected and real impacts of a changing climate in British Columbia.

Without increasing the protection of our dwindling natural ecosystems, including the life-supporting services and knowledge that they provide, our communities and the diversity of other wildlife and species, including the Earth's biosphere, will have little ability to adapt to the upcoming challenges of climate change. As this report clearly demonstrates, protecting ecosystems achieves mitigation and adaptation goals, in addition to providing the protection of the essential ecological services and processes in the face of a changing climate.

Sheila Harrington,
Executive Director, The Land Trust Alliance of British Columbia

Conservation organizations, government agencies, public and private foundations, corporations and businesses associated with land development or resource extraction, and the general public need to recognize that protecting natural areas is an essential and cost effective way to mitigate and adapt to the impacts of climate change.

1. The Canadian Land Trust Alliance defines a land trust as: "a charitable organization that, as all or part of its mission, actively works to conserve land by undertaking or assisting in land or easement/ covenant /servitude acquisitions, or by engaging in the stewardship of such land or easements /covenants/servitudes."

2. A conservation covenant is a legal agreement between a landholder and a designated land trust organization. It is registered on title to the land and will remain in effect after the land is sold or transferred, binding future owners of the land to the terms of the covenant.

Executive Summary

> **It is not the strongest of the species that survive, nor the most intelligent, but the most responsive to change.**
>
> ***- Charles Darwin (1835)***

Climate change will have wide-ranging impacts on natural, managed and human systems. These impacts pose challenges and opportunities for human settlement and resource use as well as the conservation, management and stewardship of lands. The combination of climate change and human conversion and the degradation of natural landscapes threatens ecosystems and the services they provide.

Current and future climate change will impact forests, wetlands, rivers, and coastal areas, as well as the human communities that depend upon them. International studies have reported that northern forests and the Arctic region are the most affected by the changing climate. Climate in northern areas, including British Columbia is warming, and will likely continue to warm, more rapidly than the global average

This report provides an overview of:

- the role that natural ecosystems play to mitigate and adapt to climate change;
- the projected impacts of climate change on ecosystems in British Columbia; and,
- strategies to reduce impacts, focusing on conservation and ecosystem protection.

Valuing Nature in an Era of Climate Change

Biomass and soils, the living carbon of ecosystems, remove and store carbon dioxide from the atmosphere naturally. Adapting to and reducing the degree of climate warming demands more than reducing or replacing the use of ancient carbon, namely fossil fuels, for energy. One of the essential life support services provided by ecosystems is the protection of the climate through carbon cycling. We suggest that "Carbon Stewardship" is an important concept that needs to be incorporated into policies and planning for climate change. This includes protecting the carbon stored in natural and semi-natural ecosystems.

Natural ecosystems provide an enormous range of goods and services that sustain our health and well-being including food, materials, clean air, clean water, nutrient cycling, as well as recreation, education and spiritual uplift. A recent global assessment of human impacts on the world's ecosystems found that 60 percent of ecosystem services including fresh water, air and water purification, and the regulation of climate are in decline. The loss of natural habitat worldwide due to human impact has resulted in an estimated loss of $250 billion per year. Climate change will exacerbate the degradation of ecosystems and the loss of ecosystem services.

Natural ecosystems provide key services related to climate change notably carbon dioxide absorption and carbon storage. For example, global ocean and land ecosystems typically remove about 50-60 percent of human-caused carbon dioxide emissions. Intact natural ecosystems are the most resilient to change, therefore they provide the best opportunities for adaptation as the climate changes through the provision of corridors for migrating wildlife, water storage, and flood protection. Intact natural systems also store the most carbon.

British Columbia ecosystems play an important role in carbon cycling and storage. Forest ecosystems in particular are huge reservoirs of carbon, storing it in living plants, soil and peat. Globally, forest ecosystems contain more than half of all terrestrial carbon and account for about 80 percent of the exchange of carbon between terrestrial ecosystems and the atmosphere. British Columbia forests have the some of the highest carbon stores in Canada averaging 311 tonnes per hectare with some coastal forests holding 600 to 1,300 tonnes per hectare. Based on the average estimates, the total carbon stored by BC's forests amounts to 88 times Canada's annual greenhouse gas emissions. (989 times BC's GHG annual emissions). This stored carbon is worth an estimated total of $774 billion, or $62 billion per year ($1,072 per hectare). In addition, British Columbia's peatlands hold 6.8 billion tonnes of carbon and remove a further 1.5 million tonnes per year.

Conversion of forests to non-forest land use rapidly releases stored carbon as carbon dioxide impacting the atmosphere and climate for centuries. The conversion of a coastal old-growth forest to a younger plantation forest reduces carbon storage by 305 tonnes of carbon per hectare over a 60-year rotation, and total carbon storage is reduced for at least 250 years. For example the past century's conversion of five million hectares of old-growth forests to younger plantations in Oregon and Washington released 1.5 to 1.8 billion tonnes of carbon to the atmosphere. As a result, the conservation of British Columbia's natural ecosystems can have a strong impact on the avoidance of carbon emissions. In comparison, the planting of trees on an unforested site has no net carbon dioxide benefits over the first 10-20 years, and thereafter the benefits are much less than the avoided emissions from a protected forest of equal area.

Nature Under Threat from Climate Change

British Columbia's ecosystems and the services they provide are at high risk to the impacts of climate change. Average annual temperature and precipitation have changed significantly in British Columbia consistent with the projections from climate change models. Climate change impacts such as earlier snowmelt, the mountain pine beetle outbreak, and declining health in western redcedar are already evident in British Columbia.

Studies of fossil records demonstrate that the projected changes in British Columbia's climate will result in a different pattern of terrestrial and aquatic ecosystems than exists today and will force widespread species migrations. Climate impact models project several changes across our landscapes including an overall shift of southern ecosystem types towards northern BC. Dry forest and grassland ecosystems, and lowland conifer forests will spread upslope along the coast and in the interior. A major decline in spruce forests and alpine ecosystems will occur. A wide range of changes in wetlands and aquatic ecosystems such as the drowning of estuaries and erosion of shorelines are predicted as sea level rises. In addition, increased damage from storms, flooding, erosion, droughts, and pest outbreaks are expected.

Strategies to Reduce the Impacts of Climate Change

Carbon Offsets

Offsets are intended to counteract greenhouse gases that are emitted into the atmosphere at a specific source by sequestering them elsewhere. Carbon offsets are purchased by individuals and companies to offset their own carbon emissions. The voluntary market for carbon offsets by corporations and individuals is growing very rapidly. In 2006, it was worth an estimated $100 million.
The major concerns regarding the validity of voluntary carbon offsets are the verification of the quality of offsets, the long term accountability of projects, and the lack of a universal standard. Some offset providers have a certification

process, but it is difficult to verify the validity of many projects. The key issues are whether the offset is in addition (i.e. additionality) to what would occur as a normal matter of course (i.e. business as usual), and whether or not a project results in increased GHG emissions elsewhere (i.e. leakage).

There is however much support for carbon offsets because they prompt people and communities to factor in the cost of their carbon footprint when making decisions. Carbon offsets also result in a price on carbon, a value that begins to filter into people's thinking and business operations.

Carbon offsets for the protection of stored carbon (i.e. avoided emissions from ecosystem degradation and conversion), are not currently available in carbon markets, although reliable institutions such as the Chicago Climate Exchange provide offsets from managed lands including agricultural, forest and range lands. There are also other mechanisms for land trust and conservation agencies to directly facilitate financial contributions towards the protection of forests and peatlands as a gift or to reduce a business or individual's carbon footprint.

British Columbia's Climate Change Initiatives

The BC government has mandated the reduction of GHG emissions by at least 33 percent below 2007 levels by 2020, and that government agencies become carbon neutral by 2010. For every tonne of GHGs emitted by government travel, the province will invest $25 in a new BC Carbon Trust to ensure that taxes are invested in valid offset projects in BC. Also a new carbon-trading registry will allow BC residents to offset their personal carbon footprint beginning in 2008.

BC's local governments also have committed to be carbon neutral by 2012. The Union of BC Municipalities and the BC government will establish a joint Green Communities committee and Working Groups to develop actions to address climate change and meet the 2012 target. These initiatives may provide opportunities for land trusts and other conservation agencies to form partnerships on land-use planning, land stewardship projects, and conservation or management agreements on natural areas for building resiliency to climate change.

Conservation Strategies: Adaptation and Mitigation

The protection of land offers multiple values in addition to fostering biodiversity. The protection of healthy, functioning and diverse ecosystems provides resilience for natural areas and nearby human communities and reduces the risk of rapid changes and loss of ecosystem values and services. In the last ten years, British Columbia land trusts have protected more than a quarter million hectares of land in trust for public benefits. Land trusts will benefit by expanding their partnerships with local, provincial and federal agencies and protected area strategies to ensure that the areas and ecosystems will continue to provide benefits to society.

It is now imperative that land use planning including conservation initiatives anticipate climate change impacts and integrate appropriate strategies to avoid risks and optimize opportunities. Local, regional and national agencies will need to review their objectives in the context of climate change. For example, conservation planning for relatively large areas and a wide range of values are at less risk to climate change than those focused on small areas for specific values such as single species conservation. In addition, it will be even more important for conservation objectives to be linked to other land management decision-making.

Decisions concerning land acquisition or conservation strategies need to consider the potential impacts of climate change, links and corridors to other natural lands for species migration, and in setting the priority for multiple ecosystem values rather than a single specific value. Providing the greatest options for the changing character of habitats ahead will be critical.

Decision Support for a Responsive Climate Change Strategy

We ranked BC's ecosystems according to their sensitivity to climate change, carbon storage capability, biodiversity habitat, and the degree of human impacts. Accordingly, for BC ecosystems:

1. The Coastal Douglas-fir zone is of very high importance.
2. The Interior Douglas-fir and Ponderosa Pine zones, Garry Oak and related ecosystems and wetlands are of high to very high importance.
3. Coastal Western Hemlock, Bunchgrass, and Interior Cedar Hemlock zones are of medium importance.
4. Mountain Hemlock, Sub-Boreal Spruce, Sub-boreal Pine Spruce, Boreal White and Black Spruce, Spruce Willow Birch, Montane Spruce and Engelmann Spruce- Sub-alpine Fir and the aggregate Alpine Tundra zones are of low to medium importance.

Conclusions

The immense stores of carbon in existing ecosystems are of great importance for both mitigation and adaptation to climate change, especially compared to the potential of removing atmospheric carbon by planting new forests. Carbon storage in young forests takes a long time especially in terms of replacing lost carbon. Second, because there is so little time to slow global warming, the priority should be on preventing carbon losses and conserving the carbon stores that exist. Third, by protecting existing ecosystems there will be a wide range of habitat to provide connecting corridors for plant and animal migration as the climate warms. Fourth, the protection of intact ecosystems provides resiliency for ecosystems and the communities that depend upon them.

This report clearly demonstrates that conserving land with healthy natural ecosystems is a cost effective and important strategy to both mitigate and adapt to climate change. The report concludes that the conservation of intact ecosystems for the numerous values and services they bring humans, in addition to providing habitats for wildlife, biodiversity and ecosystem functioning and the health of communities needs to be a significant part of any climate change strategy for both mitigation and adaptation to changing climates.

TABLE OF CONTENTS

"The change with the greatest potential to alter the natural infrastructure of Earth is the chemical experiment humans have been conducting on the atmosphere for the past century and a half."

Living Beyond Our Means: Natural Assets and Human Well-Being Millennium Ecosystem Assessment

Introduction

Warming of the earth is now confirmed according to the latest assessment by international scientists participating in the UN-sponsored Intergovernmental Panel on Climate Change (IPCC).[2] The release of the Fourth Assessment Report (FAR) on the science of climate change by international experts states that global atmospheric concentrations of greenhouse gases (GHGs), namely carbon dioxide (CO_2), methane and nitrous oxide, have increased markedly. This is demonstrated by the increase in atmospheric concentrations of CO_2, which have risen by about 30 percent since 1750 (from 280 parts per million (ppm) to 379 ppm in 2005), exceeding by far the natural range over the past 650,000 years.[3] Approximately two-thirds of human-caused CO_2 emissions are a result of fossil fuel burning for energy, with land-use change contributing about one-third.[4]

Human activities contribute to climate change by altering the amount of greenhouse gases and aerosols (small particles) in the Earth's atmosphere. These changes affect climate by shifting the Earth's energy balance especially between the incoming and outgoing solar energy. Changes in the level of gases and particles in the atmosphere can lead to a warming or cooling of the climate system. Since the beginning of the industrial era, human activities have had a net warming influence.

The rapid warming of the Earth is already evident on the ground. Observations by scientists show increases in global average air and sea-surface temperatures, widespread melting of snow and ice, and rising global sea levels.[5] The FAR predicts an average rise in temperature of about 0.2 degrees Celsius per decade over the coming decades. In the best case scenario, the climate will warm by about 1.8 degrees Celsius by the end of this century; however, this scenario assumes that major shifts to clean technologies and lower global GHG emissions. If our economies remain fossil-intensive, the climate is projected to warm by 4 degrees Celsius or more by 2100.

Climate change will have wide-ranging impacts on natural, managed and human systems. Rising temperatures already are affecting many natural systems and processes globally. Glacial lakes are increasing in area because of melting glaciers, permafrost is melting, and there are more rock avalanches in mountainous regions. Spring melt runoff and earlier spring peak discharge have increased in many glacier and snow-fed rivers. Birds are migrating earlier, and plant and animal ranges have begun to shift upwards in elevation.

The impacts and costs of climate change will vary regionally, with the projected amount of warming generally increases as one moves north in the Northern Hemisphere. This means that Canada is considered to be a high impact zone for climate change. Canada also contains many of the high-risk landscapes such as mountainous regions, sub-boreal and alpine regions, coastal and other low-lying areas, forests with high fire and insect risk, and cities that experience heat waves. A recent study by the British treasury department found that if we do not take action now to halt the ongoing increase of atmospheric carbon dioxide, the overall costs and risks will be equivalent to at least 5 percent of global gross domestic product (GDP) each year, and maybe even more - costing human society as much as 20 percent of its yearly GDP.[6] The anticipated changes in climate[7] will almost certainly transform many of the landscapes and ecosystems of the Earth including those in British Columbia.

Climate change is rapidly becoming a key focus for environmental support and action. There have been numerous conferences, lectures, educational materials and scientific papers to address the issue. It is widely recognized that the conservation and protection of intact natural ecosystems are essential for sustaining biological diversity and the ecosystem services (such as clean air and water) that humans depend upon. However, it is only recently that the importance of protecting natural areas has been considered in terms of mitigating and adapting to climate change. Conserving our ecosystems takes on even greater importance in a time of climatic change and ecological flux.

In the IPCC FAR, climate scientists clearly express the immediate need to protect natural values:

> ***"Expansion of reserve systems can potentially reduce the vulnerability of ecosystems to climate change. Reserve systems may be designed with some consideration of long-term shifts in plant and animal distributions, natural disturbance regimes and the overall integrity of the protected species and ecosystems."***[8]

This report examines the values of natural ecosystems and recommends strategies associated with their conservation and protection in the context of climate change. In the following chapters, the importance of land conservation as a tool for adaptation to and mitigation of climate change is considered. The report begins with a discussion of the value and services of natural landscapes, and then assesses the potential impacts of climate change on British Columbia's ecosystems. The importance of conserving land and natural ecosystems is examined in addressing climate change. In addition, the mechanism and suitability of carbon trading and markets is considered because it has special significance to land conservation. The report finishes with a specific discussion of the issue of climate change in relationship to land stewardship including a decision support strategy for land trusts.

The strategic guidance to conservation land trusts is a key element because these organizations work in communities across BC particularly on private lands, where the bulk of the endangered ecosystems and human land-use impacts occur. Conservation organizations and agencies, as well as policy makers, planners, land-use professionals and the general public have an important role in mitigating and adapting to climate change. Much of the information and ideas presented herein may prove useful to these groups as they face the climate change challenge.

Talking Mountain Ranch, large ranch on the Fraser River, owned by TLC The Land Conservancy of British Columbia.

Carbon Stewardship

Living carbon: organisms and ecosystems; sustain humans, ecological process; provide resilience and raw material for future ecosystems and use; remove CO_2

Dead carbon: organic matter in soils, wastes; sustains living carbon, stored carbon, bio-energy source

Ancient carbon: fossil fuels; ready and reliable energy source; predominant cause of climate change

Carbon Stewardship:

Integrating mitigation and adaptation

The complexity of the climate change issue is daunting. No clear framework has yet to emerge for organizing the elements and challenges of the issue and evaluating effective strategies to deal with it. Most of the effort to address climate change is focused on reducing emissions from the use of hydrocarbons: that ancient carbon of oil, natural gas and coal. This is essential, but it pays inadequate attention to the importance of shifting energy dependence to bio-carbon or living carbon and to the impacts of climate change on the ecosystems and species upon which people depend. The living carbon element of the climate change challenge furthermore depends directly on the dead carbon of organic matter in soil and sediments.

The concept and approach of carbon stewardship, which encompasses all forms of carbon, provides a framework for developing and assessing effective strategies for the challenges and opportunities of climate change. This framework is especially pertinent to land and nature stewardship because it explicitly incorporates the living carbon of ecosystems, including the threats to it and the value of it, as part of the strategic initiatives on climate change.

Many of the direct impacts of climate change to people and their communities will be played out through the living carbon component such as forests, agricultural crops and marine ecosystems. For example, BC is contemplating the removal of huge amounts of organic matter for bio-energy from the forest landscape of central British Columbia devastated by the mountain pine beetle. The bio-energy thus generated offsets our demand on ancient carbon from hydrocarbons. Yet by removing this dead carbon we may jeopardize, and potentially starve the living carbon necessary for the recovery of future forests. In doing so, there is an increased risk for the living carbon to be converted rapidly from forest to less productive grassland ecosystems. With the tree canopy removed, the soils will warm causing organic matter to convert to CO_2 and be released to the atmosphere.

The appropriate stewardship of living carbon is a key component for addressing climate change. Forested lands and wetlands have a particular role in both mitigating climate change and especially in adapting to it because of the ecosystem goods and services they provide and their capacity to remove CO_2 from the atmosphere and store it in soils for the long term.

Our proposed Carbon Stewardship approach places the protection and conservation of land and natural systems at the same level of importance as the reduction of hydrocarbon use in terms of adaptation and mitigation. It emphasizes the role of land use and land stewardship in meeting the challenges of climate change. Most importantly, it broadens the choice of effective actions available to individuals, communities and organizations.

Part I: The Values of Nature in an Era of Climate Change

Natural Capital and Ecosystem Services

We are all ultimately dependent on ecosystems for the goods and services that they provide including the ability to grow food, breathe air, drink water, and experience nature. The resources and services that human populations obtain from ecosystems are referred to as our natural capital. Conventional economics uses the gross domestic product (GDP) as the primary indicator of a country's economic performance. The GDP measures only the market value of goods and services without accounting for natural capital assets and values. It does not recognize the value of ecosystem services until they become so degraded or scarce that human infrastructure has to replace the natural services that had been provided for free. Nor, does the GDP account for the costs of human impact on natural assets, such as the loss of natural values or ecosystem services due to extraction or pollution. As a result, the way in which we measure and count our wealth and well-being is misleading and incomplete.

Natural capital accounting takes stock of natural assets and the natural values that they provide, including ecosystem goods and services. This type of accounting includes land/water accounts that track the type, distribution and total area of land and water and the associated ecosystem goods and services that are provided by natural capital. As a result, the change in the provision of ecosystem goods and services, based on changes in ecosystem land/water cover due to human activities such as degradation from pollution can be determined.

Communities and governments are beginning to recognize the essential services that natural areas provide. The recognition and valuation of ecosystem services is an emerging trend both globally and nationally. For example, the United Nations Millennium Ecosystem Assessment studied the world's ecosystems and their services; and the decision in British Columbia . Canadian Forest Products Ltd, (also known as the Stone Fire case) by the Supreme Court of Canada confirms that ecosystem services have an economic value in law[9]. Disregarding the value of natural capital and their services in our socio-economic planning and measurements of progress and well-being will result in land-use planning and policy development that will steadily increase the pressures on our ecosystems (i.e. our "green infrastructure"). As the impacts of climate change begin to affect the Earth's ecosystems, places with low resilience and diminished green infrastructure will be the most vulnerable to adverse and costly outcomes.

Ecosystem Services of Natural Areas

Ecosystem goods and services have been defined as the benefits human populations derive from healthy functioning ecosystems. Analysis of ecosystem services is based on ecosystem functions or the capacity of natural processes and systems to provide goods and services that serve human needs.[10] These include the products received from ecosystems (e.g. food, fibre, clean air and water), the benefits from ecosystem processes (e.g. nutrient cycling, water purification, climate regulation) and non-material benefits (e.g. recreation and aesthetic benefits).[11]

An international study, The Millennium Ecosystem Assessment (MA) was carried out by the United Nations between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable

"By 2100, ecosystems will be exposed to atmospheric CO_2 levels substantially higher than in the past 650,000 years, and global temperatures at least among the highest of those experienced in the past 740,000 years. This will alter the structure, reduce biodiversity and perturb functioning of most ecosystems, and compromise the services they currently provide. Present and future land-use change and associated fragmentation are very likely to impede species' migration and thus impair natural adaptation via geographical range shifts."[15]

use of ecosystems. The MA provides a comprehensive classification for ecosystem services based on ecological functions, and their contribution to human well-being.

The MA uses four main categories: supporting services, provisioning services, regulating services and cultural services (Appendix III). Supporting services are those services that are necessary for the production of all other ecosystem services, such as nutrient cycling, soil formation, and biological production. Provisioning services are the flows of market and non-market goods from ecosystems, including food, water, wood, and fuel. Regulating services refer to the non-market services that ecosystem processes provide, such as the regulation of climate, floods, and water flows. Cultural services are the aesthetic, spiritual, educational, and recreational benefits that people obtain from ecosystems.[12]

The MA study found that over the past 50 years, humans have changed the Earth's ecosystems more rapidly and extensively than in any other period in human history to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel. The assessment concluded that approximately 60 percent (15 out of 24) of the ecosystem services examined are degraded or used unsustainably, including fresh water, air and water purification, and the regulation of regional and local climate. The full costs of these losses are difficult to measure, but they are substantial and growing.[13]

The MA also concluded that it is likely that the impacts on ecosystems are increasing, noting that "the likelihood of nonlinear changes in ecosystems (including accelerating, abrupt, and potentially irreversible changes) will have important consequences for human well-being." Examples of such change include disease emergence, abrupt alterations in water quality, the creation of "dead zones" in coastal waters, the collapse of fisheries, and shifts in regional climate."[14] The international assessment predicts that climate change and excessive nutrient loading will become the major drivers of ecosystem change over the coming century.

In 1997, a study estimated that the global value of nature's services was between $18 and $61 trillion (2000US$),[16] similar to the size of the global gross national product. Although several economists criticized the methodology of this study, it provided the first estimate of these services on a global scale. In response to the criticisms of the 1997 study, a follow up study focused on the marginal values of ecosystem goods and services, or the incremental value of conserving natural capital. Their analysis found that the net value of a hypothetical global nature reserve network would provide services worth about $4400 billion per year.[17] The study also estimated the average rate of habitat loss since 1992 to be -1.2 percent per year, or -11.4 percent over 10 years, a loss of about $250 billion in services each year.

The World Bank has published an assessment of the natural capital asset values for all nations in the world.[18] Canada ranked third in terms of the country's per capita market values for natural capital including timber, oil, gas, cropland, pasture land, non-timber forest products, and protected areas. This reflects the real advantage that Canada possesses in terms of the expanse of its natural capital. However, this assessment did not include the non-market values of the services provided by Canada's natural capital, nor does it provide an assessment of the costs to our natural capital resulting from resource extraction, food production, and pollution from manufacturing and transportation.

Two Canadian studies have considered the economic value of natural capital for Canada's boreal region. The most recent report assessed the natural values of the Mackenzie Region in Western Canada. This study found that the non-market value of the region's natural capital was an estimated $484 billion per year, (an average of $2,839 per hectare), 11 times the market value of its natural resources.[19] The carbon stored by the Mackenzie watershed was estimated at a value of $250 billion, 56 percent of the total non-market value. An earlier study that assessed the value of Canada's boreal region included a preliminary estimate for the costs of pollution and public subsidies for natural capital extraction.[20] These costs were an estimated $11 billion per year for the region, of which air pollution costs were the most costly. These costs reduced the estimated market value of the region's natural capital from $49 billion to $38 billion per year.

There is no comprehensive account of the state and value of British Columbia's natural capital and the province's ecosystem services. Because of the province's rich natural capital and the predicted extent and impact of climate change and land-use change over the coming decades, it would be prudent to create a natural capital account for the province. Using the MA classification of ecosystem functions, the potential ecosystem services by land cover type for BC are outlined in Table 1.

"While there is no right way to value a forest or river, there is a wrong way, which is to give it no value at all."

Paul Hawken,
Natural Capital

Table 1: Potential Ecosystem Services from different Land Cover in British Columbia

	Terrestrial			Water & Marine			Agricultural & Urban	
	Forests	Grasslands	Alpine	Inland Water	Wetlands	Coastal	Cultivated	Urban[i]
ECOSYSTEM GOODS								
Food	✔	✔	✔	✔	✔		✔	
Fiber		✔	✔			✔	✔	
Timber	✔					✔	✔	
Fuelwood	✔	✔				✔	✔	
ECOSYSTEM SERVICES								
Fresh water	✔		✔	✔	✔	✔		
Air quality regulation	✔					✔		✔
Carbon sequestration	✔	✔			✔	✔	✔	
Erosion control	✔	✔	✔		✔	✔		
Climate regulation	✔		✔		✔	✔		
Local climate regulation	✔	✔				✔		✔
Storm/Wave protection					✔			
Pest regulation	✔	✔				✔	✔	
Pollution control	✔			✔			✔	
Waste processing					✔			
Flood regulation	✔			✔	✔	✔		
Sediment retention	✔	✔		✔	✔			
Disease regulation				✔		✔		
Nutrient Cycling	✔	✔		✔			✔	
Medicines	✔					✔		
Recreation & ecotourism	✔	✔	✔	✔	✔			✔
Aesthetic values	✔	✔	✔	✔		✔	✔	
Spiritual Values	✔	✔	✔	✔		✔		
Cultural heritage	✔	✔	✔	✔	✔	✔	✔	✔
Education		✔	✔	✔	✔	✔	✔	✔

[i] Includes parks and gardens

The ecosystem services that are linked directly to the regulation of the climate are those that impact the global carbon cycle. In terrestrial systems, the plant biomass, decomposing material on the ground, and the soils of forests, wetlands and grasslands absorb, cycle, store, and release carbon. In semi-natural areas such as agroecosystems, the type of agricultural practices that impact the soil (e.g. the use of tilling), the crops grown, and the degree of natural vegetative cover in and around the cultivated land impact carbon storage and the release of carbon to the atmosphere.

> *"During the course of this century the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification) and in other global change drivers (especially land-use change, pollution and over-exploitation of resources), if greenhouse gas emissions and other changes continue at or above current rates."*[22]

The impacts of climate change will affect the structure, resilience and biological make-up of our ecosystems. Scientific studies have documented that habitat loss and biodiversity loss results in a decline in ecosystem services.[23] As a result the impacts will be felt across natural areas, agricultural lands, and in communities. Changes in ecosystem structure, function, and components will affect the services that they provide. Although it is difficult to predict the exact type and timing of changes, it is certain that climate change will impact the most direct services that humans require such as the supply of water, the regulation of water flows (i.e. droughts, flooding), and food production (i.e. pollination, water, temperature).

"There are significant opportunities for mitigation and for adapting to climate change, while enhancing the conservation of biodiversity, and achieving other environmental as well as socio-economic benefits. However, mitigation and adaptation have been considered separately in the global negotiations as well as in the literature until very recently. Now, the two concepts are seen to be linked."[25]

The Role of Ecosystems for Mitigation and Adaptation to Climate Change

> ***"Forests, agricultural lands, and other terrestrial ecosystems offer significant carbon mitigation potential. Although not necessarily permanent, conservation and sequestration of carbon may allow time for other options to be further developed and implemented. Biological mitigation can occur by three strategies: (a) conservation of existing carbon pools, (b) sequestration by increasing the size of carbon pools, and (c) substitution of sustainably produced biological products, e.g. wood for energy intensive construction products…"*** [24]

The interaction of the impacts of the Earth's carbon cycle on the climate, increasing greenhouse gas emissions, the vulnerability of ecosystems to the impacts of climate change, and the need for adaptation demands that a mix of strategies include mitigation, adaptation and technological change and development. According to the IPCC Working Group II, a portfolio of mitigation and adaptation can minimize the risks associated with climate change:

Synergistic approaches are needed among mitigation measures, adaptation strategies and local, regional and national planning. The most important indirect link between mitigation and adaptation is through biodiversity because it is a key factor influencing human well-being in general and provides coping options in particular.[26] For example, avoiding forest degradation (i.e. loss in carbon density) and deforestation creates synergistic benefits because it results in increased habitat and biodiversity (i.e. resiliency or ability to cope with change) and climate benefits (i.e. protects carbon stored in forests). There are secondary benefits including the reduction of water run-off and river siltation, erosion control, the protection of fisheries and hydro electricity.[27]

The value of nature and its ecosystems services will increase over the coming decades as human demands on ecosystems, land, and the services they provide continue to increase and as the impacts of climate change exacerbate the pressure on natural areas and communities.

Terrestrial Ecosystems

Terrestrial ecosystems play an integral role in the global carbon cycle by exchanging carbon with the atmosphere through photosynthesis, respiration, decomposition, and burning. As a result, large amounts of carbon are stored in plants, roots, and soils. Globally, forests and wetlands function as large terrestrial storage banks of carbon, preventing increases in the global concentration of greenhouse gases. In fact, oceans and terrestrial ecosystems remove about 50 to 60 percent of human-caused greenhouse gas emissions (fossil fuel and land use emissions), and curb more intense global climate change.[28] Globally forest ecosystems contain more than half of all terrestrial carbon, and account for about 80 percent of the exchange of carbon between terrestrial ecosystems and the atmosphere.[29]

Forests

Forest ecosystems are a significant part of Canada's natural capital, providing numerous ecosystem services (Table 1). A recent assessment of Canada's boreal ecosystem services estimated that the annual benefits of intact boreal forests and peatlands are worth at least $665 per hectare and $5,300 per hectare, respectively. One of the most significant boreal ecosystem values is carbon storage.[30]

British Columbia's forests cover 58 million hectares of the province. The Montane Cordillera ecozone covers 54 percent of BC's forests, with a smaller forest area in the Pacific Maritime, Boreal Cordillera, Taiga Plains and Boreal Plains ecozones (Figure 1).[31] The Pacific Cordilleran (PC) and Interior Cordilleran (IC) ecoclimatic provinces store some of the highest levels of carbon per hectare in Canada.

Table 2: Forest Carbon Storage Estimates for British Columbia's Ecozones

Ecozone	Area	Carbon density	Total Carbon stored (million tonnes C)		
	million ha	tonnes C/ha	biomass	soil	ecosystem
Taiga Plains	5.8	266	104	1,436	1,540
Boreal Plains	3.1	171	101	429	530
Boreal Cordillera	7.2	256	502	1,329	1,832
Pacific Maritime	10.8	375	1,542	2,504	4,046
Montane Cordillera	31.1	324	2,717	7,340	10,057
Total	**57.9**		**4,966**	**13,040**	**18,005**
Average Carbon (tonnes C/ha)			86	225	311

Source: Carbon content estimates are author's calculations based on carbon density estimates from Kurz and Apps 1999 and the CANFI 2001 forest inventory data

British Columbia has the highest forest biomass contents in Canada, and hence the highest carbon.[32] According to a national forest carbon study, the carbon stored in the trees, roots and soils of BC's forests ranges from 171 to 375 tonnes of carbon per hectare in the Pacific Cordilleran ecozone and 324 tonnes of carbon per hectare in the Interior Cordilleran ecozone.[33] The average carbon storage by BC's forests is 311 tonnes per hectare, based on total carbon stored and total forest area. Using these estimates and the latest Canadian forest inventory (CANFI 2001), the total carbon stored by BC's forest ecosystems is an estimated 18 billion tonnes of carbon (Table 2).[34] This is about 88 times Canada's annual greenhouse gas emissions(989 times BC's GHG annual emissions).[35],[36] the equivalent of 8.5 billion households electricity use for one year or 14 billion cars not driven over one year.[37] However, direct measurements within coastal and montane forests reveal that these forests can store averages of 600 to 1300 tonnes of carbon per hectare (see Coastal and Montane section below).

The economic value of the carbon stored can be estimated based on recent estimates of the global cost of carbon, and carbon trading prices. In 2005, the average social cost of carbon is estimated at US$43 per tonne of carbon. Using this value, the carbon stored by British Columbia's forests is worth an estimated $774 billion.[38] If we consider the carbon values as a 20-year investment, then the value of carbon stored is worth an estimated $62 billion per year or $1,072 per hectare per year.[39]

Carbon Storage and Cycling

The stewardship of carbon is an important consideration for forest management in the context of climate change. Such stewardship requires the tracking of carbon stores and the changes in storage resulting from human and natural disturbance. There is a lot of misinformation and confusion around the issue

Figure 1: Terrestrial Ecozones of Canada:

Source Environment Canada, State of Environment Infobase of carbon sequestration and carbon storage by new forests and old growth forests. Carbon sequestration refers to the net amount of carbon absorbed each year by a biological system, component or area, after the carbon released to the atmosphere is accounted for. Forest carbon storage refers to the total amount of carbon contained in all the components of a forest ecosystem at a given time. Scientific studies show that net carbon uptake (i.e. the carbon removed from the atmosphere) by forests has a complex relationship with age. Review papers show that annual net carbon uptake is generally low or negative (i.e. net carbon release) in forests less than 20 years old (because of high decomposition rates), reaching a peak rate in intermediate-aged forests (e.g. 30-120 years), and declining but remaining positive in forests older than 160 years old.[40] For example, one hectare of old-growth Douglas fir forests at the Wind River Experimental Forest in Washington is estimated to sequester between 0.2 and 2.2 tonnes of carbon each year.[41]

Similarly, carbon cycling especially by soils is still not fully understood. A few studies have suggested that while older forest trees become less productive (i.e. are not growing as fast and therefore are not taking up as much carbon on an annual basis), their ecosystem's net carbon uptake may be higher than we think as they are accumulating large amounts of carbon in the soil below the canopy. [42] This is demonstrated by the study of a 500-year old forest in southern Washington State that reported a significant annual carbon sink (sequestration rate) of 1.3 to 1.5 t C/ha/year.[43]

The average carbon storage by BC's forests is 311 tonnes per hectare, based on total carbon stored and total forest area. Using these estimates and the latest Canadian forest inventory (CANFI 2001), the total carbon stored by BC's forest ecosystems is an estimated 18 billion tonnes of carbon. This is about 88 times Canada's annual greenhouse gas emissions (989 times BC's GHG annual emissions), the equivalent of 8.5 billion households' electricity use for one year or 14 billion cars not driven over one year.

Coastal and Montane Forests

Older forests may accumulate relatively small amounts of carbon each year, but they store enormous amounts of carbon in standing wood and in the soil by comparison to younger ecosystems.[44] The Carbon Budget for Canada's Forests (1999) estimates that BC's Pacific Maritime and Montane Cordillera ecozones store an average 349 tonnes of carbon per hectare (estimates used in preceding section).[45] However, specific studies within coastal and montane forests reveal that these types of ecosystems can store averages of 619-1127 tonnes of carbon per hectare.[46] Coastal BC forests on Vancouver Island (Coastal Western Hemlock zone) contain from about 500 up to a high of 1300 tonnes of carbon per hectare.[47]

The conversion of old-growth forests to younger second-growth (i.e. managed) forests results in an immediate release of some of the carbon around the time of logging, as well as a reduction in the overall carbon store because managed forests only grow to rotation age (i.e. next scheduled logging). They do not re-establish the store of carbon that was in the primary forest ecosystem.[48] For example, a Pacific Northwest study found that total carbon storage was 2.2 to 2.3 times in a 450-year old forest compared to a 60-year old plantation. They estimated that the conversion of a typical Pacific Northwest old-growth forest (Douglas fir and hemlock) to a younger forest (i.e. plantation) reduces carbon storage by 305 tonnes of carbon per hectare during one 60-year rotation, even when the storage in buildings is included. Further, the harvest of old-growth forests reduced total carbon storage for at least 250 years. Based on the study's simulations, the authors estimate that the conversion of five million hectares of old-growth forests to younger plantations in Oregon and Washington over the last 100 years has released an estimated 1.5 to 1.8 billion tonnes of carbon to the atmosphere. In other words, when old-growth forests are logged, they release carbon to the atmosphere for decades and possibly for over a century.

Sub-Boreal Forests

A British Columbia study found that old growth interior spruce forests in central BC also store large amounts of carbon, between 324 and 423 tonnes of carbon per hectare.[49] The University of Northern BC study similarly reported that the harvesting of old-growth (141 to 250 years old) in BC's interior spruce forests (e.g. Sub-Boreal Spruce zone), and conversion to managed forests lowers the total carbon stored within the ecosystem by 41-54 percent.

Subalpine Forests and Meadows

Estimates of carbon storage in mountainous ranges are rare. However, such regions contain a mosaic of forests and meadows that may be particularly sensitive to future changes in climate. Therefore, it is important to include them in estimates of terrestrial carbon storage. A University of Washington study in the Olympic Mountains of Washington State found that the region's subalpine forests store 329 to 1075 tonnes of carbon per hectare in their trees, litter and mineral soil; subalpine meadows store between 154 and 269 tonnes of carbon per hectare. Ecosystem carbon in this study is high compared with the few other studies that have documented carbon storage in the Pacific Northwestern States. There is high variability in soil carbon content among subalpine sites so it is difficult to extrapolate for other areas. Further study for these ecosystems is needed in British Columbia.

Including land-use mitigation options as abatement strategies provides greater flexibility and cost-effectiveness for achieving stabilization (of climate change). Even if land activities are not considered as mitigation alternatives by policy, consideration of land (land-use and land cover) is crucial in climate stabilization for its significant atmospheric inputs and withdrawals (emissions, sequestration, and albedo). Recent stabilization studies indicate that land-use mitigation options could provide 15–40 percent of total cumulative abatement over the century.[50]

Maintaining Forest Ecosystem Carbon Stores for Mitigation and Adaptation

The immense stores of carbon in existing ecosystems are of great importance for both mitigation and adaptation of climate change, especially compared to the potential of removing atmospheric carbon by planting new forests. First, as noted earlier, carbon storage in young forests takes a long time especially in terms of replacing lost carbon. Second, because there is so little time to slow global warming, the priority should be on preventing carbon losses and conserving the carbon stores that exist. Third, by protecting existing ecosystems there will be a wide range of habitat to provide connecting corridors for plant and animal migration as the climate warms. Fourth, the protection of intact ecosystems provides resiliency for ecosystems and the communities that depend upon them.

The importance of forest management and land use choices to address climate change is most clearly seen when looking at the net effect on atmospheric carbon dioxide under different options (Figure 2: a) When a mature forest is converted to a field, urban, or suburban landscape, the disturbance of the natural vegetation and soil results in carbon being rapidly released to the atmosphere as organic materials decompose. Carbon continues to be released for many decades and the original carbon store may not be replenished for centuries. A replanted field or degraded forest still continues to release carbon dioxide to the atmosphere for decades because the original organic material continues to decompose. Until the trees grow large enough to take up more carbon into living material and litter than is released from the soil, there is a net release of CO_2 to the atmosphere. In a mature or old growth forest, carbon continues to be removed from the atmosphere at a slow but steady pace, in contrast to the massive release of CO_2 when a forest is converted to other uses.

The consequences of land use and thus mitigation choices are most obvious when looking at the accumulated CO_2 effects in the atmosphere (Figure 2). By the end of 50 years, a converted BC coast forest may have released hundreds (see Coastal and Montane Forests values above) of tonnes per hectare of carbon as CO_2 into the atmosphere and contributed to climate change. An equivalent area of replanted forest will not have had any positive effect on atmospheric CO_2 for decades. Depending on the specific conditions, the replanting strategy may not even have caught up to the steadily accumulating benefits of removed CO_2 by a conserved old forest for half a century. Like the proverbial turtle, the slow and steady CO_2 removal benefits of a conserved old forest end up ahead even of a replanted stand in the short and medium term. Both approaches end up tonnes of atmospheric CO_2 ahead of the choice of destroying a natural forest.

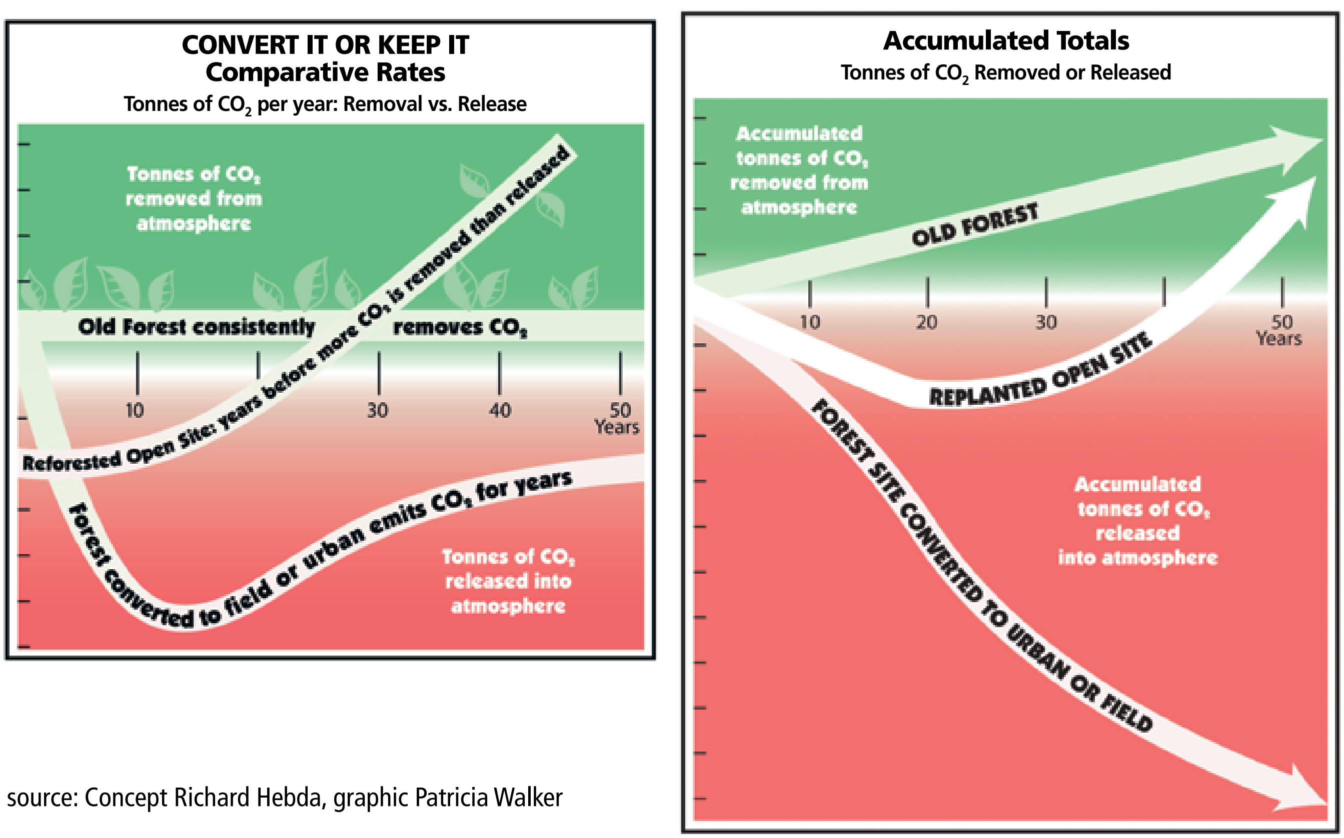
Considering all the benefits of natural ecosystems the message is clear. Keeping healthy natural ecosystems, especially forests, is the best thing we can do with land to mitigate, adapt, and build resiliency to global warming.

Grasslands

Natural grasslands are the potential natural land cover of approximately 25 percent of the Earth's surface.[51] Humans use these lands as grazing lands and have transformed many of them into croplands depending on water availability and monetary incentives for agriculture. Grassland ecosystem services include climate regulation, genetic biodiversity, and soil conservation.

Sixteen percent of BC's southern interior grasslands have been converted for agriculture and urbanization since the mid-1800s. Although 84 percent of southern interior grasslands remain, the Grasslands Conservation Council of BC reports that about 90 percent of all BC's grasslands are grazed by domestic livestock and that poor land management practices, such as overgrazing, and spread of introduced, invasive plants has degraded many grassland ecosystems.[52] For example, Antelope brush now occupies less than 50 percent of its former range and is one of the four most endangered plant communities in Canada. The Bunchgrass zone is one of the three rarest biogeoclimatic zones in the province. Less than one percent of the provinces' remaining grasslands are protected.[53]

Figure 2: Old Forest Carbon Storage versus Reforestation and Conversion Impacts on Carbon Storage



source: Concept Richard Hebda, graphic Patricia Walker

In comparison with cultivated land (i.e. agriculture land-use), grasslands store and sequester more carbon because they form a complete vegetative cover, and because they grow for seven to eight months of the year, instead of the typical 3-5 months for agricultural crops.[54] In addition, long-lived native perennial bunchgrasses place a greater proportion of their biomass belowground than other plant types, making it less available for microbial breakdown and CO_2 production. Furthermore, many agricultural fields are tilled bringing old buried carbon to the surface, which leads to decomposition and the release of CO_2 to the atmosphere.

Grasslands sequester large amounts of carbon in their soils, which is rapidly transferred to the atmosphere when they are plowed and converted to agricultural lands. These carbon losses can be large. A study that compared native and cultivated soils in the Great Plains of the United States demonstrated that between 8 and 20 tonnes of carbon per hectare can be released to the atmosphere upon cultivation.[55] In general, carbon losses are greater due to tillage where soils have high carbon stocks.

Grassland carbon loss due to cultivation occurs rapidly; even when land is allowed to revert to its natural state, carbon recovery is slow. Studies have shown that even after 50 years of abandonment, carbon stocks in the soil were not equal to the levels in the native soils.[56]

The value of carbon sequestration by grasslands has been estimated in terms of the effects of cultivation on carbon storage and the estimated costs of carbon dioxide emissions. In 1997, a study on nature's services estimated that the value of maintaining native grasslands was $200 per hectare (range of $160/ha to $400/ha).[57] The costs of CO_2 emissions have increased since then and will continue to increase because an extra tonne of CO_2 added to an increasingly inflated atmospheric stock of CO_2 will result in more damage as the stock increases. If we use the global average social cost of carbon, maintaining natural grasslands would be worth an estimated $430 per hectare..[58]

Grasslands also provide other vital services such as soil conservation and genetic resources. A strong relationship exists between plant biomass and sediment run-off. Overgrazing removes biomass, exposes bare ground and results in soil erosion. When grasslands are plowed and cultivated as croplands, soil losses are even larger. Soil erosion results in losses in production, water infiltration, water availability and nutrient availability.

Grasslands are a source of a great biological knowledge and provide a large genetic storehouse. Humans depend on a relatively small number of grassland species for food, medicine and other uses. Most of our domesticated species originated from grasslands, and they still hold the potential for new sources of food plants that are resistant to diseases or unique genetic features useful for human society.

Fresh Water and Marine Ecosystems

Wetlands

Wetlands are a dominant feature of the Canadian landscape, covering approximately 13 percent of Canada's land.[59] Wetlands provide essential services such as retaining, purifying and supplying fresh water, storing carbon, absorbing pollutants and supporting numerous species of plants and wildlife, many of them identified as endangered.

Peatlands (formerly referred to as organic terrain or muskeg) are wetlands with massive deposits of peat at least 40 cm thick.[60] These ecosystems are carbon-rich with high organic carbon content. Canada's peatlands contain approximately 147 billion tonnes (Gt) of soil carbon, about 59 percent of the organic carbon stored in all Canadian soils.[61]

Most peatlands occur in the boreal and subarctic regions. They cover about 5.4 million hectares of BC - 6 percent of the province.[62] It is estimated that BC's peatlands store 6.8 billion tonnes (Gt) of carbon. This is approximately 5 percent of the 147 billion tonnes of carbon stored in Canada's peatlands.[63] The annual value of the carbon stored in BC's peatlands is an estimated $4,400 per hectare per year, based on the global average social cost of carbon.[64]

Peatlands continue to sequester carbon on an annual basis. Using Canadian estimates for the British Columbia regions, BC's peatlands may sequester about 1.5 million tonnes of carbon per year. This service is worth at least $12 per hectare per year.[65]

Coastal and Marine ecosystems

Coastal areas have great ecological, social and economic value. 77 percent of the world's ecosystem goods and services are provided by coastal ecosystems.[66] Canada has one of the longest coastlines in the world, of which British Columbia's coastal ecosystems are arguably the most productive. A recent global study that assessed the value of the world's coastal ecosystems estimated that Canada's coasts provide $124 billion (US$) from natural areas and $234 million from semi-altered areas.[67] These coastal zones provide goods such as food, salt, minerals and oil resources, and construction materials. They also provide increasingly valuable ecosystem services: they protect shorelines against extreme events (e.g. storms), store and cycle nutrients, sustain biodiversity with habitat and food sources, provide valued recreation and tourism areas, and capture water.

Changes on land (e.g. land use) can affect the quality of coastal watersheds and fish habitat as well as the goods and services provided by these watersheds. A recent Strait of Georgia study demonstrated that the value of protecting coastal watersheds and the ecosystem services that maintain coho habitat range from $0.93 to $2.63 per hectare of drainage basin.[68]

Lehmans' Springs Conservation Area: a 60 acre forest protecting wetland area that feeds Osoyoos Lake, pumping apx. 300 gallons a minute, and also protecting Species at Risk

– photo: Sheila Harrington

While marine ecosystems are not central to this report, it is worth mentioning that marine and estuarine ecosystems provide many essential ecological services. One-half of the oxygen we breathe is produced by marine plants. Oceans are also a significant carbon sink. They store over 50 times the carbon that is in the atmosphere, and they absorb about 25 percent of the carbon emissions released by fossil fuel burning. Once carbon is absorbed by ocean waters, the storage time can be up to 500 years.[69]

Semi-Natural Areas: Agricultural and Peri-Urban Areas

The Lower Mainland of British Columbia is densely settled and is the most human impacted region of the province. The Lower Fraser Valley contains some of Canada's best agricultural lands, sensitive wetlands, forests, and is home to 57 percent of BC's human population. A national study by a resource economist at Simon Fraser University examined the natural value of the ecosystem services provided for the people living in the region.[70] The study's results include:

- The annual value of waste treatment of phosphorus and nitrogen produced by the Fraser Valley's wetlands is estimated to range from $452 to $1,270 per hectare.
- The annual value for some of the valley's forests goods and services is estimated as a lower bound at $134 per hectare per year, if uncut ($824,000 for total valley). This estimate does not include services such as erosion control, water storage and water purification.
- The annual value of the valley's forests for carbon storage was estimated at $15 to $608 per hectare.
- Recreational benefits such as wildlife viewing provide $53.45 per hectare per year in natural areas.
- Each hectare of estuary is worth $22,832 per year (est. total ecosystem value)
- Lakes and rivers ($2,007 per hectare per year) (est. total ecosystem value)
- Grass/rangelands ($232 per hectare per year) (est. total ecosystem value)

The land settlement patterns in the Fraser Valley have decreased forest, soil and wetland biomass and carbon storage. A study of carbon storage of the Lower Fraser Basin for the period 1827 to 1990 indicates that a total of 238 million tonnes (Mt) of carbon from biomass pools has been transferred to the atmosphere due to human land use and land use change.[71] The major sources of carbon loss were soils (43 percent), logged forests (42 percent), and wetlands (14 percent). Lower Fraser Basin carbon emissions are 29 times greater than the global average.

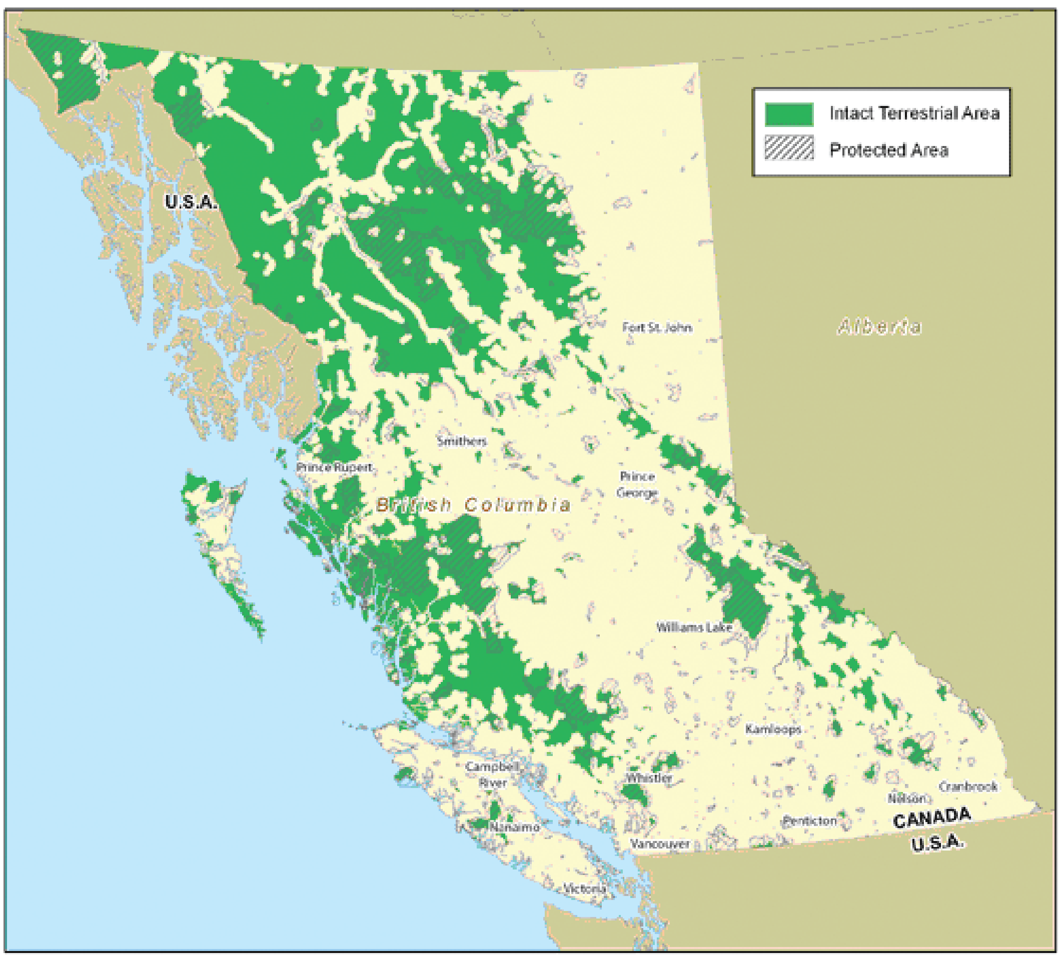
Conservation Values and BC's Ecosystems

BC's ecosystems have already been impacted by human settlement, resource extraction and land conversion. The historical loss of terrestrial ecosystems in British Columbia by biogeoclimatic zone indicates that 48 percent of the Coastal Douglas Fir zone has been converted to other land use since settlement. The Garry Oak woodlands in the Coastal Douglas fir zone and the South Okanagan Antelope brush grasslands in the Bunchgrass Zone have been the hardest hit and are now the most endangered ecosystems in B.C. The other hotspot in terms of loss of natural cover is the Fraser Valley, which is reported on in the preceding section. In this region, 85 percent of wetlands and 15 percent of its streams have been converted to other land use as a result of urbanization and agricultural development. The remaining intact natural areas are shown in Figure 3.

Conservation of natural areas in the watersheds surrounding human settlements and within urban areas provides essential services for communities. An assessment of the net value for conserving the natural capital or converting tilled lands to natural areas in the Grand River Watershed in southern Ontario has been estimated at $195.25 per hectare per year. This is the incremental value of conservation, rather than the total value as reported in the above paragraphs. This value is comparable to the average market price for agricultural land in the watershed, which is about $74/ha to $247/ha.[72]
The protection of watersheds in particular, will become increasingly important as the climate changes. Forests remove pollution such as particles from the air, and reduce runoff from watersheds thereby curbing flooding and maintaining a steady flow of water supply. Both forests and wetlands improve water quality by filtering assimilating, and degrading sediment and chemicals as the

Figure 3: The Remaining Intact Natural Areas in BC (2007)

Map of ecologically intact areas (i.e., areas without roads) that are more than 5 kilometres from a road and over 2,000 hectares in size.



Source: (B.C. Ministry of Environment. 2007. Environmental Trends in British Columbia: 2007. State of Environment Reporting. Victoria, B.C. www.env.gov.bc.ca/soe/et07/)

water flows through.[73] The protection of forests and wetlands in particular, are important for human communities. They provide vital services that people depend upon.

The preceding sections have provided an overview of the importance and value of land and water systems for protecting the climate and the services which communities rely upon. In summary, the protection of watersheds, including conservation and environmental management of the land and water systems that provide drinking water, clean air and healthy food as well as protection against floods, landslides and other impacts will become increasingly important. The protection of the carbon stored in forests, wetlands, and soils in particular, will be highly important for avoiding additional emissions of carbon to the atmosphere, in addition to sequestering it from other activities. Furthermore, the protection of these ecosystems will provide additional benefits, including providing options for wild species and human communities to adapt as the climate changes and maintaining ecosystem services that may become increasingly scarce as the temperature increases. The projected impacts of climate change on BC's ecosystems and the implications for human land use and the supply of ecosystem services is the subject of the next section, Part II.

Chatterbox Falls – protected by Princess Louise International Society and The Nature Conservancy of Canada

– photo: Sheila Harrington

Part II: Nature Under Threat from Climate Change

Global Climate Change Impacts

The Intergovernmental Panel on Climate Change (IPCC) provides a comprehensive summary of the predicted climate change impacts on ecosystem properties, goods, and services. The 2007 contribution of the Climate Change, Impacts, Adaptation and Vulnerability Working Group (WGII)[74] states at the outset that the resilience of many ecosystems is likely to be exceeded because of the unprecedented combination of climate change and associated disturbances. As a consequence the structure, biodiversity, and functioning of most ecosystems will be perturbed. The IPCC authors have high confidence that services provided by these ecosystems will be compromised. We must therefore prepare for widespread ecological transformation.

Many BC ecosystems are among the most vulnerable.[76] Northern British Columbia has already experienced a high rate of warming, being part of northern North America which has experienced the greatest temperature increase globally.[77]

The IPCC WGII report emphasizes that the vulnerability of natural and human systems to the impacts of climate change will be exacerbated by other stressors such as human land use and the degradation of natural systems and the services they provide. The report also highlights the following impacts[75]:

- The stability of carbon stored in terrestrial ecosystems is at risk due to climate change and/or land use impacts (i.e. more carbon dioxide is likely to be released to the atmosphere as a result of climate change in addition to fossil-derived emissions).
- Globally, 20-30 percent of animal species assessed so far, are likely to be at increasingly high risk of extinction with 2-3 degrees Celsius warming above pre-industrial levels.
- Substantial changes will occur in the functioning and structure of terrestrial and marine ecosystems with a 2-3 degrees Celsius warming.
- Ecosystem vulnerability to climate change will vary based on ecosystem-specific critical thresholds. The most vulnerable ecosystems include coral reefs, the sea-ice biome and other high-latitude ecosystems such as the boreal, mountain ecosystems, and Mediterranean-climate ecosystems.

The IPCC WGII reports on many studies that demonstrate that widespread ecosystem change is already underway on our continent and in our region:

- Earlier green-up (10-14 days) bud burst in aspen and flowering time for example
- Increased length of fire season and area burned
- Wildlife responses - earlier breeding, migration, mortality
- Pest responses - mountain pine beetle population increase and spread
- Earlier snow melt and more rain instead of snow.

Three important points from the IPCC WGII North American summary are directly pertinent to land conservation, impacts and adaptation:

1. Ecosystem disturbances, notably fire and insect outbreaks are increasing, and will intensify with drier soils, higher temperatures, and longer growing seasons.
2. Seasonal availability of water will decline as rising temperatures diminish snow-pack and increase evaporation, constraining supplies for the competing needs of agriculture, cities, industries and ecosystems.

3. The current North American response to climate change impacts focuses on coping, rather than preventing problems through adaptive planning.
4. In this section, we examine potential impacts of climate change as they apply specifically in British Columbia with a view to developing strategies for ecosystem protection and conservation.

Climate Change Impacts in British Columbia

Methods of assessing Impacts

Predicting the future is difficult. General outcomes or end-points of the process of ecological change can be "anticipated," or projected by studies of the recent fossil record, examining current trends and using climate impact models.[78] Each of these in turn will be considered as a means of gaining insight on climate change impacts.

The fossil record is often used to interpret the past, especially for effects of past climate change. It clearly demonstrates that widespread biome reorganization and changes in geographic range have occurred within the last 10,000 years in response to smaller changes in climate than currently projected for the 21st century.[79] Climate change of the scale and amplitude anticipated in this century is unambiguously demonstrated to result in widespread ecological change and shifts in species ranges.[80]

Current biological and physical responses to measured climatic trends provide strong indications of upcoming changes as they are directly observed. The study of current trends can identify responses that are not considered and/or projected by climate impacts models nor detectable through studies of the fossil record.

Climate impact models depend on the characteristics of a particular model and the biological and ecological data used. On both counts, our current understanding of how ecosystems work and how species respond to climate change is incomplete. Impact models allow us to "experiment" with a wide range of future conditions and evaluate mitigation and adaptation options.

The fossil record reveals biophysical responses to past climatic fluctuations and reflects real ecological phenomena. Unlike the observation of current trends, the precise climatic conditions related to past responses are not known. Climate models are adapted as we observe current trends and develop better understanding of the underlying processes. When the evidence from all three approaches points to similar outcomes, then there is increased confidence in anticipating what the future may hold.[81]

The specific characteristics, rate and mechanism of such change is, however, challenging to establish.[82] Some changes may take place quickly as a disturbance such as fire forces an ecosystem over a threshold into a new state. In other cases, ecosystem conversion may take place gradually, such as the invasion of the alpine zone by trees. Considering the rapid rate and amplitude of climate change, ecosystem reorganization and species shifts will continue for centuries before equilibrium is reached. As a result, the timing and characteristics of future BC landscapes is highly uncertain.

Thus, the description of climate change impacts that follows is neither a prescription of future conditions nor a strict framework for conservation and land use planning; rather it is a guide for the degree and direction of change to be expected.

Evidence of impacts from the fossil record

Climate change occurs both gradually and rapidly, in response to natural variations in the global climate systems, resulting in variable ecosystem impacts. Such changes are well documented particularly in southern British Columbia.[83] Conditions that existed when climates were 2-3 degrees Celsius warmer than the present (e.g. between 10,000 and 6,000 years ago) are particularly instructive.[84] Fossil studies have uncovered major differences in the pattern of ecosystems and distribution of dominant species compared to the present:

- Southern BC contained forest ecosystems that are not present now (e.g. widespread Sitka spruce-western hemlock coastal forest)
- Interior grasslands occurred further north extending from valley bottom to mountain top in the Okanagan.[85]
- Garry oak and associated meadow ecosystems occurred inland and somewhat northward of their current position[86]
- Dry coniferous forests occurred more widely in the Interior and on the coast[87]
- Lowland forests extended into subalpine zones and tree-lines stood higher in southern BC.[88]
- Bog wetland types were less common than today.
- Lakes and ponds were shallower, some even being ephemeral, in the southern interior (i.e. river and stream discharge may have been more irregular).[89]
- Fires were more active both in the interior and on the coast.

In summary, the recent fossil record points to the likelihood of a widely different pattern of terrestrial and aquatic ecosystems under future climates.

Current climatic and biophysical trends

Evidence of current climate change is evolving as longer term data sets reveal statistically detectable trends. These trends are especially helpful in identifying regions of high sensitivity to climate change. Several trends are evident in British Columbia and adjacent regions, which inform the analysis of impacts[90]:

- Daily temperatures are increasing rapidly throughout the province, especially in the north and in the interior (Figure 4). For example, winter temperatures have increased as much as 3-3.5 degrees Celsius at Dease Lake since 1950.
- Annual precipitation has increased by about 22 percent on average over the past hundred years, with significant regional variation.
- Snow pack has notably decreased over the past 50 years, with significant regional variation.
- Spring runoff in snowmelt-fed rivers and spring break-up of ice is now occurring earlier.
- Warmer air temperatures are resulting in warmer water temperatures in rivers. For example the Fraser River increased by 1.1 degrees Celsius between 1953 and 1998.
- Warmer temperatures have created a longer fire season with more fire activity in the boreal forest.
- Flowering time and bud break in aspen trees occurs many days earlier.[91]
- The explosive outbreak of the Mountain pine beetle infestation and the intensification of the Dothistroma needle blight have been linked to changing climates.

Dead cedars near Parksville, Vancouver Island

– Photo: Richard Hebda

Climate change impacts from models

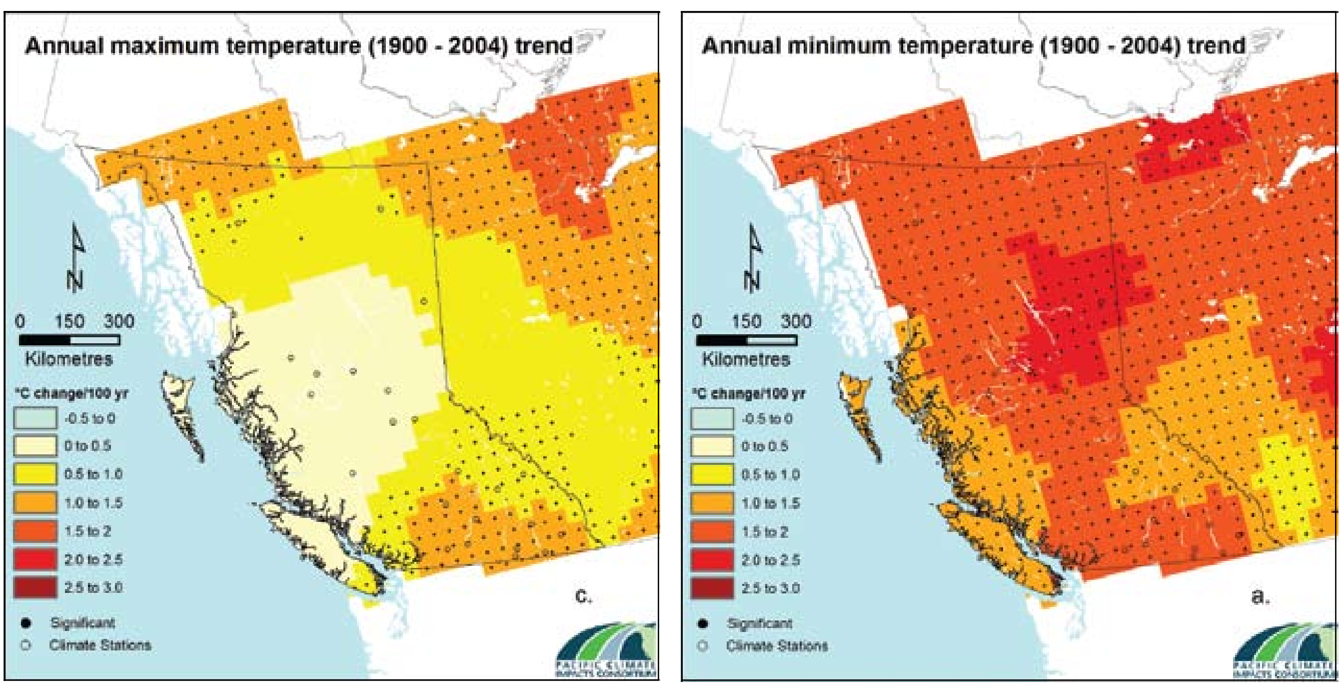
Several climate-ecosystem impact models have been developed on broad continental and sub-continental scales. Predicting climate change impacts for British Columbia is inherently difficult due to BC's complex topography and climatic regimes, and steep ecological gradients. The models tend to simplify vegetation-climate relationships.

General ecosystem impacts based on basic principles have been summarized in Hebda (1992) and Hebda (1997).[92] In addition:

- Spatially explicit impacts have been derived from climate model data using the proxy of biogeoclimatic zones by Hamann and Wang (2006).[93]
- The Royal British Columbia Museum has also developed a series of spatially explicit models for selected species and phenomena using the approach of climatic envelopes.[94]
- A model of fire response to climate change prepared by Flannigan et al.[95] in 2002 is available.
- A snow pack model for the Columbia Basin has been developed[96].
- A comprehensive examination of the effect of climate change on sea levels is nearing completion by the Geological Survey of Canada[97].

It is important to be somewhat familiar with the primary climatic context being used in climate impact models. Having an impression of future climatic conditions is a useful tool that provides a sense of the amount of future change, the degree of uncertainty in what that change may be, and the rapidity at which the change will take place

Figure 4: Maximum and Minimum Temperature Changes



Annual Minimum and Maximum temperature trends maps courtesy of Pacific Climate Impacts Consortium, University of Victoria, http://www.pacificclimate.org/impacts/overview/

Data: CANGRID (50 km), Meteorological Service of Canada Adapted from Zhang et al. 2000.Analysis: PCIC staff Support: BC Hydro and BC Ministry of Environment

Projected impacts of Climate Change

The summary that follows is based on a synthesis of insights from studies of the fossil record, current trends, and impacts models. This synthesis is in part subjective and is not intended to be a comprehensive literature review. Potential impacts that apply broadly to the province are summarized first, followed by a zonal analysis focusing on ecosystems in southern BC where more land is privately owned and land trusts are especially active.

Climate change impacts are examined largely at the level of Biogeoclimatic Zones, which are the standard for biodiversity planning and assessment in British Columbia (see Figure 5 for example) [98] In addition, predicted impacts are provided for selected ecosystems (e.g. estuaries) not recognized at the biogeoclimatic zone level, and ecological processes (e.g. fire) important in planning conservation and protection but not captured by the zonal classification.

It is important to keep in mind three points in reviewing the impacts described in the following sections:

1. Impact models predict only changes in the geographic distribution of climatic conditions required by an ecosystem or species. They do not show where an ecosystem will be or even if such an ecosystem will occur at the time horizon shown in the model.
2. Ecosystems do not migrate, only species do; hence changes in the geographic position of an ecosystem are only an indication of the degree of change and the future ecological potential of a location. The models do not include the possibility that new ecosystems will likely be formed and that invasive species may play major roles in those ecosystems.
3. The potential geographic range for many species will expand greatly, but slowly migrating species, such as dominant trees, will need many decades and probably centuries to occupy that potential range.

Province-wide impacts

The predicted general trends to the end of this century include:

- A general overall shift of the southern pattern of ecosystem climates to the northern half of BC.
- Major expansion northward and upslope of dry non-forest (grasslands) and dry forest ecosystem climates (especially in the Interior but also on the coast).
- Major expansion of moist coastal and interior conifer forests upslope at cost of subalpine forests.
- Major decline in Cordilleran boreal (spruce forests) in north and central B.C.
- Major decline of alpine ecosystem climate throughout the province.
- Wide-ranging changes in wetlands and aquatic ecosystems with warming water temperatures and changes in hydrology related to shrinking glaciers and decreased snow pack.

The potential shifts in ecosystem distribution by the year 2080 are illustrated by Hamman and Wang (2006) Figure 5.

Impacts on specific terrestrial ecosystems

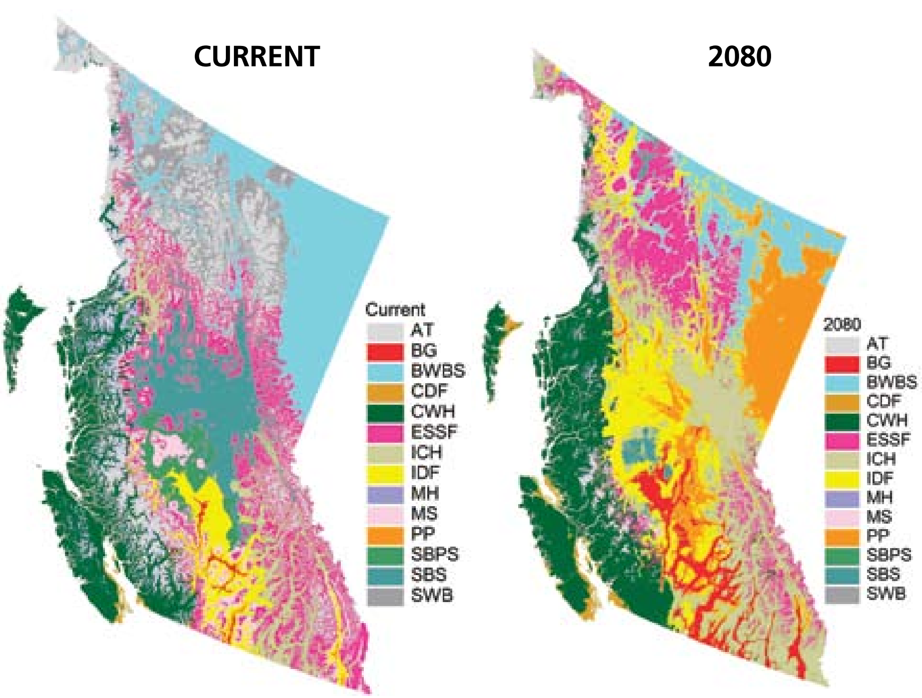
Coastal Western Hemlock Zone (CWH)

Bog and lake core studies reveal that major shifts in geographic range and in composition of the Coastal Western Hemlock zone (CWH) are likely under a warmer climate.[99] In south coastal BC, Douglas-fir dominated stands will almost certainly displace western redcedar-hemlock stands in relatively dry regions such as east and central Vancouver Island and the Lower Mainland.

Fire activity is likely to increase and provide a mechanism for conversion of CWH to Douglas-fir dominated forests.[100] Most of the area now covered in CWH will likely remain as some sort of forest, the character of which will depend on the degree to which rising temperatures and evaporation are off-set by increased precipitation. Soil conditions, especially organic matter content, may play a key role in slowing down impacts. Where soils are disturbed or dry, the loss of western hemlock and Pacific silver fir may be likely, especially with fire disturbance.[101] Least likely to be impacted are the cool and moist oceanic parts of the CWH, such as the west side of Vancouver Island and the central coast.

The area of redcedar-western hemlock forest is projected to increase steadily inland and at higher elevations, resulting in a loss of subalpine forests according to Hamann and Wang (2006).[102] However, the Royal British Columbia Museum species impact model predicts widespread decline for western redcedar in southern BC lowlands beginning as early as 2020, under high climate change conditions, and by 2050 under median climate change conditions.[103] The same model shows widespread potential for expansion of the range of redcedar on the north coast. Recent western redcedar die back on the south coast, especially the east side of Vancouver Island, suggests that the species model may be a

Figure 5: Potential effects of climate change on ecosystem distribution of Biogeoclimatic (BEC) zones in British Columbia - comparison of the current pattern to the pattern in 2080.
(Hamman and Wang 2006)



Alpine Tundra (AT)
Bunchgrass Zone (BG)
Boreal Black and White Spruce (BWBS) Zones
Coastal Douglas-Fir Zone (CDF)
Coastal Western Hemlock Zone (CWH)
Interior Douglas-fir (IDF)
Interior Cedar-Hemlock Zone (ICH)
Mountain Hemlock Zone (MH)
Montane Spruce (MS)
Ponderosa Pine zones (PP)
Northern Spruce Forests: Sub-boreal Pine Spruce (SBPS)
Sub-Boreal Spruce (SBS)
Spruce Willow Birch (SWB)

good proxy for the future of the dry CWH in the south. Novel species combinations may be expected too if the past occurrence of Sitka spruce-western hemlock forests under warm climates is an indication.[104]

Coastal Douglas-Fir Zone (CDF)

Hamann and Wang's (2006) impacts model projects a rapid expansion of the Coastal Douglas-fir zone (CDF), reaching a 336 percent increase by 2085. Paleoecological studies confirm that the zone was much more extensive under warm, dry climatic conditions.[105] The greatest expansion is expected on the east side and south end of Vancouver Island, the Port Alberni valley, and the Lower Mainland.

The current decline of cedar is particularly evident in the CDF, a pattern consistent with the forecast of the western redcedar species model, evidence that the Coastal Douglas-fir forest is already undergoing change. Although the potential area of expansion for the CDF zone is small compared to the area of the province, it is large in relation to the densely settled portion of the province in which it occurs.

Garry Oak and associated ecosystems (GO)

Although the Garry oak and related ecosystems are not recognized as a distinctive zone at the provincial scale, they deserve special attention because they are recognized as distinctive and endangered. In particular they harbour an exceptional number of provincially and federally listed species.[106]
It is highly likely that Garry oak ecosystems could expand substantially in the coming century. This is strongly suggested by evidence from the fossil record and from a species impact model for Garry oak.[107], Based on the Garry oak model, climates suitable for this species could spread up the coast, in the rain shadow of mountains, as far as the Skeena and Nass river valleys, and inland throughout the province[108]. Another analysis however does not demonstrate such widespread expansion[109].

This ecosystem is a strong candidate for preservation and conservation because of the high number of rare species and the near certainty that the ecosystem's climate zone will expand widely. Dry sites in the adjacent CDF forests, already supporting characteristic Garry oak species such as sea blush, are strong candidates for acquisition.

Mountain Hemlock Zone (MH)

This coastal subalpine forest and parkland zone is a relatively recent ecosystem that developed its current range in response to cool and moist climates.[110] According to Hamann and Wang (2006) the Mountain Hemlock zone may potentially decline by 79 percent by 2085 as climate warms. This zone has a varied fire history[111] and may be prone to burn more often and more intensely under warmer conditions[112]. The measured and further anticipated decline in snow pack on the coast may also play an important role in the decline of this zone.

Bunchgrass Zone (BG)

Grasslands were much more widespread during the early Holocene warm/dry interval reaching perhaps as far north as the latitude of Quesnel.[113] At the biome level, climate impact models predict the potential for a major expansion of grassland climates in southern interior of BC, throughout valley bottoms and adjacent lower slopes.[114] Grassland climates may expand approximately 150 percent by 2025, more than 400 percent by 2055, and nearly 800 percent by 2085, reaching well into the Chilcotin River watershed and north of Quesnel.

Models use climatic data for areas classified strictly as grasslands excluding mixed grassland and forest. Thus, grassland patches can be expected to occur well beyond these limits. For example, the species impact model of Behr's Hairstreak butterfly, associated with south Okanagan antelope bush climates, shows the occurrence of suitable climate for grassland in northwest BC just south of the Yukon border by 2080.[115]

Despite an apparently positive future for the Bunchgrass zone overall, it may face losses of native species because of the high proportion of rare species exposed to chance climatic events and land use pressures. Invasive species may also be a threat as they spread in response to increasing fires and disturbance and invade areas that become deforested by tree death and insect attack before native species migrate.

Interior Douglas-fir and Ponderosa Pine zones (IDF & PP)

Dry coniferous forests, dominated in particular by pine species, were once much more widespread under warm/dry climates.[116] Hamann and Wang's (2006) analysis shows the potential for a large increase in suitable climate for both IDF and PP zones within this century. The IDF climate may spread widely throughout central BC, whereas PP climates may develop over a huge area between 2055 and 2085 in the Peace Region of northeast BC. However, the rate of spread of the species required for such large expansions over such great distance prohibits anything like the modern zones to develop in this interval. Transient ecosystems of undetermined composition must be expected. The character of these will likely be mediated by pest outbreaks and fire. Fire activity is expected to increase as summer conditions become drier than today and the length of the fire season increases.[117]

Interior Cedar-Hemlock Zone (ICH)

The diverse moist conifer forests of southern interior BC are a relatively recent feature, arising in response to the relatively cool and moist climates of the last few thousand years.[118] If evidence from the fossil record is used as a reference, widespread decrease of the zone is projected. Impacts modeling, however anticipates a doubling of ICH forest by 2085, primarily in central BC.[119] Further complicating the picture, the species model for western redcedar shows widespread decline in the valleys of southern BC. Decreases in the south may be compensated by widespread expansion in north central BC.[120]

Of all the zones, this globally distinctive system needs further study as evidence from different models offer different potential outcomes. The ecological and species range adjustments suggested by models will take many decades if not centuries. Summer drought and fire, both of which are expected to increase in influence, may be the determining factors.

Northern Spruce Forests: Sub-boreal Pine Spruce (SBPS)/ Sub-Boreal Spruce (SBS)/ Boreal Black and White Spruce (BWBS) Zones

Climate impact modeling suggests a high risk for the transformation of these forests to ecosystems typical of southern BC.[121] Hamann and Wang (2006) predict that the area of suitable climate for the northern spruce forests (SBS and SBPS zones) will decrease by more than half by 2055, and by more than 80 percent by 2085. The climate of the BC Boreal forest (BWBS) persists in place through to 2055, but thereafter its area declines by about half by 2085.

The mountain pine beetle epidemic has already changed these forests; other pests could also reach epidemic levels[122]. In addition, the incidence of fire in boreal conifer forests is on the increase and will likely increase further.[123] As soil temperatures warm due to temperature increases the growth of forest floor mosses, a key ecological element of northern spruce forests may decline. Changes in the composition and structure of northern forests are likely to impact ungulate populations.

Spruce-Willow-Birch zone (SWBS)

The Spruce-Willow-Birch (SWBS) zone is poorly understood ecologically and its fossil history in not well known. Climate impact models suggest that this northern subalpine zone climate could largely disappear by 2055.[124] Accordingly, it is predicted to be the most negatively impacted of all the BEC zones in the province. Predicted losses of permafrost will certainly contribute to changes.

Montane Spruce and Engelmann Spruce-Subalpine fir zones (MS and ESSF)

The Engelmann Spruce-Subalpine fir (ESSF) zone, similar to the Interior Cedar Hemlock zone, is a young system that spread in response to cool and moist high elevation climates.[125] On this basis, the ESSF zone could be expected to decline in area with climate change. Hamann and Wang (2006) models show the ESSF area remaining largely stable until 2085 as increases in the north offset widespread losses in the south. The mid-elevation Montane spruce zone climate region is projected to decline progressively over the century to about a third of its original area, replaced largely by interior cedar hemlock and dry conifer forest climates.

Alpine Tundra (AT)

Cold climate, high elevation ecosystems are particularly vulnerable to climate change because of their restricted landscape position.[126] Tree-lines stood higher by about 100 metres during warmer climates only 8000 years ago.[127] The area of climate suitable for alpine ecosystems may decline by 60 percent by 2025, and 97 percent by 2085, with tree lines rising by 168 and 542 metres, respectively.[128] Alpine and subalpine patches of southern BC are small and especially vulnerable to climate change. Some alpine climates will likely persist where the mountain climate gradient is steep.

Freshwater and Marine Ecosystems

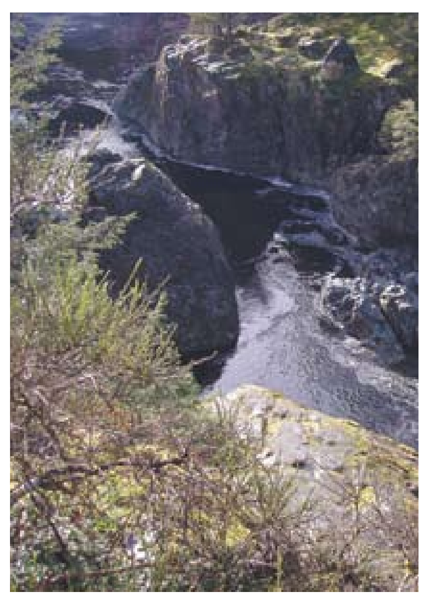
Wetlands

Wetlands are particularly sensitive to climate change.[129] As physiographically-limited systems, wetlands cannot migrate; hence they are vulnerable to changes in water table levels (i.e. hydrology) and nutrient cycling. Fossil studies suggest that shallow interior wetlands are likely to dry up.[130] Cool, moist climate wetlands with stable hydrology, such as bogs, will be negatively impacted; marshes with fluctuating water-tables and higher nutrient levels are more likely to persist. Changes in wetlands will impact obligate species, and may have consequences for birds that use wetlands for breeding and migration. Climate change is projected to constrain water resource availability in many regions, so increasing demand for water by human activity will likely intensify the impacts of climate change on wetlands.

Coastal Ecosystems

Current trends suggest that global sea levels are rising more rapidly than predicted by models.[131] Regionally, the actual rate of sea-level rise depends on several factors mostly related to geological phenomena. For example, the west side of Vancouver Island is rising relatively slowly out of the sea, thus reducing the effects of global sea-level rise. In contrast, the land surface of the Fraser River Delta is subsiding, making it more vulnerable to the global sea

Sooke Potholes, now protected as a park and campground, thanks to thousands of people and BC's Land Trusts
– photo: Sheila Harrington



level increase. Consequently, the impacts of sea-level rise will vary along the coast of British Columbia. Comprehensive sea-level change models have been developed by the Geological Survey of Canada,[132] and a draft study prepared by Hill et al. for Roberts Bank on the Fraser Delta provides key insights for the low-lying parts of the Lower Mainland.[133]

Lambert et al.[134] project a sea level rise of between about 20 and -100 centimetres with a median value of about 0.60 metres. The Roberts Bank report concerns itself with Roberts Bank, but the projected sea-level rise and impacts will affect the delta up-stream at least as far as the tidal influence of today. All low-lying areas within this zone will have an increased risk of flooding and erosion. Salt water will penetrate further inland, resulting in the potential for delta-front freshwater marshes to turn brackish.

The dyke system will require re-enforcement and raising due to the predicted increase in sea-level. The cost of maintaining ever-higher dykes and the need to offset the loss of estuarine habitat due to flooding by the rising ocean will result in some delta lands returning to marsh.

In general, rising sea-levels along B.C.'s coast will certainly lead to increased erosion and a reshaping of the shoreline and its inhabitants. A key adaptation strategy is to ensure sufficient land adjacent to the shore to accommodate increases in erosion patterns and shifting shoreline habitats, especially in built up areas.

Aquatic Systems

The potential effects of climate change on British Columbia's aquatic habitats have not been comprehensively evaluated. However, major impacts are expected as changes in temperature and precipitation combine to impact the province's wide range of aquatic environments (i.e. warmer and drier summers). Furthermore, aquatic environments are particularly prone to extreme climatic events such as floods and droughts. Many aquatic systems are already stressed and degraded by other human impacts including water use for irrigation, agricultural run-off, trampling by range animals, and human and industrial pollution.

Studies of ocean, lake and river waters suggest that climate change may already be impacting salmon and other fish populations by changing migrations times, food availability, and limiting the use of river systems.[135] Models of future conditions indicate increasing temperatures exerting further stress on salmon populations.[136],[137] In addition, changes in run-off will have impacts on salmon spawning beds through erosion or sediment deposition during winter high flows and flood events, or by exposing them during low water periods. Streams driven by rainfall will likely experience extended summer low-flow periods, warming shallow waters even more, and favouring warm water species. In snowmelt and glacier-fed streams, the timing and intensity of freshet floods will change, resulting in earlier and perhaps more intense peak run-off flows. As temperatures rise, and more precipitation falls as rain rather than snow, some river systems will become rainfall driven and their ecology will also be altered.

The ecology of lakes is similarly dependent on temperature. Many lakes develop characteristic patterns of temperature stratification, which change seasonally mixing nutrients from the lake bottom upwards, to feed the entire water column. This key process will be altered as lake water temperatures increase, and as winter ice on lakes diminishes.

Fossil studies demonstrate that the composition of the invertebrate fauna changes as lake ecosystems cool.[138] Such studies also reveal the potential for small lakes to shallow up and shrink in size with warming temperatures.[139] A lessened water volume clearly would result in alterations in shoreline and plankton communities, and affect water fowl.

Agricultural Lands

A comprehensive assessment of climate change impacts on British Columbia's agricultural lands is not available. Some obvious effects however can be anticipated:

- Fields in bottomlands will be at greater risk to erosion, deposition, and crop loss from predicted increased flooding.
- More frequent and intense storms may destroy crops in the fields.
- Lands along the marine shoreline on deltas may become unsuitable or unsustainable for agriculture as the sea-level rises and saltwater intrudes.
- In summer-dry areas such as the southern interior, summer droughts may become more intense leading to a higher demand for irrigation water and potential increases in conflicts over water resource availability for urban and biodiversity purposes.
- Warmer temperatures may bring more pests or worsen pest problems kept in check by winter cold.

Despite the potential for negative impacts, the choice of crops will likely increase under certain more favourable climatic conditions. Royal BC Museum models for growing degree days point to an increase in the potential area of crop production and crop selection.[140] Today, cereal and cool weather crops grow in the Peace River area, a greater variety of crops are cultivated mainly in the southern interior and on the coast, while most of the province is unable to sustain much beyond pasture.

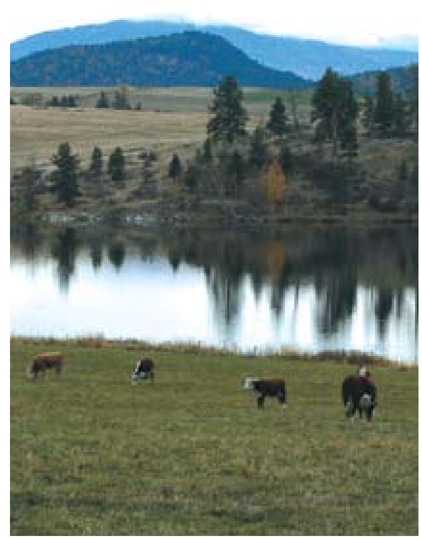
By 2050, much of southern British Columbia, with suitable soils and adequate moisture, will be able to support cereals; large parts of southern B.C. as far north as Prince George may support the cultivation of corn, tomatoes and apples. By 2080, the warmer parts of central B.C. might have a climate suitable to the cultivation of crops typical of the Okanagan. In the south, the commercial cultivation of crops typical of the northern half of the Central Valley of California such as pecans, rice, and olives may be possible.

The gains in yields may however be constrained by other factors related to climate change, including increases in severe weather events causing damage to crops and soil erosion; heat stress due to higher temperatures and heat waves; salinization of irrigation water and freshwater systems; and increased water demands accompanied by less reliable water supply.[141] In general, moderate climate change in the early decades of this century is projected to increase aggregate yields of rain-fed agriculture by 5-20 percent, with major challenges for crops near the warm end of their range and those that depend on highly utilized water resources. By the second half of the century other stressors may include increased fire, pests and diseases.[142]

Summary of Impacts

Whether on the local, provincial or global scale, major impacts on ecosystems from climate change are inevitable. Species will be migrating, the structure and function of ecosystems will be challenged and many will likely be altered irreversibly. The precise nature of these changes is difficult to foresee in part be-

Pine Butte Ranch: covenanted by the Nature Conservancy of Canada.
– photo: Sheila Harrington

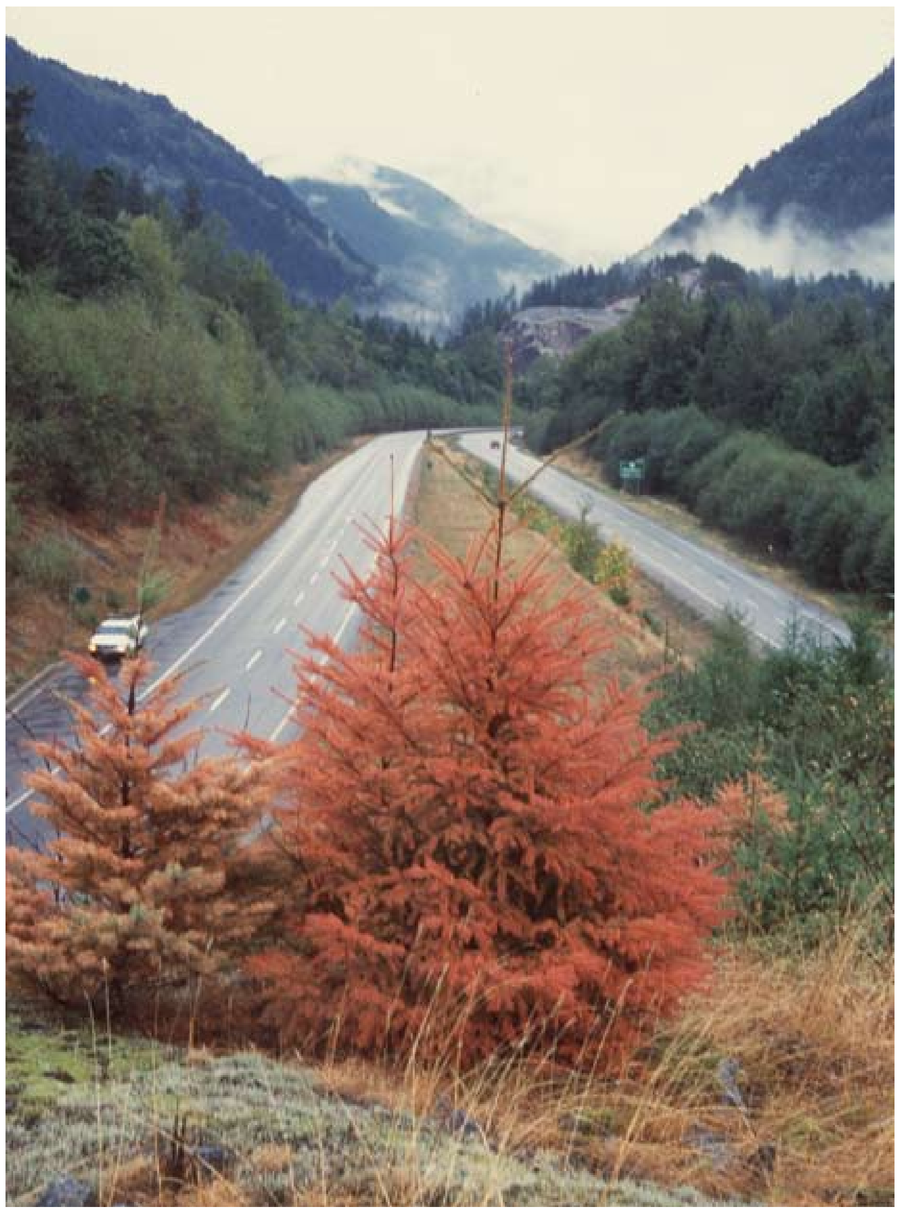


cause of our limited knowledge and in part because the amount and character of climate change is uncertain. Furthermore, the impacts and resulting changes will continue for many decades and likely for centuries.

Ecosystems from continental biomes to local water sheds and woodlots will undergo changes. Grasslands, in places, will likely replace forests, and forests will likely replace alpine meadows. The extent and character of wetlands will be altered. Ecosystems along the marine shore will shift and some will disappear. Fundamental ecological process such as fire disturbance and pest and disease intensity and frequency will be altered. The abundance of some species and populations may increase in the long run whereas others are likely to go extinct. All of these effects will influence not only biodiversity but also all the vital ecological services upon which humans depend.

Understanding the likely impacts of climate change will be key to both managing for the future of natural values and to identifying the importance of the conservation of natural areas in addressing climate change.

Photo: Richard Hebda, *Douglas fir, Coquihalla highway*



Part III: Strategies to Reduce Climate Change Impacts

Carbon Markets

Carbon markets have been developed as a strategy to reduce GHG emissions in response to climate change. The global carbon market emerged as a result of the 1992 UN Framework Convention on Climate Change and the 1997 Kyoto Protocol, which set GHG emissions limitations for ratifying parties and established mechanisms for reducing overall GHG emissions by at least 5 percent below 1990 levels. Although there are several types of greenhouse gases, markets measure emissions in terms of carbon equivalents or CO_2 eq. Two types of carbon markets have emerged: 1) regulated cap-and-trade markets and, 2) voluntary carbon offset markets.

Regulated Cap-and-trade Markets

Regulated emissions trading is a market-based mechanism that aims to achieve reductions at the least cost based on a limit or cap on the total amount of greenhouse gases that can be emitted. Under this system, companies or other entities that emit carbon dioxide are given credits or allowances that represent the right to emit a specific amount, with the total amount of credits below the set cap. Companies that pollute beyond their allowances can purchase credits from those who pollute less than their allowance. The trading of greenhouse gas emissions is purportedly cost effective as it maximizes emissions reduction efforts where they are the least costly. They are also environmentally sound in terms of the global impact of climate change. For instance, greenhouse gases that enter the atmosphere move quickly around the Earth so that the location of reductions is irrelevant.

Regulated GHG emissions' trading occurs only in countries that have either ratified Kyoto or have set internal cap-and-trade systems under their emissions targets (e.g. European Union). The regulated global carbon market was worth an estimated US$30 billion in 2006.[143] The primary market is the European Union Emissions Trading Scheme (EU ETS), which is worth about $25 billion. At this time, only direct GHG reductions are included in cap-and-trade markets.

Voluntary Carbon Offsets

A greenhouse gas or carbon offset is generated by the reduction, avoidance, or sequestration of GHG emissions from a specific project. Offsets are intended to counteract greenhouse gases that are emitted into the atmosphere at a specific source by sequestering them elsewhere. Carbon offsets are purchased by individuals and companies to offset their own carbon emissions. In contrast to emissions trading, which is regulated by a formal and legal framework, carbon offsets are arranged by commercial or not-for-profit carbon offset providers. Ideally, carbon offsets are used only after all feasible GHG emissions reductions have been undertaken. A common offset transaction is one that offsets carbon emissions from air travel. The voluntary market for reductions by corporations and individuals is growing very rapidly. In 2006, it was worth an estimated $100 million.[144] Proponents of offsets assert that they can be an important part of an effective climate policy, implemented quickly at a relatively low cost.

Additionality: Additionality of a carbon offset means showing that the emissions reductions being used as offsets are not "business as usual". Business-as-usual emissions are generally referred to as the emissions "baseline".

Leakage: Leakage occurs when activities that reduce GHG emissions in one location cause emissions to rise somewhere else. This can reduce or eliminate the net benefit of the project.

Carbon Neutral: A concept that refers to consumers, organizations and businesses neutralizing their personal or corporate GHG emissions or their carbon footprint by offsetting all or some of the emissions associated with their lives and activities.

Carbon offset: The act of reducing or avoiding GHG emissions in one place in order to "offset" GHG emissions occurring somewhere else. A carbon offset negates or "neutralizes" a tonne of CO_2e (carbon dioxide equivalent) emitted in one place by avoiding the release of a tonne of CO_2e elsewhere or absorbing/sequestering a tonne of CO_2e that would have otherwise remained in the atmosphere. Unlike most pollutants, GHGs travel around the planet's atmosphere quickly so it doesn't really matter where the reduction takes place. Offsets are designed to take advantage of the differing costs and logistics of achieving GHG emissions reductions by sector and geographical location. [148]

The focus of many early carbon offset projects was tree planting, though renewable energy, energy efficiency and methane capture offsets are now common. In general, carbon offsets are created by:

- increasing energy efficiency in buildings, factories or transportation
- generating electricity from renewables such as wind or solar
- modifying a power plant or factory to use fuels that produce less GHG
- putting wasted energy to work via cogeneration, and
- capturing carbon dioxide in forests and agricultural soils.[145]

There are a number of criticisms of carbon offsets. Some critics feel that offsets provide companies and consumers with an excuse to pollute.[146] Critics note that offset markets have questionable results in reducing carbon emissions and express concern that the use of carbon offsets may actually increase emissions in the absence of a cap on overall emissions.[147] Unlike the regulated markets, the voluntary sector lacks a universal standard. This has resulted in significant skepticism of carbon markets in genral and the credibility of offsets in particular.

Forestry projects, especially tree planting projects, have been criticized because of a number of issues including permanence. For example, a forestry sinks project may absorb carbon while living but at some point it will succumb to disease, fire and/or logging. As a result, many people consider them to be temporary offsets and/or disregard them as reliable offsets altogether.

Although there is much disagreement over the effectiveness of the voluntary carbon market in terms of averting global warming, there is considerable support for carbon offsets because they prompt people and communities to begin factoring in the cost of their carbon footprint when making individual, business and community decisions. Carbon offsets also result in a price on the emissions of carbon, a value that begins to filter into people's thinking and business operations.

There may also be important environmental and social benefits in addition to the GHG emissions reductions that carbon offsets provide. For instance, depending on the type of offset, investments in offset projects can result in other environmental, social and economic benefits such as:

- Reductions in other atmospheric pollutants
- Restoring degraded lands
- Improving watersheds and water quality
- Protecting endangered species

The development of a single comprehensive standard that addresses all of these issues is necessary for a credible voluntary market. Several different standards have been developed by various sectors. For example, the UK government has undertaken a consultation to develop a Code of Best Practice for the provision of carbon offsetting for UK customers; non-governmental organizations have developed the Gold Standard (endorsed by 40 NGOs), and international agencies have developed The Voluntary Carbon Standard.

Some carbon offset providers are working to ensure that the offset projects they invest in are quantified and verifiable. The Climate Trust, located in Oregon, is one of the largest and most experienced offset buyers in the U.S. and globally. Their current projects are expected to offset nearly 2.6 million metric tons of carbon dioxide from $8.8 million in investments. They use a set of criteria to ensure additionality and rigorous measurement of benefits including a measure of a baseline projection of emissions without the project against the actual emissions. In addition, a third party with no financial interest must verify the approach and calculations of these results.

Consequently, if an organization is considering projects that may qualify as carbon offsets, it is essential to evaluate their ability to provide valid and measurable benefits as well as their ability to manage the projects and provide long term accountability.[149] The primary issue is how to gauge the quality of an offset project. The main focus is on the topic of "additionality." Additionality is determined by answering the question: Would a project have happened anyway? If yes, the offset cannot be said to have additionality. If no, then it may qualify as a true offset. Although this may seem to be a simple question to answer, the problem is there is often disagreement on whether a project may or may not have happened.[150] A "guideline" for determining an offset project would include:

1. a baseline determination of business-as-usual GHG emissions;
2. measurement or quantification of the GHG emissions reductions (or sequestration) resulting from the offset project relative to the baseline emissions;
3. account for the permanence of the offset or GHG reductions including whether there is the potential for reversal in the future;
4. account for key potential uncertainties such as leakage, and;
5. the offset project should be monitored and verified over time.[151]

The importance of avoiding the release of carbon to the atmosphere due to deforestation and degradation of forests and wetlands, is not well represented in the carbon markets. The overview of carbon storage by natural areas in Part I illustrates that investment in the storage of carbon in ecosystems is a good investment for mitigation (i.e. avoided emissions) and for adaptation purposes. Such investments will be beneficial for communities and jurisdictions as part of their planning for adapting to climate change, whether or not such projects may qualify as carbon offsets. Other financial mechanisms include providing the opportunity for contributions toward conserved lands with legal and permanent protections through conservation covenants (easements/servitudes in other provinces).

Carbon Offset Opportunities for Land Trusts and other Conservation Agencies

This section provides some examples of the opportunities for land trusts and other conservation agencies regarding retail carbon offset providers as well as examples of land trust initiatives to provide their own carbon offsets in the form of contributions or donations to protected lands.

The Chicago Climate Exchange (CCX) is the world's first (and North America's only) legally binding rules-based GHG emissions allowance trading system. Its members make voluntary but legally binding commitments to meet annual GHG emissions reduction targets, whereby those who reduce below target have surplus allowances to sell or bank and those who are above target comply by purchasing CCX Carbon Financial Instrument (CFI) contracts. These contracts include Exchange, Allowances, and Exchange Offsets based on standardized rules. Exchange Offsets are generated by qualifying offset projects, which include: agricultural methane, agricultural soil carbon, forestry, and rangeland soil carbon.[152]

To address the critiques of carbon offsets, the CCX has adopted several standardized rules for issuing their contracts. In the instance of forest carbon sequestration, the following specifications include long-term commitment to maintain carbon stocks in forests, approved methods of quantification of carbon stocks and independent verification by a CCX-approved verifier. To address the issue of permanence, each year 20 percent of the CFI contracts generated though reforested land are placed into a reserve pool from which they compensate any carbon storage reversal in an amount corresponding to the CO_2 tonnage loss resulting from the reversal.

Entities and individuals in the agricultural, forestry, waste management and renewable energy sectors can participate in CCX by registering offsets - emissions credits earned by eligible offset projects that sequester, destroy or displace greenhouse gas (GHG) emissions. These entities may join CCX as Offset Providers or Offset Aggregators. An Offset Provider is an owner of an offset project that registers and sells offsets directly on the Exchange (http://www.chicagoclimatex.com/content.

Trees In Trust is an organization based in Ottawa, Canada that provides the opportunity to contribute money towards the protection of forests to give as a gift, as a memorial, or to reduce an individual's or a business' carbon footprint. The purchase is a contribution to the organization that then uses it to protect areas which are held in the name of the contributors by a not-for-profit charitable land trust which protects the woodland in perpetuity. The first land trusts in Canada who have targeted conserved lands as an offset with Trees in Trust are the Island Nature Trust in Prince Edward Island and the Nature Trust of New Brunswick. For more information see: http://treesintrust.ca.

The World Land Trust is an example of an international non-profit organization/land trust that offers its own carbon offsets for conserving land and conservation purposes. The World Land Trust offers individuals and companies investment opportunities through offsets on their website for rainforest conservation in developing countries.[153] However, in a global context, it is important to consider the local community. Conservation of land must only be undertaken if it meets the social and ecological needs and desires of the surrounding community. The carbon offset purchaser and provider must both make every effort to address local needs and concerns.

There may be opportunities for land trusts and other conservation organizations and agencies to set up some form of conservation-based carbon offset or carbon stewardship registry. As discussed above, conservation projects that meet the issues of additionality and permanence may qualify as viable offsets. The adoption of certification processes and standards by offset providers will be crucial for building confidence in both independent and government created offset registries.

BC's Climate Plan and Local Initiatives

The British Columbia government has recently taken several steps to begin addressing climate change. Most recently, the government introduced the Greenhouse Gas Reductions Target Act. This Act puts British Columbia's target of reducing GHG emissions by at least 33 per cent below 2007 levels by 2020. It also requires that interim targets for 2012 and 2016 be set by the end of 2008, and establishes an emissions reduction target of 80 percent below 2007 levels by 2050. The Act will also require a published report every two years outlining the progress made towards reaching the emissions reduction targets. The Act also requires the provincial government, including provincial ministries and agencies, schools, colleges, universities, health authorities and Crown corporations to become carbon neutral by 2010 and to make public a report every year detailing actions taken towards carbon neutrality. In addition, the government has committed to legislating a cap-and-trade system next spring to require hard caps on GHG emissions from all of BC's heavy emitters.

The provincial government has also joined international and inter-regional partnerships. In October 2007, the BC government joined the International Carbon Action Partnership (ICAP)[154], which is an international organization of governments that are adopting caps on greenhouse gas emissions that will provide a forum for sharing information on best practices and strategies such as the development of compatible global carbon trading systems.[155] British Columbia has joined with five western U.S. states to partner in the Western Regional Climate Action Initiative (WRCAI), a partnership designed to identify, evaluate and implement ways to collectively reduce greenhouse gas emissions in the region and to achieve related co-benefits. The initiative requires partners to set an overall regional goal to reduce emissions, develop a market-based, multi-sector mechanism to help achieve that goal, and participate in a cross-border greenhouse gas (GHG) registry.

The BC government has also set up a provincial Climate Action Team to advise the province's Committee on Climate Action on the targets for 2012 and 2016. These targets will be legally mandated, through regulation, by the end of 2008, and the team will identify further actions in the short and medium term to reduce emissions to meet the 2020 targets. In addition, the team will provide advice on the provincial government's commitment to become carbon neutral by 2010. Final recommendations will be available by July 31, 2008.

As part of the WRCAI, a new carbon-trading registry for the province will be set up in 2008. This registry will allow BC residents to offset their personal carbon footprint such as air travel. The carbon offset projects that the government invests in will be audited under the carbon trading registry once it is set up.[156]

Because the government has committed to becoming carbon neutral, all government travel will have to be offset starting in 2008. Emissions from government travel will be tracked, calculated, peer reviewed and audited. Starting this fiscal year, for every tonne of GHGs associated with official government travel, the Province will invest $25 in a new BC Carbon Trust. The trust will be launched early next year and will ensure tax dollars are invested in valid offset projects in B.C. It will also be open to individuals, companies and other levels of government to help them become carbon neutral and help reduce emissions by supporting a made-in-B.C. offset project. Projects funded by the trust may include enhanced energy efficiency, produce clean, renewable energy or sequester carbon through incremental afforestation measures.[157] The BC Carbon Trust therefore may provide an opportunity for new conserved lands that meet the trust's requirements (e.g. avoided carbon emissions).

Many local governments across the province have also made commitments to address climate change. In September 2007, BC local governments committed to becoming carbon neutral by 2012 by signing on to the province's Climate Action Charter.[158] Carbon neutrality involves measuring the greenhouse gas emissions that come from government operations such as buildings and fleet vehicles and then reducing those emissions to net zero. Governments achieve carbon neutrality by reducing emissions where possible, by purchasing carbon offsets to compensate for its greenhouse gas emissions or by developing projects to offset emissions.

The Union of BC Municipalities and the provincial government will establish a Joint Provincial-UBCM Green Communities committee and Green Communities Working Groups to define a range of actions that can affect climate change, build local government capacity to plan and implement climate change

Other provincial initiatives on climate change include:

- Greenhouse gas emissions reduction strategies and targets will be legally required in all official community plans and regional growth strategies.
- Municipalities will be given the power to waive development cost charges as a way to encourage green developments, small unit housing and small lot subdivisions.
- All new government buildings or facilities shall be built to a minimum LEED Gold or equivalent certification.
- Legislation will be introduced next spring to require the adoption of California tailpipe emission standards to be phased in from 2009 to 2016.
- BC will be the first province in Canada to legally adopt California's low carbon fuel content standards, a requirement that will reduce carbon intensity of all passenger vehicles by a further 10 per cent by 2020.
- BC will implement a five per cent average renewable fuel standard for diesel by 2010 and support the federal government's plan to increase the ethanol content of gasoline to five per cent by 2010.
- The Province will provide an additional $50 million this year for BC Transit to purchase new, clean buses and expand public transit service across BC.

initiatives, support local governments in taking actions to make their own operations carbon neutral by 2012, and share information to support climate change activities. These initiatives may also provide opportunities for land trusts and other conservation agencies to form partnerships on land-use planning, mitigation through conservation projects, and stewardship or management agreements on natural areas for building resiliency to climate change.

The BC government Climate Change Initiatives are focused on reducing the use of fossil carbon. This is one, very important, component of a Carbon Stewardship approach. Protecting land, and thus the living and dead carbon storage capacity of ecosystems, has not yet been recognized in government initiatives. As we have shown in this report, conserving land for carbon storage services can be a very cost effective investment, especially when one considers the added benefits of protecting watersheds, wildlife habitats, soils and other human values.

To qualify as carbon offsets, conserved lands would have to demonstrate GHG emissions reductions. For example, if a newly protected forest area was previously slated to be clear cut under 'business as usual', an estimate of the avoided GHG emissions due to the conversion could be calculated and the carbon sequestration rate under conservation could be measured. Regardless, conserving land for carbon storage services protects other essential services that will be impacted by climate change. The most cost effective investment, in terms of financial resources for wise carbon stewardship is an investment in the protection of natural areas for mitigation and adaptation and the protection of ecosystem services.

Conservation of Land and Ecosystems: Mitigating and Adapting to Climate Change

Land trusts, land owners, conservation agencies and resource managers have a central role in the mitigation and adaptation to climate change. There are also strategic and practical implications of climate change for community planning, land management, restoration, conservation, stewardship and monitoring activities. From a strategic perspective, land trusts now have a major opportunity to play a key role in adaptation to and mitigation of climate change.

The benefit of protecting land for ecological values has been well described in Part I of this report, while Part II demonstrates that climate change brings major uncertainty for biodiversity, for key human needs, such as food security, and the maintenance of ecological services (e.g. pollination services, natural pest control). The risk varies according to the amount of climate change, the vulnerability of a region, ecosystem or species, and the opportunities for adaptation. Although some climate change is now inevitable given the current level of CO_2 in the atmosphere, the degree of change depends on the steps taken today to reduce human-caused greenhouse gas emissions. Considering the potential timing and extent of the consequences of climate change, immediate action on both mitigation and adaptation fronts is vital.

Even the most stringent global mitigation efforts cannot avoid the climatic consequences of increased CO_2 in the atmosphere. For this reason planning for adaptation is absolutely necessary particularly to address near-term impacts. If we do not significantly reduce GHG emissions, climate change in the long-term is likely to exceed the capacity of natural, managed and human systems to remain stable or shift without serious disruption. A mix of adaptation and mitigation measures diminishes the risks of unmanageable change. A strategy of adaptation and mitigation is especially important because of the stress on global systems from other human impacts such as ecological fragmentation, land use change, and pollution. Both strategies need to be part of policies and fiscal directives especially for those involved in development and land-use planning.

The benefit of protecting land for ecological values has been well described in Part I of this report. It bears emphasis that preserving and conserving land for multiple values and functions beyond preserving biodiversity is an overarching benefit of land trusts in the larger conservation field. Thus an effective strategy should combine biodiversity objectives with other key values such as water conservation, water quality, water detention and storage, agroecology, ethno-cultural values, and adaptive management choices. Conservation of ecosystems through land management strategies and protection for all these values is a wise adaptive strategy for the uncertainties ahead associated with climate change.

Adaptation

Ecosystem values and services will be increasingly at high risk as climate change progresses. The degree and extent of change are such that global and provincial ecological reorganization will likely ensue. Retaining areas that provide options for species to persist in the face of change and migrate to new locations will be an important strategy as we strive to maintain biodiversity. Human demands on ecosystems and the services they provide will intensify as resources become less predictable and in some cases, such as water, more limited. The protection of healthy, functioning and diverse ecosystems provides resilience for natural areas and human communities, and reduces the risk of rapid changes and loss of ecosystem values and resources.

The IPCC clearly notes that there will be progressive loss of options to respond or adapt to climate change. For example, global and local extinctions are certain to reduce society's options for adaptation by limiting choices and possibilities. Land trusts, governments, and conservation organizations have a vital role in ensuring the protection of ecosystems both for conservation as well as for providing options for adaptation to climate change.

Great Beaver Swamp on Galiano Island, protected by the Galiano Island Conservancy

The protection and conservation of ecosystems for specific values today may also provide key options for implementing adaptive strategies as the climate changes in the future. For example, protected agricultural lands could provide key biodiversity roles (i.e. corridors for important ecological processes and species migration). Conserved lands could temporarily serve as sites for propagating or holding and testing rare plant species in anticipation of changing climatic conditions. Protected ecosystems and lands also afford opportunities for adaptive monitoring under controlled and secure conditions to develop response strategies to climate changes.

Mitigation

Mitigation concerns actions and policies that either reduce GHG emissions to the atmosphere or enhance their removal (act as sinks) from the atmosphere. The FAR Working Group III emphasizes technological change and substitution in their definition of mitigation (Verbruggen 2007). However, natural ecosystems are deeply involved in both processes because plants take (scrub) CO_2 from the atmosphere through photosynthesis and almost all organisms release CO_2 through respiration.

Thus the conservation of ecosystems mitigates climate change through sustaining functioning ecosystems that scrub CO_2 from the atmosphere. Furthermore, the conservation of ecosystems avoids the conversion or degradation of ecosystems and the subsequent release of CO_2.

From this perspective, conserving intact ecosystems has a double benefit to the mitigation of climate change. For this reason protecting and conserving natural ecosystems is the best natural way to mitigate climate change, because the benefits are immediate (prevention of emissions) and long term (continued scrubbing of CO_2). Conserved ecosystems also offer the potential to enhance primary productivity and improved CO_2 removal through good stewardship and management such as restoration.

In short, from the perspective of mitigation, planting trees is good but conserving and protecting natural ecosystems is better because it helps avoid emissions and removes atmospheric carbon dioxide.

The beauty of conserving ecosystems (and protecting lands) is that it provides strategies to counter climate change on both fronts: mitigation and adaptation. Mitigation values are protected and even enhanced and at the same time the resilience of ecosystems and their ability to adapt is maintained and also enhanced. Not only do the benefits accrue to biodiversity, they also accrue simultaneously to human communities through protected watersheds, wildlife habitat, healthy food, human health, recreation, and culture, especially providing for adaptation options, as necessary. These expanded options are vital, because ecosystems converted for human use offer fewer options for mitigation and adaptation.

Protecting ecosystems, especially natural areas, comprehensively addresses the challenges of climate change. It covers the spectrum of strategies from reducing CO_2 concentrations in the atmosphere to preparing for inevitable changes.

Decision Support Strategy for Conservation Organizations, Agencies and Land Trusts

As this report demonstrates, climate change will have unavoidable impacts on terrestrial and aquatic ecosystems and the people that use them. There exists considerable uncertainty on the specific outcomes and geography of where they will occur. Nevertheless, it is possible to suggest strategies and a decision-making framework to anticipate the consequences of climate change and reduce the risks of making specific land acquisitions and management choices.

The impact of climate change on ecosystems is very complex and, therefore, strategies need to be adapted to the specific situations of land trusts and other conservation agencies and their objectives. It is imperative that the effects of climate change be incorporated into conservation strategies immediately. Appropriate land acquisition and management decisions taken now will reduce risks in the near future and foster the efficient use of financial and human resources.

Two key principles in a responsive climate change strategy are

a) shifting from a framework of a relatively static landscape to one that is highly dynamic; and
b) assessing the site's sensitivity to climate change.

Land protection decisions are traditionally based on preserving land and its values in place. Nature, however, will be "on the move" and key physical and biological processes will be changing too. As a result, strategies/acquisitions that focus on assumptions of a static landscape may fail to meet long term goals.

In the second case, the site's sensitivity to climate change or the value being conserved at the site may vary or change over time. In some cases, climate change may not be an issue of concern; in other cases it will be a major factor.

Thus, conservation organizations have the two strategic aspects to consider. The first relates to an organization's objectives in recognizing climate change, while the second relates to a conservation strategy on a specific site.

Evaluating Organizational Objectives in the Context of Climate Change

Step 1: Are your organization's objectives achievable in the context of climate change?

Each land trust or conservation agency has a set of conservation and stewardship, management or restoration objectives and a set of guidelines for decision-making. The first step is to review the objectives and incorporate the projected impacts of climate change. For example, a land trust with the sole objective of maintaining cold climate species in southern regions may have unrealistic expectations.

If, however, the general objectives seem achievable then the next step is to evaluate the level of risk to those objectives.

Step 2: What are the risks of not achieving your objectives because of climate change?

At first glance, it might seem that all land trust objectives should be achievable, despite climate change, considering that land acquisition and conservation provide options and flexibility for the uncertain future. Some objectives however are exposed to a significant risk of failure. In general the following two principals can be applied:

Sapsuckers
– photo: Todd Carnahan

1. Objectives related to large geographic area (i.e. province of BC) are at less risk than those applied to a restricted area such as a municipality.
2. Objectives applied to general values (such as protecting green space) may be at less risk than those applied to specific values such as the preservation of an individual species or fish population.

Considering these two principles, the objectives of land trusts and other conservation organizations operating over a large geographic range and encompassing broad values are at a lower risk to climate change, whereas those focused on a local area for a specific value are at a higher risk.

To evaluate your organization's risk, evaluate your objectives using the preceding principles. If your objectives fall into the small area/specific value category, then you may proceed to review their suitability in relation to climate change for each specific project. Evaluation of specific values or ecosystems can be considered using the Decision Support Table (Table X). If your objectives fall into the other categories, your objectives may be attainable with adjustments in your approach. For example, you may have acquired a piece of land to protect a rare species that may not survive on that specific property. The property may still provide a corridor for species migration. Furthermore, by linking with other conservation agencies and organizations, province-wide, your specific objectives, though at risk, may still lead to acquisitions and strategies that are important to broader objectives applied at a large geographical scale.

The concept of linkage leads to a third strategic principal, one that is already in practice but one that is even more important in the context of climate change:

Step 3: Consider and adjust objectives in the context of the objectives of all other conservation agencies.

This principal is applied now with respect to efficiency of resources and coverage of values (i.e. representation of ecosystems) or geographic areas. In the context of climate change, ask yourself the question: "Do our objectives, even if they are at risk to climate change, support objectives and current or future conservation plans of other lands trusts and land management initiatives?" If the answer is yes to this question, then risky objectives may still be acceptable. If the answer is no, the objectives likely need to be revised.

Several other principles, largely related to the sensitivity of ecological values to climate change, are worth considering too. These can also be applied to specific locations when considering a land acquisition or conservation strategy.

Step 4: Review objectives related to ecological zones of transition and highly sensitive ecological gradients.

The scale and degree of climate change is such that almost all zones of ecological transition will undergo impacts.

From this perspective, if your objectives focus on protecting or conserving northern ecosystem attributes at the southern limits of their range, they are at high risk of failure. Conserving a small patch of relatively low elevation alpine tundra, or a boreal wetland in southern BC are examples of high risk initiatives. Similarly, objectives that focus on populations of northern species such as mountain caribou in isolated or small populations occupying southern regions may not be achievable because the species may be unable to survive in general under new climatic conditions; the required habitat may not persist; and weather extremes may lead to singular extirpation events of small populations.

Conversely, protecting southern ecosystems at the northern limits of their range (e.g. Okanagan grasslands, Garry oak meadows) and possibly coastal ecosystems may have a relatively low risk of failure.

A specific example which highlights the importance of land-use planning in which land trusts may play a role is the Fraser Delta area. Unoccupied low-lying lands on the delta could be set aside or acquired for estuarine habitat and to provide detention storage as the risk of flooding increases. Adjacent agricultural lands could also be candidates for protection, as they could return to wetland habitat once they become unsuitable arable lands because of permanently wet soils and/or increased salinity as the sea-level rises.

All wetland ecosystems need close consideration too. Wetlands have a range of key values and conserving them is clearly vital, while they will undergo some changes as described in the Part II. Wetlands often exist as discrete isolated units within a matrix of non-wetland ecosystems. General climatic trends and an increase in weather extremes strongly point toward instability in wetland ecosystems, including the possibility of both flooding and drought. Numerous wetland species and plant communities have narrow ecological space (niches) and for this reason alone are at high risk to climate change. Human demand for an uncertain water supply will increase the risk. Wetland services such as water detention and release will be even more vital with climate change. Other conservation objectives however, such as those related to small populations of narrow ecological tolerance may be extremely sensitive to climate change Thus, objectives that result in acquisition of small wetlands or patches of wetland within a larger wetland complex which is not protected or covered by a conservation strategy may not be achievable.

Step 5: Consider multi-value objectives

Land trusts and conservation agencies should continue to apply the basic criteria when considering a conservation project, such as size, shape, ecological context, watershed characteristics, amount of disturbance, and connectivity. As usual, a consideration of existing or potential threats to the land must be factored in, including the impacts of climate change. In addition, the landscape setting of a property such as the potential for creating migration corridors is especially important because species will need to move.

The potential of acquisitions to contribute to the mitigation of climate change through avoiding the release of stored carbon or by removing carbon through photosynthesis is another factor to consider when evaluating a site or conservation strategy. The mitigation value of sites has not traditionally been considered as part of the acquisition analysis in the past. Yet as Figure 2 demonstrates, the mitigation value of land acquisition may be considerable in terms of avoided emissions given the amount of carbon stored per hectare of ecosystem.

Evaluating Specific Land Acquisition or Management Strategy

These apply to making a decision about a specific parcel of land or land management strategy.

Evaluate the sensitivity of a specific parcel of land or strategy to climate change.

Conserving a parcel of land for protection of wet conifer forests and other values in an area shown by models or the fossil record to be highly sensitive to conversion with warmer temperatures is a poor choice. Acquisition of a historic property or building in a site with increasing risk to extreme weather events (such as catastrophic flooding) might be a poor choice too.

Look to link areas rather than protecting isolated fragments. Providing opportunities to migrate is a key adaptation strategy to climate change. Small isolated parcels tend to be subject to a higher risk of accidental events such as fires, than large, well-connected parcels. There is also a well demonstrated tendency for the loss of species from small areas compared to larger ones. In general, ecosystems on the entire landscape will need an adaptation strategy for the future. More than ever, conservation plans and specific projects need to be part of an integrated, landscape scale approach.

Focus first on key ecological processes rather than limited attributes such as single populations of rare species. As species ranges shift and ecological re-organization ensues each population and species will respond according to its own capacity. Individual populations may experience exceptional risk in specific locations especially if the area involved is small. A more effective strategy might be to understand the Essential Ecosystem Characteristics (EEC's)[159] of an ecosystem (what it needs to thrive or even gradually change into another natural ecosystem) especially those which support and include the species or group of species of interest. Thus a conservation strategy should be designed to sustain key ecological processes and features rather than to protect and preserve a single population, species or ecological attribute.

For example, acquiring a small segment of stream in which to place gravel for spawning is not likely to be successful in the long term if the watershed is not (or won't be) protected in some way. A more important initiative might be to conserve large segments of a watershed including the headwaters, to ensure a reliable annual water supply of appropriate quality.

Keep in mind that species may take many years to adjust to climate change.
For many species and ecosystems, there will be a major decline in area of occurrence before expansion into new climatically suitable zones. The reason for this is the slow migration rates, especially of species associated with mature or old ecosystems (such as old growth forests). In this context, the value of an acquisition or conservation project may not be so much in what it is but rather what it can become. In some cases, it may be more important to anticipate future conditions. For example, acquiring dry natural openings in now forested areas may be an effective strategy to anticipate the expansion of Garry oak meadow communities and species or interior grassland patches.

Factor in restoration and on-going management to maintain the resilience of the site
For a cultural or agricultural site you may need to factor in managing for increased flooding or fire risk impacts for example. For a natural area, the control of insect pests or invasive species may be necessary. The costs and resource demands of these real future risks must be factored into the evaluation of an acquisition.

Factor in carbon mitigation value.
When looking at a choice of sites, consider the net benefit to CO_2 concentration in the atmosphere. There may be an opportunity for land trusts to buy land primarily to keep carbon stored. This has not been a primary objective in the past but it is an emerging opportunity to engage support. As noted earlier, conserving land for carbon storage (i.e. preventing the release of CO_2 by conversion) is a more effective way to counter climate change then planting trees.

Incorporate multiple values
Link biodiversity values with other values, especially those related to climate change. Acquiring and conserving headwater forest lands for example, may

mitigate CO_2 emissions, ensure water supply for downstream settlements and improve fish habitat. Multiple value initiatives will almost certainly gain strong public support.

Incorporate the "options" value

When considering a land protection strategy for a specific purpose, also think about future uses of the land should climate change impact the original objective. For example, preserved lowland agricultural land may eventually become unsuitable because of rising sea levels but still have enormous value as wetland habitat.

Decision Support Table

The general principles and strategies presented in the preceding section eventually must be tied to specific data about the mitigation and adaptation potential and sensitivity to climate change on sites and the overarching values of interest to land trusts and other agencies. Objective data are either unavailable or sparse. Table 3 uses available data and models to provide a summary matrix to help conservation agencies, land trusts and indeed other land management agencies to think about climate change in their acquisition strategies and conservation planning. The table is a first attempt to draw together several factors related to climate change as an aid in the assessment process. It is intended to be used along with other tools that all conservation organizations and agencies have in helping them achieve their goals.

The support table is designed to be applied at the provincial scale, but it could also be adapted to regional and local scales by subdividing Biogeoclimatic zones into smaller units such as variants and even site series. Wetland and aquatic ecosystems can also be subdivided further and evaluated for climate change impacts. The summary ranking is not intended to exclude or favour a specific ecosystem type, but it does point to areas and ecosystems such as the Coastal Douglas-fir and Garry oak ecosystems that may need special consideration in light of climate change. The basis for the construction of the table, including assumptions, follows.

Testing and use of the decision table combined with improved information on sensitivity to climate change may lead to the development of an improved or expanded tool for conservation planning as climate change progresses. Monitoring indicators of impact for trends needs to be undertaken to improve the effectiveness and applicability of the table.

Table 3: Decision Support Table: Assessing Lands in the Context of Climate Change
(sources for evaluation follow)

BEC zone or land use	Impact Trends	Paleo Evidence	Model Predici-ton	Mitigation Conversion	Mitigation Scrubbing	Biodiversity ranking	Human impact	Summary rank Priority for Conservation
Coastal Douglas-fir (CDF)	Negative cedar de-cline	Strong increase	Strong increase	Strong emitter	High	High	Very high	Very high
Garry Oak	unknown	Strong increase	Strong increase	Emitter	Medium	High (As-sumed -CDF)	Very high	High-Very high
Coastal Western Hemlock (CWH)	Negative cedar de-cline	Decrease in south	Increase, decrease in south	Strong emitter	High	Medium	Medium	Medium
Mountain Hem-lock (MH)	Negative	Decrease	Strong decrease	Strong emitter	Medium	Medium	Low	Low
Bunchgrass (BG)	Unknown	Strong increase	Very strong increase	Emitter	Low	High	Medium	Medium
Interior Douglas-fir/Ponderosa Pine (IDF/PP)	Negative Mountain Pine Beetle	Strong increase	Strong increase	Emitter	Medium	Medium-high	High	High
Interior Cedar-Hemlock (ICH)	Possibly negative cedar de-cline	Decrease	Strong increase, possible decrease in south	Strong emitter	High	Medium	Medium	Medium
Sub-boreal Spruce/ Sub-bo-real Pine Spruce (SBS/SBPS)	Strong negative Mountain Pine Beetle	Decrease	Strong decrease	Moderate emitter	Medium to high	Medium	Medium	Low-Medium
Boreal White and Black Spruce (BWBS)	Negative Fire	Decrease	Decrease	Moderate to strong emitter	Medium	Low	Medium	Low-Medium
Spruce-Willow-Birch (SWB)	Unknown	Un-known	Strong decrease	Emitter	Low to medium	Medium	Low	Low-Medium
Montane Spruce/ Engelmann Spruce-/Subal-pine Fir (MS-ESSF)	Likely negative Snow pack	Strong decrease	Decrease to strong decrease	Moderate to strong emitter	Medium	Low-Medi-um	Low-Medi-um	Low-Medium
AT	Negative	Decrease	Strong decrease	Low	Low	Low -Me-dium	Low	Low
Wetlands	Unknown	Change and de-crease	Un-known	Strong emitter with con-version	Variable	See BEC zone for inferred rank	See BEC zone for inferred impact	High
Agricultural land	Unknown	n/a	Very Strong increase	low	Medium to high	n/a	n/a	n/a

Sources of evaluation used in Decision Support Table
Impacts trends: Based in reported impacts: Trends used include mountain pine beetle infestation (interior BC), cedar decline south coast and interior), snow pack decline for alpine and subalpine zones (provincial trend), increased fires in boreal regions. More trends could be integrated as additional data accumulate. For references to trends, see Part II.

Impact paleo: based on paleoecological evidence for differences in the zone or ecosystem under warm dry climate of early Holocene compared to modern conditions. "Strong increase" indicated if the zone occurred in place of adjacent BEC zones (in other words was much larger in extent in the past), "increase" indicated if the zone occupied part of adjacent BEC zones, "decrease" indicated if the zone was absent or of much smaller extent in early Holocene.

Impact models: Based on anticipated changes as described in text: increase of >500% in area ="very strong increase", increase of >100% = "strong increase", increase of >0% ="increase", decrease of 0 to 50% in area = "decrease", decrease of 50 to 100% = "strong decrease". Verified and modified by visual inspection of RBCM maps (specifically: potential for change in agricultural crops (derived from degree days); cedar range change)

Mitigation Conversion: Based on carbon stored as biomass or soil carbon and potential for release of CO_2 if converted to agricultural, industrial or urban use: These values are subjective and largely related to general impression of soil organic matter and standing biomass. Real data are either yet to be obtained or compiled for all ecosystems.

Mitigation scrubbing: based on potential for afforestation, sustainable forest management and rate of growth of trees: subjective, largely based on the type and rate of growth of dominant tree species.

Biodiversity ranking: from Biodiversity BC 2007 unpublished draft : Based on index of sum of provincial (S1-5) plus global (G1-5) ranking plus Global Responsibility (1-7) /2 from Table 7 of report. Low values represent high biodiversity importance.
Index ratings: 2.5-6.5 high, 7-10 medium 10.5-13.5 low. (Index created by R. Hebda)

Human Impact: is a measure of threat to and condition of the ecosystem as an added stress factor (exacerbating) to climate change: based on intensity of roads see Appendix x from Hectares BC (2007): >30% roaded ranks very high, 20-30% roaded ranks high, 10-20% ranks medium, 0-10% roaded ranks low. Ranking assumes that the higher the stress the more acute the stress on ecosystem and the need to conserve it.

Summary Rank: a subjective summary of all columns for the zone or ecosystem type expressed as a priority for conservation, acquisition, management from the perspective of the challenges of climate change. A similar approach can be developed and applied for ecosystems within a BEC zone or land management area such as Regional District or municipality. Generally, ecosystems with strong evidence for decrease with climate change and inferred low potential for mitigation (emissions and scrubbing) and low biodiversity ranking and threats rank low. Those with high likelihood of large increase in area with high rankings in other categories rank high to very high.

Conclusions

The purposes of this report were to examine the role that natural ecosystems play to mitigate and adapt to climate change, to examine the projected impacts of climate change on ecosystems in British Columbia, and to evaluate the implications of climate change to land conservation and ecosystem protection. Considering the significant anticipated widespread impacts of climate change, conservation agencies including governments, organizations, and land trusts will have to factor both mitigation and adaptation into their present and future planning for stewardship, conservation and restoration activities. Climate change poses both challenges and opportunities for the conservation of natural diversity. Objectives linked to natural values, such as biodiversity and protection of ecosystems require close scrutiny because of anticipated widespread ecological changes.

People are becoming acutely aware of the challenges posed by climate change and are searching for opportunities to take positive action. As this report illustrates, the conservation and stewardship of landscapes and ecosystems provides just such an opportunity to counter climate change, in addition to the inherent values of sustaining natural ecosystems and processes, including their ecological services for people. Land Trusts have a valuable role to play as they provide both voluntary and legal protection of private lands and local or regional parks, through both direct acquisition and the use of conservation covenants.

On the mitigation side, conserving natural areas avoids GHG emissions that would otherwise occur upon conversion to other land uses or to managed landscapes. Land trusts and other government agencies typically register the only perpetual legal protection currently available to a land title – through conservation covenants. Furthermore, because land trusts have annual monitoring and enforcement provisions, they provide an excellent mechanism for responsible, long term stewardship of the carbon stored in forests, wetlands, and grasslands. Some conserved lands, such as agricultural lands, may provide an opportunity for expanding food growing options as the climate changes, or for restoration activities such as planting trees or increasing native vegetative cover, which then will remove carbon dioxide from the atmosphere. In the case of avoided emissions and enhanced removal of GHGs there likely will be real economic value within carbon markets as carbon offsets.

On the adaptation side, conserving land/ecosystems is remarkably effective. First, conserved lands help sustain resilience of ecosystems and provide biological diversity. Second conserved lands help support a wide range of ecological goods and services, such as those related to water, that will come under increasing stress as the climate continues to change, and as human demands on land use and ecosystem services continue to grow. Third, conserved lands provide options and flexibility for adaptive decisions. A single parcel of land can meet a wide range of objectives from biodiversity conservation to providing corridors for species migration, or range and agricultural options as ecosystems and climates change, in addition to sustaining water flow to reduce the risk of catastrophic floods. A network of conserved areas can broaden that range of achievable objectives and afford opportunities to adapt objectives to shifting conditions. Another role that conservation properties could provide is as sample sites for monitoring changes and collecting data on elements of biodiversity and ecological processes central to adapting to climate change.

Decisions concerning acquisition, conservation and management of specific sites need to have built in mechanisms for factoring in the risks of climate change impacts. At this time the understanding and data needed to inform decisions about specific sites are based on regional projection trends and predicted changes in ecosystems. More needs to be learned before detailed information will be available for local projects.

Land trusts and similar conservation organizations including regional or local park planners and councils now have a major opportunity to use the remarkable value of conserved lands as a vital strategy to address climate change. Protected and conserved lands will contribute to good carbon stewardship through providing ecosystem resiliency, community well-being, the potential for carbon sequestration, adaptation options, and the security of ecosystem services. As the public begins to recognize these values it will increase its support for the protection of lands, especially those with intact ecosystems and the potential to maintain a range of values and services.

It is time to get the message out that conserving land is an essential strategy to prepare for climate change.

Great Blue Heron
– photo: Todd Carnahan

Appendix 1: Land Trusts in BC in 2008

LAND TRUST	GEOGRAPHICAL AREA	HECTARES	MISSION
Bowen Island Conservancy	Bowen Island	2.00	The BIC works to protect plants, animals and natural communities through gifts, exchanges, covenants and land purchases in a co-operative manner to benefit all who enjoy our natural environment.
Central Okanagan Land Trust	Central Okanagan	103.00	COLT is committed to the long-term permanent protection of natural or cultural heritage in the Central Okanagan area, primarily for the conservation of land for wildlife and parks.
Comox Valley Land Trust	Comox Valley	113.00	Comox Valley Land Trust is dedicated to protecting the Comox Valley's heritage of land and resources through voluntary conservation.
Conservancy Hornby Island	Hornby Island	215.00	Focus is on acquisition, removal of invasives, care of parks.
Coquitlam Land Trust Fund Committee	Coquitlam	1.00	CLTF provides for the acquisition, conservation, and stewardship of sites, areas and objects of ecological, historical, recreational or agricultural interest in or near the City of Coquitlam.
Cowichan Community Land Trust	Cowichan Valley	42.00	CCLT is committed to conserving, protecting, and enhancing the quality of the human and natural environment in and near the Cowichan Valley Regional District.
Denman Conservancy Association	Denman Island	200.00	DCA is committed to preserve, protect and enhance the quality of the natural and human environment on Denman Island.
Discovery Coast Greenways Land Trust	Campbell River		DCGLT's mission is to enhance the community through the creation and management of greenway's networks within public and private property partnerships.
Ducks Unlimited Canada	Canada	167,929.00	Ducks Unlimited Canada conserves, manages and restores wetlands and associated habitats.
First Nations Land Trust	province wide		The First Nations Land Trust protects and manages lands for the preservation and enhancement of Indigenous plants, animals and other wildlife.
Fraser Valley Conservancy	Fraser Valley	1.00	Fraser Valley Conservancy promotes the acquisition and preservation of areas with ecological and historic value in the Fraser Valley.
Gabriola Land & Trails Trust	Gabriola Island	2.00	The Gabriola Land and Trails Trust works to conserve and connect the natural areas and neighbourhoods of Gabriola Island.
Galiano Conservancy Association	Galiano Island	237.00	The GCA is a community-based non-profit society and registered charity dedicated to protecting the natural and human environment of Galiano Island, British Columbia.
Habitat Acquisition Trust	Southern Vancouver Island and Southern Gulf Islands	200.00	HAT's focus is on conserving natural environments on southern Vancouver Island and the southern Gulf Islands.
Islands Trust Fund	Southern Gulf Islands	872.00	The Islands Trust Fund preserves and protects land in the Islands Trust Area
Kootenay Land Trust Society	West Kootenay area	105.00	The mission of Kootenay Land Trust is the preservation and protection of the natural environment.

Appendix 1: Land Trusts in BC in 2008

LAND TRUST	GEOGRAPHICAL AREA	HECTARES	MISSION
Mayne Island Conservancy	Mayne Island	New	MICS works with the community to preserve the ecological integrity of the island for future generations. It encourages community participation in conservation of sensitive land on Mayne Island through land purchases, covenants and stewardship initiatives.
Nanaimo and Area Land Trust	Nanaimo & area	31.00	To promote and protect the natural values in the Nanaimo area.
Naramata Conservation Initiative	Naramata	New	To preserve, protect and enhance the human and natural environment of Naramata.
Nature Conservancy of Canada BC region	Canada wide	25,283.00	NCC is a private, non-profit organization working for the direct protection of Canada's biodiversity through the purchase, donation or placing of conservation easements on ecologically significant lands.
North Okanagan Parks & Natural Area Trust	North Okanagan	1.00	The North Okanagan Parks & Wildlife Trust works to preserve ecological areas in the North Okanagan
Pender Islands Conservancy Association	Pender Islands	0.50	The Pender Island Conservancy Association provides education and stewardship of natural areas and shares conservation responsibilities with other land trusts to protect Pender Island.
Quadra Is. Conservancy & Stewardship	Quadra Island	7.00	The Quadra Island Conservancy and Stewardship Society works on Quadra Island to protect natural areas and trails.
Salt Spring Island Conservancy	Salt Spring Island	258.00	Salt Spring Island Conservancy (SSIC) was formed to help the community preserve natural habitats on Salt Spring Island and in surrounding waters.
Salt Spring Island Water Preservation Society	Salt Spring Island	118.00	Our purpose is to protect and preserve watersheds and all sources of potable water on Salt Spring Island.
Savary Island Land Trust Society	Savary Island	101.00	The Savary Island Land Trust Society (S.I.L.T.) was established to preserve and protect natural areas and biological diversity on Savary Island for present and future generations.
Silva Forest Foundation	Canada	126.00	Silva works with forest-based communities on developing sustainable, ecoforestry plans, including the use of covenants.
TLC The Land Conservancy of BC	British Columbia wide	46,539.00	TLC protects important habitat for plants, animals and natural communities as well as properties with historical, cultural, scientific, scenic or compatible recreational value.
The Nature Trust of BC	British Columbia wide	60,703.00	The Nature Trust protects BC's natural diversity of wildlife and plants and their critical habitat through the acquisition and management of ecologically significant land.
Many land trusts help with community, regional or provincial park protection and management.	**Total**	**303,189.50**	This total includes duplicates of areas co-held by two land trusts - total overall in January 2008 is approximately 253,863 hectares.

Appendix 2: A typology for the classification, description and valuation of ecosystem functions, goods and services.

Functions	Ecosystem Processes or Components	Ecosystem Services
Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O2 balance, ozone layer)	UVb protection by O3, maintenance of air quality
Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favourable climate (temperature, precipitation), carbon regulation, cloud formation
Disturbance prevention	Influence of ecosystem structure on environmental disturbances	Storm protection, flood control, drought recovery
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation, transportation
Water supply	Filtering, retention and storage of fresh water	Provision of water by watersheds, reservoirs and aquifers
Soil retention	Role of the vegetation root matrix and soil biota in soil retention	Prevention of soil loss/damage from erosion/siltation; storage of silt in lakes, and wetlands; maintenance of arable land
Soil formation	Weathering of rock, accumulation of organic matter	Maintenance of productivity on arable land; maintenance of natural productive soils
Nutrient cycling	Role of biota in storage and re-cycling of nutrients (e.g. nitrogen)	Maintenance of healthy soils and productive ecosystems; nitrogen fixation
Waste treatment	Role of vegetation and biota in removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification, filtering of dust particles, abatement of noise pollution
Pollination	Role of biota in the movement of floral gametes	Pollination of wild plant species and crops
Biological control	Population and pest control	Control of pests and diseases, reduction of herbivory (crop damage)
Habitat	Role of biodiversity to provide suitable living and reproductive space	Biological and genetic diversity, nurseries, refugia, habitat for migratory species
Food production	Conversion of solar energy, and nutrient and water support for food	Provision of food (agriculture, range), harvest of wild species (e.g. berries, fish, mushrooms)
Raw materials	Conversion of solar energy, nutrient and water support for natural resources	Lumber, fuels, fodder, fertilizer, ornamental resources
Genetic resources	Genetic materials and evolution in wild plants and animals	Improve crop resistance to pathogens and crop pests, health care
Medicinal resources	Biochemical substances in and other medicinal uses of biota	Drugs and pharmaceuticals, chemical models & tools
Recreation	Variety in landscapes	Ecotourism, wildlife viewing, sport fishing, swimming, boating, etc.
Education, Culture & Spirituality	Variety in natural landscapes, natural features and nature	Provides opportunities for cognitive development: scenery, cultural motivation, environmental education, spiritual value, scientific knowledge, aboriginal sites

Source: Adapted from: De Groot, R.S. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics. 41: 393-408.

Appendix 3: Classification of Ecosystem Services for the Millennium Ecosystem Assessment.

Ecosystem Service	Types of Ecosystem Service			
	Supporting	Provisioning	Regulating	Cultural
Nutrient Cycling	✔			
Soil Formation	✔			
Primary Production	✔			
Food		✔		
Fresh Water		✔		
Wood and Fiber		✔		
Fuel		✔		
Climate Regulation			✔	
Flood Regulation			✔	
Disease Regulation			✔	
Water Purification			✔	
Aesthetic				✔
Spiritual				✔
Educational				✔
Recreational				✔

Endnotes

1. Canada's 2005 GHG emissions were 747 million tones CO_2 equivalent. British Columbia's 2004 GHG emissions were 66.8 million tones. BC's forests store 18 billion tones of carbon (66,075 Mt CO_2).
2. IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available from http://www.ipcc.ch/). (CO_2 remained between 180 and 300 ppm over past 650,000 years)
3. Ibid (global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005); Stern, N, 2006. The Stern Review on the Economics of Climate Change [Accessed Nov. 1, 2006.] Available from http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/
4. Solomon, S. et al. 2007. Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and H.L. Miller (eds.). Cambridge University Press. Cambridge, UK.
5. Ibid;
6. Stern N. et al. 2006. Stern Review on the Economics of Climate Change.
7. IPCC, 2007: Summary for Policymakers. In: 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, 7-22.
8. Fischlin, A., G.F. MIDGLEY, J.T, Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, A.A. Velichko, 2007: Ecosystems, their properties, goods and services. 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, 211-272.
9. (2004) 2 Supreme Court Reports. 74 http://www.millenniumassessment.org/en/Condition.aspx
10. De Groot, R.S. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics. 41: 393-408.
11. Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well-being: A Framework for Assessment. World Resources Institute, Island Press. Washington, D.C.
12. Ibid.
13. Millennium Ecosystem Assessment. 2005.Ecosystems and Human Well-being: Synthesis. Island Press. Washington, DC.
14. Ibid.
15. Fischlin A. et al. 2007. Ecosystems, their properties, goods and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press. Cambridge, UK.
16. Costanza, R. et al. 1997. The value of the world's ecosystem services and natural capital. Nature. 387:253-259.
17. Balmford, A. et al. 2002. "Economic Reasons for Conserving Wild Nature." Science. 297: 950-953.
18. The World Bank. 2006. Where is the Wealth of Nations? World Bank. Washington, D.C.
19. Anielski, M., and Wilson, S. 2007. "The Real Wealth of the Mackenzie Region: Assessing the Natural Capital Values of a Northern Boreal Ecosystem. Canadian Boreal Initiative. Ottawa, Canada.
20. Anielski, M. and Wilson, S.J. 2005. Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems. The Pembina Institute and Canadian Boreal Initiative. Ottawa, Canada.
21. Includes parks and gardens
22. Fischlin A. et al. 2007. Ecosystems, their properties, goods and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press. Cambridge, UK.
23. Dobson, A. et al. 2006. "Habitat loss, trophic collapse, and the decline of ecosystem services. Ecology. 87:1915-1924.
24. Banuri, T. 2001. Climate Change 2001: Mitigation. Summary for Policymakers. IPCC.

25. Nabuurs, G.J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T. Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, X. Zhang, 2007. Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

26. Ibid.

27. Ibid.

28. Solomon, S. et al. 2007. Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and H.L. Miller (eds.). Cambridge University Press. Cambridge, UK.

29. Facts on Forests Around the World. Society of American Foresters.

30. Anielski, M. and Wilson, S.J. 2007. The Real Wealth of the Mackenzie Region: Assessing the Natural Capital Value of a Northern Ecosystem. Canadian Boreal Initiative. Ottawa, Canada.

31. 2001 National Forestry Inventory (CANFI 2001; http://nfi.cfs.nrcan.gc.ca/canfi/data/index_e.html)

32. Bonnor, G.M. 1985. Inventory of forest biomass in Canada. Canadian Forest Services. Petawawa National Forest Institute. Chalk River, Ontario.

33. Kurz, and Apps 1999. "A 70-Year Retrospective of Carbon Fluxes in the Canadian Forest Sector." Ecological Applications. 9: 526-547.

34. S. Wilson's calculations using the area for forest lands in British Columbia's ecozones (Taiga Plains, Boreal Plains, Boreal Cordillera, Pacific Maritime and Montane Cordillera) as reported by the 2001 National Forestry Inventory (CANFI 2001; http://nfi.cfs.nrcan.gc.ca/canfi/data/index_e.html), and carbon content estimates for the relevant ecoclimatic provinces from: Kurz, and Apps 1999. A 70-Year Retrospective of Carbon Fluxes in the Canadian Forest Sector. Ecological Applications. 9: 526- 547. (total ecosystem carbon density 248.1, 170.7,255.7, 374.6, and 323.9 t C/ha, respectively).

35. Canada's 2005 GHG emissions were 747 million tones CO_2 equivalent. British Columbia's 2004 GHG emissions were 66.8 million tones (Environment Canada).

36. Using the above data the author calculates that BC's forests store 18 billion tones of carbon (66,075 Mt CO_2)

37. Calculated using The US Climate Technology Cooperation Greenhouse Gas Equivalencies Calculator; 4.62 metric tons CO_2E /passenger car/year; Source: EPA (2003). U.S. Inventory of Greenhouse Gas Emissions and Sinks 1990-2001. Office of Atmospheric Programs, U.S. Environmental Protection Agency, Washington, DC. EPA 430-R-03-004.

38. Author's calculation using Wilson's carbon estimates (footnote 92) and the average social cost of carbon from IPCC FAR report (US$43/tC in 2005).

39. Author's calculations based on a 20-year investment at 5%. Adapted from Anielski and Wilson (2007).

40. Suchanek, T.H., Mooney, H.A., Franklin, J.F., Gucinski, H., and Ustin, S.L. 2004. "Carbon Dynamics of an Old-growth Forest." Ecosystems. 7: 421-426; In the boreal region, net additional carbon absorbed on an annual basis peaks in forest ecosystems aged between 71-120 years and total ecosystem carbon storage increases with age, peaking in boreal forests aged 120-200 years (see: Pregitzer, K.S., and Euskirchen, E.S. 2004. "Carbon cycling and storage in world forests: biome patterns related to forest age." Global Change Biology. 10:2052-2077).

41. Harmon, M.E., Bible, K., Ryan, M.G., Shaw, D.C., Chen, H., Klopatek, J. and Li, X. 2004. "Production, Respiration, and Overall Carbon Balance in an Old-growth Pseudotsuga-Tsuga Forest Ecosystem." Ecosystems. 7: 498-512; Paw, U., Falk, K.T., Suchanek, T.H., Ustin, S.L., Chen, J. Park, Y-S., Winner, W.E., Thomas, S.C., Hsiao, T.C., and Shaw, R.H. 2004. "Carbon dioxide exchange between an old-growth forest and the atmosphere." Ecosystems. 7: 513-24.

42. Zhou, G. et al. 2006. "Old-Growth Forests Can Accumulate Carbon in Soils." Science. 314:1417-

43. Suchanek, T.H., Mooney, H.A., Franklin, J.F., Gucinski, H., and Ustin, S.L. 2004. "Carbon Dynamics of an Old-growth Forest." Ecosystems. 7: 421-426

44. In the boreal region, net additional carbon absorbed on an annual basis peaks in forest ecosystems aged between 71-120 years and total ecosystem carbon storage increases with age, peaking in boreal forests aged 120-200 years (see: Pregitzer, K.S., and Euskirchen, E.S. 2004. "Carbon cycling and storage in world forests: biome patterns related to forest age." Global Change Biology. 10:2052-2077).

45. Kurz, and Apps 1999. "A 70-Year Retrospective of Carbon Fluxes in the Canadian Forest Sector." Ecological Applications. 9: 526-547.

46. Smithwick, E.A.H., Harmon, M.E., Remillard, S.M., Acker, S.A., and Franklin, J.F. 2002. Potential upper bounds of carbon stores in forests of the Pacific Northwest. Ecological Applications. 12: 1303-1317.Harmon, M.E. et al. 2004. "Production, Respiration, and Overall Carbon Balance in an Old-growth Pseudotsuga-Tsuga Forest Ecosystem Forest Ecosystem." Ecosystems. 7:498-512.

47. Trofymow, J.A., and Blackwell, B.A. 1998. Changes in Ecosystem Mass and Carbon Distributions in Coastal Forest Chronosequences. Northwest Science. 72: 40-

48. Harmon, M.E., Ferrell, W.K., and Franklin, J.F. 1990. "Effects on carbon storage of conversion of old-growth forests to young forests.": Science. 247:699-702.

49. Fredeen, A.L. et al. 2005. Comparison of coniferous forest carbon stocks between old-growth and young second-growth forests on two soil types in central British Columbia, Canada. Canadian Journal of Forest Research. 35: 1411-1421.

50. Fisher, B.S., N. Nakicenovic, K. Alfsen, J. Corfee Morlot, F. de la Chesnaye, J.-Ch. Hourcade, K. Jiang, M. Kainuma, E. La Rovere, A. Matysek, A. Rana, K. Riahi, R. Richels, S. Rose, D. van Vuuren, R. Warren, 2007: Issues related to mitigation in the long term context, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge.

51. Sala, O.E., and Paruelo, J.M. 1997. Ecosystems Services in Grasslands. In: Nature's Services: Societal Dependence on Natural Ecosystems. G.C. Daily (Ed.). Island Press. Washington, D.C.

52. B.C. Ministry of Environment. 2007. Environmental Trends in British Columbia: 2007. State of Environment Reporting. Victoria, B.C. www.env.gov.bc.ca/soe/et07/

53. The Status of Biodiversity in B.C. Draft II, May 28, 2007.

54. Personal communication (Don Gayton, via Sheila Harrington September 13, 2007)

55. In regions where average C content of soils is between 2 and 5 kg/m2 (Burke et al. 1989) cited in Sala, O.E. and Paruelo, J.M. 1997. "Ecosystem Services in Grasslands." Nature's Services: Societal dependence on natural ecosystems. Ed. G.C. Daily. Island Press. Washington, D.C.

56. ibid.

57. Ibid. average carbon loss of 10 tonnes/ha and cost of $20/tonne of carbon.

58. US$43/tC reported as global average social cost of carbon by IPCC.

59. Tarnocai, C. 2005. Peatlands of Canada Database. Version 2 (March 2005).

60. National Wetlands Working Group, 1988. Wetlands of Canada. Canada Committee on Ecological Land Classificiation. Environment Canada. Ecological Land Classification Series, No. 24. Ottawa, Canada.

61. Tarnocai, C. 2005. Peatlands of Canada Database. Version 2 (March 2005).

62. Tarnocai, C. 2005. Peatlands of Canada Database. Version 2 (March 2005).

63. For example, Burns Bog in the Lower Mainland of BC stores between 1-2 million tonnes of carbon (Hebda, R.J. K.Gustavson, K. Golinski And A.M.Calder. 2000. Burns Bog Ecosystem Review: Synthesis Report for Burns Bog, Fraser River Delta, South-western British Columbia, Canada. Environmental Assessment Office, Victoria, B.C. 271p plus appendices.)

64. Author's calculations based on peatland area from Tarnocai 2005 databse, the average social cost of carbon reported by the IPCC (US$43/tC), (2005) for 20 years investment at 5%. Adapted from Anielski and Wilson 2007.

65. The estimated rate of carbon sequestration by peatlands is 0.274 tC/ha/year from Kurz and Apps 1992 study. The value is based on the total carbon sequestered by BC's peatlands per year using the global average social cost of carbon reported by the IPCC (US$43/tC).

66. Martinez, M.L., Intralawan, A., Vazquez, G., and Perez-Maqueo, O. 2007. "The coasts of our world: Ecological, economic and social importance." Ecological Economics. 63:254-272.

67. Ibid.

68. Knowler, D.J., MacGregor, B.W., Bradford, M.J., Peterman, R.M. "Valuing freshwater salmon habitat on the west coast of Canada." Journal of Environmental Management. 69:261-273.

69. IPCC Working Group I. Climate Change 2001: The Scientific Basis. http://www.grida.no/climate/ipcc_tar/wg1/104.htm (accessed Dec. 1, 2007)

70. Olewiler, N. 2004. The Value of Natural Capital in Settled Areas of Canada. Ducks Unlimited Canada and the Nature Conservancy of Canada.

71. Boyle, C.A., and Lavkulich, L. 1997. Carbon Pool Dynamics in the Lower Fraser Basin from 1827 to 1990. Environmental Management. 21:443-455.

72. Olewiler, N. 2004. The Value of Natural Capital in Settled Areas of Canada. Ducks Unlimited Canada and the Nature Conservancy of Canada.

73. de Brun, C.T.F. (ed.) 2007. Economic Benefits of Land Conservation. The Trust for Public Land. San Francisco, California. http://www.tpl.org/tier2_rp1.cfm?folder_id=175 (accessed Nov. 5, 2007)

74. Fischlin, A., Midgely, G.F., Price, J.T., Leemans, R., Gopal, B., Turley, C., Rounsevell, M.D.A., Dube, O.P., Tarazona, J. and Velichko, A.A. 2007. Ecosystems, their properties, goods and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds., Cambridge University Press, pp 211-272.

75. All impacts are reported with high to very high confidence (except the second bullet is reported with medium confidence) by IPCC WGII.

76. Field, C.B., Mortsch, L.D., Brklacich, M., Forbes, D.L., Kovacs, P., Patz, J.A., Running, S.W., and Scott, M.J. 2007: North America.Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds., Cambridge University Press. UK.

77. Ibid: Figure 14.1

78. Hebda, R.J. 1998. Atmospheric change, forests and biodiversity. Environmental Monitoring and Assessment. 49: 195–212.

79. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire 49:55-79; Heinrichs, M.L., Hebda, R.J. and Walker, I. 2001. Holocene vegetation and natural disturbance in the Engelmann Spruce - Subalpine Fir biogeoclimatic zone at Mt. Kobau, British Columbia. Canadian Journal of Forest Research 31:2183-2199; Brown, K.J. and R.J. Hebda. 2002a. Origin, development, and dynamics of coastal temperate conifer rainforests of southern Vancouver Island, Canada. Canadian Journal of Forest Research. 32:353-372.

80. Fischlin, A., Midgely, G.F., Price, J.T., Leemans, R., Gopal, B., Turley, C., Rounsevell, M.D.A., Dube, O.P., Tarazona, J. and Velichko, A.A. 2007. Ecosystems, their properties, goods and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds., Cambridge University Press, pp 211-272.

81. Fischlin, A., Midgely, G.F., Price, J.T., Leemans, R., Gopal, B., Turley, C., Rounsevell, M.D.A., Dube, O.P., Tarazona, J. and Velichko, A.A. 2007. Ecosystems, their properties, goods and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds., Cambridge University Press, pp 211-272.

82. Hebda, R.J. 1998. Atmospheric change, forests and biodiversity. Environmental Monitoring and Assessment. 49: 195–212.

83. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire 49:55-79; Heinrichs, M.L., Hebda, R.J. and Walker, I., and S. L. Palmer. 2002. Postglacial paleoecology and inferred paleoclimate intervals in the Engelmann Spruce-Subalpine Fir forest of south-central British Columbia, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology 148: 347-369; Brown, K.J. and R.J. Hebda. 2002a. Origin, development, and dynamics of coastal temperate conifer rainforests of southern Vancouver Island, Canada. Canadian Journal of Forest Research 32:353-372; Brown, K.J. and Hebda, R.J. 2002b. Ancient fires on southern Vancouver Island, British Columbia, Canada: A change in causal mechanisms at about 2,000 ybp. Environmental Archaeology 7: 1-12.

84. Hebda, R.J. 1998. Atmospheric change, forests and biodiversity. Environmental Monitoring and Assessment. 49: 195–212. Heinrichs, M.L., Hebda, R.J. and Walker, I. 2001. Holocene vegetation and natural disturbance in the Engelmann Spruce - Subalpine Fir biogeoclimatic zone at Mt. Kobau, British Columbia. Canadian Journal of Forest Research 31:2183-2199.

85. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

86. Pellatt, M., Hebda, R.J., and R.W. Mathewes. 2001. High resolution Holocene vegetation history and climate from Hole 1034B, ODP Leg 169S, Saanich Inlet Canada. Marine Geology. 174:211-226.

87. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

88. Brown, K.J. and Hebda R.J. 2003. Temperate rainforest connections disclosed through a late-Quaternary vegetation, climate, and fire history investigation from the Mountain Hemlock Zone on southern Vancouver Island, British Columbia, Canada. Review of Palaeobotany and Palynology, 123: 247-269

89. Mathewes, R.W., and M. King. 1989. Holocene vegetation, climate and lake level changes in the Interior Douglas-fir Biogeoclimatic Zone, British Columbia. Canadian Journal of Earth Sciences. 26:1811-1825.

90. Information summarized from http://www.pacificclimate.org/publications/ClimateOverview.v2.0_PCIC.pdf

91. Barr, A.G., Black, T. A., Hogg, E.G., Griffis, T.J., Morgenstern, K., Kljun, N, Theede, A., and Nesic, Z. 2007. Climatic controls on the carbon and water balances of a boreal aspen forest, 1994–2003. Global Change Biology 13:3, 561–576.

92. Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia. In Taylor, E. and B. Taylor. Responding to Global Climate Change in British Columbia and Yukon: Volume 1 of the Canada Country Study: Climate Impacts and Adaptation. Environment Canada and British Columbia Min. of Environment, Lands and Parks. Vancouver and Victoria. 13:1-15.

93. Hamman, A., and T. Wang. 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology 87: 2773-2786.

94. Full report accessible at www.pacificclimate.org

95. Flannigan, M.G., Wotton, B. M., Todd, B., Cameron, H., and Logan, K. 2002. Climate change implications in British Columbia: Assessing Past, Current and Future Fire Occurrence and Fire Severity in BC. Report prepared as part of the Collaborative Research Agreement by the Canadian Forest Service for the British Columbia. Ministry of Forests and Range, Protection Program.

96. Murdock, T., Fraser, J., and Pearce, C. 2006. Preliminary analysis of climate variability and change in the Canadian Columbia River Basin: Focus on water resources. Pacific Climate Impacts Consortium and Columbia Basin Trust. Available at http://www.pacificclimate.org/publications/CBT.Assessment.pdf

97. Lambert, A., S. Mazzotti, M. van der Kooij, and A. Mainville, 2008, Subsidence and relative sea level rise in the Fraser River Delta, Greater Vancouver, British Columbia, from combined geodetic data, Geological Survey of Canada Open File 5698, 44p

98. Meidinger, D., and Pojar, J. 1991. Ecosystems of British Columbia. British Columbia. Biogeoclimatic zones and their subdivisions (in addition to species) are the standard for biodiversity planning and assessment tool used in BC. The zones are mapped, thus providing a spatially explicit tool for land trusts. Impact modeling has been carried out using the zones or species that can be related directly to specific zones. BEC zone analyses can be compared and integrated with understanding gained from paleoecological and trend studies.

99. Brown, K.J. and R.J. Hebda. 2002a. Origin, development, and dynamics of coastal temperate conifer rainforests of southern Vancouver Island, Canada. Canadian Journal of Forest Research. 32:353-372.

100. Brown, K.J. and Hebda, R.J. 2002b. Ancient fires on southern Vancouver Island, British Columbia, Canada: A change in causal mechanisms at about 2,000 ybp. Environmental Archaeology. 7: 1-12.

101. Ibid.

102. Hamman, A., and T. Wang 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology 87: 2773-2786.

103. Available at: http://www.pacificclimate.org/impacts/rbcmuseum/

104. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

105. Ibid; Brown and Hebda 2002a.

106. Garry Oak Ecosystem Recovery Team www.goert.ca

107. Pellatt, M., Hebda, R.J., and R.W. Mathewes. 2001. High resolution Holocene vegetation history and climate from Hole 1034B, ODP Leg 169S, Saanich Inlet Canada. Marine Geology. 174:211-226.

108. See http://www.goert.ca/about_species_at_risk.php and http://www.pacificclimate.org/impacts/rbcmuseum/index.cgi?oak for examples

109. Bodtker, K., Cannon, A., and Pellatt, M., 2007. unpublished study.

110. Brown, K.J. and Hebda R.J. 2003. Temperate rainforest connections disclosed through a late-Quaternary vegetation, climate, and fire history investigation from the Mountain Hemlock Zone on southern Vancouver Island, British Columbia, Canada. Review of Palaeobotany and Palynology, 123: 247-269.

111. Hallett, D., D. Lepofsky, R. Mathewes and K. Lertzman. 2003. 11,000 years of fire history and climate in the mountain hemlock rain-forests of southwestern British Columbia based on sedimentary charcoal. Canadian Journal of Forest Research 32(2): 292-312.

112. Hebda, R.J., McDadi, O. and Mazzucchi, D. 2005. Habitat history and the decline of the Vancouver Island Marmot (Marmota vancouverensis). In T.D. Hooper, editor. Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. March 2-6, 2004, Victoria, British Columbia. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, British Columbia. http://www.speciesatrisk2004.ca/

113. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

114. Hamman, A., and T. Wang 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology. 87: 2773-2786; (http://www.pacificclimate.org/impacts/rbcmuseum/)

115. Ibid.

116. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

117. Ministry of Forests and Range. 2006. Preparing for Climate Change: Adapting to impacts on British Columbia's forest and range resources. British Columbia Ministry of Forests, Victoria, B.C. 79 pp.

118. Rosenberg, S.M., I.R. Walker, and R.W. Mathewes. 2003. Postglacial spread of hemlock (Tsuga) and vegetation history in Mount Revelstoke National Park, British Columbia, Canada. Canadian Journal of Botany 81: 139-151.

119. Hamann, A., and T. Wang 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology 87: 2773-2786.

120. http://www.pacificclimate.org/impacts/rbcmuseum/

121. Hamann, A., and T. Wang 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology. 87: 2773-2786; (consistent with the model of the future distribution of western redcedar).

122. Carroll, A.L., Regniere, J., Logan, J.A., Taylor, S.W., Bentz, B.J., and Powell, J.A. 2006. Impacts of Climate change in range expansion by the mountain pine beetle. Natural Resources Canada Mountain Pine Beetle Initiative Working Paper 2006-14. 20 pp.

123. Field, C.B., Mortsch, L.D., Brklacich, M., Forbes, D.L., Kovacs, P, Patz, J.A., Running, J.W., and Scott, M.J. 2007. North America. 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, 617-652.

124. Hamman and Wang 2006.

125. Heinrichs, M.L., Evans, M.G. Hebda, R.J., Walker, I., and S. L. Palmer. 2004. Holocene climatic change and landscape response at Cathedral Provincial Park, British Columbia, Canada. Geographie Physique et Quaternaire. 58:123-139.

126. Hebda, R.J. 1998. Atmospheric change, forests and biodiversity. Environmental Monitoring and Assessment. 49: 195–212.

127. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

128. Hamann, A., and T. Wang 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology. 87: 2773-2786.

129. Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia. In Taylor, E. and B. Taylor. Responding to Global Climate Change in British Columbia and Yukon: Volume 1 of the Canada Country Study: Climate Impacts and Adaptation. Environment Canada and British Columbia Min. of Environment, Lands and Parks. Vancouver and Victoria. pp 1-15.

130. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

131. Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J. E., Keeting, R.F., Parker, D.E., and R.C.J. Somerville. 2007. Recent climate observations compared to projections. Science 316: 709.

132. Lambert, A., S. Mazzotti, M. van der Kooij, and A. Mainville, 2008, Subsidence and relative sea level rise in the Fraser River Delta, Greater Vancouver, British Columbia, from combined geodetic data, Geological Survey of Canada Open File 5698, 44p.

133. Hill et al. unpublished draft.

134. See footnote 23.

135. Hyatt, K.D., Stockwell, M.M., and Rankin, D.P. 2003. Impact and adaptation response of Okanagan River sockeye salmon (Onchorhynchus nerka) to climate variation and change during freshwater migration: stock restoration and fisheries management implications. Canadian Water Resources Journal. 28:689-713; McFarlane, G.A., King, J.R., and Beamish, R.J. 2000. Have there been recent changes in climate? Ask the fish. Progress in Oceanography. 47: 147-169.

136. Morrison, J., Quick, M.C., and Foreman, M.G.G. 2002. Climate change in the Fraser River watershed: flow and temperature projections. Journal of Hydrology. 263: 230-244.

137. M. Nelitz, K. Wieckowski, D. Pickard, K. Pawley, D.R. Marmorek. 2007. Helping pacific salmon survive the impact of climate change on freshwater habitats. ESSA Technologies Ltd. http://fish.bc.ca/helping-pacific-salmon-survive-impact-climate-change-freshwater-habitats.

138. Palmer, S.L., Walker, I.R., Henrichs, M.L., Hebda, R.J., and G. Scudder. 2002. Postglacial midge community change and Holocene paleotemperature reconstructions near treeline, southern British Columbia (Canada). Journal of Paleolimnology. 28:469-490.

139. Hebda, R.J. 1995. British Columbia vegetation and climate history with focus on 6 KA BP. Geographie Physique et Quaternaire. 49:55-79.

140. Available at http://www.pacificclimate.org/impacts/rbcmuseum/

141. Parry, M.L., Canziani, O.F.,, Palutikof, J.P., and Co-authors. 2007. Technical Summary. 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. 23-78.

142. Ibid.

143. The World Bank. 2007. State and Trends of the Carbon Market 2007. World Bank Institute. Washington D.C.

144. Ibid.

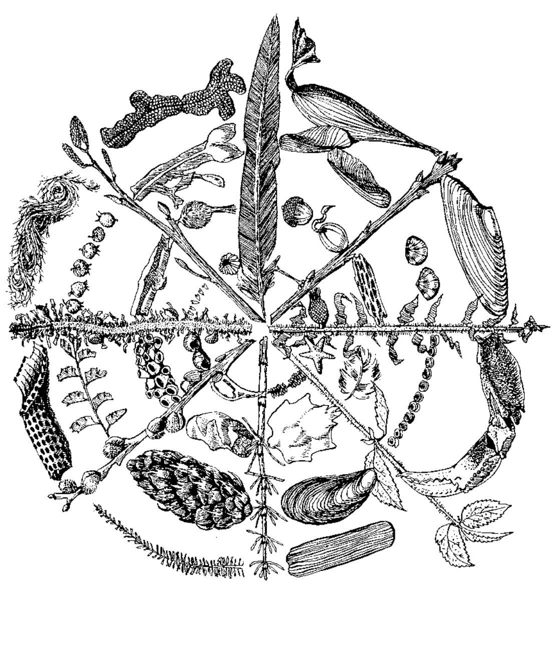
145. The Climate Trust. Offsets are part of the solution! www.climatetrust.org/about_offsets.php, accessed October 1, 2007.

146. Monbiot, G. "The trade in carbon offsets is an excuse for business as usual." The Guardian. October 18, 2006.

147. "Cutting Carbon". The Economist. February 28, 2006.

148. Adapted from "A Consumers Guide to Carbon Offsets." Clean Air – Cool Planet, 2006. http://www.cleanair-coolplanet.org/Consumers-GuidetoCarbonOffsets.pdf (Accessed Nov. 28, 2007) and Taiyab, N. 2006. "Exploring the market for voluntary carbon offsets." International Institute for Environment and Development. London, UK.
149. See: "Velasquez-Manoff, M. 2007. "Do Carbon Offsets Live up to their Promise." Christian Science Monitor. http://www.csmonitor.com/2007/0110/p13s02-sten.html (accessed Nov. 20, 2007).
150. Velasquez-Manoff, M. 2007. "Do Carbon Offsets Live up to their Promise." Christian Science Monitor. http://www.csmonitor.com/2007/0110/p13s02-sten.html (accessed Nov. 20, 2007).
151. Adapted from "A Consumers Guide to Carbon Offsets." Clean Air – Cool Planet, 2006. http://www.cleanair-coolplanet.org/Consumers-GuidetoCarbonOffsets.pdf (Accessed Nov. 28, 2007)
152. Chicago Climate Exchange. www.chicagoclimatex.com (accessed October 2, 2007).
153. See: www.carbonbalanced.org (accessed October 3, 2007).
154. (See: www.icapcarbonaction.com)
155. Trading systems currently exist in Europe and systems are being developed by Eastern U.S. States and the Western Climate Initiative, of which B.C. is a member.

    http://www2.news.gov.bc.ca/news_releases_2005-2009/2007OTP0166-001376.htm (accessed Nov. 30, 2007)
156. Cernetig, M. 2007. Would you like carbon credits with those fries? CanWest News Service. May 29, 2007.
157. http://www2.news.gov.bc.ca/news_releases_2005-2009/2007OTP0141-001209.htm (accessed Nov. 30, 2007)
158. http://www2.news.gov.bc.ca/news_releases_2005-2009/2007OTP0139-001194.htm (accessed Nov. 30, 2007)
159. Harwell, Mark A., Victoria Myers, Terry Young, Ann Bartuska, Nancy Gassman, John H. Gentile, Christine C. Harwell, Stuart Appelbaum, John Barko, Billy Causey, Christine Johnson, Agnes McLean, Ron Smola, Paul Templet, Stephen Tosini. 1999. A framework for an ecosystem integrity report card. BioScience 49(7):543-556.
160. provided by Tory Stevens, **BC Ministry of Environment**



Produced by LTA The Land Trust Alliance of British Columbia
204-338 Lower Ganges Road, Salt Spring Island, BC V8K 2V3
250-538-0112 fax 250-538-0172 www.landtrustalliance.bc.ca