PAPER

13 CLIMATE CHANGE AND ADAPTIVE RESOURCE MANAGEMENT IN THE SOUTHWEST NOVA BIOSPHERE RESERVE

CLIFF DRYSDALE[1], TIM WEBSTER[2], CHRIS McCARTHY[3], DARIEN URE[3], DAN KEHLER[3], IAN SPOONER[4], MICHAEL BRYLINSKY[5], MONIK RICHARD[6], ADAM FENECH[7], ANTHONY LIU[8], KYLA MILNE[9], MARGARET MURPHY[10], DAVID COLVILLE[11] and ANDREW ROSS[12]

[1] Mersey Tobeatic Research Institution Cooperative, Nova Scotia
[2] Applied Geomatics Research Group, Annapolis Valley Campus, Nova Scotia Community Colleges
[3] Kejimkujik National Park, Nova Scotia
[4] Acadia University, Nova Scotia
[5] Acadia University Centre for Estuarine Studies, Nova Scotia
[6] Acadia University Biology Department
[7] Adaptation and Impacts Research Division, Environment Canada
[8] Meteorological Service of Canada
[9] Energy Markets and Climate Change, Nova Scotia Department of Energy
[10] Public Affairs, Nova Scotia Power Co. Ltd.
[11] Applied Geomatics Research Group, Annapolis Valley Campus, Nova Scotia Community Colleges
[12] Nova Scotia Community Colleges, Lunenburg Campus

ABSTRACT: Recognition of the global phenomenon of climate change is stimulating government response internationally and nationally. However, there is a need to better define regional climate change impacts, and develop strategies to enhance ecological and socioeconomic resilience at the community level. This paper describes several selected research and monitoring activities being carried out to define impacts from climate change in southwestern Nova Scotia, Canada, followed by strategies being developed by government, industry and community colleges in response to potential climate change impact. Research and monitoring projects conducted in the Southwest Nova Biosphere Reserve region include ecosystem process and biodiversity monitoring in Kejimkujik National Park and National Historic Site; analysis of Blanding's turtles growth rings as indicators of climate dynamics; monitoring of microclimate and sea level change modeling using LIDAR technology; and assessment of wetland and aquatic system changes. Climate change response initiatives described include strategic planning by the Government of Nova Scotia; response strategies of Nova Scotia Power Company; use of climate data for agricultural planning by the Applied Geomatics Research Group of the Nova Scotia Community College (NSCC); NSCC Lunenburg Campus forestry training initiatives; and collaborative community based public education initiatives by the Mersey Tobeatic Research Institution and the Southwest Nova Biosphere Reserve Association.

Keywords: climate change, ecological and socioeconomic resilience, impacts, biodiversity, monitoring, microclimate, response initiatives

1. Introduction

While the scientific community has increasingly become aware of the measurement challenges, facts and interrelationships associated with the climate change phenomena over the past few decades, the global public at large has only much more recently begun to be informed. As risk of significant environmental impact due to anthropogenic causes increases, democratic societies must understand and support regulation while making personal choices to reduce the pollutants contributing to the problem. In industrialized nations, this represents a huge challenge. Many economies that were developed in the 20th century depend on large and often inefficient use of coal and petroleum products. Hence, there are major socioeconomic implications associated with addressing the climate change threat in developed countries. Acknowledging that most governments in the world have now recognized the threat and reality of climate change, the process has begun to address the challenge of change. While climate change discussions associated with the Kyoto Protocol, and more recently in Bali, have been advanced at the national level, there is a growing recognition that resiliency strategies also have to be developed and implemented at the regional and community level.

Climate change impacts can vary widely across geographic regions. The ecology, including hydrology, soils, vegetation, and socioeconomic characteristics will affect the nature the responses to problems in a given area. In a socioeconomic context, climate change impacts can directly affect economic health in a specific region, or indirectly as a consequence of impact elsewhere. For example, it has been suggested that the high rate of climate related mountain pine beetle (Dendroctonus ponderosae) range extension, and subsequent salvage tree harvest in western Canada, has impacted the economic viability of sawmills in eastern Canada.

The following paper discusses some methods by which climate change is being studied in the UNESCO Southwest Nova Biosphere Reserve in Nova Scotia, Canada, and examines some of the adaptive response approaches being developed in the region.

2. Discussion area

The area to be discussed forms the southwestern portion of the peninsular Province of Nova Scotia, in eastern Canada. The region is bounded on its north shore by the Bay of Fundy, with the world's highest tides, and on the eastern coast by the North Atlantic Ocean. The areas' terrestrial land base has been designated the UNESCO Southwest Nova Biosphere Reserve and is comprised of 5 municipal counties; Annapolis, Digby, Queens, Shelburne and Yarmouth (13,770 km^2) with a population of approximately 100,000 people. The core protected area of the Biosphere Reserve is comprised of Kejimkujik National Park and National Historic Site (381 sq km), and the Tobeatic Wilderness Area

(1038 km^2). The bedrock of southwestern Nova Scotia is primarily igneous, with some metamorphic and sedimentary elements. Forest soils tend to be thin and acidic. The landscape shows the effects of previous glaciation, and features a large number of shallow lakes, rivers and other wetlands. The climate is strongly influenced by the sea and weather systems originating over continental North America. Surface fresh waters in the region tend to be acidic and nutrient poor, with low mineral content and buffering capacity (Kerekes, 1973a). Nova Scotia's geographic positioning downwind from North America's industrial heartland results in high levels of acidic precipitation from air pollution on the continent.

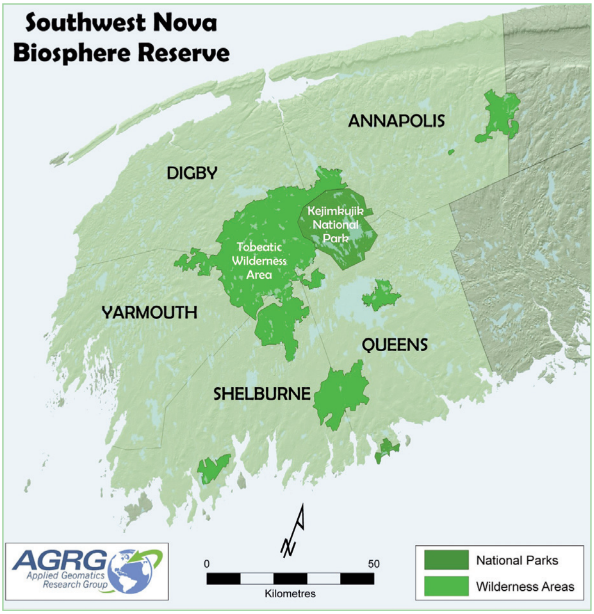

FIGURE 1
The Southwest Nova Biosphere Reserve region.

2.1 Terrestrial Biodiversity

Forests in the Southwest Nova Biosphere Reserve area are classified as part of the Acadian Forest region, one of eight forest types in Canada (Rowe, 1972). Tree species include red spruce (*Picea rubens*), white spruce (*Picea glauca*), white pine (*Pinus strobes*), eastern hemlock (*Tsuga canadensis*), and larch (*Larix laricina*) interspersed with red maple (*Acer rubrum*), red oak (*Quercus borealis*), sugar maple (*Acer saccharum*), white birch (*Betula papyrifera*) and white ash (*Fraxinus* *americana*) in the complexity of the landscape. Harvesting, fire, insects and storms play a role in influencing succession. While much of the biodiversity is typical of the boreal/mixedwood forest, areas with warmer microclimate may account for some of the southern originating coastal plain flora and fauna including the water-pennywort (*Hydrocotyle umbellata*), Blanding's turtle (*Emydoidea blandingii*), northern ribbon snake (*Thamnophis sauritus septentrionalis*), and southern flying squirrel (*Glaucomys volans*).

2.2 Human use in the Southwest Nova Biosphere Reserve region

Use of the area began with aboriginal activity more than 4500 years ago. The Mi'kmaq traversed the region and utilized both forest and coastal resources. European presence started in the 17th century and primary industry initially included forest harvest for ships timbers, and the fishery. Nova Scotia ports were also considered important as strategic military bases. The Annapolis valley rose in importance for agriculture beginning in the 18th century. Currently, southwestern Nova Scotia socioeconomic fabric has diversified, as reflected in the nature of the towns, businesses and transportation in the region. Forestry, the fishery and agriculture remain as important industries, despite increased global competition and fish harvest decline. Tourism, based on the picturesque landscape, is an important contributor to the economy. The people in the region are hard working and progressive. The Southwest Nova Biosphere Reserve, beginning 100 Km west of the provinces' capital Halifax, is comprised of smaller coastal and inland communities that depend on natural resources to sustain their populations.

A large protected area complex, including Kejimkujik National Park and National Historic Site and the Tobeatic Wilderness Area in the core of the Biosphere Reserve, feature a high standard of biodiversity protection and visitor experience. The National Park has served as an important national monitoring site for long range transported air pollutants and there is strong collaboration among land users, local and regional educational institutions for environmental research and monitoring. Modern communities in southwestern Nova Scotia struggle with the economic, social and ecological challenges typical of many northern hemisphere countries. However indicators of climate change are beginning to raise concerns in an environmental and socioeconomic context.

2.3 Modeling climate change

While monitoring for climate change can simply be a function of weather documentation and assessment at a given site, the projection of climate trends and impacts for a specific geographic region, using current information and understanding of global processes, is a far more complex modeling process.

Climate can be thought of as an average of the weather over a period of years or decades. It describes the characteristic weather conditions to be expected in a region at a given time of year, based on long-term experience. By international convention, weather observations are commonly averaged over a period of 30 years to produce the statistics that describe the climate "normals". These averages are helpful for providing "average" temperatures and precipitation, or when comparing one location to another, but they do not provide the necessary information to assist communities in planning for climate change adaptation (Fenech and Liu, 2007).

Climate change monitoring and assessment in southwestern Nova Scotia is being carried out as a consequence of a number of Environment Canada programmes. The Atmospheric Environment Service continues to monitor weather and air pollutants at the Kejimkujik site. Parks Canada has collaborated with the Adaptation and Impacts Research Group to apply General Circulation Models (GCM) to project climate change impacts in Kejimkujik, and other national parks across Canada (Scott and Suffling, 2000). The projections for Kejimkujik inland and at Kejimkujik Seaside could be considered representative for southwestern Nova Scotia. Based on a 100 year projection for doubling of atmospheric CO_2 projections (Shaw *et al.*, 1998), sea level rise around the coast of Nova Scotia increase by 0.5m, with resultant altered marine terrestrial interface, intercoastal erosion and salt water intrusion. Changes in currents are projected to occur as a result of cooling coastal waters resulting in more fog.

Air temperatures is projected to increase by 3.4°C in winter and 3.9°C in summer (Scott and Suffling 2000). Rainfall is projected to increase in the spring and fall, but decrease by 3-5% in the summer. Storm frequency is projected to increase. Clair (1998) has suggested that peak run-off would change from May to April, with minimum flow changing from September to August, with decreased summer water levels. These climate changes could increase forest fire frequency and intensity, insect pest distribution and subsequently forest succession. Red maple and poplar would likely show a positive response to the change in climate, while red spruce, sugar maple, hemlock, beech and white ash may show a negative response.

2.4 Climate change validation studies

To observe manifestations of climate change, it is desirable to assess a number of indicators which can help with impact and trend determination. The following 11 sections are selected examples of climate change effects studies in southwestern Nova Scotia.

3. Sea level change modeling using LIDAR technology; Coastal Flooding Analysis Tools

■ Project purpose

A model was required that would first help accurately determine land elevations, and flood elevations from past storms. Second, a model was required that would help determine flood frequencies, that is, probabilities, for different flood levels, including climate change impacts on flood levels. LIDAR with Water Modeler was chosen for the study, which was then tested in Annapolis Royal, Nova Scotia, the coastal flooding test community.

■ How the Model Works

LIDAR (Light Detection and Ranging), is used for collecting elevation data from an aircraft using a laser. It has emerged in the last 5-10 years as the most accurate means of topographic mapping. The result of a LIDAR survey is a dense set of elevation points (on the order of cm or m spacing) that include the earth's surface as well as features such as trees and buildings. The points can be brought into a geographical information system (GIS) and used to build surfaces that represent the earth's topography. The level of detail and the accuracy of the elevation maps, known as digital elevation models (DEMs) are far superior to traditional methods and provide the ideal map to determine flood risk.

■ Modeling software development

Applied Geomatics Research Group (Nova Scotia Community College), with partners in the private sector under the leadership of Roger Mosher has developed tools to facilitate the analysis of coastal areas vulnerability to flooding from storm surges. Tools that were developed include a software package known as the "Water Modeler" that allows observed water level records to be analyzed and probabilities and return periods to be calculated based on observed water levels. The approach taken calculates empirical annual probabilities of accedence of a given water level, and allows a model to be constructed for the prediction of probabilities with relative sea-level changes incorporated, to simulate possible climate change effects. The method is based on the "Gumbel extreme value distribution".

■ Model testing and historical analysis

In order to ascertain historic flood levels, past floods were examined and ground-truthed with interviews of Annapolis Royal businesses and residents located near the boundaries of these floods. The flood that occurred on February 2, 1976 (known as the Groundhog Day storm) was the highest historical flood for which accurate records were available. Thus, this became the primary flood for analysis of future impacts of climate change.

The 1976 flood extent was mapped with LIDAR, and using GIS the stages of the flood in terms of when dikes and levees were breached was determined. The storm surge at St. John, NB was modeled on top of the elevation of the predicted high tide to calculate the still flood water level. Wind records were used with a bathymetric and land elevation model to simulate the waves during the storm. These data provided the inundation area but did not address the frequency of this flood, that is, what the return period, or probability was of it occurring in any given year.

Bernier Model

In order to help determine the probability of such a flood as the 1976 occurring, a sea level rise and storm surge model developed by Bernier (2005) was used. The model analyzed water level records from various tide gauges around the region for the last 40 years to calculate return periods of storm surge water levels and how they might change under climate change scenarios. The storm surge model was driven by historical wind records reported at every 6 hours, thus the observed water levels were averaged from hourly to every 6 hours, resulting in underestimating some short lived storm events.

Water Modeler

Concurrent with the Bernier (2005) study, Water Modeler was being developed and was compared to the results of Bernier (2005). Water Modeler was used to analyze the hourly tide level data, recorded by the Department of Fisheries and Ocean, for Saint John, New Brunswick. The water levels were then translated from St. John to Annapolis Royal across the Bay of Fundy. Testing showed that translation was sufficiently accurate so that the extent of the 1976 flood could be mapped. The long time series of water levels at St. John were compared with a shorter time series at Digby west of Annapolis Royal. The difference in storm surge magnitudes between St. John and Digby was on average 1 cm with a standard deviation of 30 cm. Thus the water level predictions for Digby and Annapolis Royal were expected to be accurate within 40 cm (for example, 1 standard deviation). Climate change factors were incorporated as follows.

Climate Change

The cumulative flood probabilities were plotted for the Groundhog Day storm in St. John (4.95 m orthometric) using the current relative sea level rise rate of 22 cm per century and the projected climate change potential rate of 80 cm per century. The flood level-return period graphs constructed demonstrate how any water level return period can be extracted, with or without sea level rise from climate change.

Model Results

The use of LIDAR, with the adaptation of Water Modeler to our site, proved to be an excellent method of determining probabilities for floods of different levels. The resulting flood elevations we obtained using LIDAR and Water Modeler together allowed the modeling of many different actual and hypothetical flood elevations for the test site of Annapolis Royal (Figure 2). Also, this combination of tools provided a probability factor for the 1976 Groundhog Day storm: 1 in 121 years. These results were used in Annapolis Royal coastal flooding analysis,

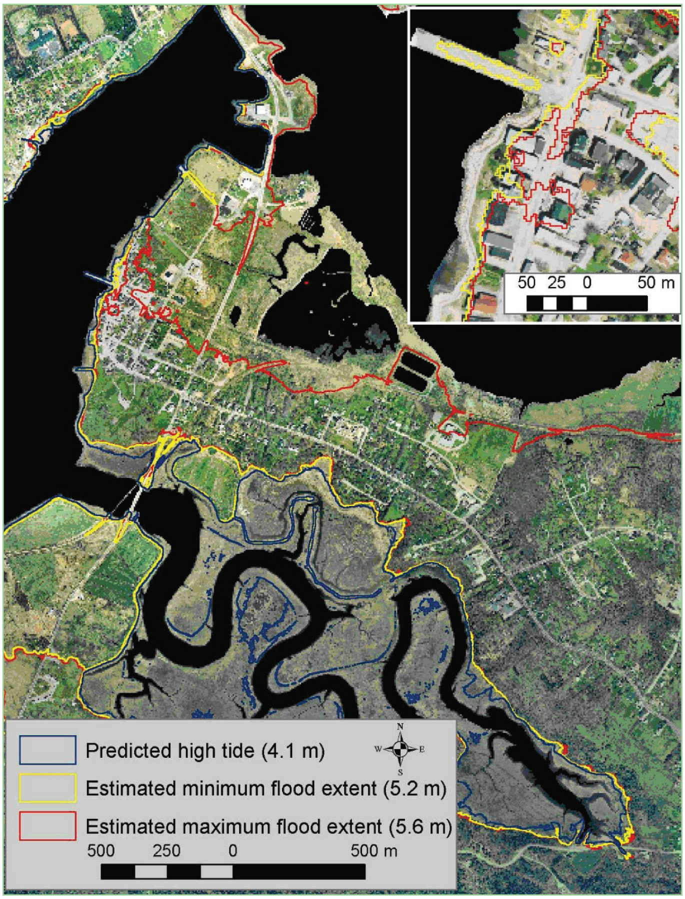

FIGURE 2

GIS mapping of Annapolis Royal showing estimated flood extent.

which in turn, was used in the GIS mapping analyses. The blue line in Figure 2 represents the predicted high tide level and the yellow and red lines represent the predicted flood levels of the Groundhog Day Storm. The yellow line represents a level of 5.2 m, representing the minimum flood extent, and the red line represents a level of 5.6 m, representing the maximum extent of the flooding, considering the precision of the method used.

Conclusions for Land Use Planning

Accurate coastal flood risk mapping, with climate change factored in, will become increasingly important to land use planning. This is an issue in most of Atlantic Canada, and will become increasingly important as existing development in the floodplain is flooded more frequently, and new development threatens coastal shores. As demonstrated in this study, a difference in water level of 40 cm can have a significant impact of flood extent. Many costal communities have vulnerable infrastructure to such events that are expected to increase in the future as a result of climate change.

4. Biodiversity and climate monitoring studies in Kejimkujik National Park and National Historic Site

Kejimkujik National Park and National Historic Site has been the focus of significant Environment Canada research and monitoring activity beginning in 1978 with the Long Range Transport of Air Pollutants study programme (LRTAP). Information gathered at Kejimkujik contributed to international agreements to reduce acid rain producing pollutants. It is also a participant in the Environment Canada Ecological Monitoring and Assessment Network (EMAN). One hectare SI/MAB study plots have been used at Kejimkujik to study multi-taxa forest biodiversity (Drysdale and Howell, 1998), exotic species occurrence, and forest insect defoliation impact. While Environment Canada continues to collect climate and airborne pollution data on site, Parks Canada Agency scientists have continued to develop strategies to understand ecosystem stressors and their implications for maintenance or restoration of park ecosystem integrity.

Currently, Parks Canada is developing a monitoring strategy incorporating a bioregional perspective for a variety of measures. With the participation of other national parks in eastern Canada, this approach is intended to facilitate efficient use of study resources, and provide documentation of environmental change over a large geographic area. Standardized protocols are used and results are being recorded in a national databank, as well as being stored and updated on site. Exceeded thresholds will be linked to specific management responses to ensure maintenance of protected area ecological integrity.

At Kejimkujik, forest plot scale monitoring will document changes in vegetation community composition, tree recruitment, tree growth and mortality, arboreal lichen diversity, occurrence of exotics, changing soil moisture, and decay rates. Monitoring birds, white-tailed deer and salamanders will also contribute to knowledge associated with forest ecosystem dynamics. At a landscape scale, change in forest composition, net primary productivity, change in successional pathways, larger scale disturbance tracking, including insects, fire, and blow down will be documented using geomatics tools. In aquatic ecosystems, changes to fish populations due to loss of quality coldwater habitat and invertebrate change will be monitored. Water quality, lake freeze and thaw dates, wetland wells and sea level changes will also be documented.

Continuing work on species at risk recovery including Blanding's turtle, northern ribbon snake and piping plover will also incorporate consideration for potential climate change effects.

Recent research has shown a change appears to be occurring in lake cold water temperatures. Kejimkujik has very few lake refugia that can develop thermoclines and trap cold water required for brook trout survival in summer.

In 2002, a native forest insect largely unknown to science became a major player in forest dynamics. The Pale-winged gray (*Iridopsis ephyraria*) had affected some hemlock stands in the region. In some stands it destroyed up to 90% of mature tree needles within the first year, and eliminated most understory growth. Forest insects such as the gypsy moth (*Lymantria dispar),* the oak leaf roller (*Tortrix viridana*), chain-spotted geometer (*Cingilia catenaria*), and jack pine budworm (*Choristoneura pinis*) have defoliated forest stands in the park within the last five years. (Pers Con. Chris McCarthy, Kejimkujik National Park and National Historic Site, Maitland Bridge, Nova Scotia).

Increasing numbers of invasive exotic vegetation species are being identified and removed from the park to maintain ecosystem integrity. Monitoring continues to safeguard against invasive exotic fish from neighboring waters.

5. Assessment of wetland changes

From 2004-2007 stratigraphic and paleobotanical (pollen) studies have been conducted on sediment cores from the Pleasant River Fen in southwestern Nova Scotia to determine how climate change may have influenced the wetland (Martin *et al.*, 2005). Wetlands constitute an important terrestrial sink for carbon. A decrease in productivity or change in groundwater regime will affect this sink and a net release of greenhouse gases could result. Wetlands in Nova Scotia also provide habitat for several rare, disjunct species, most notably the Blanding's Turtle. The survival of these species may be dependent on the stability of these environments.

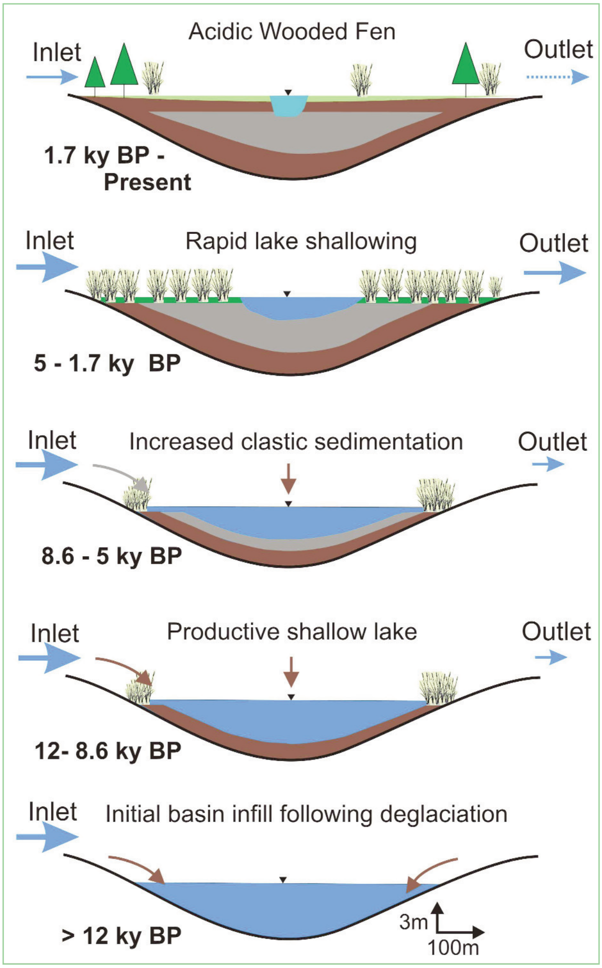

FIGURE 3
Cartoon indicating how the Pleasant River Fen has evolved since deglaciation.The fen has been strongly influenced by climate driven changes in groundwater levels as well as the natural evolution of the wetland environment.

Vibracoring, sonar mapping and dating of wood recovered in sediment cores indicated that over 5 m of dominantly organic sediment has been deposited since deglaciation (~12000 ^{14}C yr BP). Transitions in the abiotic properties of the bog sediment indicate that the water table was likely much lower than at present during the middle Holocene (8000 – 3000 ^{14}C yr BP) and that the region was dominated by a forest assemblage consistent with drier and slightly warmer than present conditions. A transition in the pollen and sediment record at about 3000 ^{14}C yr BP is coincident with the onset of modern moist cool climate in the region, and a significant rise in the water table. The upper 40 cm of the core (300 BP – Present) exhibits much lithostratigraphic variability which appears related to human activity (fire, water level management) in the region. The results of this study indicate the Pleasant River Fen (Figure 3) has evolved significantly in response to past climate change. Future climate change has the potential to further modify this environment.

6. Assessment of aquatic system changes

A major objective of the Mersey Tobeatic Research Institute/Parks Canada project to advance understanding of water quality and habitat connectivity, is to assess the status and quality of aquatic ecosystems in the upper Mersey River watershed. With respect to cold water fish species, such as brook trout (*Salvelinus fontinalis*), a major limiting factor is the presence of summer refugia having cold water and adequate dissolved oxygen. Information on the locality and status of cold water lake habitats within the Mersey River watershed is important for development of conservation and protection efforts intended to preserve these important habitats. Increasing pressure is also being placed on many lakes in Nova Scotia as a result of forestry and agricultural activities and the increase in lakeshore cottage and residential home development that is evident in many areas of the Province.

The research team approach adopted to meet these objectives was to initially identify lakes within the upper Mersey watershed likely to contain cold water habitat based on information contained in the FINS database (The FINS database is maintained by the Nova Scotia Department of Agriculture and Fisheries and contains all of the data collected as part of the Province's Lake Survey Program) and the extensive database developed on lakes within Kejimkujik National Park by Kerekes (1973a), and Kerekes and Schwinghamer (1973b). The primary condition for selection was that the maximum depth of the lake had to be >6 m to ensure sufficient hypolimnetic volume to serve as cold-water habitat. A secondary selection condition, necessary to assess the degree of change in cold water habitat, was the availability of historical survey data collected during either July or August, the time when water column stratification is strongest and hypolimnion dissolved oxygen concentrations are the lowest. A total of 45 lakes met these conditions. Of the 45 lakes identified, five were selected for survey during August 2005.

The five lakes within the upper Mersey watershed were surveyed to determine if they contained suitable cold water habitat during summer. Of the five lakes surveyed, four lacked suitable cold water habitat during August, and the remaining lake only contained suitable cold water habitat within the lower portion of the metalimnion (Figures 4 ad 5). In 2006 an additional six lakes located within the Mersey watershed were surveyed. All but one lacked suitable cold water habitat during August, and the remaining lake only contained suitable cold water habitat within a small area of the thermocline. When compared to surveys carried out two to three decades earlier, all of the lakes except one exhibited a significant decrease in cold water habitat. This decrease was due to reduced levels of dissolved oxygen rather than elevated water temperatures.

These results are similar to those obtained by Brylinsky (2002) in a similar survey of 20 lakes located throughout Nova Scotia. In that study it was suggested that the differences observed over time could be a result of either a change in the trophic status of the lakes, or to a difference in the length of the growing seasons between survey years. In that study it was also determined that there was very little difference between the degree of temperature stratification and hypolimnetic dissolved oxygen concentration measured during July and August.

Because of the lack of data on trophic state for the early surveys, it is not possible to determine if the decrease in cold water habitat may be related to changes in trophic status. However, the majority of lakes surveyed do not appear to have been subjected to conditions that would result in nutrient over-enrichment leading to eutrophication. It is thus possible that the change observed in cold water habitat is a result of a shorter ice-free period and a corresponding longer growing season which would result in a longer period of time for depressed hypolimnetic dissolved oxygen concentration to develop.

7. Analysis of Blanding's turtles growth rings as indicators of climate dynamics associated with species at risk recovery

Richard (2007) used digital plastron scan images to measure growth ring sizes of immature Blanding's turtles and attribute temperature and precipitation variables to growth ring size in the endangered south western Nova Scotia population. A new methodology was developed for standardizing measurements of plastral growth rings by adapting dendrochronological techniques such as the statistical software tools COFECHA, ARSTAN and PRECON.

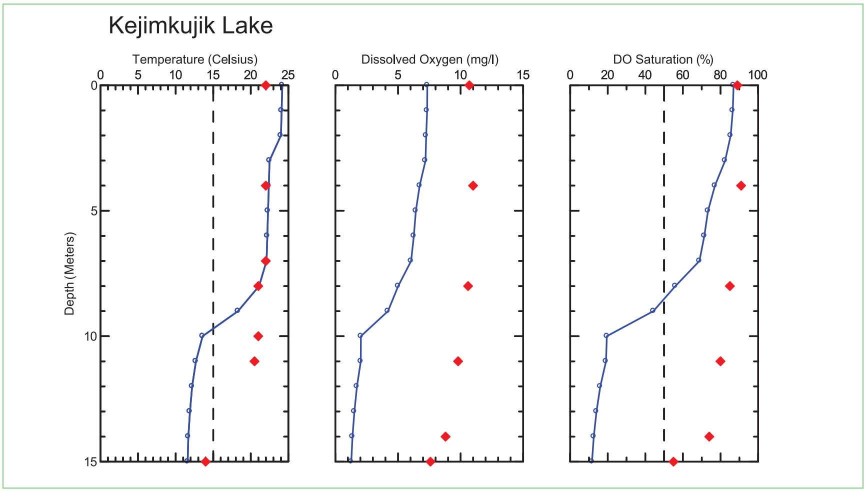

FIGURE 4
Temperature, dissolved oxygen and percent dissolved oxygen profiles for Kejimkujik Lake collected on 23 August 2005 (diamonds) and 3 August 1971 (circles). (dashed lines represent approximate upper temperature and lower percent dissolved oxygen limits for cold water salmonids).

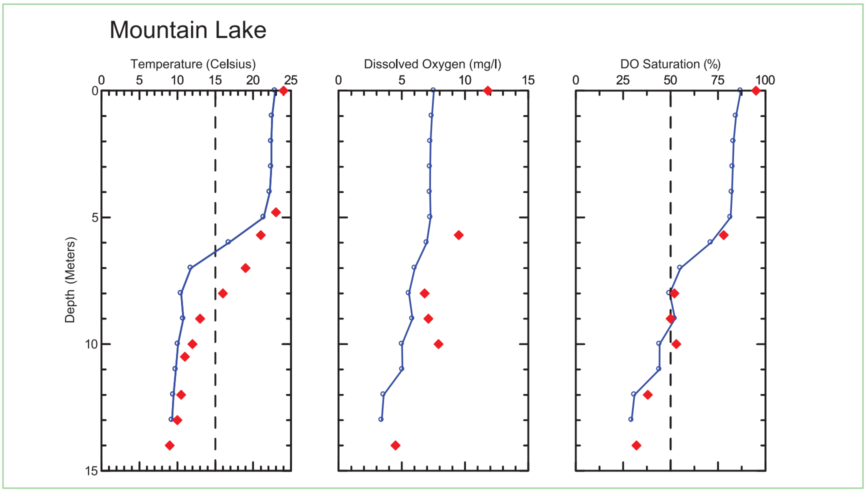

FIGURE 5
Temperature, dissolved oxygen and percent dissolved oxygen profiles for Mountain Lake collected on 24 August 2005 (diamonds) and 5 August 1971 (circles). (dashed lines represent approximate upper temperature and lower percent dissolved oxygen limits for cold water salmonids).

COFECHA was used to verify that the growth ring series for each individual turtle cross-dated across the entire sample size (N=116). A total of 56 individual chronologies cross-dated (series intercorrelation = 0.443) with each other, the remainder were mostly very young in age (< 10 years). COFECHA also allowed the correction of aging errors within individual chronologies. ARSTAN was used to remove the age variable (detrend) in the cross-dated series (N=56) and create one "master chronology" for the data set (N=30 years) using growth index as scale, where a growth index value of 1 indicates an average year of growth while >1 indicates above average and <1 indicates below average. PRECON was designed for tree ring studies and longer data sets and requires 39 years of data to run its analysis. Richard added 9 years of average growth (growth index = 1) to the master chronology to explore its use on a turtle chronology. PRECON was used to estimate the R-square value of mean monthly temperature and precipitation response functions for the master chronology (R square = 0.51).

Because of PRECON's limitations, Richard conducted a series of calibration/verification linear regression models using MINITAB on the master chronology (N=30), mean monthly precipitation and temperature, previous mean monthly precipitation and temperature and previous year's growth ring index in order to strengthen the climate response analysis. The model chosen (60% calibration/ 40% verification) had an R Square value of 0.81 and corresponded to response variables outlined from the PRECON analysis (positive response to current September temperature, current March temperature and current June precipitation). The model was then used to hindcast and forecast Blanding's turtle growth using climate data from the third generation coupled Global Climate Models made available through Environment Canada's Canadian Centre for Climate Modeling and Analysis.

Tree ring data from five softwood species (larch, eastern hemlock, red spruce, white pine, balsam fir) adjacent to Blanding's turtle habitat and collected by the Mount Allison University Dendrochronology Lab did not significantly correlate with the Blanding's turtle master chronology. Because Blanding's turtle growth is closely linked to climate, climate change impacts could be numerous. Larger females lay larger clutches (McNeil, 2002; Congdon and van Loben Sels, 1991), thus an increase in growth could lead to larger clutch sizes and consequent greater fitness and turtle abundance throughout Nova Scotia if evolutionary forces are maintained. However, change in climate could also result in a change in mean nesting dates, habitat and food availability changes, skewed sex ratios (due to temperature sex determination in the nest) and other unknown behavioral and physiological responses.

The y axis represents growth index is as described above (1 = year of average growth, <1 below average growth, >above average); x axis is years. The master chronology from ARSTAN is in green (N=30). Two models using the Canadian Centre for Climate Modeling and Analysis data are in red and blue, red representing no stabilization of CO_2 emissions, blue if emissions are stabilized to 550 ppm. The hindcast model (model of what happened in the past) is represented in grey.

8. Climate Change Adaptation Through Learning (ATL): Using past and future climate extremes science for policy and decision-making

Communities need information on extremes of climate so that they can determine how they adapted in the past to these extremes, and subsequently how to best plan for the future. This approach is known as Adaptation Through Learning (Fenech and Liu, 2007), and applies in a preliminary way to the Southwest Nova Biosphere Reserve. In order to provide for community-based climate change adaptation planning, a history of climate extremes (hot-cold,

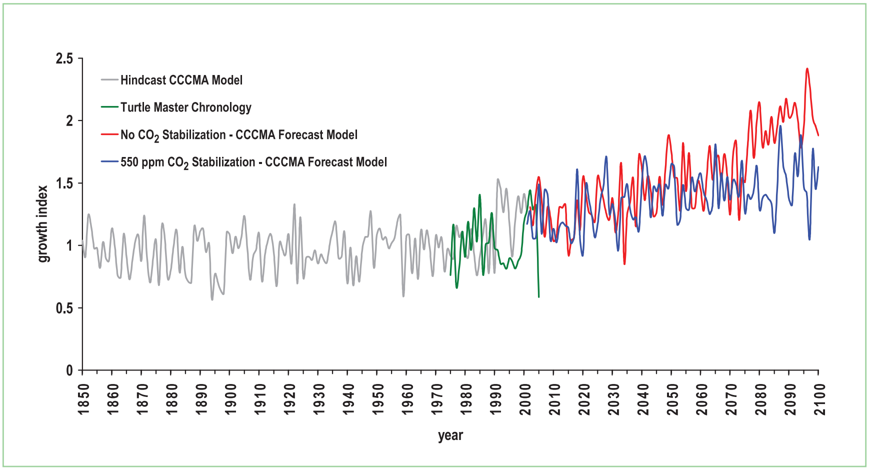

FIGURE 6
Blanding's turtle plastral growth ring hindcast and forecast linear regression models (60/40 calibration/verification).

wet-dry) is required for the Southwest Nova Biosphere Reserve located in Nova Scotia, Canada. Figure 7 shows mean daily temperature that be modified to show annual extreme hot days (Figure 8).

What lessons does the community learn from past climate events that can be useful in the future? Climate records document a year of extreme hot days just 15 years ago (Figure 8). This extreme year may have required intervention to save agricultural crops, or ensure a supply of potable water for communities. Similarly, civic preparedness for extreme storm events benefit from assessment of the past. Hence, this information becomes invaluable for response planning to address challenges associated with climate change.

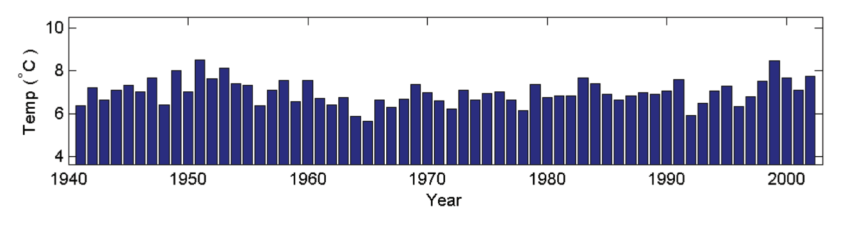

FIGURE 7
Mean Daily Temperature of Yarmouth Station A (8206500) from 1941-2002.

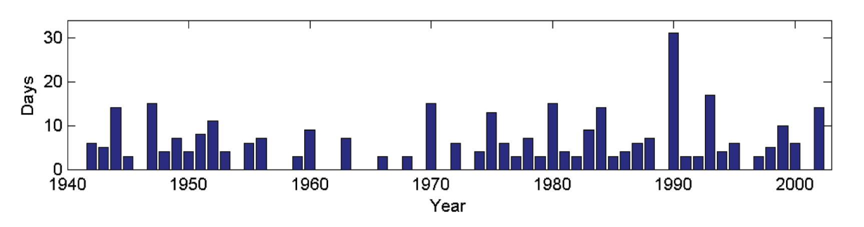

FIGURE 8
Annual Extreme Hot Days at Yarmouth Station A (8206500) from 1941-2002.

9. Examples of resilience planning and response

Development of resilience strategies must include an adaptive approach based on modeling, risk assessment, and precise observations of the land, sea and atmosphere. The following is an example of response strategies for climate change submitted by a variety of contributors for this discussion. They describe initiatives taken at the policy level by governments, energy industry, educational institutions, and actions taken in Southwest Nova Biosphere Reserve communities.

■ Province of Nova Scotia strategic planning and response

In general, the government of Nova Scotia is including impacts and adaptation considerations in various plans and strategies. Nova Scotia outlined its key environmental economic goals in the Environmental Goals and Sustainable Prosperity Act (EGSPA June 2007), including commitments to reducing greenhouse gases (GHG) and to protecting biodiversity. Reducing GHGs to ten percent (10%) below 1990 levels is a significant commitment for Nova Scotia. The Province of Nova Scotia remains one of the few provinces in Canada to have legislated GHG targets. With regards to biodiversity, the EGSPA commitment is to develop strategies by 2010 to ensure sustainability of forestry, mining, parks and biodiversity. (Pers com. Andrew Murphy, Manager, Air Quality Branch Department of Environment and Labour, Halifax Nova Scotia).

■ The Nova Scotia Department of Energy perspective

Climate change will have economic, environmental and social repercussions for virtually all sectors and regions of Nova Scotia. As a coastal province Nova Scotia is particularly vulnerable to the effects of sea-level rise and storm surge from more frequent and extreme weather events. Adapting to climate change is about taking proactive steps *now* to manage the risks and take advantage of any opportunities from climate change. It is recognized that it is far more cost effective to prepare now than to react later.

The NS Department of Energy has been the lead on climate change adaptation since 2001. It worked closely with provincial, municipal and federal departments to address the issue and support adaptation research and policy responses. The department has partnered with a number of other provincial agencies, has supported and developed research work, information guides, policy tools and a comprehensive public issues paper that discusses potential impacts, responses and departmental responsibility. As of April 1, 2008, the new Department of Environment will be taking the lead role on climate change adaptation.

In recognition of the need to better coordinate and mainstream adaptation responses across the government, the Department of Environment will work closely with other agencies and municipalities to try and develop a provincial strategy for adaptation, to be included in the Climate Change Action Plan, to be released later in 2008. The intent is to have the strategy prioritize and focus adaptation work, coordinate responsibility across departments, and enhance access to local information on climate risks and possible policy responses.

Already many departments have begun to take climate change impacts and adaptation options into consideration when developing their operational strategies. The NS Department of Environment and Labour is examining the impact of climate change on water supplies for their Water Strategy, while the NS Department of Natural Resources is looking at how climate change will affect parks, recreation, minerals and biodiversity in their Natural Resources Strategy. The NS Department of Fisheries and Aquaculture is also exploring the issue of coastal management.

10. Nova Scotia Power initiatives

Over the past eighty years, the province's main electricity supplier, Nova Scotia Power, and its predecessor utilities were designed and built to use indigenous fuels such as hydro power and coal. Now, Nova Scotia Power is diversifying by adding cleaner sources of energy such as natural gas and rapidly expanding its portfolio of renewable energy sources. Approximately 11 percent of the electricity consumed in Nova Scotia comes from cleaner, greener energy sources such as hydro, wind, biomass and tidal power. That number will grow to around 20 percent by 2013.

(Photo courtesy of OpenHydro)

FIGURE 9

In stream tidal power generation.

Nova Scotia has more installed wind power for domestic consumption than any other Atlantic province - 40 turbines rated at 60 megawatts. Nova Scotia Power is in the process of issuing contracts for an additional 240 megawatts of electricity from wind power. New wind farms are scheduled to be up and running in 2010. Nova Scotia Power is partnering with OpenHydro of Ireland to develop in-stream tidal power technology. A demonstration unit will be tested in a new provincial test facility in the Minas Passage of the Bay of Fundy, beginning in 2009 (Figure 9).

In recent years the company has reduced sulphur dioxide emissions from existing coal fired plants by 25 percent. Nitrogen oxides will be reduced by 40 percent. Greenhouse gases pose a significant challenge. Nova Scotia Power believes all options are on the table including looking outside Nova Scotia for electricity imports free of GHGs. The company is exploring the importation of nuclear power from New Brunswick and/or hydro power from Newfoundland. NSPI is a member of the Canadian Clean Power Coalition and is working with Dalhousie University to undertake research into new technologies such as carbon sequestration.

Recent customer surveys show that Nova Scotian's support a strategy that includes adding more renewables and cleaner energy choices and measures that save energy in their homes and businesses. Nova Scotia Power is working with stakeholders to develop a comprehensive demand side management program that will offer new energy conservation incentives and assistance for all customer classes: residential, commercial and large industry, with specific programs designed for low income households.

Hurricane Juan landed in Nova Scotia in 2003 and post tropical storm Noel caused damage in 2007 (Figure 10). To combat stronger storms Nova Scotia Power is spending more on vegetation management, cutting trees back from transmission line corridors and power lines. The goal is to reduce the opportunity for trees and tree limbs, combined with high winds, to cause power outages.

11. Annapolis Valley Temperature Mapping Study

To better understand the environmental landscape of the Annapolis Valley region the Applied Geomatics Research Group (AGRG) at the Centre of Geographic Sciences (COGS) has for years compiled numerous geospatial data layers of the Valley region. Landsat TM, Ikonos, and high-resolution digital aerial photography have been used to map over two decades of land cover change throughout the region. Since 2000 the AGRG began mapping the entire valley area using both CASI and LiDAR.

AGRG has also deployed meteorological monitoring equipment in association with AgraPoint International and the Grape Growers Association of Nova Scotia (GGANS). To date 16 Campbell Scientific meteorological stations and 75 Hobo temperature data loggers have been installed. While the 75 loggers record temperature, the meteorological stations record a full suite of parameters including wind speed, direction, solar radiation, air temperature, relative humidity, barometric pressure, rainfall, soil temperature and moisture.

All of the meteorological stations are wirelessly accessible via 1xRTT digital modems and a server set up at the AGRG lab. Automated processes summarize the data collected, and post the results, including monthly minimums, maximum, and mean temperatures, along with the monthly total heat accumulation (that is, Growing Degree Days base 10°C) on the AGRG website in near real-time.

This information, as well as the number of days making up the frost free growing season and the minimum winter temperatures, provides the grape growers with information that is useful when deciding on the variety of grape suitable for their vineyards.

Additionally, the AGRG is integrating the data collected from these in-situ sensors with other geospatial layers to analyze the meteorological conditions of the Annapolis Valley region. This provides an opportunity to understand the


(Photo courtesy of NS Power)

FIGURE 10
Effects of post tropical storm Noel in 2007.

relationships that exist between the temperature and physical measurements of the topographic landscape (that is, elevation, slope, aspect, proximity to the coast, and land cover). This will lead to a much more comprehensive understanding of the temperature/climate conditions throughout the entire Annapolis Valley region, and provide insight into global climate change and the implications for the future of Nova Scotia's agricultural industry.

12. Training initiatives by the Lunenburg Campus of the Nova Scotia Community Colleges (NSCC) to advance sustainable forest management

The NSCC Lunenburg Campus Natural Resources Natural Resources Environmental Technology training programme focuses on forest management in theory and practice in the region. The programme has evolved over the years to include course segments on biology, forest dynamics, forest ecosystem management, wildlife, and riparian zone management, in context with sustainable forestry. Climate change is discussed in context with implications and possible solutions for the Acadian forest typical southwestern Nova Scotia. We discuss forest species shifting from their natural ranges, increased exotic insect/disease attacks, remedies for these attacks, and consideration that increased annual temperature could lengthen the growing season. Students learn about the visual signs of trees under stress or dying.

Forestry dynamics are examined including carbon storage and carbon sinks in context with implications for industry and small woodlot owners. Long term management of growing forests must consider whether trees planted today will be healthy 50 years from now.

Students develop case studies and presentations on various resource management challenges including silviculture projects for Region of Queens Municipality, the Nova Scotia Department of Natural Resources, forest companies and private landowners. Similarly, wildlife habitat improvement, riparian zone management, uneven forest management and Acadian Forest restoration techniques, and the use of prescribed burning in Kejimkujik National Park and National Historic Site are addressed.

Students spend 4 weeks on an on the job placement, at the end of their course. Placements vary with the student's desire however some continue their careers as silviculture specialist.

13. A community-based response to local science information needs: The Mersey Tobeatic Research Institution Cooperative

The non profit Mersey Tobeatic Research Institute Cooperative was established as a community-based response to advance the use of science for decision-making on working landscapes and protected areas. Its registered mandate is to educate and increase public understanding of biodiversity conservation and sustainable resource management, while conducting ecological research associated with land use, species at risk, climate change and biodiversity assessment. MTRI functions in collaboration with the Southwest Nova Biosphere Reserve Association, as well as with universities, colleges, government agencies, communities and businesses in the region.

MTRI's multi-disciplinary board of directors includes scientists, administrators, educators, land owners and interested community members. Research and monitoring, education and communication, building, planning, and finance committees facilitate programme operations. The cooperative employs a project scientist and other staff to support project implementation, and field station operation at Kempt in the Region of Queens Municipality.

The MTRI field station provides office and lab workspace, basic accommodation and a venue for public presentations and training.

MTRI has undertaken a range of habitat connectivity, species at risk planning, research, monitoring and education projects.

14. The Southwest Nova Biosphere Reserve: A region wide approach to advance sustainable development and public education

The designation of the UNESCO Southwest Nova Biosphere Reserve in 2001 has facilitated significant collaboration among government, business, science and communities to advance sustainable resource management, biodiversity protection and associated public understanding in southwestern Nova Scotia.

A number of education initiatives have been implemented, and the public profile of the Biosphere Reserve continues to grow. The organization is exploring new opportunities to support operational staff, and enhance collaboration with participating municipalities, provincial and federal governments, and industry partners.

The Southwest Nova Biosphere Reserve provides important regional coordination function to facilitate understanding of environmental and socioeconomic issues such as climate change, while encouraging cooperative response and associated educational initiatives.

15. Conclusions

The general nature of this paper precludes definitive assessment of the full range of climate change studies and response planning in Nova Scotia. However, it appears that there are a variety of collaborative programmes being implemented by government agencies, educational institutions, sectors of the energy industry, and at the community level, in the South West Nova Biosphere Reserve.

While the terrestrial Biosphere Reserve area is well studied, there is a need for continuing research, monitoring, and analysis to understand the processes and implications for biodiversity, forests, watersheds, agriculture and marine fisheries in the region. There is a need to engage the public and enhance education associated with the climate change challenge and its implications for all sectors of society in Nova Scotia. Public understanding of the consequences of inefficient use of fossil fuels, and of greenhouse gas emission impact will help in the formulation of effective public policy in Canada.

References

Bernier, N. 2005. Annual and Seasonal Extreme Sea Levels in the Northwest Atlantic: Hindcasts Over the Last 40 Years and Projections for the Next Century. PhD Thesis. Dalhousie University.

Brylinsky, M. 2002. Nova Scotia Lake Hypolimnion Project- Searching for Cold-water Fish Habitat. Report prepared for the Nova Scotia Department of Agriculture and Fisheries. 51p.

Clair, T., Ehrman J., Higuchi, K.: 1998, Changes to the Runoff of Canadian Ecozones Under a Doubled CO_2 Atmosphere. *Canadian Journal of Fisheries and Aquatic Sciences,* 55, 2464-2477.

Congdon, J.D. and R.C. van Loben Sels. 1991. Growth and body size in Blanding's turtles (Emydoidea blandingii): relationships to reproduction. *Can. J. Zool.* 69: 239-245.

Drysdale C. and Howell G. 1998. Building a Network for Ecological Research and Monitoring In Canada: Emphasis on SI/MAB Plot-Based Methodology in Kejimkujik National Park. In Forest Biodiversity in North America and South America: Research and Monitoring (vol 21). Dallmeier F. and J. Comiskey, editors. UNESCO Man and the Biosphere Series, Parthenon Publishing Group. 1998.

Fenech, A. and A. Chen. In Press. Climate Change Adaptation Through Learning (ATL): Using past and future climate extremes science for policy and decision-making. *Integrated Assessment* Vol. 8. No. 1.

Gachon, P. 2005. A first evaluation of the strength and weaknesses of statistical downscaling methods for simulating extremes over various regions of eastern Canada. Environment Canada.

Kerekes J. 1973a. Aquatic Resource Inventory Kejimkujik National Park: Chemical composition of lake and river waters (part 5). Canadian Wildlife Servce, Halifax, Nova Scotia. 66pp (GB1631N8K45 1973).

Kerekes J. and P. Schwinghamer. 1973b. Aquatic Resource Inventory, Kejimkujik National Park; Selected limnological measurements (Aquatic Resource Inventory Kejimkujik National Park Part 4) Canadian Wildlife Service, Halifax, Nova Scotia, 113pp.

Martin, B. Spooner, I. and Caverhill,. B. 2005. Environmental Evolution of the Pleasant River Wetland, Nova Scotia. Program and Abstracts, Atlantic Geoscience Society Colloquium and Annual General Meeting 2005, St. John, New Brunswick. p. 29.

McNeil, J.A. 2002. Distribution, movements, morphology and reproduction in a population of Blanding's turtle (*Emydoidea blandingii*) in an unprotected landscape in southwestern Nova Scotia. M.Sc. Thesis. Acadia University, Wolfville, Nova Scotia, Canada.

Richard, M., Laroque, C.P., Herman, T., Bondrup-Nielsen, S. May 21 - 26, 2007. Poster: Climate Change Impacts Linked to Nova Scotia Blanding's Turtle Growth. The Science and Management of Protected Areas Association Conference. Acadia University, Wolfville NS, Canada.

Ross, Pitman et al., 2007, Nickerson 2007. Training initiatives by the Bridgewater campus of the Nova Scotia Community Colleges (NSCC) to advance sustainable forest management.

Rowe, J.S., 1972. Forest Regions of Canada. Department of the Environment, Canadian Forestry Service. Ottawa.

Scott D. and Suffling R Edit. 2000. *Climate Change and Canada's National Parks System; A Screening Level Assessment*. Report by the Environment Canada Adaptation and Impacts Research Group, and the University of Waterloo School of Planning. Catelogue number En56155/2000E, ISBN:0-662-28975-5.

Shaw J., Taylor R.B., Forbes, D.L., Ruz, M.-H. and Solomon, S.:1998, Sensitivity of the Coasts of Canada to Sea Level Rise. *Geological Survey of Canada, Bulletin* 505, Ottawa.

Wang, X.L., 2003: Comments on "Detection of undocumented change points: A revision of the two-phase regression model". *Journal of Climate,*16, 3383-3385.