# 4 INTEGRATED APPROACHES

## 4.1. New Integrated Models

### 4.1.1. Integrated Modelling and Mapping

In addition to climate variability and change, a multitude of other atmospheric processes directly affects the structure and functioning of ecosystems and, consequently, the changing state of biodiversity in Canada. Many existing biological and atmospheric monitoring systems collect systematic observations using inventory-type protocols and schedules to record, archive and detect changes. However, few abiotic and biotic observations have been collected over the long term at the same site. Even fewer databases, such as those on climate, have the universality to provide the connecting spatial linkages with site-based biological observations.

Established in 1999, the Integrated Mapping Assessment Project (IMAP) uses geo-referencing of these data observations to spatially map and overlay different thematic surfaces. For example, if the cumulative impacts of the chemical atmosphere are layered onto the climate-based biodiversity map for southern Ontario, along with the location of some of the SI/MAB plots such as the site at Long Point Biosphere Reserve, it readily becomes apparent that human intervention and management is needed in order to reduce cumulative atmospheric stressors, rehabilitate and adapt native biodiversity, and decrease the potential for invasion of native vegetation by exotic species (MacIver and Dallmeier, 2000).

The example of Long Point, an international biosphere reserve with some of the greatest biodiversity in southern Ontario, illustrates this conservation challenge. The reserve is subject to the highest loading of ground-level ozone in Canada, high UV-B (latitude), exceedances of acid deposition targets, increasing heating and future global warming, and is furthermore surrounded by a highly altered agricultural landscape. Undertaking climate-based studies in the forest monitoring plots located in the Long Point Biosphere Reserve helps in obtaining quick and relevant information on the changing state of biodiversity.

### 4.1.2. Mapping of Bioclimatic Zones

Biodiversity in Canada is facing multiple threats. The fragmented landscape is creating islands of isolated habitats, adversely impacting the ability of biodiversity to adapt naturally to a changing climate. Many ecosystems have to simultaneously contend with invasive species, disease, acid rain, nitrogen loading, hunting and a host of other stressors. Moreover, all of these impacts act synergistically to create even greater change.

An examination of probable new bioclimatic zones in Canada reveals that most reserves and conservation areas are in places where cities and major agricultural zones are obstacle courses for successful climate-driven dispersal, rapid responses and community reorganization. To begin with, Canada's parks are inadequate to protect biodiversity. Seventy-five to 80% of national parks are expected to experience shifts in dominant vegetation under scenarios of doubled $CO_2$ levels (Scott and Stuffling, 2000). This situation is true of many such reserves, underscoring the inadequacy of the current protected-area system under climate change.

Climate is a major control of where certain plant species will grow and flourish. Hence, as climate changes, ecosystems, with time, will change their location. If natural or artificial barriers prevent this from happening, the consequences for biodiversity will be severe.

A doubling of $CO_2$ levels, which will likely occur within the next 50 years, would significantly reduce the areas suitable for boreal forests in Canada, while increasing the areas suitable for grasslands and temperate forests (Figure 63). Since forests migrate very slowly, the transition of these ecosystems to new climatic zones would be out of sync with changes in climate. Current ecosystems, such as the boreal forests, will be situated in completely novel climatic regimes. This is likely to cause dieback and loss to insects, diseases and fire in regions where climate change imposes the

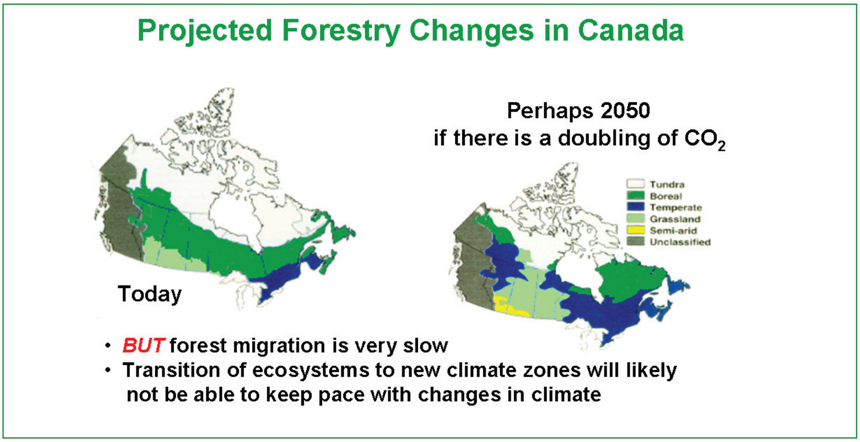


**Figure 63. Projected forestry change in Canada for 2050 with a doubling of $CO_2$**

greatest stress. In turn, changes in ecosystems can significantly affect regional climates.

The results of IMAP suggest that the number of forest families or the biodiversity currently supported by the heat of the Windsor area has the potential to be situated north of Sudbury later this century with a doubling of $CO_2$ (Figure 64). The heat currently available to support tree biodiversity in the Greater Toronto Area could move well into northern Ontario. These represent truly major changes in growing season heat, and it may in fact be beyond the capacity of trees to respond. Theoretically, forests could eventually shift northward given the warmer temperatures in more environments under climate change. In reality, however, trees and other vegetation cannot migrate at fast rates. The result is more likely to be stressed woodlots, dieback, loss of native biodiversity and wildlife, along with more limited habitat.

Modelling studies suggest that species at the southern boundary of the boreal zone (e.g., southern Algonquin Park) will experience increased mortality and eventually be replaced by species from communities to the south. What is unknown is the time it will take to replace the northern species and whether the northern species will die out before the southern species can assume their place. Sometimes, events triggered by extreme weather, such as severe ice storms, windstorms and fire, can rapidly wipe out stressed forests well before their replacements are able to arrive. As the number and magnitude of extreme climate events continues to escalate, the capacity of natural ecosystems to act as buffers to climate change is undermined.

Results from modelling studies also bear out the need for biodiversity monitoring that can detect changes sparked by a warming climate, such as invasions of unwanted species. While a warmer climate may eventually, in an optimal scenario, support more biodiversity, many of the increases in future species are likely to come from invasions of exotics and other species moving north. This will also mean losses of native biodiversity. Policies may be required to protect native biodiversity and defend against invasions of unwanted species.

Figure 64 shows the potential outlook for forest biodiversity based only on the climatic influence of temperature. In reality, land management or land use will also play a major role in influencing the changes that may occur. For example, agricultural lands under active cultivation will not become woodlots. Humans can further negatively impact the situation by adding to the seed stocks through planting exotics for landscaping and introducing exotic pests (e.g., gypsy moth and Asian longhorn beetle).

### 4.1.3. Climate Change Sugar Maple Study

Maple syrup production in Canada has grown by 76% in the last 80 years (Statistics Canada data for 1924-2003). But with recent declines in sugar maple production and concerns over global environmental change, there is a need for a more thorough understanding of the impact of climate change on sap flow, quality and quantity of maple syrup production.

Climatic parameters that impact maple syrup production include temperature, precipitation, drought, snow cover, carbon dioxide concentration, acid precipitation and ozone concentration. These factors, in turn, alter nutrient profiles of the soil and trees, respiration and photosynthesis rates, pest and disease vulnerabilities, and stress response (subject to the age of the tree).

The results of a combined optimal minimum and maximum temperature analysis are presented in Figure 65. The number of days with minimum and maximum temperatures in the optimal range has increased significantly: approximately two to four days over a 90- to 109-year period at three Quebec stations (La Tuque, La Pocatiere and Les Cedres). Non-significant increasing trends are found at the remaining Quebec and Ontario stations, while the two stations in Vermont show a non-significant decrease in the indicator. As any statistically significant increasing trend in this indicator would be beneficial to syrup production, the trend results suggest that conditions for this indicator are improving at some sites in Quebec (MacIver et al., 2006).

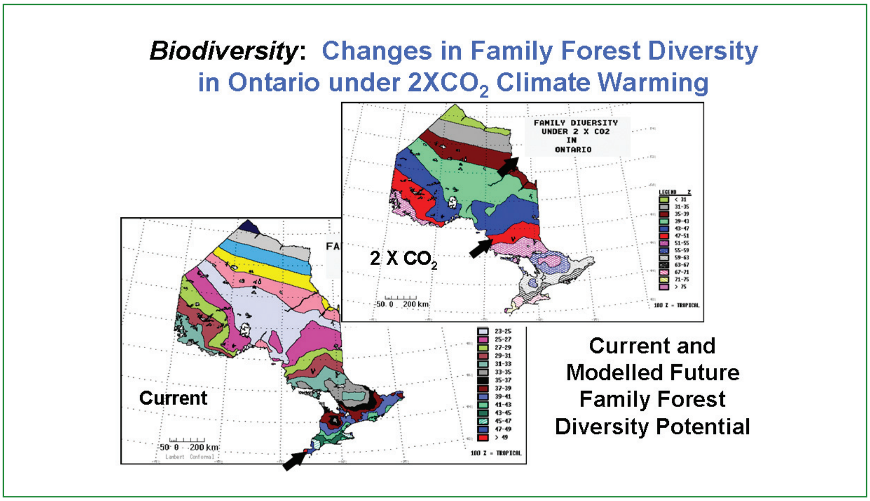


**Figure 64. Changes in family forest diversity in Ontario with a doubling of $CO_2$**

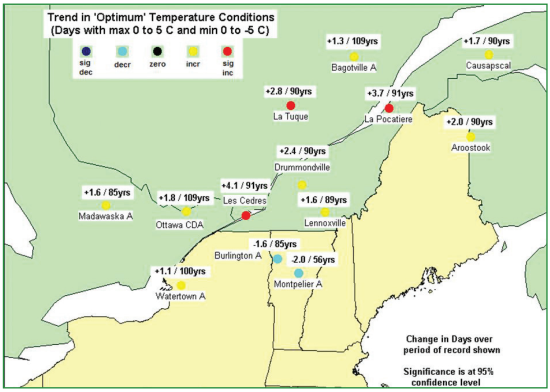


**Figure 65. Best fit linear regression in number of days with minimum temperature ≥-5ºC to +5ºC**

**The optimum temperature range preferred for sugar maple sap production between February 1 and March 1 is -5ºC to +5ºC, so an increasing trend in this indicator is beneficial for maple syrup production. (Source: MacIver et al., 2006)**

There is a significant decrease of snow cover and minimum temperature at La Pocatiere, Quebec (7.6 days over 83 years). Non-significant decreases are found at the remaining locations, except for non-significant increasing trends at the two Vermont locations (see Figure 66). Significantly increasing trends in this indicator would not be beneficial to syrup production (MacIver et al., 2006).

The overall conclusion is that high-production areas for maple syrup are moving northward and Canadian production has surpassed U.S. production because of the better optimum conditions for sap production in Canada.

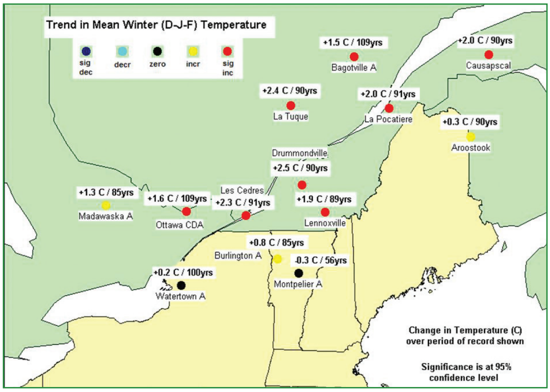


**Figure 66. Best fit linear regression in number of days with <5 cm snow and minimum temperature ≤10ºC**

**An increasing trend in this indicator between December 1 and March 31 is not beneficial for maple syrup production. (Source: MacIver et al., 2006)**

## BOX 16

### Gaps: New integrated models

Additional examples of integrative models using biodiversity and climate parameters for a variety of species, processes and ecosystems are needed.

## 4.2. Climate Change Adaptation Options for Biodiversity

By scientific consensus, atmospheric change is a reality and one that directly affects the biosphere and biodiversity. Most key habitats and many species in Canada will be subject to some change (coastal areas more than others), to which some may prove unable to adapt. Insects and fungi are capable of adapting quickly to a changing environment because of their genetic makeup and short generation times, but trees are much slower to respond. These differences in adaptive abilities will likely lead to an increased risk of insect and fungi infestation as the climate changes.

Climate change adaptation options encompass efforts to restore resilience to ecosystems, since resilient ecosystems maintain biodiversity, continue to deliver ecosystem goods and services, and protect human, plant and animal communities from climate hazards such as erosion, flooding and drought.

While a wide range of adaptation activities has been designed or planned by Canada, few have been implemented to date. In many cases, adaptation actions have been delayed because the knowledge base and partnership processes required to support implementation must be strengthened first.

To document changes over time, there is a need to know the adaptation baseline. Yet studies indicate that many additional species will be lost if adaptation- and resilience-building actions are delayed, while management options will become more limited and expensive and have a lower likelihood of success.

The integration of adaptation and mitigation actions within the context of climate extremes, biodiversity conservation and sustainable development all call for greater synergy in implementing the CBD and other relevant multilateral environmental agreements. Synergies in protecting biodiversity will be facilitated by joint action on these international measures, including the reduction of GHG emissions from deforestation.

### 4.2.1. Examples of Climate Change Adaptation Options for Biodiversity

Adaptation options can be classified under many general thematic approaches, which include the following:

#### i) Adaptation Strategies

- Ensure options are of the "do-no-harm" variety
- Improve predictions or plausible scenarios of future climate change
- Develop National Adaptation Plans that include biodiversity
- Undertake Adaptive Capacity Studies
- Prioritize intact or relatively unaffected habitats for protection
- Engage local people in planning and implementing mitigation and protection strategies
- Design reserves to protect vulnerable life stages
- Respond to changes already inherent in the system
- Improve integrated monitoring and detection programs

#### ii) Planned Adaptation

- Build corridors
- Reintroduce species, with great care
- Assist species regeneration
- Employ *ex-situ* conservation if extinction is imminent
- Manage for disturbances to the ecosystem
- Account for projected effects of climate change when designing new protected areas
- Track and manage invasives (e.g., control or eradicate invasive species)

#### iii) Building Ecological Resilience

- Reduce fragmentation
- Protect space, functional groups, climate refugia and multiple microhabitats in replicated areas
- Maintain a natural diversity of species, ages, genetic diversity and ecosystem health

- Provide buffer zones and flexibility of land uses
- Ensure connectivity of habitats along gradients
- Reduce other related and cumulative stressors

### iv) Technological Adaptation Solutions

- Efficient management of rain/snow water availability
- Changes in timing/type of irrigation and fertilization
- Inoculate soil with soil biota to support plant vigour
- Establish aquaculture
- Diversion of fresh water
- Build seawalls, dikes and tidal barriers
- Build bridges to cross inundated areas
- Increase density and reliability of climate monitoring

### v) Behavioural Adaptation Solutions

- Early Warning Climate Alert and Response Programs for Biodiversity
- Prediction of climate extremes and hazards for emergency preparedness and disaster management of critical biodiversity
- Risk-management assessments and priority setting of behavioural-based action plans to reduce the impacts of a changing climate on the functioning of biodiversity
- Redefinition of critical biodiversity thresholds to the new multiplier climate

### vi) Regulatory/Policy Adaptation Actions

- Re-zone coastal areas
- Establish protected areas
- Natural forest regeneration or avoided deforestation
- Decrease nutrient-enhanced runoff
- Non-chemical control of pest/disease outbreaks
- Establish “no-take zones”
- Landscape scale management of water availability and quality
- Change trade policies

## vii) Economic Adaptation Approaches

- Changes in grazing management and water management
- Apply modifications in agricultural land base and incentives for more sustainable agriculture and forestry
- Offer incentives to control the spread of invasive species
- Eliminate incentives that accelerate habitat loss
- Adopt energy-efficient technologies for both adaptation and mitigation benefits

## viii) Adaptation Science

- Model the buffering capacity of forest habitat for biodiversity in a changing climate, especially in urban parks and schoolyards
- Reduce other pressures/threats
- Introduce species tolerant to salt, drought, pests or higher temperatures
- Rehabilitate damaged ecosystems
- Introduce multi-cropping, mixed farming, low-tillage cropping or low-intensive forestry
- Apply integrated models for climate and biodiversity prediction
- Improve the understanding of extremes/hazards and cumulative events

## BOX 17

### Climate change adaptation options for biodiversity

Climate change's consequences for biodiversity need to be investigated further and more fully quantified. There is a particular need to identify the limiting thresholds in duration, intensity and severity of climate extremes, below which ecological resilience and adaptive capacity of biodiversity declines. Scenarios for managing extremes need to be developed and tested and creative solutions must be explored.

Classic management and planning approaches to adaptation are too passive and sluggish to accommodate climate change. Reactive adaptation approaches, such as providing corridors, fail to take into account climate extremes and rapid rates of change. There is a need to expand beyond these approaches to accelerate the environment's adaptive capacity to build resilience. The fact that adaptation options are scale-dependent must also be given due consideration; otherwise, biodiversity losses will continue.

One of the lessons learned at the Humber Arboretum climate change experimental site is that there are surprises: in that specific case, warmer springs resulted in unexpectedly high rates of browsing in the urban forest. More experimental sites should be set up to test adaptation scenarios.

Future adaptive management actions recognize the urgency to adapt now, adopt proactive, anticipatory adaptation (e.g., climate change experimental sites), accelerate science, planning and solutions, engage communities, initiate partnerships and foster education.

Research priorities should lie in developing improved modelling and other assessment methods to investigate and predict potential interactions between climate change (including increasing carbon dioxide levels), disturbances such as fire, invasive species, diseases, salinity, grazing and habitat fragmentation, interactions between species such as competition, predation and habitat provision, and other factors affecting species' ranges and distributions, including the effects of population and ecosystem dynamics. There is a need to identify other threats and stresses likely to affect biodiversity and determine how these will interact with climate change impacts (e.g., the effects of climate change on fire regimes).

The combined effects of multiple stresses have cumulative and additive effects on species, habitats and ecosystems. It is critical to monitor environmental indicators at test sites that are potentially within the influence of local or regional anthropogenic stressors and to compare these with results from suitable reference sites. There continues to be a lack of basic knowledge about biodiversity and biodiversity-climate interactions, including interactions with other drivers of global change and elevated carbon dioxide, both in the atmosphere and in the ocean.

## 4.3. Transfer Functions: Sensitivity Analysis

Transfer functions provide an understanding of how ecosystems function and interact. Essentially, they are concepts that can be used in another context or for a problem other than the one for which they were originally developed. As well as identifying the linkages between climate and organisms, an understanding of ecosystem processes is crucial in applying transfer functions. The knowledge that can be derived from transfer functions – coupled with an understanding of the factors that influence how organisms adapt to climate change and climate extremes – aids in predicting how multiple stresses will impact an ecosystem and the environment (MacIver et al., 2005).

### 4.3.1 Heat Unit by Family Diversity

Heat is a powerful trigger. Changes of 1°C or 2°C translate into significant biological impacts, adaptations and vulnerabilities. Thus, the heat unit by family diversity model for forests suggested by Rochefort and Woodward (1992) provides a useful global adaptation baseline against which to examine and evaluate SI/MAB sites for environmental prediction and future planning.

The heat unit is the accumulation of heat above the base temperature of 5°C commonly referred to as growing degree days (GDD). As well as providing a yardstick for assessment based on expected versus observed findings, the correlation between the heat unit and family diversity, illustrated in Figure 67, makes for an effective diagnostic tool to identify sites where the biodiversity is or is not in equilibrium with the present climate.

This baseline relationship proved to serve an important transfer function when researchers merged it with long-term bioclimate maps for Ontario (Watson and MacIver, 1995). First, the spatial variability of climate-based biodiversity was mapped; then, climate change scenarios were used to calibrate and map anticipated and future changes in biodiversity (MacIver, 1998).

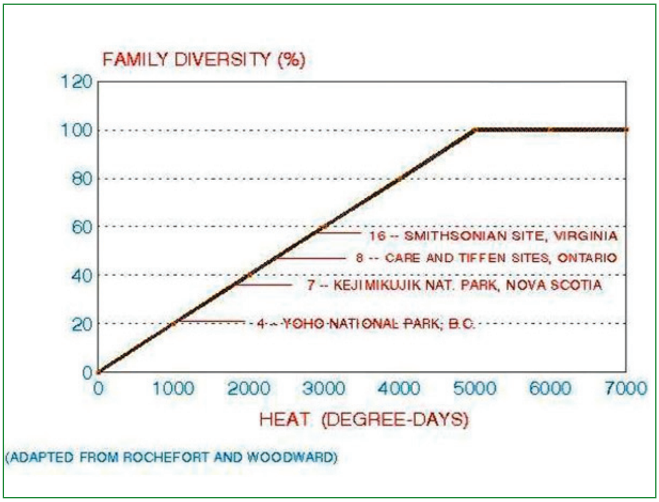


**Figure 67. Basic heat-by-family biodiversity forest baseline vis-à-vis SI/MAB sites**

The technique helped to identify areas in southern Ontario that will require enhanced conservation practices for the adaptability of native species, including areas that will be vulnerable to invasive exotic species.

The SI/MAB sites provided initial verification of the family diversity baseline nationally. More importantly, they have allowed for the construction and calibration of the biodiversity baseline for mixedwood forest species due to the abundance of SI/MAB plots across ecological, climate and chemical gradients in southern Ontario. Figure 68 depicts this gradient analysis approach and the relative linearity of the basic-heat-by-family biodiversity relationship for mixedwood forest sites (MacIver, 1998). Figures 69 and 70 show the actual forest biodiversity using individual SI/MAB results along the climate family diversity baseline versus heat units, defined as growing degree days above 5°C.

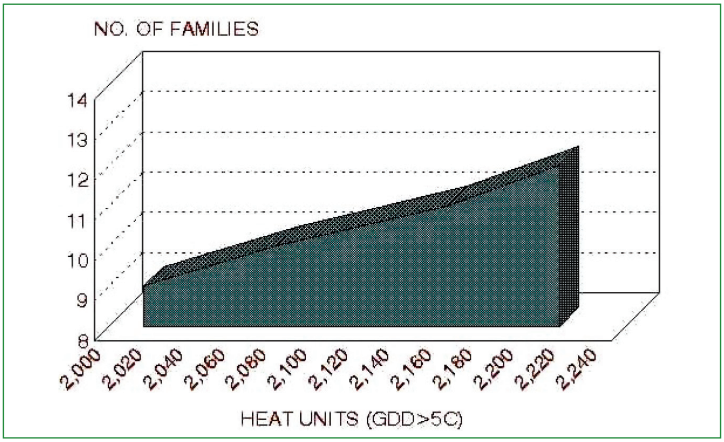


**Figure 68. Heat-by-family biodiversity for mixedwood forests in southern Ontario based on SI/MAB sites observations**

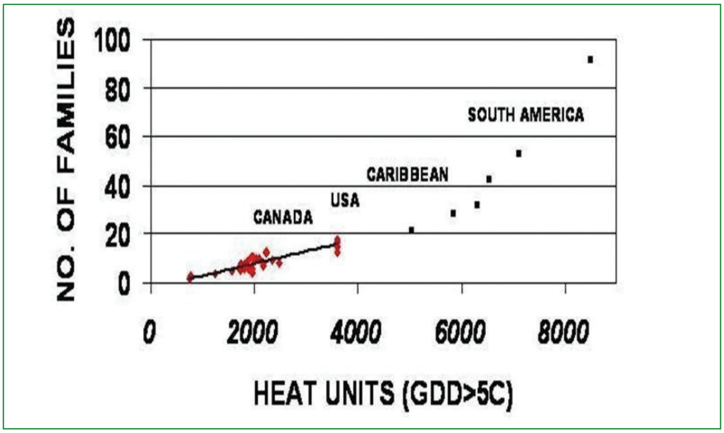


**Figure 69. Number of families as related to heat units in Canada compared to SI/MAB reference sites in the U.S.A., Caribbean and South America**

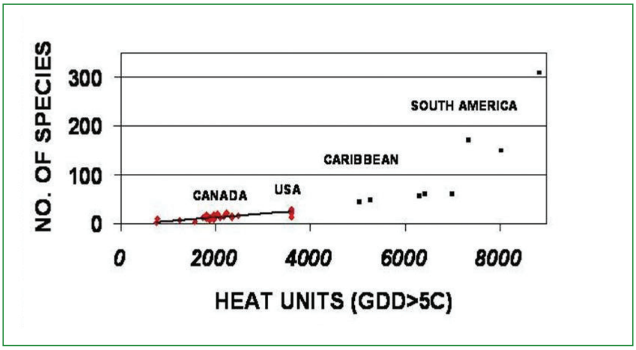


**Figure 70. Number of species as related to heat units in Canada compared to SI/MAB reference sites in the U.S.A., Caribbean and South America**

## BOX 18

### Gaps: Transfer functions: Sensitivity analysis

There is a need to compile transfer functions relating interactions between:

- key ecological processes (dispersal, reproduction, primary production, nutrient cycling, etc.) and climate change;
- interactions between extreme events and climate variability and ecosystems;
- species interactions and climate change;
- interactions between increasing carbon dioxide in the atmosphere and oceans, combined with temperature and rainfall changes;
- climate parameters and limitations to species distributions; and
- bio-physical requirements of key taxa in the context of climate change.