Summary of the report: "Seasons of Change: Global Warming and New England's White Mountains"

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NOTE: At the NECCI workshop, Steven Hamburg gave a talk which summarized the findings of a technical report on global warming and the White Mountains. This paper is a summary of the technical report, and provided the basis for Steve's talk.

There is scientific consensus that emissions of greenhouse gases from fossil fuel combustion, deforestation and agriculture have contributed to and will continue to cause global climate change (IPCC 1996, volume I). Climate models used by the Intergovernmental Panel on Climate Change, an international group of more than 2,000 scientists, project that the Earth will warm by two to six degrees Fahrenheit by the year 2100. Warming is predicted to increase with latitude therefore New England and the White Mountains will generally experience higher than the globally averaged temperature increases. For New England in general and the White Mountains specifically, global climate change of the predicted speed and magnitude could mean significant and, in some cases, significantly negative, impacts to its natural resources, ecosystem health, and way of life. In addition to changes in forest types and productivity, there exists a significant risk of disruption of the fall foliage season, a shortened ski season, a decrease in trout habitat, declines in maple syrup production, and changes in the productivity of the timber industry.

While comprising a relatively small geographical area, the White Mountains region is home to diverse communities, industries, and ecosystems, all of which are important to defining the regional and extra-regional economy. The long-standing traditions of timber management, maple-syrup gathering, and fishing, as well as the more modern economies of skiing, foliage viewing, and other tourism and outdoor recreation activities are key elements defining the region. The persistence of the traditional White Mountain way-of-life relies in large part on the persistence of historical climate patterns, patterns poised to change substantially over the next century.

Global and regional climate models suggest that over the next few decades and century, shorter winters; longer, drier summers; and increased frequency of flooding, winter thaws, and summer droughts associated with global warming are likely to occur in the White Mountains. These changes could have profound effects on the forest composition, water resources, snowfall, growing season length, atmospheric visibility, and local weather patterns, which could lead to negative impacts on maple-syrup production, skiing, and fishing, and mixed, but likely negative, impacts on the overall tourism, recreation, and forest products industries as well.

The fall foliage season in the White Mountains brings visitors from around the world to view its brilliant natural display. The weekends during the fall foliage season, running between mid-September and mid-October, are often the busiest of the year for the tourist industry (Goss, pers. comm). This display is susceptible to climate change in a variety of ways. Forest decline, summer drought, a longer fall season, and species boundary shifts could all significantly affect the timing and brilliance of the fall foliage display in the White Mountains. The existing forests are vulnerable to decline as a result of possible climate changes including increased drought and pollution, more frequent thawing and freezing cycles and disturbances such as fire, wind, flooding, and pest and pathogen outbreaks. In addition, higher numbers of dead and dying trees would mute the hillsides of brilliant colors. If summer droughts become more common, as is predicted by some climate models, the quality of the display may dim. Prolonged drought can cause leaves to dry, shrivel, and fall to the ground before producing any significant color (Kozlowski et al., 1991).

Warmer temperatures are likely to continue longer into the fall which could cause the peak foliage display to shift to later in the season. However, leaf fall and color change are triggered by both temperature and day-length (Kozlowski et al., 1991). This could lead to an uncoordinated display where those trees more influenced by day length would change color and drop their leaves earlier than those trees more influenced by temperature. As climate change continues and local growing conditions are no longer ideal for certain tree species, trees from further south are projected to dis-

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place the northern hardwood and spruce/fir forests (Kirschbaum et al., 1995). If current northern hardwood species such as sugar maple, spruce, and fir populations decline while oak and other trees currently found south of the region increase, then the unique combinations of brilliant red maples, yellow birches, and touches of dark green conifers may be replaced by the more uniform browns of the oaks.

Certain economically important wintertime activities are also vulnerable to climate change. The ski industry in New Hampshire plays a significant role in the state's economy and especially in the economy of the White Mountains region. Direct spending by ski area visitors in New Hampshire during the 1995-96 ski season totaled nearly $190 million, 8.6 percent of the state-wide total for direct visitor spending (Institute for New Hampshire Studies, 1993). The length of the ski season and therefore the success of the ski industry is inherently tied to weather. Any significant warming in the region will most likely cause the ski season to begin later and end earlier. One scenario that models the influence of warmer temperatures on season length estimates a loss of 10 and 20% in the number of winter season days (defined as days with maximum temperature below 32°F) with a 3.6 and 7.2 degree Fahrenheit warming respectively.

While most of the warming would serve to shorten the overall length of the season, some would occur as mid-season thaws, leading to losses in snow base during the season. Some climate models also predict that precipitation will increase in the winter, while others predict similar or slight decreases (Kattenberg et al., 1995). If precipitation falls as snow, this could reduce the need for snowmaking. However, if precipitation falls as rain due to warming temperatures, this could lead to rain-on-snow events that could wash away much larger portions of the snow base. To compensate for the shorter season, mid-winter thaws, and losses of snow from rain-on-snow events, ski resorts would need to increase their snowmaking activities. Ski resorts already invest heavily in snowmaking equipment to extend the ski season. Running costs, mostly due to energy usage, can be considerable. For example, Attitash Mountain in New Hampshire currently spends $750,000 per year on snowmaking, which represents 20 percent of their operating cost. Successful snowmaking requires temperatures less than 28°F and is generally performed at night so as not to disrupt ski operations (McBoyle and Wall, 1987). Under future climate scenarios, comparatively more warming is predicted to occur during the night than the day (Kukla and Kar, 1993). Combined with overall warming this translates into a reduction in the amount of opportunities a ski area will have to make snow. For ski resorts that draw their water from ponds and small streams, there is the added concern that increased water withdrawal from these sources will damage fish habitat (EPA, 1995). Current and future technological advances in snowmaking could help alleviate some of these problems but as temperatures continue to warm, these mitigation strategies may not be able to provide long-term relief.

Recreational fishing in the White Mountains could also be significantly affected by climate change, especially in cold-water rivers and streams. According to a recent EPA study, suitable habitat for cold-water fish including rainbow, brook and brown trout may be partially or completely eliminated in the White Mountains if warming occurs as projected by the middle to end of the next century (EPA, 1995). Warmer air temperatures will lead to warmer stream temperatures eventually making habitat unsuitable for some cold-water fish species whose thermal tolerance is exceeded. Reproduction could also be directly affected by warmer temperatures since some species will only spawn within a narrow temperature range that is lower than what they can tolerate as adults. Although warmer stream temperatures may suggest that cool- or warm-water fish could replace cold-water fish, warm-water fish may have trouble colonizing these streams because they may be unused to the inherently fast stream flow rates found there. Lower water levels and reduced flows due to changes in precipitation and snowmelt patterns might increase the availability of warm-water habitat, but could decrease food availability and prevent fish migration to spawning grounds (USDA, 1992). Reduced flows and ice formation in winter may result in the suffocation, desiccation, and freezing of trout eggs.

The EPA study's worst case estimation of the economic loss associated with the impact of climate change on recreational fishing showed that nationally, the number of cold- and cool-water fishing days (defined as person-days spent fishing) declined by 50 million while the number of warm-water and rough guild fishing days increased by 64 million. Since the economic value of cool- and cold-water fishing is greater than that for warm-water fishing, there was a net annual loss of $320 million nationally (EPA, 1995). These losses could be felt in the White Mountains not only because of the importance of cold-water fishing, but also because of the economic contribution of direct spending by recreational fishers. In 1991, two mil-

lion people devoted 24 million days to fishing and spent a total of $1.3 billion in New England.

Other forms of recreation in the White Mountains could also be affected by the projected climate changes. The White Mountains region is a Mecca for hiking and summer-time recreation attracting millions of visitors from sightseers to mountaineers with its spectacular peaks, alpine meadows, and verdant forests. The summit of Mount Washington, found within the borders of the White Mountain National Forest, is one of the most popular vistas in the world. While global warming will probably lead to a longer hiking season for the White Mountains region, it might also be much less enjoyable due to hotter, and potentially drier, smoggier summers, and larger areas with dead and dying trees. Ground level ozone and other smog-producing pollution is already a problem in the White Mountains region. An Appalachian Mountains Club study has shown that ozone in this area is comparable to that of urban areas in southern New England (Hill et al., 1995). Higher heat will increase low-level ozone concentrations and could damage both human and forest health. With warmer temperatures and altered climate, the types of forest trees in the region are predicted to change. High elevation spruce and fir may disappear early followed by susceptible members of the northern hardwood forest community. The process of forest decline may include increases in pest and pathogen outbreaks and more frequent forest fires as trees become dried out and vulnerable. Eventually new forests will become established but during the time of transition, there may well be large amounts of dead and dying trees making for a more open but significantly less attractive forest for recreation.

Sugaring, the harvesting of sugar maple sap to produce maple syrup, is a tradition in the White Mountains region and throughout New England that dates back to pre-colonial days, but may be threatened by future warming. To residents and tourists alike, it wouldn't be spring in New England without the maple syrup season. Sugar maple sap flows best when night temperatures are cold (less than 25ºF) and day temperatures are relatively warm (greater than 40ºF) (Tyree, 1983). But both the records of the last century and some climate scenarios for future warming suggest that temperatures may warm more at night than during the day. This could significantly decrease the number of days for sap flow. Scenarios of temperature increases of 3.6ºF and 7.2ºF with warming occurring predominantly at night resulted in a decrease in the number of optimal sap flow days by 17 and 39% respectively. Sugar maple trees are also susceptible to mid-winter thaws and summer drought, which may accompany climate change. When snow cover is lost during the winter through a mid-winter thaw, sugar maple's shallow roots can be killed when temperatures drop again. Large-scale die-off or declines have occurred during the last century when temperatures were warmer than normal. Even before the trees die, sap production lessens as trees sicken (Wilmont et al., 1995 and Allen et al., 1992). In addition, if warming occurs more in the spring than in the winter (as some models suggest), buds may break early, making the sap bitter and leading to a shorter, less productive season (Morselli 1988).

The timber industry is a vital component of the White Mountains region and could experience a mixed response to climate change. Timber management occurs within the White Mountain National Forest, the largest management unit in the region, as well as in forests owned and managed by private individuals, large timber companies, and the state government. One EPA model of the effect of warming on the yield of timber species in New England showed increases in hardwoods, but decreases in softwoods (conifers) (Callaway et al., 1995). However, in models where forest species are allowed to migrate in response to changing climate, some timber species associated with this region currently may no longer be able to grow there in the future. The timber industry in New England has been remarkably flexible in the last few centuries since colonization by Europeans began, and may well be able to adapt to potential losses of spruce and fir and some northern hardwood species by potential increases in white pine or oak. However, during transition periods before establishment of new forest species, productivity could be greatly reduced. Climate change presents potential risks and benefits to the timber industry of this region, but further research is needed to clarify the economic impacts.

These predictions, though based on current ecosystem and climate models and observable phenomena, can only serve as an illustration of potential outcomes of climate change; no one can predict with certainty whether the climatic and ecological response will undermine, destroy, or even benefit local communities and economies in the long run. Available evidence and informed judgment indicate, however, that climate change will dramatically reduce many of the values we currently associate with the White Mountains region, and that the people of the region face a very uncertain future if current trends continue. Because the risks are great, the prudent course would be to try to avert a potentially disastrous result. This im-

plies action to slow and reduce the emissions of greenhouse gases at local, national and international levels

The talk and this paper were based on a technical report, "Seasons of Change: Global Warming and New England's White Mountains", by Janine Bloomfield and Steven Hamburg published by and available from the Environmental Defense Fund.

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