The New England Regional Assessment
Key Issues and Relevant Case Studies

The New England region (including upstate New York) is dominated by weather and physical climate, and New Englanders have come to expect to be able to "work around" their weather. They also expect their weather forecasts to be reasonably accurate, and their weather predictable. Recent weather-related events have raised public awareness that the "typical" New England weather may be changing, as evidenced by recent mild winters and the occurrences of extreme weather events such as the ice storms of January, 1998, the heavy rains and flooding of October, 1996, and June, 1998, and the odd fall, 1998.

The New England Regional Assessment has been undertaken to assess the extent to which the climate of the region may be changing, to document the impacts of potential future climate change, and to identify possible adaptive strategies appropriate for the region. In this assessment activity, upstate New York has been included as part of the "New England" Region. The New England Region is one of 18 Regions involved in the process of assessing the impacts of potential climate change and variability, at the regional-scale, as part of a larger National Assessment effort. For the New England Region, the following three sectors have been identified as key areas of interest to New Englanders: Forests, Water Resources, and Human Health.

The following Key Issues and Relevant Case Studies were selected by the participants attending three sector-specific workshops, held March 30 (Forests Sector), March 31 (Water Resources Sector), and April 8 (Human Health Sector). In order to be included below, each case study needed to meet three criteria: 1. the case study is important to the stakeholders of the New England region; 2. each had to exhibit a clear connection to either physical or chemical climate impacts; and 3. each case study needed to be well-documented and thoroughly-understood, based on existing data.

1.) Air Quality Issues

Tropospheric (ground-level) ozone across the New England region may reach unhealthful levels during summer months, especially during periods of days when maximum temperatures exceed 90^{o}F. The combination of high temperatures and full sunlight, coupled with nitrogen oxides (NO_x - generated primarily by automobile traffic) and volatile organic compounds (VOCs - from both natural and anthropogenic sources) result in elevated levels of ozone, a form of air pollution. Exposure to elevated levels of anthropogenic ozone has been shown to have a negative impact on both forest health and human health.

Due to the topographic variability typical of New England (and upstate New York) and to the fact that the New England region is downwind from the rest of the country and parts of Canada, upper-elevation sites (generally above 3,000') can be characterized by unhealthful levels of anthropogenic ozone. Long-distance transport of NO_x, combined with high levels of naturally-occurring VOCs (terpenes from trees) and intense sunlight combine to produce elevated levels of ozone (above 80ppb*) across much of the summer season. These unhealthful levels of ozone can lead to significant problems for both trees and people.

*ppb = parts per billion

Case Study - Forest Health and Productivity. Exposure of sensitive forest tree species to levels of tropospheric ozone above 80 ppb over several hours may reduce the productivity of these species by approximately 10%. Although increasing levels of CO_2 may result in increased productivity and carbon sequestration, the accompanying increases in temperature (and in particular, an increase in the number of 90^{o}F+ days) may well result in an increase in tropospheric ozone levels, which could counteract this CO_2 enhancement effect. In addition, the continued deposition of high levels of nitrogen and other forms of chronic pollution to the region's forests are likely to result in degraded productivity. Although nitrogen acts as a fertilizer, and the forest of New England are generally nitrogen-limited, too much nitrogen in a forest ecosystem results in damage to that ecosystem. Recent research shows that we may be killing our trees with kindness, that addition of excess amounts of fertilizer (nitrogen in particular) to forest ecosystems will lead to forest decline across the region. One of the significant unknowns at this point is how forest species will react to increases in CO_2, temperature, ozone and excess nitrogen.

Case Study - **Hiker Health Impacts**. The same tropospheric ozone that impacts forest health has also been shown to have acute, adverse effects on human health, specifically pulmonary function. In a hiker health study, conducted in the White Mountains National Forest (NH) by personnel from the Harvard School of Public Health, public health research centers, and the Appalachian Mountain Club, it was found that exposure to ambient levels of anthropogenic ozone, fine particulate matter ($PM_{2.5}$), and strong aerosol acidity typically found at elevations above 3,000' reduces hikers' pulmonary function. With prolonged outdoor exercise, these three air-pollution factors were shown to have significant adverse effects on pulmonary function in adults. Hikers with a history of asthma or wheeze exhibited a four-fold greater response to ozone exposure than others.

2.) Seasonal Dynamics Issues

Based on the regional scenarios generated using the Canadian Climate Model (CGCM1) and the Hadley Climate Model (HadCM2), the New England region is likely to experience a warming trend and an increase in precipitation over the next 100 years. Both climate models suggest future warming by 2095, but to differing degrees (an increase of 5.0^{o}C/9.0^{o}F, based on CGCM1; 3.0^{o}C/5.4^{o}F based on HadCM2). In terms of precipitation, the models differ as well, suggesting a 5% increase based on CGCM1; a 25% increase based on HadCM2. In both models, minimum temperatures increase at a greater rate than maximum temperatures over this time frame. Such changes could have a profound effect on seasonal dynamics across the region: milder winters (especially warmer nighttime temperatures), warmer and wetter summertime conditions, etc. Such changes would have dramatic and potentially negative effects on many industries, as well as on current conditions that typify New England.

As examples of how changes in those climate conditions that have typified New England in the past could impact the New England of the future, the following case studies are offered.

Case Study - The Migration of the Maple Syrup Industry. A successful maple syrup season in New England depends on the proper combination of freezing nights and warm daytime temperatures, as well as prolonged cold temperatures (resulting in a recharge of sugar to the sap) during the months of February and March. When the right combination of these climatic conditions occur, the result is the production of sap containing 2-5% sugar by the sugar maple tree. In addition, the first flow of sap in a given season generally produces the highest quality maple syrup. Thus, a sustained, early flow heralds a good year for the syrup producers in an area. If the initial flow occurs too early, before many of the producers have tapped their trees, they will miss this profitable opportunity. The maple industry in New England depends to a large extent on the timing of these critical climate events. Due to changes in both technology (the advent of tubing) and climate (very early initial flows, a reduction in enough freeze/thaw cycles and cold recharge periods), the maple syrup industry is moving from New England into Canada.

In the past, maple syrup production in Canada was limited by deep snow cover (limiting access to individual trees) and fewer freeze/thaw cycles due to prolonged periods of low nighttime and daytime temperatures. The development of tubing-based sap collection methods, which provide easier access to trees, and eliminates the need to make frequent collections, has allowed the Canadians to become more competitive in recent decades. However, changes in climate over the past several decades has also allowed the Canadians to collect more sap, over a longer "sugar season," than in the past. Conditions appropriate for sustained sap flow now mark the Canadian season, while warmer daytime temperatures and nighttime temperatures (fewer freeze/thaw cycles and reduced cold recharge periods) in New England, coupled with increasingly earlier initial flows over the past decade, has resulted in a shift in the volume of syrup production from the United States to the Gaspe Peninsula of Quebec. It is interesting to note that in 1928, the major syrup production center in the United States was located in Garrett County, Maryland. There has been a northward migration of the maple syrup industry during this century.

The CGCM1 and HadCM2 model scenarios may provide some insight regarding potential impacts of future climate change on the maple syrup industry in New England. The CGCM1 projects an increase in annual temperature of $5.0^{o}C/9.0^{o}F$ with little change in precipitation by 2095, while the HadCM2 projects an annual increase of $3.0^{o}C/5.4^{o}F$ and a 25% increase in precipitation. In either case, if wintertime minimum temperatures increase more rapidly than the maximum temperatures (as indicated in both models) then the current northward shift in production will continue, resulting in the loss of the maple syrup industry in New England.

Case Study - Lyme Disease. The spread of Lyme disease is dependent on deer tick population dynamics, in turn dependent on the severity of wintertime minimum temperatures, changing landuse and the resulting disturbance patterns, the population dynamics of deer and white-footed mice, as well as the production of acorn crops (mast) across the region. The highest number of cases reported in the United States for Lyme disease in humans centers on the New England region, where the highest number of cases reported for 1998 were in New York and Connecticut. Massachusetts is ranked fifth (after Pennsylvania and New Jersey) in the number of cases reported in 1998.

Although some years are good mast years for oak (up to 50,000 acorns per mature tree) and others are poor mast years (1,000 acorns per tree), the actual connection between climate and acorn production is poorly understood. Every third or fourth year tends to be a good mast year, and an assessment of past temperature/rainfall patterns and acorn production may allow for the prediction of mast production. The warmer winters suggested by both CGCM1 and HadCM2, especially if minimum temperatures rise more rapidly than maximum temperatures, will allow for the overwintering of more deer and ticks in northern New England, thus potentially extending the range and impact of Lyme disease on humans across the region.

Current research indicates that two years following a good mast year, the risk of contracting Lyme disease goes up dramatically, and conversely, two years following a poor mast year, the risk goes down. Since 1997 was a good mast year, there is the potential for 1999 to be a high risk year for contracting Lyme disease. If a connection can be shown to exist between climate and one or more factors associated with the occurrence of the disease, an important predictive capability may be developed. The monitoring of changes in landuse patterns, and the use of a regionally-calibrated Palmer drought index may also prove to be useful in tracking potential vector distributional changes across the region. This is work in progress.

3.) Extreme Weather Events

Although the links between regional climate patterns and the frequency/occurrence of extreme weather events are not well documented or understood, the warming trends and increased precipitation patterns suggested by both CGCM1 and HadCM2 may lead to more extreme weather events. Two historical examples of such extreme weather events that impacted the New England region provide the case studies.

Case Study - 1998 Ice Storm Damage. In January of 1998, a series of devastating ice storms hit northern New York and New England, along with portions of eastern Canada, causing extensive damage to forests, energy and transportation infrastructure, as well as impacting human health, and in general, disrupting life in the region in a number of significant ways. While it is not uncommon for the region to suffer from such ice storm events, the extensive area of impact (37 counties were declared Federal disaster areas) was very unusual, and the storm has been referred to as at least a 100-year event.

The ice storm had a very great impact on human health, including 17 deaths across New York and New England, many due to carbon monoxide poisoning and asphyxiation from improper ventilation of power generators. These generators were used by homeowners to replace home electric sources needed to restore power, heat, and water. In Canada, 26 deaths were reported, many due to hypothermia. In addition, nearly 17 million acres of rural forests and urban trees were affected; with five million acres classed as severely damaged. Hardwood species were most heavily damaged with trees bent and limbs and branches broken under the weight of the ice coating. Many people across the region were without power for up to three weeks, resulting in inconvenience and frustration for many and carbon monoxide poisoning and deaths from asphyxiation for a few. In Maine, a full 70% of the state’s population of 1.2 million people were without power for at least some period of time. Over the entire region (portions of New York, Vermont, New Hampshire and Maine) approximately 1.5 million people were without electricity for up to three weeks.

It is important to note that the icing conditions typical for the 1998 ice storms occur when mid-altitude temperatures are too warm for normal snowfall to occur. While the icing conditions required for such ice storms are highly unusual and unpredictable, a warming of wintertime temperatures may lead to their more frequent occurrence in the future.

Case Study - The Mid-1960s Drought. In the last century, the New England and New York region has been subjected to several periods of drought: incidences where precipitation and streamflow were less than normal. Prolonged periods of drought can have impacts on the region's water quality and quantity, and if severe enough can affect forest health, human health and ecosystem dynamics. These impacts in past have resulted in quality-of-life and socio-economic consequences for residents of the New England/New York region.

Based on precipitation and streamflow records, this region experiences moderate drought conditions approximately once a decade. By far the worst episode this century was the period of prolonged drought across the entire New England region and mid-Atlantic states during the mid-1960s. This event impacted regional agriculture, water quality and quantity, forest health, and human health. Dry conditions reached critical levels by 1965, resulting in wide-spread forest fires, crop failures, fish kills, water shortages, harmful algal blooms, and heat-related deaths. As a result, President Johnson declared a regional national emergency.

The 1960s drought was a result of an anomalous upper-level trough off the east coast, inducing a persistent cold dry air flow from the Northwest. Some studies have attempted to link drought conditions during this century to the occurrence of El Niño events, but no clear pattern appears to have emerged. Though no direct link has been made to date between human-induced climate change and the occurrence of drought conditions, the climate shift seen in the CGCMI and HadCM2 scenarios may further exacerbate the periodicity and severity of droughts in this region. The mixture of changing population dynamics, incidences of drought and potential changes in climate, especially seasonal shift, could have significant impacts on the New England/New York region.

For more information on the New England Regional Assessment, please contact Ms. Faith Sheridan at (603) 862-1792 or faith.sheridan@unh.edu. The New England Regional Assessment Web Site is: http://www.necci.sr.unh.edu/.