- *Connecticut*
- *New Hampshire*
- *Maine*
- *Massachusetts*
- *Rhode Island*
- *Upstate New York*
- *Vermont*

New England Regional Climate Change Impacts Workshop

WORKSHOP SUMMARY REPORT

September 3-5, 1997
Institute for the Study of Earth, Oceans, and Space
University of New Hampshire
Durham, New Hampshire

sponsored by
The National Science Foundation
White House Office of Science and Technology Policy

New England Regional Climate Change Impacts Workshop

WORKSHOP SUMMARY REPORT

September 3-5, 1997
Institute for the Study of Earth, Oceans, and Space
University of New Hampshire
Durham, New Hampshire

sponsored by
The National Science Foundation
White House Office of Science and Technology Policy

Foreword

We are very pleased to present the Workshop Summary Report of the "New England Regional Climate Change Impacts Workshop," held at the New England Center on the University of New Hampshire's campus in Durham, New Hampshire from September 3-5, 1997. The Workshop was hosted by the University's Institute for the Study of Earth, Oceans, and Space, with funding support provided by the National Science Foundation. This report summarizes the results of the Plenary and Sectoral Breakout sessions held during the Workshop.

The New England Workshop, including upstate New York, was one of a series of Regional Workshops held at the request of the U.S. Global Change Research Program and the Office of Science and Technology Policy for the purpose of assessing the potential impacts of climate change and climate variability on the region. A focused effort was made to include participants from a broad range of stakeholders representing Business, Industry and Insurance, Energy and Utilities, Government and Resource Management, Human Health, Information Transfer, Natural Resources, and Recreation/Tourism, from the seven states. These stakeholders were brought together with climate change research scientists and federal agency representatives in order to open a dialogue between interested parties regarding the latest information on climate change, as well as local and regional concerns and perceptions of sectoral vulnerabilities to climate change impacts. Efforts were also made to identify coping strategies and mitigation approaches appropriate for the New England region. This Workshop Summary Report will be integrated along with other regional reports into the first National Assessment Report, to be developed as part of the US Climate Forum, hosted by the National Academy of Sciences in Washington, D.C., November 12-13, 1997.

Of the 122 participants attending the two-day workshop, approximately one-half (57) represented non-academic, non-agency sectors from across the region. We view the Workshop as only a first step in the process of engaging the public in the climate change debate. A continuing effort must be made to solicit a broader range of input regarding climate change impacts to the New England/upstate New York region.

We wish to express our thanks to the members of the Steering Committee: David Bartlett, Thomas Baerwald, Richard Birdsey, Robert Brower, Ann Bucklin, Paul Epstein, Kate Hartett, Wanda Haxton, Clara Kustra, Paul Mayewski, Fay Rubin, and Shannon Spencer, who helped design and organize this highly-successful Workshop format. We also recognize the role of the New England Region of the Environmental Protection Agency (EPA) for assisting us with identifying speakers and participants, and the Workshop Co-organizers for the development of the White Paper (Appendix I) and the final Agenda (Appendix III). Finally, we wish to thank all of the authors of this Workshop Summary Report and editorial team of Jane Fithian, Denise Hart, Clara Kustra, and Shannon Spencer who assisted us with compiling all that was said and discussed. Both the Workshop and this Report are excellent examples of the combined efforts of stakeholders, research scientists, and University personnel willing to engage in open and honest discussions both during and after the Workshop, and then rolling up their sleeves in order to produce a document that captures the flavor and the details of this regional Workshop.

Dr. Berrien Moore III
Workshop Co-Chairman

Dr. Barrett N. Rock
Workshop Co-Chairman

Table of Contents

Executive Summary

Barrett N. Rock, Shannon Spencer,
Clara Kustra and Denise Hart*

THE WORKSHOP

The New England Regional Climate Change Impacts Workshop, hosted by the University of New Hampshire's Institute for the Study of Earth, Oceans, and Space, was held at the New England Center on the University's campus in Durham, New Hampshire from September 3-5, 1997. Funding support for the workshop was provided by the National Science Foundation. More information about the workshop can be found at our website: **http://www.necci.sr.unh.edu**.

A total of 122 participants, representing a broad range of stakeholders from all the New England states plus upstate New York, attended the first two days of the workshop. September 5th was a writing day involving breakout session leaders, rapporteurs and facilitators focused on production of a draft version of the Summary Report. Representatives from each of the seven sectoral breakout groups (Business/Insurance and Industry, Energy and Utilities, Government and Resource Management, Human Health, Information Transfer and Public Awareness, Natural Resources and Recreation and Tourism) have reviewed and contributed to the final version of the report. This Summary Report provides input to the U.S. Climate Change Forum held November 12-13, 1997 in Washington, D.C.

The first day of the workshop was focused on soliciting stakeholder/sectoral perspectives and concerns. Invited stakeholder/sectoral presentations occurred during a morning plenary session, followed by sector-based breakout sessions in the afternoon. The breakout groups were tasked with identifying current stress factors impacting each sector noted above. Daniel Goldin, NASA Administrator presented a lunchtime keynote address.

The second day's plenary session focused on the science of climate change, followed by presentations on the current regional climate, evidence of past climate variability, and Alaskan evidence of the impact of climate warming at high latitudes. The seven sectoral breakout groups addressed additional impacts of climate change on the current stresses affecting each sector. They also identified knowledge gaps, research needs and appropriate response strategies.

NASA Administrator, Daniel S. Goldin, presents keynote address at the New England Regional Climate Change Impacts Workshop.

Over the course of the two-day workshop, each sectoral breakout session met for a total of three two-hour periods. Session leaders reported back to the general assembly at the end of each day on the group's findings and recommendations. Summaries of each of the sectoral breakout groups are given below.

The third day of the workshop was devoted to writing the initial draft of the workshop summary report.

Workshop Attendees

Of the 122 participants attending the two-day workshop, approximately one-half (57) represented non-academic, non-agency sectors from business and industry, non-governmental organizations, state and local governments and education. It is important to note that while nearly half of the workshop participants represented a range of stakeholders, their views, as expressed in this report, represent a limited cross-section of stakeholder opinions and perspectives. A continuing effort must be made to solicit a broader range of input regarding climate change impacts to the New England/upstate New York region. Over 100

* See Appendix V for authors' affiliations and addresses.

workshop participants returned for day two of the workshop, and 75 were present for the final wrap-up session at 6:00 p.m. Twenty-seven people participated in writing the initial draft of the Workshop Summary Report on September 5.

Media Coverage

Media coverage for the workshop was a component of planned outreach to provide education about climate change issues. Media relations and communications were coordinated by a consulting professional with experience in dealing with the campus, state, regional and national media. Coverage was extensive, and included local (New Hampshire TV, Channel 9, New Hampshire Public Radio and print media), regional (Boston Globe, New York Times) and national (several Associated Press stories) media outlets.

The Plenary Sessions

Following welcoming remarks and an overview of workshop goals and objectives, representatives from each of the seven sectors presented regional climate change issues of concern and relevance to these stakeholder groups. While the first day of the workshop was focused on stakeholder perspectives, the second day focused on the science of climate change. Plenary presentations again were both sectoral and regional in scope and provided scientific evidence regarding likely climate change impacts on each sector in the New England region.

SECTORAL BREAKOUT SUMMARIES

The **Business/Insurance and Industry** sector concluded that enough information and understanding was available on the topic of climate change to suggest that human activities contribute to global warming and climate change. Suggestions included providing a centralized and authoritative source for data, greater utilization of current technologies which control heat trapping gas emissions, providing incentive programs to reduce emissions, enacting programs which preserve existing carbon dioxide sinks, and demonstrating that the political will at regional and national levels exists to address the issues of climate change.

Key findings and recommendations reported by the **Energy and Utilities** group focused on development of policies which are "no regrets" or policies which are economically viable and result in reductions of greenhouse gas emissions. Additionally, their recommendations included the greater use of renewable energy sources for New England's future energy requirements, adapting policy to ensure maximized energy efficiency, investment of national funding into research and application of new technologies, an industry-wide initiative for addressing climate change issues, and the development of a centralized and factual information base.

Generally, the findings of the **Government and Resource Management** group reflected those which were found by the Energy and Utilities group. Additional points highlighted by this group included the need to develop a strong educational network to address and engage all members of society in focusing attention on climate change issues, with particular emphasis on policy makers, industry representatives, meteorologists and foresters. A need for cost-efficient programs which result in win/win strategies was identified.

The **Human Health** group focused on the impacts that climate change may have on health related issues. A strong concern issued by the group was the current lack of information and attention to the human health effects of climate change. It was pointed out that the Northeast may be particularly vulnerable to climate change due to its geographical location. Specific concerns included the risks of increased UVB radiation due to stratospheric ozone reduction, air, land and water contamination via long-distance pollution transport, the increase of severity and frequency of high temperature events, reduction in air and water quality due to complex factors of climate, the potential increase in incidences of algal blooms in coastal areas, and the little-understood effects climate change could have on disease occurrences and pathways. Several symptoms of these impacts were considered.

The **Information Transfer and Public Awareness** group discussed one of the sentiments echoed by all of the other breakout groups: the need for greater public awareness and understanding about climate change issues. This group focused their discussion on four areas: the need for advancement of scientific literacy regarding climate change issues, identification of key climate change concepts, the current lack of effective and useful information on climate change, and the increasing need for effective and accurate communication. Key recommendations included the need for better communication from knowledgeable, accurate and credible sources like scientists and researchers, developing on-going relationships with the local, regional and national media to facilitate accurate reporting, and developing experiential-based science learning methods and programs for schools and other general public audiences.

The **Natural Resources** group highlighted the complex nature of issues confronting their group by addressing the ecological, sociological, economic and sector-based aspects of the Northeast. This group believes that natural resources and natural resource industries will be sensitive to climate change. Yet, they believe that the issues are not currently well understood and stakeholders, in general, from this sector are not aware of the issues. Their recommendations include research focused on improving climate models which can provide temperature and precipitation variability scenarios for New England, as well as research to improve the understanding of impacts on ecological, economic, and agronomic variables. Several other recommendations and win-win situations were pointed out in their report.

The **Recreation and Tourism** group stated that climate conditions profoundly affect recreation and tourism in the Northeast, and that this sector is a strong contributor to the regional economy. Most activities occur outdoors and are therefore strongly affected by climate, yet indoor activities are also climate driven. It was recognized that climate concerns are not evenly distributed across all activities: some stand to lose while some stand to gain from climate change. A number of examples of adverse effects on the sector were presented in their report. A strong recommendation, among many, from this group was to focus on long-term mitigation strategies of climate change rather than on short-term coping. The need for education of stakeholders from this sector on climate change issues was also pointed out.

SIGNIFICANT FINDINGS

Cross-cutting significant findings were drawn from each of the breakout session reports and plenary summaries. These findings, the plenary summaries, and the breakout session reports, have been reviewed by interested participants.

1. Education on issues related to climate change is not readily available and is essential for informed discussion of these issues; education should include a critical review of the evidence for climate change.
2. A regional integrated assessment of climate change impacts to New England is needed.
3. Regional examples of climate change are needed.
4. Stakeholder perceptions are that the consequences of global warming and climate change have the potential for substantial impacts.
5. The levels of uncertainty are high, but policy, research and continued awareness need to be addressed now on the issues of climate change.
6. The consequences of climate change will exacerbate current environmental stresses for all sectors.
7. "Next steps" and guidance (what to do) are needed to direct appropriate and effective public response to climate change issues (i.e., increasing levels of greenhouse gases).
8. Access to scientific and regional data on climate change, including critical evaluation of evidence for recent changes in climate, does not exist and needs to be developed.
9. The potential role of the El Niño-Southern Oscillation (ENSO) as a factor influencing the weather of New England/upstate New York was recognized and seen to be of great importance.
10. Although the workshop did not dwell on the "bad news," the overall climate change impact on New England is likely to be negative, with some sectors possibly benefiting from these impacts.
11. Policy and funding issues need to be addressed at the local, state, and federal levels to show stakeholders that government views climate change as an important issue—one which all members of society need to pool resources and work together in order to solve.
12. Incentive programs to reduce emissions and/or preserve and enhance existing CO_2 sinks must be developed.

KNOWLEDGE GAPS AND RESEARCH NEEDS

Specific knowledge gaps and research needs were identified and are listed below:

1. A clear relationship between human activities and climate change must be established;
2. A "danger level" for CO_2 must be identified as well as appropriate target levels for both reducing and eliminating the threat of global warming;
3. The ability to separate noise (the natural background or variability in the system) from signal (human contributions) in CO_2 data must be developed;
4. A quantitative assessment of the environmental and economic impacts of climate change for the New England region is needed to assess the risks of a "business as usual" scenario;

5. Appropriate policy responses to limit emissions must be identified;
6. A range of response options must be developed for possible implementation, from new enhanced technologies to selective use of fossil fuels;
7. A research program focused on enhanced technologies must be developed;
8. Improved models (climate, integrated assessment, economic) and predictions must be developed;
9. The cause and effect relationships between specific remedial actions and CO_2 level reductions must be identified and quantified;
10. An understanding of the interaction of multiple stressors on natural systems is lacking but essential for determining the impacts of climate change on natural and managed systems;
11. Effective educational programs must be developed and presented to the public.

WIN-WIN SCENARIOS

During the course of the workshop several examples of significant win-win scenarios were identified by workshop participants. These regional examples were:

1. Promoting the development of more extensive and efficient forest stands through selective management practices will result in increased CO_2 uptake (i.e.,, improved carbon sinks) as well as more productive sources of fibers for the pulp and paper industry.
2. The development of high-efficiency/alternative energy sources will not only reduce the CO_2 produced but will eliminate many air pollutants (SO_x, NO_x, O_3) currently impacting the New England region.
3. Investment in cleaner technologies that alleviate the problem of CO_2 production also reduce business and industries liabilities, strengthen its good neighbor image, and create a strong regional manufacturing presence.
4. Implementation of energy efficiency programs have the potential to decrease the cost of doing business and make regional industry more competitive (the Germans and Japanese use half the energy per dollar of gross domestic product as the U.S.).
5. Improving scientific and environmental literacy among the general public can be accomplished by supporting research professionals for their direct involvement in outreach activities. By broadening the role of scientists and public officials to include communication, we are likely to engage the public in the debate on the seriousness of global environmental issues.
6. Documentation of human health issues by medical professionals for the purposes of studying the impacts on health by climate change can motivate commitment and action to mitigation strategies by government, industry and individuals. This can then have feedbacks to preventative health care and diagnosis. Demonstrating a direct link between climate change and human health will bring climate issues to the forefront of the public's attention.
7. Improvement of techniques for preserving and improving soil quality in managed and natural ecosystems and farmlands will benefit industry and landowners by helping to sustain productivity and enhance the carbon sequestration by such soils. Incentive programs which encourage landowners to sequester carbon in their soils should be developed, which will benefit the landowner and help to reduce the carbon dioxide levels in the atmosphere.

WORKSHOP RECOMMENDATIONS

Three broad recommendations, based on the outcomes of the workshop, are as follows:

1. This workshop was a success in bringing stakeholders and experts together for a dialogue on climate change impacts in New England; but, this workshop represents only a first step in a process which must be continued in order to develop a viable regional assessment.
2. More in-depth background research must be conducted, both to understand the regional impacts as they relate to individual stakeholder groups and to precisely define the human impact on climate change.
3. The final recommendation is that we need to begin work with stakeholders and the general public on action items.

A clear message from participants, which was reiterated several times, was that the research and findings on climate change issues and the implications for New Englanders need to be stated in clear, easy to read and understand language. Scientists and other experts in the field of climate change need to communicate in "plain English."

INTRODUCTION

Barrett N. Rock, Shannon Spencer,
Clara Kustra and Denise Hart*

The New England region, including the six New England states and upstate New York, represents a part of the United States that is somewhat unique in terms of climate change impacts. Weather affecting the rest of the United States soon affects the New England region. Figure 1 shows that the region is in the unenviable position of being downwind from the rest of the country. Weather and climate are clearly global processes, and climate change impacts affecting the rest of the U.S. will also have likely impacts in New England. The heavy impact of the ice storms of January, 1998, is an example of the impact that continental weather patterns can have on New England. In a similar fashion, coal-fired power generation in the Midwestern states reduces air quality and visibility in New England, as well as contributes to the acid rain problems impacting the region. Changes in both the physical and chemical climate may well have profound impacts on the New England region.

These issues and the potential impacts were discussed in detail at the New England Regional Climate Change Impacts Workshop. The findings of this workshop are described below in this report and are summarized in the Summary of Findings section.

THE WORKSHOP

The New England Regional Climate Change Impacts Workshop was one in a series of regional climate change workshops held by the White House Office of Science and Technology Policy (OSTP), in cooperation with the U.S. Global Change Research Program (USGCRP) and various funding agencies. This event was hosted by the Institute for the Study of Earth, Oceans, and Space (EOS) at the University of New Hampshire (UNH). It was convened at the New England Center on the University's Durham campus, from

* See Appendix V for authors' affiliations and addresses.

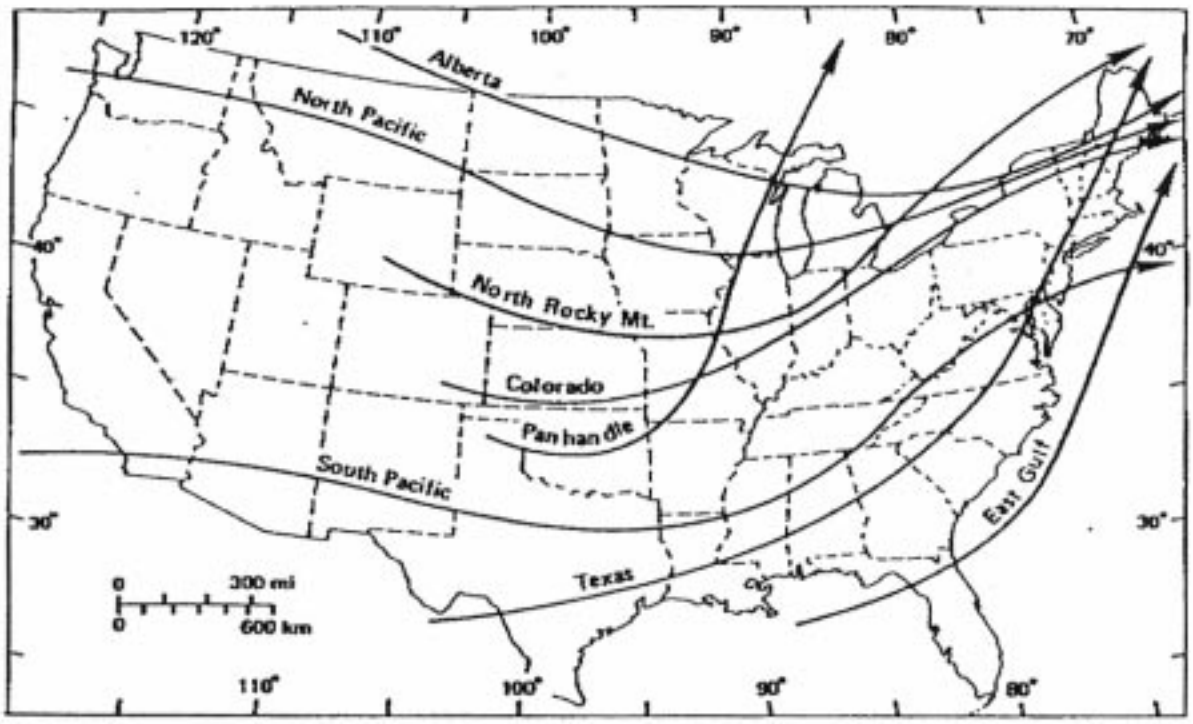


Figure 1. Major storm and airmass patterns for the United States show that the Northeast's weather is intricately linked to weather phenomena in the rest of the nation and Canada. Additionally, this airmass pattern results in the Northeast receiving high concentrations of chemical pollution from outside the New England region.

Jerry Melillo, Co-Director of the Ecosystems Center, Marine Biological Laboratory, outlines the workshop goals and presents the four questions to be addressed by workshop participants.

September 3-5, 1997. The UNH workshop was funded by the National Science Foundation (NSF).

An extensive effort was made to identify and connect with targeted stakeholder groups (sectors) through personal contacts, individualized letters of invitation, and a specifically-designed White Paper. This White Paper (Appendix I) was written in non-technical terms, with examples of current and potential future climate change impacts to New England. Additionally, a website was developed to provide on-line reports and information regarding the workshop, this site will also host the final report at: **http://www.necci.sr.unh.edu**.

A total of 122 participants, representing a broad range of stakeholders from all the New England states plus upstate New York, attended the first two days of plenary and breakout sessions. The third day was reserved for writing the draft Workshop Summary Report. This report will provide input to the U.S. Climate Change Forum held in Washington, D.C., November 12-13, 1997.

The morning plenary session of the first day was focused on soliciting stakeholder/ sectoral perspectives and concerns (see Agenda, Appendix II). Following opening remarks from the president of the University of New Hampshire and the director of the host institute, presentations from stakeholder perspectives included natural resources, human health, insurance, energy and utilities, government and resource management, and recreation and tourism. Mr. Daniel Goldin, NASA Administrator, presented a luncheon keynote address regarding NASA's commitment to climate studies and outreach. An afternoon plenary session introduced participants to present and past climates, followed by afternoon breakout sessions which were given the task of identifying current stress factors impacting each sector noted below. A reception and poster session was held at the end of the first day.

The second day focused on the science of climate change. The topics included evidence of the current impact of climate warming in Alaska, sea-level rise issues and impacts, agricultural impacts, weather variability/predictability, air quality, and the challenge of developing an integrated assessment. The same sectoral breakout groups met in the afternoon, addressing the likely additional impacts of climate change in each sector, knowledge gaps and response strategies. The closing plenary session provided an opportunity for the breakout session chairs to present their group's findings to the workshop and respond to questions concerning common issues.

The third day of the workshop was devoted to writing an initial draft version of the workshop report. Representatives from each of the seven sectoral breakout groups— Business/Insurance and Industry, Energy and Utilities, Government and Resource Management, Human Health, Information Transfer and Public Awareness, Natural Resources, and Recreation and Tourism—worked together to contribute to this report. A review pro-

cess was implemented by emailing second drafts to breakout session members for their comments.

Of the 122 participants attending the two-day workshop, approximately one-half (57) represented non-academic, non-agency sectors from business and industry, non-governmental organizations, state and local governments and education (Appendix III). Over 100 non-agency participants from business and industry, non-governmental organizations, state and local governments and education as well as research communities returned for day two of the workshop, and 75 were present for the final wrap-up session at 6:00 p.m.

It is important to note that while nearly all of the workshop participants represented a range of stakeholders, their views, as expressed in this report represent a limited cross-section of stakeholder opinions and perspectives. A continuing effort must be made to solicit a broader range of input regarding climate change impacts to the New England/ upstate New York region.

Media coverage for the workshop was a component of planned outreach to provide information about regional climate change issues. A communications plan was developed for internal and external media coverage. Pre-conference news stories were made available through press releases. When possible, public information officers from the speaker's institutions were contacted and informed about the workshop. Press releases were sent to local, regional, and national venues. Environmental, agricultural, and science reporters were identified and faxed releases. Members of the press were invited to attend plenary and breakout sessions. A media coordinator was available following the workshop to assist reporters with fact-checking and gaining access to researchers and data necessary for their stories.

Media coverage was extensive, and included local (New Hampshire TV, Channel 9, New Hampshire Public Radio and print media), regional (Boston Globe, New York Times) and national (several Associated Press stories) venues. The coverage of the workshop began with a media breakfast held the first morning of the workshop; every effort was made to assist reporters in gaining access to workshop participants, national speakers, research scientists, and sectoral representatives in attendance. A complete media press package was available at the start of the workshop, and the media coordinator facilitated interviews, television coverage, and reporter requests for more information and background on the workshop participants. Representatives of the media expressed gratitude and satisfaction regarding the efforts made to facilitate their coverage of the workshop.

WORKSHOP GOALS

The New England Regional Climate Change Impacts Workshop had the following goals:

- To initiate and open a dialogue between the broadest-possible range of stakeholders regarding regional climate change issues, impacts, and vulnerabilities. This dialogue must be two-way, and solicited from the key stakeholder groups within the New England/ upstate New York region.
- To identify specific regional climate change issues and uncertainties, using the direct input of the stakeholders attending the workshop.
- To identify key regional vulnerabilities, knowledge gaps and research needs, as well as possible coping skills and mitigation strategies appropriate to the New England region.
- To inform participants that climate change is likely to be one of many stress factors to impact our region in the future. Many of these stress factors will be interrelated, and collectively may have a significant impact.
- To facilitate connections and networking among the stakeholder groups attending the workshop.

Following the first day of the workshop, Thomas Baerwald, of the National Science Foundation, and Wanda Haxton, from the Environmental Protection Agency, have a moment to discuss workshop progress during the evening reception and poster session.

- To generate a Workshop Summary Report reflecting the climate change issues, vulnerabilities, coping skills, and mitigation strategies identified by the workshop participants as important to the New England/upstate New York region.

These goals were met through a combination of plenary presentations from stakeholders and research scientists, three sector-based breakout sessions, and an open dialogue among all participants. A final agenda is attached as Appendix II.

THE FOUR QUESTIONS

In order to meet the above goals, the four questions raised by Jerry Melillo, Co-director and Senior Scientist, Marine Biological Laboratory at Woods Hole, during national organizing workshop held at the Aspen Global Change Institute were addressed by all participants during the course of this workshop:

1. What are the current concerns and stresses identified by regional stakeholders in each sector?
2. How will climate variability and climate change modify the current concerns and stresses?
3. What information and data are needed in order to fully understand and address these climate-related issues?
4. What types of strategies and approaches are available for coping with or mitigating climate change stresses?

SUMMARY OF WORKSHOP FINDINGS

Barrett N. Rock, Shannon Spencer,
Clara Kustra and Denise Hart*

SIGNIFICANT FINDINGS

Below is the list of significant findings drawn from the breakout session reports and plenary presentations. It is important to note that these findings, as well as the workshop report, were available for review and comment to all interested participants through a secured website. The significant findings are:

1. Education concerning climate change issues is lacking and is badly needed. All the breakout groups recognized the need for clearly-written educational materials appropriate for a broad audience, ranging from classroom materials to media materials for the general public. Time and again comments were heard regarding the need for understandable ("...speak to me in my language, not yours...") and relevant information that is readily accessible and meaningful to everyone. In addition, this information needs to be targeted to specific sector interests such as insurance, utilities, the ski industry, forestry, etc. As part of any educational program, a critical review of the current evidence must be included.
2. A regional integrated assessment is needed to provide sound climate change scenarios by which informed policy decisions can be made. This assessment must objectively address the uncertainty in climate change predictions by integrating scientific, economic, technological, and societal parameters. The lack of an integrated climate scenario assessment for New England was identified as a critical missing piece, the results of which would be of great value to the broad stakeholder audience. Resources must be provided to fill this current gap in our ability to understand both the issues and the impacts of climate change at the local level.
3. Regional and relevant examples of climate change impacts are needed. Stakeholders clearly identified a need for regional examples in terms that they can understand (i.e.,, what will the potential impact of increased diseases have on my health insurance premiums, what will my timber yields look like under a certain model scenario, etc.).
4. Generally, stakeholder perceptions are that global warming and climate change are important concerns, and the consequences of both have the potential for substantial impacts on many of the sectors represented at the workshop. Although, a minority were skeptical of the human influence to climate change and questioned the role of climate change on impacts in the Northeast.
5. The levels of uncertainty associated with climate change are high, but we need to act now by addressing policy, research and public awareness on the issues of climate change. Many in the audience were surprised by the level of uncertainty associated with many regional climate change issues. Significant knowledge gaps exists in many areas, and must be filled using focused studies integrating climate change science and regional sectors' issues and concerns (insurance, utilities and energy, forestry, fisheries and agriculture, human health, local governments and resource management, recreation and tourism, etc.).
6. The consequences of climate change will likely exacerbate current environmental stresses on all sectors.
7. The overall participant reaction was to ask for appropriate "next steps" and for guidance on what they can do to limit climate change and its impacts on the New England and upstate New York region.
8. Easy access to scientific and regional data on climate change is not available and needs to be developed. A centralized, authoritative source of data concerning regional climate change impacts, sea-level rise, and regional high risk areas does not currently exist, and needs to be developed. Critical evaluation of the data and evidence for recent change in climate should be provided as part of any database.
9. The potential role of the El Niño - Southern Oscillation (ENSO) phenomenon as a factor influencing the weather of New England and

* See Appendix V for authors' affiliations and addresses.

upstate New York was recognized and seen as of great importance, particularly as a phenomenon that may allow us to predict seasonal patterns (drought, snow fall, average temperatures) in advance. This was seen by all participants as highly significant. The relationship between El Niño effects and climate patterns in the Northeast is unclear and requires more research. One participant, an owner of a major ski area, expressed the opinion that learning more about the ENSO would have a major impact on the ski and related hospitality industries. He asked, "Where can I get more information on El Niño?"

10. Although the workshop did not dwell on the aspects of climate change considered "bad news," the overall impact on New England is likely to be negative or at least result in unwanted change to "quality of life" issues important to New Englanders. It must be noted, however, that some sectors may possibly benefit from these impacts. In either case, we need to prepare for the coming changes. More relevant information must be made available and presented in a format that stakeholders understand and will find useful for their sectoral interests.
11. Policy and funding issues need to be addressed at the local, state, and federal levels to show stakeholders that the governing bodies of this country view climate change as an important issue—one which all members of society need to pool resources and work together in order to solve.
12. Incentive programs to reduce emissions and/or preserve and enhance existing CO_2 sinks must be developed. Programs like these currently do not exist at the regional level; these programs could provide an impetus to reduce CO_2 emissions by investment in renewable and efficient energy technologies.

WHAT WE LEARNED

The New England Regional Climate Change Impacts Workshop was very successful, especially in the areas of stakeholder participation, media coverage and opening a dialogue between the technical (scientists, researchers, etc.) and the average person (local government officials, business owners, students, public school teachers, the "person-on-the-street," etc.).

Several important lessons were learned regarding how to organize and present a workshop that will attract non-technical participants, along with members of the research community, local, state and federal agencies. These include:

James Platts, Senior Engineer from Northeast Utilities, presents the view of potential impacts of climate change from the utilities industry perspective.

1. Personal Contacts–Our original mailing list was provided by the EPA. Additional names were added following personal contacts within each sectoral group. The resulting list was screened to ensure a representative number of non-technical stakeholders were invited. Each letter of invitation was individually addressed and personally signed by the director of the host institute. About 400 letters were sent out as part of a packet that included the tentative agenda and a statement of the workshop goals; 122 participants attended. Approximately half of the invitees were non-technical/non-agency stakeholders representing business/industry, energy/utilities, human health, tourism/recreation, natural resources/agriculture, education/information transfer, local government, resource management and NGOs. Access to and information about the workshop was available in a specially developed website: **http://www.necci.sr.unh.edu**.
2. Engaging The Stakeholders–The first day of the workshop focused on stakeholder perspectives, instead of the science of climate change. The initial six presentations of the first plenary session were all made by stakeholders representing the sectors cited above in #1. Most attendees felt excited about participating in the workshop, and found the interaction between stakeholders and researchers, scientists, and agency personnel to be "stimulating," and "a great opportunity to speak with the experts."
3. Speaking "Plain English"–The White Paper for the workshop was intentionally written so as to be understood by the average person, rather

Samuel Adams, President of the Loon Mountain Recreation Corporation, Dr. Theodore Loder, UNH, and Lynne Carter, Visiting Scientist, URI, discuss educational needs highlighted during the first day's discussions.

than as a collection of scholarly articles produced by scientists. All plenary session speakers were asked to design graphics aimed at the average person, not a scientific audience, and to speak in "plain English." The science presenters were thanked at the end of the workshop by a stakeholder participant for "...speaking to us in our language, not yours."

4. Detailed Instructions–Providing detailed instructions to session chairs, rapporteurs, and presenters regarding expectations, audience, anticipated products, and required duties helped to create a collaborative, supportive environment.
5. The Four Questions—The four questions raised by Jerry Melillo at the national organizing workshop held at the Aspen Global Change Institute, were presented to all participants as defining the workshop approach/format. These provided an excellent focus for discussions in the sectoral breakout sessions.
6. Food/Facilities—The excellent food and facilities provided by the New England Center were a major contributing factor to the success of the workshop. This was mentioned often in participant evaluations as contributing to "a professional atmosphere" conducive to discussion and active involvement. Telephone, fax, and laptop plug-in stations, and computer printers were available on-site. Refreshments were provided throughout the day so participants could take a quick break when needed and return easily to the workshop.
7. Media Coverage—The use of a media coordinator, a Media Breakfast (held on the first day, with a group of the invited presenters available to answer questions and a distributed press kit), easy access to telephones and ready access to workshop presenters and keynote speakers, facilitated the highly successful media coverage of the workshop. Reporters were seen as part of the effort to educate the public about climate change, and their participation was welcomed in all aspects of the workshop. The media coordinator facilitated access to presenters and the keynote speakers, provided technical assistance when asked, and was available as a resource to the media. Several of the reporters for the major outlets (AP, New York Times, Boston Globe, NPR) all cited feeling welcome, well-informed, and part of a well organized, well-facilitated activity.

During the media breakfast local, regional, and national members of the press query scientists and representatives from federal agencies about climate change issues.

STAKEHOLDER MESSAGE

If there was a single message to come from the workshop, it was that there exists a need for a strong educational program to be developed on regional climate change issues and impacts, aimed at the classroom and the boardroom, the media and the non-scientific residents of the region. The scientific and research community needs to do better at informing the American public or engaging them in a discussion of the climate change issues
that will affect their lives—and those of their children—in the future. The public wants to know and are hungry for information—it's just not easily accessible.

We were asked to address stakeholders in their own forums in order to "get the word out" to the broader stakeholder groups (i.e.,, presentations at trade shows, special workshops to include more stakeholder representation, etc.).

The general perception of many participants was that the political will and conviction to act in face of the current scientific understanding about climate change does not exist. This must be countered if we hope to implement necessary mitigation and coping measures strategized during the workshop.

SOME SURPRISES

One of the most significant scientific surprises to come from the workshop was the strong correlation seen in the various data indicative of warming in Alaska (a shift in mean air temperature, the melting of permafrost, the loss of salmon habitats, sea ice recession, tree core data, etc.) attributed to a "regime shift" that began in the mid-1970s. Similar patterns of change are being seen in the growth parameters of New England forest species (based on increment core samples) and significant thaw/freeze events leading to forest decline, with the occurrence of a "turned-on" El Niño covering the same time period. These concurrent events suggest a hemispheric teleconnection that is only now being recognized and documented.

A second surprise was seen as several stakeholders became aware of the value of learning more about the El Niño and its potential economic impact on the New England ski industry, energy and utilities planning, and resource management planning. Prior to the workshop, few participants were aware of such knowledge or its high value in planning ahead for their day-to-day operations.

Dr. Glenn Juday, University of Alaska, describes Alaskan climate experience.

CROSS-CUTTING THEMES FROM THE BREAKOUT SESSIONS

Over the course of the two-day workshop, several common themes emerged from two or more of the sectoral breakout discussions which captured many of the major concerns or perceptions of the stakeholders. These cross-cutting themes represent significant regional issues which need future research and effort in order to clarify for stakeholders the extent to which they represent either real threats- or real solutions regarding climate change impacts.

1. Education and Public Awareness—Clear and understandable information on climate change issues and impacts was noted by all sectors as a significant missing component. This information is badly needed for both the classroom and the boardroom. Misinformation abounds regarding climate change, both intentional and unintentional, and all participants expressed the importance of correcting this situation. Additionally, it is important to clearly state the misgivings about the current data and understanding of climate change science.
2. Air Quality—Changes in chemical climate (increasing levels of air pollution) have had a significant impact on the New England/upstate New York region. Poor air quality impacts human health, and subsequently, the insurance industry, ecosystem health, and subsequently the timber and tourist industry, as well as agricultural productivity. Recent changes in EPA-mandated ambient air quality standards will lead to financial and technical challenges to the energy and utilities sector.

3. Quality Of Life—Changes in both the chemical climate (#2 above) and physical climate (warming trends, changes in precipitation patterns, altered seasons) will lead to significant impacts on the New England quality of life. Warmer winters, hotter summers, altered forest composition, and reduced air quality were examples frequently raised by participants as changes considered unwanted and to be avoided.
4. El Niño—If there was one topic that attracted the most interest among participants, it was El Niño, and the need to know more about it. It will be essential that future efforts be directed toward improving our understanding of the connections between this natural weather phenomenon, potential interactions between anthropogenic forcing factors and El Niño, and the impacts that El Niño has on the New England region.
5. The Need To Know The Truth—All participants expressed the need to know and understand the "reality" of climate change—not the scare tactics (disease, droughts, floods, etc.) or the misinformation (global warming isn't real, or that it will be a good thing) related to "the debate among scientists."
6. The Need For Practical "Action Items"—Participants seemed to accept climate change as a reality, and wanted to know what steps they could take now to help correct the situation.
7. The Need To Know More About The Models—Participants wanted more information about the models (General Circulation Models) used to predict future climate change scenarios, their relative strengths and weaknesses, and potential sources of errors.
8. A Regional Integrated Assessment—An integrated assessment should incorporate scientific, economic, technological and societal components to provide model scenarios of climate change impacts. Such models must be developed in order to assist regional efforts to implement coping and/or mitigation strategies. Regional focus will be essential, since impacts on people's livelihood and quality of life will get the attention of the people of the Northeast.

KNOWLEDGE GAPS AND RESEARCH NEEDS

During the course of the workshop, participants identified specific knowledge gaps and research needs considered either to be lacking at present, or not in a form which is readily usable to the non-specialist. It was noted that while some of the desired information may be found in the research literature, a focused effort is needed which translates the research findings into a form that may be easily understood by interested stakeholders. These are as follows:

1. A clear relationship between human activities and climate change must be established. Although the science behind climate change is credible and compelling, the weak link is the cause and effect relationship between human activities, rising CO_2 levels and the warming trend over the past 100 years. Subtle variations in CO_2 level curves can be connected to changes in human activities (such as the oil embargo in 1973) and a compelling case could be made (but hasn't). A similar comparison should be made between volcanic eruptions and CO_2 levels, since a common "explanation" for the increasing CO_2 levels is volcanic activity. Such studies must be conducted and the results presented in clear and convincing manner that can be understood by a non-technical audience.
2. A "danger level" for CO_2 must be identified as well as appropriate target levels for both reducing and eliminating the threat of global warming. Further research of ice cores and seafloor sediments should be supported so that global impacts (temperature, rainfall, sea level, etc.) can be predicted for specific CO_2 levels, with an acceptable degree of accuracy. In this manner, the average person will have an idea of what to expect if the CO_2 level reaches a specified level (e.g., 400 ppm, 700 ppm, etc.).
3. The ability to separate noise (the natural background or variability in the system) from the signal (human contributions) in CO_2 data must be developed. To do this, a detailed assessment of both background CO_2 sources (respiration, others) and natural variations (volcanic eruptions, others) must be conducted so that the relative contributions of both human activities and natural sources can be calculated. Are there ways to identify the sources of each type of CO_2? If not, could such a capability be developed? In addition, other sources of global temperature rise (variation in solar activity, changes in surface reflectivity, etc.) need to be identified and quantified, so that these potential sources can be put in perspective to greenhouse gas emissions.
4. The risks and benefits of waiting for certainty in the relationship between human activity and

climate change must be identified. What are the predicted impacts of doing "business as usual" until the year 2050, 2100, etc.? What will the costs of such a "business as usual" approach be, vs. the costs of taking action now? Are there additional benefits (win/win scenarios) to taking action? Answering these questions will require the development of more accurate models (climate, integrated assessment and economic).

5. Appropriate policy responses to limit emissions must be identified and presented as realistic options to the people of the United States. Honest and accurate options must be developed that address conservation approaches, the new technology options, renewable energy sources and natural CO_2 sequestration methods. Most participants indicated a willingness to "take action" if mandated to do so by policy changes.
6. A range of response options must be developed for possible implementation, from new enhanced technologies to selective use of fossil fuels. As stated above, many of the participants indicated a willingness to "take action" if mandated to do so. People are looking for direction and need to know what their options are.
7. A research program focused on enhanced, low-impact technologies that actually reduce emissions must be developed. For example, the fuel cells that produce water as a by-product and the electric/internal combustion hybrids, actually use gasoline as a hydrogen source (producing CO_2 in the process). Alternative energy sources have yet to be proven as reliable and practical. A focused research program is needed to identify and prioritize, both in terms of estimated costs and emissions reduction, the most effective and appropriate approach(es) to be used.
8. Improved models (climate, integrated assessment, economic) and predictions must be developed. While many of the current models work well at the global scale, few regional models have been developed, in part due to regionally-specific input parameters. Since regionally-specific models were identified by participants as needed, a focused effort on the development and testing of such models must be made. Ronald Prinn's MIT integrated assessment model was recognized by the participants as being very valuable if available for regional applications.
9. The cause and effect relationships between specific remedial actions and CO_2 level reductions must be identified and quantified. If an 80 mpg automobile were available, and 50% of the American public drove one, what impact would it have on CO_2 emissions? If the price of gas were $5.00 per gallon, what impact would it have on CO_2 emissions? If everyone in the U.S. planted 10 trees, what impact would it have on CO_2 emissions? Would it matter if they were fast-growing or slow-growing species? What would be the most effective remedial actions to take?
10. An understanding of the interaction of multiple stressors on natural systems is lacking but essential for determining the impacts of climate change on natural and managed systems. Most of the research on how climate change might affect forests and crops is single-factor work: how higher temperatures affect plant growth, pest survival and spread, or plant vigor. Not enough science has been conducted looking at how plants, and other organisms, respond to exposure from multiple stresses such as higher than normal temperatures, increased CO_2, changes in precipitation patterns, shifts in concentration of ozone and other air and ground pollutants, etc. Not only is our understanding focused on single factors, it is dominated by studies on single species rather than on communities. And, often studies are done under laboratory conditions rather than in a natural setting. More systems-based research on natural ecosystems is needed to better understand the plasticity of these systems to climate change.
11. Effective educational programs must be developed and presented to the public. To be effective, such programs must be age-appropriate (primary, middle and high school levels, as well as adult), written in "plain English," available for both formal educators (classroom teachers) and informal educators (Cooperative Extension Specialists, Boy/Girl Scout leaders, etc.) and readily available to all. Special attention must be paid to assisting the media in its role of effectively educating the public regarding climate change issues.

WIN-WIN SITUATIONS TO ENABLE CHANGE

Participants were asked by Jerry Melillo to identify win-win situations appropriate for the New England region and its inhabitants. Such situations were defined as scenarios in which both the stakeholders/sectors and the environment/climate benefited from changes in "business as usual."

1. Promotion of CO_2 sinks (forests) that are commercially viable (sustainable forestry practices) as well as a way of removing CO_2 emissions from the atmosphere.
2. High-efficiency, combined-cycle gas turbines will not only reduce the CO_2 produced but eliminate many air pollutants.
3. Investment into cleaner technologies that alleviate the problem of CO_2 production also reduce business and industries liabilities, strengthen a good neighbor image, and create a strong regional manufacturing presence.
4. Implementation of energy efficiency programs have the potential to decrease the cost of doing business and make regional industry more competitive (Germany and Japan use half the energy per dollar of gross domestic product as the United States).
5. Improving scientific and environmental literacy among the general public can be accomplished by supporting research professionals for their direct involvement in outreach activities. By broadening the role of scientists and public officials to include communication, we are likely to engage the public in the debate on the seriousness of global environmental issues.
6. Documentation of human health issues by medical and public health professionals for the purposes of studying the impacts on health by climate change can motivate commitment and action to mitigation strategies by government, industry and individuals. This can then have feedbacks to preventative health care and diagnosis. Demonstrating a direct link between climate change and human health will bring climate issues to the forefront of the public's attention.
7. Improvement of techniques for preserving and improving soil quality in managed and natural ecosystems and farmlands will benefit industry and landowners by helping to sustain productivity and enhance the carbon sequestration by such soils. Incentive programs which encourage landowners to sequester carbon in their soils should be developed, which will benefit the landowner and help to reduce the carbon dioxide levels in the atmosphere.

RECOMMENDATIONS

Three broad recommendations, based on the outcomes of the workshop are:

1. From the coordinators' perspective, this event was an excellent first step in a series of activities which will be needed in order to fully and accurately address the regional assessment of climate change and its impacts. Based on the participant reactions, climate change/variability is certainly an issue which engages stakeholder interest. The outcomes of the breakout sessions should be looked at as an energetic start and a brainstorming event, which does not represent the true constituency of the stakeholder groups nor do the findings of the breakout sessions necessarily represent true and factual information. We must be careful not to infer agreement or consensus among stakeholders on climate change issues and concerns based on the limited sample size. In addition to reaching a larger stakeholder constituency, a coordinated public education program at all levels, from the classroom to the boardroom, needs to be implemented.
2. More in-depth background research must be conducted, both to understand the regional impacts as they relate to individual stakeholder groups and to precisely define the human impact on climate change. Regional workshops should be held for each of the stakeholder groups in order to 1) reach a broader constituency for input and feedback regarding concerns, issues, and coping strategies and 2) to allow for enhancement of public awareness through concrete and understandable examples. These activities should occur over a 2-3 year period in which people from each stakeholder group are included in the research, regional workshops, and writing activities leading to a detailed regional assessment by and for their sectoral group.
3. The final recommendation is that we need to begin work with stakeholders and the general public on action items. What can the average person do to make a difference? How can ski operators minimize their effects on climate change and what can they do to help educate their users on climate-related issues? How does a utility worker begin to influence the company's CEO of the potential benefits for using newer, cleaner technology? We need to begin to focus on positive items and actions which individuals, companies, and governments can do to help reduce human-induced climate change in order to avoid the apathy and despair surrounding the issues.

Summary of Plenary Sessions

Stuart Leiderman and Shannon Spencer*

The New England Regional Climate Change Impacts Workshop alternated between plenary sessions, where representatives of stakeholder groups and research scientists presented issues and information related to climate change impacts, and smaller, discussion-oriented breakout sessions organized by stakeholder group. This section of the report summarizes the workshop plenary sessions.[1]

Welcome Address

The conference opened on September 3, with **Berrien Moore III**, Director of the University of New Hampshire's Institute for the Study of Earth, Oceans and Space (EOS), and **Joan Leitzel**, President of the University, extending their greetings and introducing the day's events. President Leitzel specifically mentioned the importance of climate and weather to the quality of life in New England and the research leadership of the University in the areas of climate change and variability.

Introductory Remarks

Robert Corell, Assistant Director for Geosciences at the National Science Foundation and an expert on climate, described the natural forces contributing to global change. His talk addressed geological and recent history, and the influence of human population and technology over the last several centuries. He briefly reviewed the work of the U.S. Global Change Research Program (USGCRP) and the Intergovernmental Panel on Climate Change (IPCC), and asked attendees to consider the likely effects of climate change in New England.

Corell said scientists and citizens need to:

1) seek to observe and document what "is really going on,"
2) try to understand climate change on global, regional and local scales,
3) attempt to predict future climate change/variability,
4) assess the level of confidence in those predictions,
5) analyze the regional and local knowledge base, level of understanding and additional information needs regarding climate change, and
6) decide on a course of action.

Corell stated the importance of "getting more sophisticated about how we (climate change scientists) describe what we do," to the public and the press, i.e.,, the need for "a whole new lexicon" for the Earth system changes and variability that scientists observe and anticipate.

Norman Willard, Climate Change Coordinator for the U.S. Environmental Protection Agency (EPA), New England Region, welcomed attendees and briefly described EPA's new Global Warming Network for state and local governments in New England, created to provide "greater public awareness through education and outreach" on a "very aggressive" basis.

WORKSHOP CHARGE

Jerry Melillo, Co-director and Senior Scientist at the Marine Biological Laboratory in Woods Hole on Cape Cod, helped to establish the workshop series as a way to emulate the IPCC assessment process regionally and nationally within the United States. His four questions (outlined in the Introduction, page 10) provided the framework for attendees to organized their discussions in the breakout sessions.

STAKEHOLDER PERSPECTIVES ON REGIONAL CLIMATE CHANGE ISSUES

Steven Hamburg, Associate Professor at Brown University, chaired the first panel on stakeholder perspectives of regional vulnerabilities. He spoke briefly about how climate change could affect "sense of place" experienced by residents and visitors of New England. According to Hamburg, the issue is not purely one of change, because there have been major changes here in the past

* See Appendix V for authors' affiliations and addresses.

[1] Separate papers prepared by some of the invited speakers and members of the Steering Committee can be found in Appendix VI.

three or more centuries. The issue is rather one of rapid and unfavorable directions of change, that will likely diminish agricultural productivity, recreational opportunities, the enjoyment of rural life in the region, and quite possibly increase the cost of maintaining these elements of New England life.

Natural Resources — Independent forest industry consultant **Lloyd Irland**, President Irland Group, from Winthrop, Maine, objected to apocalyptic predictions of global warming effects, because they make it easy for skeptics to dismiss warnings as "sky is falling" rhetoric. Further, they create the danger of a "politically correct" orthodoxy on this subject that makes honest scientific debate more difficult. Irland described the importance of natural resources to New England's economy, taken overall, but the much greater importance to specific rural communities where farming, forestry, fishing and recreation predominate. He distinguished the degree of vulnerability to climate change among natural resource users as follows:

- In the short-term, forest landowners and fishing operations are less vulnerable as they exploit "standing crops" whose abundance and replenishment is typically determined by long-term management and environmental trends.
- Farmers and recreation/tourism managers, subject to seasonal or annual conditions, are more vulnerable to climate variability because sudden events cannot be easily predicted or avoided.

Irland said that his clients are probably less concerned about climate change than they are about short-term losses from crop failure, floods, freezes, and market fluctuations. Many stakeholders fear the immediate impacts of policies adopted to mitigate climate change, which affect their businesses now, while the adverse effects are of uncertain magnitude and occur in the distant future. He was reserved about taxes on carbon emissions—unless they were applied worldwide—saying that companies would just transfer their pollution problems to less restrictive countries.

Human Health — **Amy Langston**, Disease Database Coordinator for the Center for Health and the Global Environment at Harvard University, presented a report of environmental health and disease trends written by her colleague Paul Epstein. Many new diseases of humans, agriculture, wild plants and animals have appeared in recent years; many old ones have reappeared and many existing ones have spread. This is likely due to warmer and wetter conditions caused by climate trends or by severe episodes of drought, floods, storms, etc. Langston noted that health effects from climate change and variability are due to both chemical and physical changes in the atmosphere, at the Earth's surface, and in lakes, rivers, streams, estuaries and oceans. Opportunistic pathogens having fast reproductive cycles can take advantage of favorable short-term growing conditions to explode in numbers and establish themselves in new locations. Additionally, warmer temperatures permit agricultural pests and other disease vectors to overwinter without harm and thus begin the new year with greater numbers.

Insurance/Business and Industry — **James Russell**, Vice President of the Institute for Business and Home Safety, discussed why insurers are experiencing more frequent and higher damage claims from disasters, especially earthquakes, flood, hail, wild fires, and wind. He said property owners continue to develop and occupy dangerous locations such as coastlines, flood plains and dry forests; in fact, their exposure is increasing despite government and insurance industry efforts to discourage the trend. Russell said, "American society views insurance as an entitlement," and doesn't want to pay for premiums commensurate with the risks. Russell praised FEMA's new mitigation program and asked workshop attendees to support efforts to help reduce or eliminate the frequency and severity of disasters. All the same, however, he said that American insurers, have not yet accepted scientists' conclusions about climate change.

Energy and Utilities — **James Platts**, Senior Engineer from Northeast Utilities, said that utilities probably produce a third of the carbon dioxide emissions in the United States. He reported that several hundred utilities have pledged to reduce their carbon emissions by a total of more than 40 million metric tonnes per year toward an original government target of 100 million tonnes; a revised government target, however, is now in the 200-250 million tonnes range. Platts called for a plan to move toward zero-emitting electricity generation. Northeast Utilities is in the research and development stage for landfill methane recovery and for wind power, but he did not estimate how much of the pledged reductions for New England could come from such projects.

Government and Resource Management — **Robert Brower**, Director of Cayuga County Planning in upstate New York, provides various local governments, their agencies and municipal organizations with high-tech mapping data for landuse decisions with environmental, economic, health, and community consequences. He uses geographic

information systems (GIS), geographic positioning systems (GPS), a geodetic reference system (GRS) and Internet web sites to analyze data on more than 700 square miles in the Cayuga County, NY Finger Lakes region.

He observed that climate change coping strategies in New England will require the policy involvement of local government entities where landuse control is vested. He pointed out the existing institutional complexity in New York State, where more than 1600 municipal civil divisions currently exist. Additional governmental entities with landuse implications (e.g., sewer and water districts, zoning commissions, planning boards) increase this number in New York to an estimated 10,000 entities.

Brower said satellite imagery and anticipated data from NASA's Mission To Planet Earth will help Cayuga County understand its relationship with neighboring regions and the need for environmentally-responsible landuse policy, decisions and enforcement. He expressed concern, however, about the effects of the devolution of federal responsibility that transfers important, quality-of-life programs to ill-prepared and poorly funded state and local governments. Additionally, he was concerned about the public's general disengagement from civic involvement at all levels. He felt that these two issues need to be addressed.

Recreation and Tourism — **Ken Kimball**, Director of Research at the Appalachian Mountain Club (AMC), reported on the importance of tourism in New England's economy (in New Hampshire, tourism accounts for nearly 10% of the state's gross product). The AMC has projected that climate change in New England, when added to pollution, will damage the region's tourist economy by stressing forest, streams, lakes, wildlife and fish, obscuring scenic vistas, and endangering visitors' health.

Working with health researchers and public health officials, the AMC has shown that a visitor's health may be adversely impacted by engaging in recreational activities (hiking). Visitors are cognizant of the deterioration in both scenic visibility and landscape. Kimball found it ironic that the "recreation and tourism industry in New England is very dependent on a highly mobile public using the automobile as its primary source of transportation to travel long distances. Automobiles are a significant source of the chemical precursors that form ozone; their combustion of fossil fuels also makes major contributions to increased carbon dioxide levels."

KEYNOTE ADDRESS

Daniel Goldin, NASA Administrator, gave a luncheon keynote address that highlighted NASA as a non-political global change research and knowledge producer within the federal government. He took pride in relating one story about grade-school students in rural Maine who mastered the skills for retrieving and working with NASA's Earth Observation System imagery as a result of participating in a UNH education outreach program. Goldin detailed how NASA learned to detect Pacific Ocean El Niño events through remote sensing of sea surface temperature, ocean surface topography to within inches of accuracy, wind speed and direction, and by working cooperatively with scientists and their satellites at the French and Japanese space agencies.

Goldin cautioned against the myopia that comes from working too exclusively with either local issues or global problems. He advised a combined approach, where research was reinforced by good peer review science and cooperative programs that reached all the way from the satellite to the classroom, and from the factory floor to Capitol Hill. Goldin stated his operating slogan as "Predict, Prepare and Prevent." He pledged NASA's resources to launch "the most aggressive constellation of spacecraft in the history of the planet" that will someday make possible the multi-decade predictions of changes in climate, environment, atmosphere, oceans and land. He promised to salvage the malfunctioning Lewis hyperspectral research satellite or to launch a replacement as quickly as possible so that scientists can make extremely fine measurements of Earth's environmental processes.

The "Now" Climate

Norman MacDonald, Meteorologist and retired network television weather forecaster, explained the "now" climate and described how New England's "wait-a-minute" weather results from being at the end of the continental flow of air and the resultant interplay between high and low pressure systems from both the western and southern United States. He recalled improvements in forecasting accuracy and speed that came with computers, weather satellites and weather radar. While these tools have dramatically improved our ability to make accurate forecasts one to three days ahead, good 4-10 day forecasts are still very difficult to make.

MacDonald discussed the distinction between weather forecasting and climate forecasting, the latter still being very difficult because of the large

NASA Administrator Daniel S. Goldin, Nancy Maynard, Acting Director, Science Division, Office of Earth Science, Dr. Janet Campbell, UNH, and Dr. Berrien Moore, Workshop Co-chair, discuss climate change issues during the workshop luncheon.

mix of factors besides high and low pressure systems, air flow, temperature and humidity; namely, atmospheric chemistry, greenhouse gases, ocean circulation, solar radiation, geological forces and other long-term Earth processes and cycles. MacDonald believes that climate models insufficiently capture critical transients or extreme events, weakening their accuracy. Finally, he briefly described the history of extraordinary New England weather events, noting that the frequency of damaging hurricanes and snowstorms did not seem to be trending up or down but that the intensity of nor'easters may be increasing. "In summary," said MacDonald, "there is no question in my mind that climate will change in New England, as it will across the globe. The question is, will it be dramatic?"

THE "PAST" CLIMATE

Paul Mayewski, Director of the Climate Change Research Center at UNH-EOS, gave a "past climate" view of Earth's climate variability that scientists have assembled from ice cores taken from deep within glaciers and icefields around the world.

There are at least three important aspects of this research:

1. The science has matured to where ice layers and their contents can be retrieved and analyzed to within fractions of a year; the longest core record goes back 250,000 years. Thus, ice contains a record of atmospheric gas concentrations and particulates frozen in time that can be compared with other events known or suspected to have occurred in recent times or in prehistory.
2. Mayewski showed how some ice core records correlate well with the decline of the Mesopotamian empire in approximately 2200 B.C., and the occupation of Greenland by Norse colonies from 1000-1400 A.D. Scientists have shown that certain chemical and physical "signatures" in the ice can tell when events occurred and also point to the origin of various particles, gases, ions and compounds.
3. Oscillating patterns of ice layer thickness and contents may occur at regular intervals and reflect certain Earth and solar processes, sometimes foreshadowing the beginning of a new climatic era or the end of an old one. Some patterns seem to indicate that long periods of drastically new climate can set in after only a few years of irregular and extreme weather.

Mayewski and others want to determine whether they can match these historical patterns to the more recent erratic climate record to try to predict the characteristics of the next era—locally, regionally and globally.

THE SCIENCE OF CLIMATE CHANGE: A PANEL DISCUSSION

John Aber, Professor and a terrestrial ecologist from Complex Systems Research Center of EOS at the University of New Hampshire, chaired the panel of experts that opened the day's events on Thursday. Aber commented on the need to communicate to the public the Earth systems science background necessary to understand climate change and variability, stating that climate change needs a "Carl Sagan." He keyed his remarks to four words: complexity, uncertainty, trust and communication. Aber cited the need to "distill [the complexity of ecosystems] to its important components...make it interesting to people so that they want to know it, not just because they fear it, but because they find it fascinating."

Aber explained that trust is the high level of agreement and acceptability scientists seek from others, in and beyond their profession. In trying to make predictions from the data and trends, there are degrees of uncertainty because predictive tools, like models, only approximate outcomes; they do not give 100% certainty. Aber noted that trust prevails when there is a common understanding of the tremendous effort and motivation to tell the truth about the causes and effects of, in this case, climate change and variability. Finally, the desired understanding comes from constant communication about the near and long-term significance of global changes to people and the planet.

Ecosystems — **Ivan Fernandez**, Professor of Soil Sciences at the University of Maine, reviewed the effects of pollution on New England ecosystems, and in particular, forests. Forests have been contaminated and damaged by acid rain, heavy metals, ozone, increasing ultraviolet radiation, fertilization from atmospheric nitrogen and carbon dioxide. According to Fernandez, New England's forests are experiencing the combined growth-promoting effects of three factors:

- increased atmospheric carbon dioxide,
- elevated temperatures, and
- nitrogen deposition from acid rain.

"Although some people suggest that these factors may have a positive impact on forests, we don't know a lot about how these things interact," said Fernandez. "We are just really at the point of studying individual factors. We know less about episodic processes." As climate change continues, forest managers will try to adapt by altering tree cutting practices, forest stand composition, artificial regeneration, pest control and use of fire.

Climatology — **Barry Keim**, New Hampshire State Climatologist and a specialist in the study of severe weather, described his attempts to detect changes in the frequency or intensity of severe weather events in recent years in New England. He presented numerous examples of catastrophic events in the Northern Hemisphere, some of which appear to represent greater incidence of extreme events. But, he cautioned, this may also be due to better reporting, increased awareness and population growth—that is, more witnesses of severe weather. "What we are trying to sort out at this point, is whether or not this is real or media hype or some signal that the global climate is changing," said Keim.

Keim pointed out that the severity of events is often not measured by physical or chemical parameters but by social or economic ones. He gave the example of weather-related catastrophes in recent years being measured by dollars of damage or level of insurance claims. He also discussed the limits of global circulation models (GCMs) in predicting extreme events, especially because their scale of prediction (spatial or temporal) may be too large—decades or continents, rather than seasons or regions—to capture them. He agreed with Norman MacDonald that there is tremendous variability in the record of extreme events—so much that it may be very difficult to predict much in the way of climate change. He also agreed that temperature is trending upward, although with much inter-annual variability. For example, there seems to be a recent trend toward milder winters, as measured by decreasing days of below-zero temperatures in New Hampshire.

Keim emphasized that current models of climate change predict greater changes will happen farther from the equator, hence a changing gradient between tropical and temperate zones. If weather is seen as atmospheric behavior "trying to mix and bring more homogeneous types of conditions," Keim speculated that global warming might then moderate rather than worsen the frequency or intensity of extreme events. As for the frequency and intensity of nor'easters and heavy rainfalls, both of which may be increasing, he noted: "It appears that something is going on but what it is we don't really know."

Natural Resources — **Allan Auclair**, a forest researcher and Senior Scientist with Science and Policy Associates in Washington, D.C., discussed how sudden seasonal climate changes may be triggering forest dieback in New England and southern Quebec. Auclair traced these occurrences to periods when mid-winter temperatures prema-

turely warmed for a few weeks—promoting thawing and flow of tree sap—and then suddenly fell back to very cold temperatures, freezing the sap and damaging the trees' roots and conduction system. He proposed this as a major cause of forest damage, distinct from and perhaps more serious than acid rain.

The thaw-freeze effect is exacerbated by an apparent trend toward less snow cover—which means less protection for roots when temperatures become extremely cold. Trees experimentally deprived of snow cover had slower and more stunted growth later in spring and summer. Auclair believes there is a correlation between El Niño and thaw-freeze events. "Indeed, over this period [since the mid-1970s], it seemed that the El Niño and freezing stress patterns show a stronger correlation (two to three-fold) than what the long-term historical pattern has been." With the current year being predicted to be a strong El Niño year, Auclair anticipates significant thaw-freeze events in New England this winter.

Sea-level Rise — **Graham Giese**, Research Specialist on sea-level rise at the Woods Hole Oceanographic Institute, reported on the loss of coastal land from ocean erosion versus the passive submergence (sea-level rise) and occupation of coastal uplands caused by marshes retreating from sea-level rise. Giese reviewed the history of New England's coastline immediately after the Ice Age, when land extended to Georges Bank and Nantucket Shoals, evidenced by the remains of mammoths and mastodons in sea sediments. With subsequent sea-level rise and also, in his opinion, subsidence due to a sinking continental shelf, the coastline retreated—a process that is continuing today.

Giese mapped and compared the loss of coastal land in Massachusetts to both direct erosion and loss of uplands by passive submergence. On Cape Cod, he found that upland loss to passive submergence exceeds upland loss to active erosion by approximately 3:1. Sea-level rise of uplands in all of coastal Massachusetts results in the loss of approximately 65 acres per year.

Agriculture — **David Wolfe**, Associate Professor of Agriculture from Cornell University, discussed possible agricultural impacts from climate changes in New England. A warming trend could drive upstate New York away from its leadership in production of cabbage, apples, and other commodities well-adapted to our current climate. Increased summer temperatures would stress cow herds, affecting milk production in the New England dairy industry. A warming trend, coupled by higher atmospheric carbon dioxide concentrations, might increase production of some warm-season crops, but this will likely require an increase in fertilizer and water inputs. Wolfe explained that most classical growth experiments with high carbon dioxide have not replicated the sub-optimal conditions that some New England farmers will face; further, even with a warming trend, our spring temperatures may be too cool for maximum carbon dioxide benefits to occur. More plant growth also means more weeds, and warmer temperatures will increase insect pest pressure. This will lead to higher chemical inputs for control just when farmers in the region are trying to reduced those applications because of water quality concerns.

According to Wolfe, climate change may require a major shift in crops but "there hasn't been a comprehensive analysis for the New England area and what it might mean." Thus, substitutions of crop types may or may not be economically feasible. Wolfe predicted intense competition among growers and expects New England's future food production to become a major political and social issue. "New England agriculture should be able to adapt to climate change," concluded Wolfe. "However, those adaptations are going to be costly and could have adverse environmental impacts. There will be losers as well as winners, and the transition will be economically and politically stressful...."

A CLIMATE CHANGE CASE STUDY: THE ALASKA EXPERIENCE

Glenn Juday, Associate Professor of the Forest Sciences Department at the University of Alaska-Fairbanks, reported that climate change is underway "with a vengeance" in his state, trending towards warmer winters with heavier snowfall and warmer, but drier summers. The impacts include earlier than average ice-breakups on the Tanana River, in Fairbanks, extensive warming of permafrost south of the Yukon River, declining birch and spruce tree growth, problems in white spruce reproduction, large areas of tree death from spruce bark beetles, and higher stream temperatures that are associated with poor returns of spawning salmon.

Juday believes that a "powerful and significant climate regime shift unprecedented in at least the twentieth century and probably for the past 400 years—consisting of warming and summer drying—has occurred" in interior Alaska. He does not

know whether to attribute this to greenhouse gas induced global warming or to other factors. Reports suggest that there is a connection between the "shift" and El Niño episodes (a heat discharge mechanism in the Pacific Ocean) have caused some of the extremes of the warming.

KNOWLEDGE GAPS AND ENGAGING THE STAKEHOLDER

Lynne Carter, Visiting Scientist and education specialist at the University of Rhode Island, reported on her study of behavior changes in participants of a climate change conference. She enumerated factors accounting for improved motivation and effectiveness among participants in addressing climate change issues. Carter said that while the "majority of people in this issue recognize that there are two important sources of climate change: natural and human activities," environmental knowledge among Americans is generally very low. She said that major efforts are required to give people the factual basis for the climate crisis, because the motivation to change usually depends upon confidence in understanding issues and being able to talk about them with friends, family and work partners.

The results of her study found that involvement in a two-and-a-half day National Informal Educators Workshop and Video Conference on environmental issues caused participants to implement many personal and professional behavioral changes. These changes included the use of fewer resources, assessing purchasing choices and options, recycling, and increased awareness and discussion of environmental issues. The benefits from participating in this exercise were long-term effects, measured a full eight months following the event.

Carter is convinced that "making the environment personal," acquiring specific environmental information, increasing confidence in understanding the issues and approaching new material, and seeing a connection between local concerns and national movements, are all essential to personal behavior change. She also believes in the strength of groups to solve problems and break out of old ways, especially when the whole population is now handicapped by societal structures that promote, in her words, "unbridled growth."

Norman Willard, Climate Change Coordinator for New England EPA, briefly described a new Office of Environment and Economy Group that was established to encourage states to perform greenhouse gas emissions inventories; it will also provide incentive funding for developing less carbon intensive technologies. Also, there are approximately three million dollars in educational program money for the current federal fiscal year beginning October 1st. EPA's various energy conservation programs, including "Green Lights" and "Energy Star" building construction and appliance ratings are continuing as programs to promote energy conservation and help reduce global warming. Most EPA efforts to improve industrial emissions performance are still voluntary and market driven.

INTEGRATED ASSESSMENT CHALLENGES

Ronald Prinn, Professor and Director of the Center for Global Change Science at Massachusetts Institute of Technology, presented the results of computer models simulating economic and climatic implications of several levels of control on greenhouse gas emissions. Prinn noted that current uncertainties regarding rates of economic development and climatic response to greenhouse gases allow a wide range of plausible predictions for temperature increases by the year 2100 (e.g., 2 to 9° F).

He noted that current European Union proposals to roll-back greenhouse gas emissions to stabilize atmospheric CO_2 levels at 550 ppm would decrease climate effects (such as global warming and sea-level rise) in 2100 by one-third at most; if the response of climate to greenhouse gases is at the higher end of current predictions, this is still not enough to prevent major environmental damage and social problems. Further, not even unilateral reductions by industrialized countries would offset the increasing emissions expected from developing countries, including China, India, Brazil, and Southeast Asia.

Prinn believes that international cooperation is essential and that U.S., Europe, Japan and others will have to offer developing countries major incentives to moderate their emissions from accelerating development.

DISCUSSION OF FINDINGS AND CLOSING REMARKS

The final plenary session was a discussion of the findings from the seven breakout groups, presented by the session chairs and moderated by **Berrien Moore III**. Through the presentations,

which represented the culmination of two days of responding to the four questions with observations, data, and insights, a glimpse of the New England and upstate New York region's vulnerabilities, knowledge gaps, and response strategies to climate change issues began to emerge. Even with planes to catch and other commitments on their calendars, most of the group stayed until 6:00 p.m. learning from each other and considering next steps. The participants agreed that the workshop was but an important "first step" to what many hope will grow into a collaboration between area stakeholders and researchers interested in identifying, monitoring, and mitigating global change at the regional level.

Tom Baerwald, Deputy Assistant Director for Geosciences at the National Science Foundation (NSF) brought the workshop to a close with several upbeat and relevant remarks. Baerwald echoed the sentiments of the participants by stating that on behalf of NSF he felt the workshop was "very much a success." This workshop, along with others like it across the nation, were bringing a "better, richer understanding of the fully integrated set of issues" that are involved with climate change. He cited the fact that in the past the global change research program has focused on physical sciences, the atmosphere, and the oceans—the New England Regional Climate Change Impacts Workshop and other regional workshops are highlighting the importance that people and regional ecosystems play in the equation.

Baerwald's congratulations were extended to the Steering Committee and Planning Committee and to all participants for an actively involved workshop which enhanced the network of communication among scientists and stakeholders and resulted in "a couple of very valuable days." He emphasized that this event was a first step in a series of on-going events designed to address, at a regional level, the significance of global climate change. He heartily encouraged all participants to remain involved in the process stating, "workshops don't get things done, it's the people within them who get them done." Scientists, policy makers, and federal agencies will need to continue the dialogue and interaction with "those people who are out in the real world" in order that the science and policy surrounding climate change will be more direct and focused.

In closing, Baerwald asked that New Englanders modify their successful "minuteman strategy"—citizens rising up in defense, at a minute's notice, against a challenge from a common enemy—as the federal government modifies its strategies so that in future engagements the different roles are not adversarial but roles where the regions and the nation can work together to address the challenge of climate change.

Breakout Sector Findings and Reports

Shannon Spencer*

Participants convened in one of seven different breakout sectors during the two-day workshop to discuss and address the four questions presented in the Introduction. Each breakout sector met three times during the course of the workshop. Breakout sector Chairs, Co-chairs and Rapporteurs were asked to develop a list of significant findings from their discussions and to write-up a report for their sector.

The following sectors were convened:

1) Business/Insurance and Industry
2) Energy and Utilities
3) Government and Resource Management
4) Human Health
5) Information Transfer and Public Awareness
6) Natural Resources
7) Recreation and Tourism

A summary of each breakout group's significant findings are found below. Detailed breakout sector reports by each sector's representatives follow this section.

SIGNIFICANT FINDINGS BY BREAKOUT SECTOR

1. Business/Insurance and Industry Sector

- Scientific evidence establishes that global warming has occurred and will likely continue to occur.
- There exists a discernible human contribution to climate change.
- Climate change and global warming could have substantial consequences.
- This sector's stresses are likely to be enhanced by climate change.
- Climate change will likely increase the loss of biodiversity, which affects this sector.
- Regional level detail regarding climate change impacts is lacking.
- A need exists for a centralized clearinghouse of data regarding climate issues.
- Technology exists (but is not used to its fullest) for reducing/controlling greenhouse gas emissions.
- A need exists for incentive programs to encourage reduction of greenhouse gas emissions, for the use of newer technologies, and to preserve existing carbon sinks.
- The political will is lacking in the face of scientific understanding to implement mitigation and coping strategies for climate change.

2. Energy and Utilities Sector

- Renewable energy should play a larger role in New England's energy future.
- Energy efficiency should be maximized.
- Economically viable energy efficient policies and initiatives need to be implemented which also result in reduced greenhouse gas emissions.
- The true cost of energy needs to be reflected in the price to the consumer.
- Governments must support efficiency initiatives.
- Federal funding for research, development and implementation of new technologies is needed.
- The energy/utilities and transportation sectors need to develop constructive options for dealing with climate change issues.
- A factual base of information regarding climate change, energy/utilities, and greenhouse gas emissions is needed in order to support decision making.

3. Government and Resource Management Sector

- A need exists to design an educational network which will operate across agency/group sectors in order to inform/discuss climate change issues with the general

* See Appendix V for authors' affiliations and addresses.

public, with emphasis in addressing legislators, foresters, industry and meteorologists.

- Develop and implement new technologies to reduce greenhouse gas emissions and to make use of alternative/renewable energy sources.
- Address stakeholders on their own turf when developing action plans and strategies for dealing with climate change issues.
- Promote increased energy efficiency.
- Improve natural ecosystem carbon sink capabilities through management practices.
- Use current cost-efficient programs as models to promote win/win situations in the area of climate change issues.

4. Human Health Sector

- There exists a lack of understanding and information regarding the effects of climate change on health related issues.
- The Northeast may be particularly vulnerable to health impacts due to climate change because of the geographical location.
- Increases in UVB radiation due to stratospheric ozone reduction may be deleterious to both plants and animals.
- Chemical air pollution may result in increased health hazards.
- Health issues may arise if high temperature events increase in frequency, severity and duration.
- Water quality is likely to be affected, which impacts human, animal and plant health.
- Algal blooms have the potential for increasing in coastal areas.
- Disease occurrence and pathways are largely not well understood under a warming scenario.

5. Information Transfer and Public Awareness Sector

- Scientific literacy needs to be enhanced and advanced in the public.
- Key concepts need to be identified and developed around the issues regarding climate change in order to advance the scientific literacy of the public.
- Information availability, accuracy, and credibility need to be addressed.
- One key information source would assist in scientific literacy advancement.
- Communication needs to be increased between various stakeholder groups.
- Scientists need to be more effective in communicating their results to the non-scientific community—many win/win situations exist when credible and accurate knowledge is transferred to the appropriate users.

6. Natural Resources Sector

- Natural resources and natural resource industries of New England/upstate New York will be sensitive to climate change.
- Climate change issues, in general, are not well understood by constituents of this stakeholder group.
- Research should be conducted to improve the current climate models on a regional level to provide stakeholders in this group with different climate scenarios with which to work.
- Enhance the understanding of impacts on economic, ecological and agronomic variables.
- Policies and strategies to mitigate and cope with climate change must be equitable on a national and global scale.

7. Recreation and Tourism Sector

- Recreation and tourism in the Northeast are influenced by climate conditions.
- Outdoor activities are dependent on the environment and its condition. Indoor activities are also affected by climate.
- Climate and the potential changes in climate do not evenly affect all sectors of recreation and tourism: many sectors are expected to be affected negatively, at varying degrees, while some sectors may stand to gain from the changes.
- Access to data needs to be enhanced.
- Outreach to stakeholders of this group needs to occur. Discussions of short-term and long-term issues and solutions should be encouraged.
- Non-motorized trail systems should be developed.
- Public transportation needs to be enhanced.
- This stakeholder group needs to develop coping and mitigating strategies at the sector-wide level.

Business/Insurance and Industry Sector Report

Michael Disharoon and Petya Entcheva*

INTRODUCTION

The sectoral group meeting during the New England Regional Climate Change Impacts Workshop to discuss climate change issues facing the insurance, business, and industry areas of the economy was represented by members with the following affiliations:

Energy industry - 2
Insurance industry - 2
Pharmaceutical industry -1
Business and Industry Association - 1
Geology consulting firm - 1
State legislator - 1
Climate change scientists - 3
Data analyst - 1
Water resource management - 1

This document has been circulated and reviewed by members of the group.

SIGNIFICANT FINDINGS

The statements below represent the common conclusions reached by all members of this sectoral group from our discussions at the workshop.

- Direct scientific evidence establishes that global warming has occurred and will likely continue to occur.
- A preponderance of scientific evidence suggests that the human contribution to climate change is discernible.
- The consequences of climate change and associated global warming have the potential to be substantial.
- Most all current stresses on insurance, business, and industry are expected to be exacerbated with climate change.
- Losses of biodiversity (hence, sources of drug discovery and drug substance to pharmaceuticals) is expected to worsen with climate change.
- Definitive information is lacking as to the exact impacts of climate change, particularly at the regional level, and quantification of sources of climate change.
- A centralized, authoritative source of data on natural resources, sea-level rise, and high risk areas does not exist.
- Technologies currently exist for controlling heat trapping gas emissions from most all sources.
- Incentive programs, such as a carbon tax or tax credits, do not exist to provide the impetus to reduce CO_2 emissions by investment into renewable and efficient energy technologies.
- Incentive programs to preserve existing CO_2 sinks do not exist.
- The political will and conviction to act in face of the current scientific understanding to implement necessary mitigation and coping measures to climate change do not exist.

THE FOUR QUESTIONS ADDRESSED

1. What are the current concerns and stresses facing regional stakeholders in the business, insurance and industry sector?

- Shoreline erosion and retreat causes damage to existing and new development, in part due to coastal subsidence. Governmental regulations and subsidies in states which do not allow the full force of the free market mechanism to discriminate premiums on the basis of hazard and lack of an archive of shoreline data to allow a good measure of trends in retreat and erosion have collectively resulted in increased claims and consequential losses for the insurance industry.
- Loss of coastal resources (such as estuaries) impacts those businesses deriving their value from coastlines and coastal resources.
- Air pollution generated in the Midwest is transported to the northeast, making it possible for the Midwest region to reach its National Ambient Air Quality (NAAQ) standards

* See Appendix V for authors' affiliations and addresses.

without implementing substantial emission control measures. At the same time this makes it more difficult, perhaps impossible, for the New England and upstate New York industries to meet NAAQ standards. Businesses and industries in the New England and upstate New York areas are struggling with the need to balance this uneven "playing field" with regard to current air pollution control regulations. This is being addressed by suggesting that industries in the Midwestern states and other countries either meet the same standards of pollution control or incur a pollution tariff, thereby removing the unfair competitive market advantage these regions have over those in New England and upstate New York.

In addition, there is an ongoing effort to streamline the bureaucratic burden placed on business and industry by the implementation of pollution controls without compromising the information and enforcement needs of the regulators. An important example of this are the delays in time to market caused by many state agencies through their requirements for lengthy permit reviews.

- Potential and unquantifiable loss to the pharmaceutical industries in New England and New York of natural sources for drug discovery and drug substances has resulted from losses around the globe of ecosystems supporting microbial and higher fauna and flora biodiversity.
- It is essential for business and industry to avoid building long-term cumulative liabilities, such as those experienced under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) whereby past, irresponsible disposal practices (such as Love Canal) have, and continue to, cost business and industry billions of dollars.
- High energy costs, temporal and regional variability in energy costs, and allocation of energy use by energy commissions place continual stresses on business and industry, impacting profit margin and ability to compete.
- Availability of potable water (which varies with surface water quality, precipitation, runoff quality, and storm events) impacts business and industry.
- Pollution and weather conditions add stress on forest health and soil quality, impacting the forest products industry.
- The agricultural industry is highly susceptible to weather conditions such as temperature and precipitation.

We recognized the essential and continual need for business and industry to devote resources to maintaining a corporate "good neighbor" status within the community. A more discouraging observation was the degree of apathy that abounds and impedes the efforts to address many of the climate change related problems facing the insurance, business, and industry sector.

2. How will climate variability and climate change modify the current concerns anad stresses of the business, insurance and industry sector in the region?

The insurance, business and industrial sector in New England and upstate New York, as represented in this work group, accepts the direct record derived from ice cores and other earth measurements as adequately demonstrating a level and rate of increase in concentration of heat trapping gasses occurring in this century and unprecedented in the 150,000 year record. This sector accepts the scientific evidence that global warming has occurred within the last century and will likely continue into the next century.

This sector does not purport to know with a high degree of certainty the exact consequences of global warming or whether anthropogenic contributions to the increases in heat trapping gasses and global warming are significant. Nonetheless, this sector accepts the following:

1) the preponderance of scientific evidence weighs more heavily toward the premise that the anthropogenic contribution to heat trapping gasses in the atmosphere is significant;
2) the consequential global warming and climate change have the potential to be substantial;
3) all of the previously mentioned concerns and stresses will be adversely accentuated, with the exception of apathy which would be expected to disappear.

Based on these statements, the following would be anticipated:

- Insurance companies will be expected to incur greater losses and the availability of insurance to the insured will be expected to diminish in proportion to a growing unwillingness of insurance companies to take on new exposures.
- Loss of coastal resources is expected to increase as the sea level rises and storm magnitude and frequency are impacted by climate change.

- The implications for air pollution control are less clear. Major changes in air mass temperature and precipitation patterns expected from climate change can either exacerbate or reduce air pollution control challenges, depending upon the specific nature and magnitude of the changes.

If removing heat trapping gasses, CO_2 in particular, from industrial gas streams becomes a necessary mitigation measure, then industry will be challenged with re-thinking its current strategy for controlling its hazardous air pollutants (HAPs), volatile organic compounds (VOCs), and waste organic solvents, which are currently the ultimate mineralization of these contaminants to CO_2. At a minimum, controls downstream of those used to mineralize HAPs and VOCs will have to be added to remove CO_2. A stronger emphasis on organic solvent recycling and recovery is likely. To the extent these contaminants induce forest decline, control standards for such pollutants could conceivably become more stringent.

- Potential losses to the pharmaceutical industries are expected to increase, resulting from accelerated losses around the globe in ecosystems supporting biodiversity. As a result, sources for drug discovery and drug substances become more limited.
- Business and industry's ability to maintain its "good neighbor status" and its ability to avoid building long-term cumulative liabilities are likely to become a greater challenge with climate change. This ability will depend upon the extent to which business and industry become involved in climate change issues and act responsibly in light of this.
- Energy costs, temporal and regional variability in energy costs, and allocation of energy use are likely to become a more significant issue since the underlying parameters that influence these factors are altered with climate change and any effort to mitigate climate change. Costs of individual types of technology, such as photovoltaics and wind power, can be expected to decline with further development and mass production.
- Availability of potable water which varies with surface water quality, precipitation, and runoff quality is likely to become a more significant issue as the underlying parameters that influence these considerations will change with a fluctuating climate.
- Climatic stress to forests, will cause increases in pests, migration or local extinction of tree species (many incapable of keeping pace with the predicted rate of climate change), and dieback due to an increase in freeze-thaw cycles.
- Increasing water temperatures will impact the species distribution of fish.
- Warm weather agriculture (such as corn, soybeans, beef cattle) is expected to benefit, while cool weather agriculture (such as broccoli, dairy, apples) is expected to suffer. There will be a general need for farmers to shift their agricultural emphasis.
- Redistribution of world population as a result of sea-level rise and economically forced migration is expected to have an impact on taxes, income, etc.

It is expected that some companies will benefit and new industries will arise, namely those that address problems arising out of a climate change, such as environmental firms and investment firms.

3. What information and data are needed by businesses, insurance companies and industry to fully understand and address climate-related issues?

Business and industry requires more specific and quantifiable information from the scientific community discerning between the anthropogenic and natural contributions underlying climate change. This information is essential to solidify the business community's conviction about global climate change and facilitate its commitment to developing coping strategies that address and mitigate climate changes. In addition, we have identified the following areas where information and data are currently needed:

- We need definitive information about the impacts of climate change on weather and precipitation patterns. Many storm systems converge on New England and upstate New York; hence, any small change in one or more of these tracks may have substantial impact.
- An inventory of emission sources of carbon (both direct and indirect) and other heat trapping gasses is needed to better quantify their impact on climate change and the potential cost of mitigation.
- Improved communication of scientific findings in plain English from the research community, in both character and scope, is needed to better understand the stake and role of business and industry in climate change.

- A central and authoritative source of precise, regional data on natural resources, sea-level rise, high risk areas (flood maps, mud slide, hurricane potential), population figures and property values for high risk areas would assist insurance companies in writing policies and setting premiums in proportion to risk or damage potential.
- A cost analysis for implementing control technologies to reduce or eliminate heat trapping gas emissions (CO_2 in particular) is needed.
- Policy analyses that prioritizes the most effective and equitable means of climate change mitigation that can be implemented by business and industry are necessary.
- Dissemination of information about renewable energy alternatives and conservation practices applicable to the business/industry sector is a requirement for assisting decision and policy making.

4. What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

Technologies currently exist to either reduce or eliminate CO_2 emissions from industrial and residential gas streams: conservation (renewable technologies like wind turbines and solar hot water heating), energy efficiency (high-efficiency combined-cycle gas turbines, more energy efficient appliances), fuel switching, technology substitution (fuel cells, integrated green building designs), and CO_2 gas scrubbing.

Application of an appropriate mix of these technologies is the most direct, least complex, and probably most cost effective method of mitigation to all of the above stresses. The extent of mitigation would be proportional to the anthropogenic CO_2 contribution to climate change.

Industry also possesses the technology to control the other heat trapping gasses (O_3 and its VOC and NO_x precursors, CFCs and HCFCs) in most of its industrial processes.

- Mathematical models of energy systems exist for ranking the most cost effective CO_2 reduction schemes.
- A change to electric powered transportation would further concentrate CO_2 emissions to an industrial point source where they are most easily controlled.
- An increase in organic solvent recycle and reuse programs, as opposed to incineration, could reduce CO_2 emissions.
- Incentive programs are needed to preserve existing CO_2 sinks (such as forests and ocean ecosystems) and to develop new sinks.
- United Nations procedures could be instituted to preserve and mitigate losses to biodiversity.
- A tempering of regulations by states restricting the free market forces for risk based premiums would be helpful in reducing construction in high risk areas and mitigating losses to insurance companies, as would encouraging community attention to planning and zoning in high risk areas.
- Involvement of business and industry in policy and regulatory development to improve regionally and globally equitable regulations should be encouraged.
- Energy and environmental regulations established with foresight and cost/benefit considerations are needed. These must be regionally equitable, flexible, and incorporate the greatest possible stability.
- A regional, as opposed to local, approach to water management would help to stabilize fluctuations in water availability.
- Shoreline erosion and coastal resources can to some extent be protected by coastal engineering measures (i.e., levees, dikes, etc.). Measures need to be introduced that reduce population and development of the coastal areas at risk, such as "land swap" programs, where homeowners in the coastal areas most at risk can exchange their property for a similar property owned by the state or county further inland.

In all cases, the political will must be present to implement necessary mitigation and coping measures.

Energy and Utilities Sector Report

Norman Williard, Howard Bernstein, James Platts, Nancy Sherman,
Elske Smith, and Cameron Wake*

INTRODUCTION

The Energy/Utilities breakout group consisted of seventeen people who met over the course of three sessions. The group was comprised of:

five utility or environmental regulators
four academics
three utility representatives
two policy agency representatives
two environmental organization representatives
one New Hampshire state legislator

The Energy/Utilities group discussed and developed responses to the four questions posed to each work group. Our discussion focused mainly on utilities and energy suppliers, and to some extent on the transportation sector. We first developed a list of current concerns relating to the region's energy/utility sector. A cross-cutting issue is the opportunity for greenhouse gas reductions by more aggressively pursuing "climate sensitive technologies" such as encouraging development of hydrogen as a fuel, promoting fuel cell technologies, etc.

Given the nature of our subject area, we took a somewhat different approach to Question 2 than the other workgroups. The question seemed to be more applicable to the area of natural resources and how natural resources will be stressed with increasing climate change. We decided to answer it in the context of the current day conditions—current stresses that did not consider climate change as an factor. We concluded that virtually all the stresses included under this question would be exacerbated by climate change, with the one probably positive impact being the impetus for renewable energy sources.

Question 3 led us to identify a need to collect and organize data that already exists but is not collected in a single place where it can be easily accessed. Collecting the data into one location would mean that it could be used as a common source database for residents of upstate New York and New England to evaluate and decide what steps to take, including gathering additional data to fill information in gaps.

Our consideration of Question 4 led us to articulate some statements about what needs to be done to mitigate greenhouse gas emissions and, in the longer term, to move to zero CO_2-emitting resources for new energy sources as existing sources are eventually replaced. These were grouped into six major strategy areas:

- Energy efficiency and conservation actions
- Internalizing full costs in the price of energy
- Cleaner energy sources and increased reliance on renewable sources
- Transportation measures
- Public information and education about global warming science, greenhouse gas emissions and their impacts
- Other policies and actions

These strategies require new planning approaches, assessment of a broader scope of potential options and emerging technologies, and inclusion of costs that have previously been left to the states and society. A bold new approach is necessary to change the ways we produce and use energy and to begin to take control of greenhouse gas emissions.

SPECIAL CHARACTERISTICS OF THE REGION AND IMPORTANT DRIVERS

The uniqueness of New England as an energy region can be characterized as follows:

1. New England has no significant indigenous, carbon-releasing, fossil fuel resources. While this means we import most of our energy resources, it also leaves the region relatively less burdened by vested energy industry interests in development of its energy portfolio.
2. The region's energy costs are among the highest in the United States.
3. Most of the population is highly concentrated in metropolitan or relatively small urban/suburban geographical areas.
4. New England is at the end of the "energy pipeline." This is literally true of natural gas, which arrives by pipeline from distant gas

* See Appendix V for authors' affiliations and addresses.

fields in Louisiana, Texas, Oklahoma, and Alberta. It is figuratively true of coal, oil, and nuclear fuel, which are all shipped to New England from coal mines, oil refineries, and processing plants in distant states and foreign nations.

5. The region has renewable resource potential in hydropower, solar, wind and biomass. Improved economics and policy incentives are key drivers to greater use of all of these resources.
6. Fuel cell technology offers promise as an energy efficiency measure and is just starting to make commercial inroads into energy use.
7. States in the region are well along in the process of restructuring the electric utility industry, providing opportunities to shape our energy future and thereby reduce greenhouse gas emissions now and in the coming years. Some key features of a restructured electric industry are: the generation and wholesale and retail sale components of the electric utility industry could be opened to allow greater customer choice and competition among service providers; utilities could be required to divest their power plants; transmission and distribution components will continue to be regulated.
8. In the New England region, the transportation sector contributes significantly to greenhouse gas emissions—roughly 30-40% of total current emissions. Greenhouse gas emissions produced by the transportation sector are projected to increase dramatically in the near future, growing at a disproportionate rate compared to other sectors.
9. Since more than 90% of our CO_2 greenhouse gas contribution comes from the combustion of fossil fuels, the energy/utilities and transportation areas are critical to any strategy to reduce greenhouse gas emissions.

SIGNIFICANT FINDINGS AND RECOMMENDATIONS

The Energy and Utilities group developed the following findings and recommendations:

- Renewable energy resources can and should play a significantly greater role in New England's (and the nation's) energy future.
- As policy, energy efficiency should receive much greater emphasis with a strong commitment by the federal and state governments. Economically viable energy efficiency investments that also reduce greenhouse gas emissions, so called "no regrets" measures, should be vigorously pursued by all sectors. Fully competitive generation and retail sale of electricity under utility restructuring could mean a significant decline in utility energy efficiency expenditures unless state legislators and regulators incorporate continued support for those investments in the language of the statutes and rules of restructuring. In addition, there is a need to put in place transparent, valid, and verifiable disclosure and labeling of electricity sources for electricity consumers of all types, as supported by the New England governors.
- Internalizing full costs in the price of energy is an essential step toward making the operation of the marketplace more efficient. Additionally, this would send clear and accurate cost signals to consumers as they make energy use decisions.
- There is a need for a greater broad regional and national funding commitment to research, develop and implement new low/zero carbon technologies for the production of electricity, transportation, and the residential, industrial and commercial energy sectors.
- The electric and transportation industries, in conjunction with government support, need to develop constructive options for dealing with climate change, both new low/zero emitting carbon technologies and broad economic incentives (e.g., domestic and international "joint implementation" initiatives).[2] New ways are needed to influence the public's participation using economic incentives, such as free or low cost, clean transportation options.
- We need to assemble a foundation of information that provides a solid base for informed decision making on policies and greenhouse gas emission reduction strategies. EPA and other federal agencies should support this comprehensive climate change information clearing house.

THE FOUR QUESTIONS ADDRESSED

1. What are the current concerns and stresses facing regional stakeholders in the energy and utilities sector?

The lack of indigenous fossil fuel sources has plagued New England utilities and other energy suppliers both in the past and in the present, except for some wood and a small portion of hydroelectric

[2] "Joint Implementation" (JI) is a market-based approach for addressing global climate change that uses international partnerships to achieve low-cost reductions in greenhouse gases. Under JI, a company in the United States invests in a project that reduces emissions in another country and uses those reductions as a less expensive means of meeting its own target. The U.S. has proposed that credit for JI projects be part of a new climate change agreement.

power generation, New England must import most of its energy. We have high energy costs and are vulnerable to supply fluctuations and price shocks. Additional stresses relate to the need to provide electricity service to low income households: will state restructuring plans include ways to address these needs? Furthermore, as aging nuclear plants are phased out, the region will need extensive new energy sources.

Pollution control requirements exert a high burden on the region's energy users because of transport of airborne pollutants from energy production elsewhere in the country, especially from the mid-west. Pollution from fossil fuels include ozone precursors (NO_x and hydrocarbons), fine particulates, acid rain precursors (SO_2 and NO_x), mercury and other toxic metals. Our region has invested heavily in pollution controls on fossil electric generating plants, but in New England we are downwind of large sources of these contaminants. The uncertainty of future environmental laws and regulations and the current lack of regulations for CO_2 emissions adds to the concerns.

Restructuring the electric industry is considered a window of opportunity for increasing the adoption of renewable and sustainable energy for New England and for making New England a leader in the nation in promoting cleaner, less carbon intensive technologies. The viability in the region of biomass as an energy source needs further examination. Some believe restructuring may pose a risk to environmental quality and sustainability if it results in greater use and longer life for coal burning plants, within the region and those upwind. Cost-cutting concerns may lead to reduced commitment to energy efficiency programs and to less investment in demand side management (DSM) and renewable energy sources, if state regulators no longer require such programs. The extent to which restructuring helps or hinders progress towards an environmentally sustainable energy system will depend upon the provisions that are crafted into the statutes and rules of restructuring by the state legislators and regulators.

In the transportation sector, increasing demand, partially from increased tourism, exerts substantial stresses. These include:

- air and water pollution resulting from automobile travel;
- lack of viable and convenient alternatives to the use of cars (lack of mass transit);
- growing popularity of low gas mileage vehicles for use as passenger vehicles, such as sport utility vehicles, minivans, and light pick-up trucks, which are not subject to the same fuel economy standards (CAFE) as other passenger vehicles;
- continuing suburban sprawl and the corresponding impacts on the environment and landuse.

2. How will climate variability and climate change modify the current concerns and stresses of the energy and utilities sector in the region?

By any measure, energy is key to any discussion of climate change, for it is the major underlying contributor to carbon emissions, accounting for more than 90% of CO_2 emissions in New England. Climate change inevitably has impacts on the stressors in the energy/utility sector in virtually all dimensions. As a result, the group found that it was not useful to discuss this question in detail except to identify which of the current stresses from Question 1 will be exacerbated.
Non-transportation energy demand may increase if climate change leads to hotter summers; to an as yet indeterminable extent, this will be partially off-set by lower demand if warmer winters are experienced. We might expect an economic loss with the reduction of tourism (e.g., changes in the fall foliage and ski seasons due to climate change), unless it is replaced by new forms of tourism.

3. What information and data are needed by the energy and utilities sector to fully understand and address climate-related issues?

Much of the data required from the energy production/energy use sectors of New England's economy already exists, albeit in a variety of different forms and locations, and of variable quality. In order for stakeholders and government officials in the region to make effective decisions regarding energy while considering climate change issues, there is clear need to assemble and critically analyze this data. Subsequently this information should be made available to stakeholders as well as the general public. This task is a high priority for funding in the near-term.

An IPCC-style, peer-reviewed document should be published to provide a summary and analysis of existing data on the utility, transportation, and commercial/industrial/ residential sectors relating to energy sources, use, efficiencies, and policies in the region. Input of data for this document must be an open, but time-limited process, involving all relevant sources.

This data gathering/analysis should include at least the following information for the New En-

gland region. Many of these items should include a detailed description of the existing system.

- Cost/benefit data (graph) on cross-sector CO_2 reduction related to energy use;
- Cost/benefit data on impact of "bottom up" energy efficiency integrated design;
- Physical and technical potential for renewable energy production;
- Cost/benefit data on transportation alternatives (mass transit; alternative modes; more dense landuse);
- Potential CO_2 reduction benefits of more telecommuting;
- Implications of nuclear plant scenarios, i.e.,, earlier retirements, life extensions, new improved plant designs;
- Broad inventory of potential policy options and computer-modeled projections showing how CO_2 and greenhouse gas reduction targets could be met by implementing individual policies or selected sets of compatible policies;
- Economic impacts of adopting energy efficient technologies;
- Description of "external" costs of energy use and at least a qualitative (quantitative where possible) assessment of these costs.

An updated report on planning for future regional energy needs should be prepared, coordinating the efforts of the New England Energy Policy Council, New England Governors Conference, etc. In addition, effective communication methods and strategies must be developed and implemented for disseminating this information and providing an understanding of the issues and the available, effective technologies to all the New England states.

4. What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

The following areas are inter-related and can be seen as mutually reinforcing:

1. Energy efficiency and conservation actions;
2. Internalizing full costs in the price of energy;
3. Cleaner energy sources and increased reliance on renewable sources;
4. Transportation measures;
5. Public information and education about global warming science, greenhouse gas emissions and their impacts;
6. Other policies and actions.

Energy Efficiency and Conservation Actions

At all levels and in all sectors, energy efficiency and conservation efforts must be increased. Wasting energy means needless release of greenhouse gases. A comprehensive set of programs and policies should be pursued vigorously in all sectors.

Internalizing Full Costs in the Price of Energy

Some energy costs are now hidden from consumers and are not included in the price of fuel. These costs, such as environmental costs and others referred to as externalities, should be included in the price of fuel and electricity; currently consumers do not directly bear the full cost of environmental and other impacts resulting from energy use. Internalizing full costs in the price of energy gives a clear and accurate signal to consumers as they make choices about energy use.

Cleaner Energy Sources and Increased Reliance on Renewable Sources

There is a clear need to more aggressively develop and expand renewable and clean energy sources in New England and across the country. Renewable sources will help reduce our dependence on carbon-intensive fossil fuels, particularly coal and oil, and on electricity from aging, inefficient generating sources. Pursuing cleaner sources and replacing aging fossil fuel facilities with generation from renewables will reduce greenhouse gas emissions in New England and elsewhere in the nation.

Aggressive development of renewable and other clean electricity sources has already been mandated under electric utility restructuring in four New England states. Renewable retail electricity portfolio standards have been enacted in Maine, Vermont and Massachusetts. Restructuring legislation in Massachusetts and Rhode Island has also provided for funding renewable investments from a portion of non-bypassable system benefit/access charges. These options applied in other states (and nationally) could contribute to significant reductions in greenhouse gas emissions (CO_2 and nitrous oxide) compared to carbon intensive generating fuels. Encouraging cleaner technologies through government energy policies will have the added advantage of bringing new jobs and greater energy security to the region and the nation. Government can show leadership here with its own purchases of green power, such as the U.S. General Services Administration's recent RFP for aggregated power and energy efficiency services purchases.

Transportation Measures

State-developed greenhouse gas emission inventories have identified transportation as a major source, accounting for well over 30% of greenhouse gas emissions in the New England region. The emissions from this sector are expected to grow disproportionately in coming years. Some specific transportation-related strategies include the following:

- Increasing and broadening CAFE standards (corporate average fleet efficiency) is critical if the nation is serious about reducing greenhouse gas emissions. Gasoline miles per gallon standards must be dramatically increased, and their application must be broadened to include classes of motor vehicles such as vans, sport utility vehicles, and pick-up trucks. This is a federal government responsibility that, if the political will exists to exercise it, could have a dramatic and rapid effect on greenhouse gas emissions nationally.
- Multi-modal transportation systems must be explored and developed where appropriate. This should be accompanied by better anti-sprawl landuse planning. Additional national funding should be directed to this.
- Alternative fuel vehicles must be developed and promoted. Hybrids, electric vehicles, fuel cells, hydrogen, better battery and other energy storage systems (e.g., flywheels) must be supported with federal research and development funding.

Public Information and Education

Educate the public on energy sources and energy use and their connections to climate change and other environmental and public health concerns. Informed consumer choice in electricity, transportation, and other behaviors is a critical area to address. This public information and education program should include regional, state and local elements that can present the message succinctly to citizens and public leaders. More attention and funding are essential, and national leadership is key.

Other Policies and Actions

- There are important and serious questions to resolve concerning the role of nuclear power in the region. Issues include aging physical plants, maintenance, decommissioning, waste management, new nuclear technologies, and siting. While nuclear power can represent a zero-carbon alternative, in the eyes of the public—as well as policy makers, decision makers and the financial community—there are serious questions to resolve before considering any role for nuclear power.
- Wherever feasible and appropriate, there should be cross-state and regional coordination of policies. Likewise, regional standards would be helpful (e.g., in electricity labeling, disclosure, and generation performance standards).
- It is important that environmental and other externalities of energy production and use be identified, quantified to the extent feasible, and publicized. Mechanisms should be evaluated that can apply those costs to the users of energy, perhaps through a revenue-neutral carbon or energy tax.
- All federal government fossil fuels subsidies should be removed as an important step toward reducing CO_2 emissions. Eliminating subsidies will allow fossil fuel prices to reflect their true costs rather than artificially encouraging greater use. Lower carbon energy sources will become more economically attractive, relative to current options. Removal of federal government supports for fossil fuels will also promote development and use of more efficient, renewable, and sustainable technologies that will reduce greenhouse gas emissions.
- Greenhouse gas budget and capping programs should be considered as policy measures in the context of a world system to encourage reductions and CO_2 trading on regional, national and international basis.
- Electric industry restructuring in New England and elsewhere offers immediate and significant one-time opportunities for actions that can result in reducing greenhouse gas emissions.
- Electric generation performance standards should be explored as a state, regional and national opportunity to reduce greenhouse gases.
- Put in place transparent, valid, and verifiable disclosure and labeling of electricity sources for electricity consumers of all types as supported by the New England Governors.

Government and Resource Management Sector Report

Robert Brower*

INTRODUCTION

The following material is the result of discussions held by the Government and Resource Management Group during three breakout sessions. The discussion focused around the perspectives of eight participants representing and familiar with various sub-areas of the upstate New York/New England region. The perspectives include those of state level resource managers with particular expertise in forestry, watershed management, and air quality issues. An elected, state-level policymaker, a state-level geographic information system (GIS) administrator, and an appointed local government administrator were also included in this stakeholder group.

Each of the three breakout sessions started with an explanation of the charge to the group. A facilitated nominal (silent) process was used in the first breakout session with a 15 minute period provided for individual recording of responses. This was followed by a round table presentation by each participant, each offering one concern/vulnerability at a time.

The discussion continued until all the concerns of participants were summarized and recorded. Each participant was asked to look at the list that was generated and suggest those which seemed to be identical or very closely related. The list was collapsed only when the participants owning the responses were in agreement. The discussion process was more open as the group exercise continued and participant understanding of individual concerns increased.

It was clear during the discussion that a range of opinion existed within the group around the certainty of human impact on climate change impacts. Never-the-less, the group identified and prioritized current concerns and stresses, and reached consensus on how climate changes could act on such concerns. During the discussion the group also identified some important data and information needs. Finally, members described certain coping strategy characteristics and implementation complications.

SIGNIFICANT FINDINGS

Concerns, Information Needs, and Mitigation Complexity

Resource managers identified a general lack of awareness and understanding of environmental problems as a priority concern. This concern was coupled with the inability to influence individual and corporate behavior and a lack of resources adequate to address current resource problems. In other words, it is anticipated that the complexity of current resource management issues will increase with global climate change, making the existing need for better data and information more critical, and resource allocation for mitigation more problematic.

Some natural systems (air, water, woodlands) can not be sustained at current demand levels. Increased strain for climate change is of critical concern, particularly for those synergistic impacts which link ecosystems. Related data and information needs are particularly vexing and are expected to grow in significance and complexity with climate change. Forest fragmentation and area specific declines in vigor exemplified the need for increased synergistic and intra-system understanding.

Even if it was now clear what mitigation actions should be undertaken, it does not appear that available resources would be adequate to support such actions. Finally, complex cultural and institutional dynamics exist in upstate New York and New England, which could function as barriers to mitigation potential. The devolution of government toward local levels and civic disengagement are two such dynamics. Institutional complexities are well understood as mitigation barriers by resource managers trying to conserve/manage air, water, and woodland systems which cross boundaries of various municipal entities.

Demands for increases in clean water availability must be met, as well as concurrent demands to maintain various and often competing community

* See Appendix V for authors' affiliations and addresses.

infrastructure components. Such infrastructure demands can be driven by current population migration patterns within and between geographic regions. No infrastructure component seems exempt from the impacts of such migration patterns. Adequate housing, public health, and social service institutions, transportation systems, communication systems, water supply, and sewage systems are all impacted as population shifts occur. These related difficulties would become exacerbated if increasingly rapid population shifts occur in response to climate change impacts.

Coping And Mitigation Strategies

From the viewpoint of this sector, mitigation strategy begins with the design and piloting of multi-jurisdictional, multidisciplinary, educational networks. Such networks would comprise a range of target audiences, including the general public and specific stakeholders.

The purposes of such educational networks would include the engagement of local stakeholders on their own "turf" as well as more general convening strategies for focusing purposes. Such engagement is intended to result in short and long-term action plans and strategies.

Action plans for addressing climate change should be constructed upon present, cost-efficient programs related to climate change, particularly promoting those with anticipated mutual gains or win/win strategies. For example, energy efficiency should be promoted everywhere in all forms.

Forest management programs and practices which are intended to improve the ability of forest ecosystems to sequester carbon should be facilitated as should programs that are designed to develop and deploy alternative new technologies that reduce carbon dioxide emissions.

THE FOUR QUESTIONS ADDRESSED

1. What are the current concerns and stresses facing regional stakeholders in the government and resource management sector?

Existing concerns/vulnerabilities are presented in groupings which represent a descending order of priority. This ranking of priorities was the result of an individual balloting process which occurred at the end of the first breakout session. It was clear during the discussion that a range of opinion existed within the group around the certainty of human impact on climate change impacts.

Priority Group 1

The following concerns/vulnerabilities were each considered to be among the five most significant by four of the eight government/resource manager stakeholders in this group.

- The lack of an awareness or understanding of environmental problems and related impacts.
- The inability of the stakeholder to influence individual and corporate behavior.
- Societal resources and dollars are limiting/lacking to address the current problems.

Priority Group 2

The following concerns/vulnerabilities were considered to be among the five most significant by three of the eight government/resource manager stakeholders in this group.

- The demand for natural resources is increasing, yet some resource demands already cannot be sustained.
- We do not completely understand natural systems and resource management is complex.
- Information and data on climate-related issues is lacking.
- There exists limited resources for maintenance of existing infrastructure, yet pressure/impacts from human migration patterns on infrastructure is increasing.
- Forest/ecosystem health issues, some of which include: forest fragmentation, areas in decline, and loss of bio-diversity.

Priority Group 3

The following concerns/vulnerabilities were each considered to be among the five most significant by two of the eight government/resource manager stakeholders in this group.

- The demand for clean water is increasing.
- Local and state governments are hard-hit by un-funded state and federal mandates and by the economic impacts of complying with environmental regulations.

Priority Group 4

The following concerns/vulnerabilities were each considered to be among the five most significant by one of the eight government/resource manager stakeholders in this group.

- Shoreline erosion for some communities is a serious problem.
- The local nature of landuse controls and subsequent ability/inability to respond to resource management dynamics makes implementing coping/mitigation strategies difficult.
- Local and state governments have other non-climate concerns and have difficulty providing government services at current resource levels, e.g., housing, public health/social services.
- There are current stresses on air quality and resource management due to the complexities of synergistic reactions.
- The limitations of current economic models makes decision making difficult.
- Catastrophic events are costly and of pressing concern.

Priority Group 5

The following concerns/vulnerabilities were each identified by the group but not considered to be among the five most significant by any of the eight government/resource manager stakeholders in this group.

- The impacts of climate change on tourism is of concern.
- The uncertainty about the temporal aspects of climate variability is a concern.

2. How will climate variability and climate change modify the current concerns and stresses of the government and resource managers in the region?

Virtually all the concerns/vulnerabilities identified were felt to be amplified by climate variability and climate change one way or another. It was noted during the discussion that certain concerns, like lack of information and data (Priority Group 2) and limitations of economic models (Priority Group 4) would perhaps become more significant issues within the dynamics of global climate change.

Particular attention was also called to the amplification of the economic impact of complying with environmental regulations (Priority Group 3), from a political perspective. That is, significant legislative attention is currently directed toward the issue of un-funded mandates in the New England and upstate New York region. Debate and challenge is now occurring around the constitutionality of un-funded government mandates as an issue affecting the relationship between levels of government. Can the state, for example, mandate local government to provide specific services in the absence of providing, or allowing for, the provision of sufficient funding with which to discharge the mandate?

Similarly, the impact from climate change, along with ever increasing demands on limited societal resources and dollars, receives attention. Considerable discussion also focused on the added costs from doing nothing and putting off decisions, with the inevitable consequence of even greater costs from later mitigation strategies. A parallel example of this approach to mitigation, would be a community avoiding road maintenance to such an extent that road replacement becomes necessary at far greater costs.

3. What information and data are needed by government and resource managers to fully understand and address climate-related issues?

Although mindful of the request from workshop organizers to consider this topic, the group did not (due to time constraints) include specific discussion time focused on this topic (previous discussion did however define the value of isolating such data and information needs in relation to mitigation strategies as well as to the underlying science).

Never-the-less, the concerns/vulnerabilities identified by the group do include specific reference to data and information needs. The resource management representatives identified the need to better understand the complexity of and inter-relationships between the natural systems being managed. Discussion occurred which was specific to the need for better information about the synergistic relationships between air quality, landcover, (e.g., forest lands) and water quality.

Local and state government representatives identified data/information needs related via cultural connections. That is, assuming the realities of weather variability as a characteristic of climate change in the Northeast, with consequent synergistic impacts on the inter-relationships of natural resource systems, (e.g., earth systems: air/landcover/water), what impacts can be anticipated on community infrastructure? Within what time frame can such impacts be predicted and with what certainty can such impacts be anticipated on community infrastructure? Data and information about water quality, for example, must be correlated with data and information about water supply systems and sewage treatment facilities (infrastructure) which ultimately must be

coupled with estimations of the mitigation costs related to both.

More information is also needed on the related impacts on housing stocks, transportation systems, communication systems, food reserves, energy generation and distribution and a host of social institutions designed by governmental policymakers and implementors to provide such basic services.

4. What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

The identification of general mitigation strategies was undertaken by this stakeholder group with the preceding concerns/vulnerabilities in view. The strategies identified were thought to be responsive to multiple sets of these concerns and so they are not presented in direct one-to-one correspondence.

Time constraints prevented the group from considering mitigation strategy priorities. It does seem, however, that given the uncertainty around the temporal aspects of climate change rates and evidence from polar ice cores of extremely rapid (2-4 years) paleo-climate change (on a global scale), that short-term coping strategies should be considered along with longer-term solutions. It was not possible in fact to develop a truly comprehensive response to the need for mitigation strategies. The strategies offered and the comments made about the design characteristics of such strategies will hopefully prove useful as a starting point.

It was suggested in this discussion that certain operational efficiencies should be strongly considered in the design of mitigation strategies, including the use of and testing of pilot programs, purposefully designed to provide mechanisms which extend to local levels of government, including but not necessarily limited to towns. Discussion also included the identified need for monitoring and evaluating the results of such efforts with deliberate intent to modify the design of such programs based on such monitoring and evaluation, (including cost-effectiveness considerations). Participant awareness of telecommunication capability and interest in such programs in the Cayuga County area of upstate New York was also noted during the discussion.

As the discussion progressed it became increasingly clear that certain cultural characteristics of the upstate New York/New England region will impact mitigation potential. On one hand, the observation can be made that it has been possible within the region to absorb a high population concentration and increase woodland landcover at the same time (woodland landcover serving as a natural means to sequester carbon). Never-theless, institutional governance mechanisms are highly localized in this region and thus great in number. Mitigation strategies, particularly with landuse implications, must take this institutional complexity and diversity into account.

Summary Of Coping And Mitigation Strategies

The following list, which is not prioritized, resulted from group consideration of this question:

- Design and develop an educational network, across agency/group lines to educate the general public and particular audiences, e.g., legislators, foresters, industry, and meteorologists.
- Develop/use alternative and remarkable new technologies to reduce carbon dioxide emissions, i.e.,, hydro-electric power generation, non-fossil fuel power sources, alternative fuel vehicles, fusion, etc.
- Develop action plans and strategies for addressing climate change by engaging stakeholders on their turf as well as bringing them together for focus purposes.
- Promote increased energy efficiency everywhere, and in all forms.
- Improve the ability of the forest ecosystems to sequester (retain) carbon through forest management practices that are designed to retain maximum amounts of carbon (including the use of wood).
- Build upon present, related and cost-efficient programs. Promoting those with anticipated mutual gains or win/win strategies.

GOVERNMENT AND RESOURCE MANAGEMENT APPENDIX I

Initial Concerns From The First Breakout Session

(not prioritized, collapsed or grouped)

1. Impacts of sea-level rise
2. Education of the public
3. Impacts on future water supply and management (precipitation and runoff/demands fluctuations)
4. Budgetary impacts on federal and state agencies due to EPA regulations which are often based on less than certain data
5. Whether we have global climate change or not, there are expected to be increased demands on limited resources
6. Effect on progress already made on air quality improvements
7. Forest health and productivity as it relates to economy and quality of life
8. Complexity and average ability to relate
9. How to integrate even more complexity in resource management
10. Impacts of tourism and ski industry
11. How to pull all stakeholders together to see issue and come to agreement on actions to be taken
12. Impacts on water quality issues: ground and surface water
13. Need in New Hampshire to improve state-of-the-art meteorology
14. Impacts of forest wildlife habitat through fragmentation
15. Impacts of doing nothing and putting off approaches
16. How do we make average person aware of current issues
17. Uncertainty around temporal aspects or timing of impacts
18. The lack of sufficient funding for monitoring
19. Need to understand the limitations of various economic models and predicting impacts levels
20. Providing services: that is the impacts on infrastructure
21. Impacts on resources already at unsustainable levels
22. Synergistic effects of pollutants on people
23. local nature of landuse controls in New England
24. Increased frequency of extreme climate events and their costs
25. Complexity of dealing with landowner claims against the state that are weather driven as related to landuse patterns
26. Need to influence individual and corporate behavior patterns
27. Impacts on transportation systems
28. Impacts on housing: where and what kind of housing
29. Public health issues, home health care, and food supplies
30. Impacts on social services

Human Health Sector Report

David Bartlett and Amy Langston*

INTRODUCTION

Human health concerns related to climate change were discussed by seven individuals representing a mix of backgrounds, including: academic environmental research (4), environmental health research (1), state air quality authority (1), and federal Earth-system science management (1). A medical/environmental health researcher (Paul Epstein of Harvard University) provided a position paper to the workshop as a basic resource, and he will be part of the review of this report.

The group was struck by the current lack of substantial information and attention to health effects of climate change. The workshop position paper provided an excellent introduction to several issues of general concern, such as the increased incidence of injuries from extreme weather, etc., as well as those stresses which are more specific to the Northeast (Eastern equine encephalitis, Lyme disease, harmful marine algal blooms, etc.).

It was noted that, in general, the Northeast region may be particularly vulnerable to climate change because high latitudes are expected to see the largest relative changes in temperature, and are the locus of the greatest loss of stratospheric ozone and resultant increase in solar UVB radiation. In addition, current atmospheric transport tends to converge on the Northeast, delivering atmospheric air masses and their constituent contaminants from a number of urbanized sites throughout North America.

Following the format of the "four questions," discussions identified a number of potential direct and indirect effects of climate change on human health. The issues/effects were quite parallel with those presented in the *IPCC Second Assessment: Climate Change* (1995).

Potential direct effects include higher maximum temperatures and more frequent and longer duration high temperature events, creating unprecedented heat stress on vulnerable populations. Such problems may be exacerbated in a region unaccustomed to prolonged high temperatures.

Increased incidence of severe storms would affect large numbers of people, particularly in the Northeast with its dense population concentrated in coastal areas. If efforts to reverse the loss of stratospheric ozone through control of CFCs do not succeed, increased levels of UVB radiation have the potential to cause diseases of the skin and eyes.

Continued reductions in air and water quality are a major potential source of human health problems. Among the issues of particular concern in the Northeast is enhancement of tropospheric ozone, which could result from a number of factors either alone or in combination. These include:

- higher air temperatures,
- increased burdens of ozone or its precursors in remote source regions (e.g., the industrial Midwest and mid-Atlantic), and
- increased local production due to changing energy production requirements or automobile use.

These changes have the potential to reduce impacts as well, through alteration of the current converging atmospheric dynamics, or increases in cloud cover during summer. For similar reasons, changes in particulate material burdens may impact health in the region under some scenarios of climate change.

Water quality issues of particular concern are excess nitrogen and sulfur compounds in surface and ground waters, resulting from:

- continued atmospheric deposition on Northeastern soils which may be saturated with respect to these materials, and
- direct terrestrial application in the form of fertilizers or excessive animal waste.

Nutrient loading into water supplies, whether from terrestrial runoff or direct input, increases the incidence of harmful algal blooms (HABs) and possibly water-borne infectious diseases such as cholera.

Again, these stresses may be either exacerbated or mitigated by changes in climate and atmospheric

* See Appendix V for authors' affiliations and addresses.

dynamics—both locally and in remote locations. Increased incidence of flooding, either coastal or inland, has the potential to adversely affect sanitation of drinking water supplies by increasing the levels of pathogens such as *cryptosporidium* and *giardia*.

There is some evidence that the incidence of harmful algal blooms is increasing as, for example, in the first observations of the Canadian red tide species *Alexandrium tamarense* moving into New England waters in 1972. The incidence and distribution of a variety of harmful blooms, and their effect on humans, is the subject of ongoing research in New England and elsewhere along the Atlantic Coast.

Least understood, but potentially of great importance, are health concerns related to diseases which are mediated by living vectors or hosts. Microbial, insect, and other life forms are sensitive to local climate, and even subtle changes may have a major impact on the incidence of particular diseases. An example is Eastern equine encephalitis, which is carried by mosquitoes whose populations are enhanced by mild winters and wet springs/summers. Other vectors such as ticks, which carry *Erlichiosis*, Lyme disease, *Babesiosis*, and Powatten disease, are also amplified by mild winters and wetter conditions. A host of other diseases may be impacted by climate change, either directly or through changes in the number and distribution of vectors/hosts. In many cases the magnitude, or even direction, of change induced by particular climate effects are unknown as, for example, Lyme disease, which has several insect and animal hosts each of which will respond differently to climate.

Potential direct effects of climate change include loss of life from flood, drought, and heat waves. A basic indicator of climate change is an increased incidence of extreme weather patterns, thus floods should become more common, leading to increased stress, injury, and death. Droughts also negatively affect water quality and food supplies. Heat waves and higher minimum night-time temperatures (TMINS), can increase mortality among the old and poor, especially in inner cities.

It is clear that the health effects of climate change are both uncertain, and potentially quite large. Studies which combine expertise in climate, environmental science, and biomedical disciplines have begun quite recently, and are restricted to a few specific issues. This is an area which calls for a major enhancement of current research, including the recruitment of expertise and accumulations of data from fields which have not previously been engaged in climate change research.

One theme of the Regional Climate Change Impacts Workshops is the engagement of stakeholders from outside the academic and government research communities in both dialogue and planning for the future. Everyone has a stake in potential health effects of climate change, and it is time that careful and focused research is supported in this area. Health concerns, if found to be relevant and pervasive, have the potential to motivate—as no other factor can—the general interest and commitment to mitigation strategies.

SIGNIFICANT FINDINGS

- Direct health effects of increased temperature can be expected, and may be exacerbated in the Northeast by the relative lack of experience and adaptive mechanisms, which are present in areas more accustomed to high temperature episodes.
- Climate effects are linked with other environmental health concerns, such as contamination of air and water, by a variety of mechanisms: e.g., higher temperatures increasing the demand for emission-producing power generation, or changes in precipitation affecting pollutant or pathogen loads in surface waters.
- There is evidence of increasing incidence of harmful algal blooms in Northeastern coastal areas, and interactions of blooms with climate factors require further study.
- Very complex relationships exist between climate and vector-borne disease, and factors which may increase or reduce the activity of particular vectors and diseases require extensive study.
- The magnitude of some climate changes such as increased temperature, as well as effects of depleted stratospheric ozone on UV radiation, are likely to be greater at the relatively high latitudes of the Northeast than in some other areas of the country.

- Much more effort is required to assemble the multiple, cross-disciplinary research teams and data sets required to study the health effects of climate change.

THE FOUR QUESTIONS ADDRESSED

1. What are the current concerns and stresses facing regional stakeholders in the human health sector?

Air quality

- Respiratory disorders
- Asthma
- Allergies

Water quality

- Toxins in water
- Gastrointestinal disorders
- Endocrine disruption?
- Immune suppression?

Diseases/Pathogens

- Eastern equine encephalitis
- Lyme disease
- Water-borne diseases (*cryptosporidium, giardia*)
- Food-borne (*E. coli*)

Harmful Algal Blooms

- Paralytic shellfish poisoning
- Diarrhetic shellfish poisoning
- Amnesic shellfish poisoning
- Vibrio infections

2. How will climate variability and climate change modify the current concerns and stresses related to human health in the region?

Direct Effects of Climate Change

- Increased UV Radiation can lead to skin cancer, cataracts, immune suppression.
- Higher temperatures for longer duration (e.g., heat waves) can lead to heat stress and mortality.
- Extreme weather events (e.g., floods) can lead to direct injury and death.
- Psychological disorders can increase due to stress from all of the above.

Indirect Effects of Climate Change

- Air quality is affected by increases in ozone and particulate matter due to increasing temperatures, changing weather patterns, and/or changing transport from remote sources will increase respiratory diseases and disorders such as asthma and allergies.
- Changes in seasonal patterns, precipitation, temperature, and species distribution and abundance might increase respiratory problems and allergies due to mold spores and pollen.
- Water quality is likely to degrade due to increases in precipitation and changes in atmospheric chemistry that may increase acid (SO_4) and nutrient (NO_x) deposition onto soils and water. Extreme weather events, such as floods, often destroy infrastructure, leading to contamination of water supplies and heighten levels of pathogens (for example, *cryptosporidium, giardia, E. coli*) in recreational waters (lakes and oceans). Higher fecal coliform levels in bays and estuaries can also contaminate shellfish, leading to shellfish bed closings to prevent transmission of Hepatitis A, Shigella, Norwalk-like virus, gastroenteritis, *Vibrio parahaemolyticus*, and non-O1 Cholera.
- Changes in species distribution and abundance can lead to increased use of pesticides, herbicides and/or fertilizer, which wash into groundwater and into rivers and estuaries. Many of these chemicals are directly harmful to human and animal health, as well as acting as hormone mimickers that can cause endocrine disruption (leading to developmental difficulties, immune suppression, and reproductive cancers and anomalies).
- Vector-borne diseases such as Eastern equine encephalitis and Lyme disease are enhanced under warmer winters and wetter weather.
- Increasing nutrient deposition from air and water, increasing sea surface temperatures, changing seasonal and climatic patterns can increase harmful algal blooms and algal toxicity, increasing the likelihood of paralytic shellfish poisoning, diarrhetic shellfish poisoning, and amnesic shellfish poisoning.
- Changing climate patterns can encourage the movement/survival of other pathogens and disease vectors, leading to diseases new to the region (e.g., cholera, malaria, hantavirus).

3. What information and data are needed by human health researchers and care providers to fully understand and address climate-related issues?

- Information on environmental processes (issues and trends)
- Historical epidemiological data (baseline information)[3]
- On-going epidemiological data (research)

4. What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

- There is a need to increase the monitoring of:
  - ⇒ air quality
  - ⇒ water quality
  - ⇒ UVB levels
  - ⇒ vector-borne disease
  - ⇒ water-borne disease
  - ⇒ harmful algal blooms
- Document any links shown by the data between the above issues and climate change.
- Human health issues, properly documented, can motivate commitment and action to mitigation strategies by individuals, industry, and government.[4]

[3] There may be an issue of restricted data availability that must be addressed at the Federal level.

[4] It was unclear how or if we should include human-caused changes in landscape, etc. (i.e., development) as an agent or process affecting human health concerns. It is clearly relevant, but is it a legitimate element of climate or global change?

Information Transfer and Public Awareness Sector Report

Eleanor Abrams, Lynne M. Carter, and Denise Hart*

INTRODUCTION

Information Transfer was the title of our breakout group, however, those of us sharing a concern for increasing the public awareness of global change issues know that we cannot simply transfer information from the heads of scientists into the minds of the public. People incorporate new knowledge based upon their prior knowledge, the way they experienced the new incoming knowledge (e.g., media, hands-on), and how relevant the new knowledge is to the them. Therefore, information transfer of global change issues to individuals incorporates *how* people may learn information and *what they do* with the information once they have it.

With this broad ranging concept in mind, increasing the understanding and awareness of the public about global change issues encompasses many audiences: people differing in age, ethnic background, religion, gender, interest, and capabilities. It also incorporates a variety of venues for facilitating information transfer such as television, newspapers, radio, workshops, community groups, informal education (Cooperative Extension), K-12 education, and higher education.

Because of the difficulties in communicating complex scientific information to so many constituencies in so many forms, the group reached a consensus acknowledging there is no one way to educate the public, but many methods and procedures. In order to avoid duplication of effort, those who engage in information transfer need to communicate and educate the public in a coordinated effort.

The Information Transfer and Public Awareness group included a broad representation of individuals from education (high school and university), adult outreach and education (Cooperative Extension and Union of Concerned Scientists), climate change researchers from the scientific community interested in how information is transferred and incorporated into decision-making, state (Maine DEP) and federal (New England EPA) government representatives, and two media liaisons (one local and one federal).

The members of the Information Transfer group identified a series of problems and opportunities related to informing and educating the wide range of populations important to reach with global environmental change information. Many of these significant findings are not only specific to global environmental change issues, but are important to a public capable of coping with evolving environmental concerns.

The group identified concerns/problems which were summarized into four strands:

- the advancement of scientific literacy of the public,
- the need to identify key concepts,
- the lack of information availability, and
- the increasing necessity for communication between the various stakeholders.

Our group recognized the need for a long-term educational strategy to improve the scientific literacy of the public. Therefore, it is critical that key concepts, which comprise the most important facets of the global environmental change issues, be identified. From these concepts, we need to develop local, regional, and global examples that will help people to define global change issues in a manner relevant to their lives. A personal connection to global environmental change issues is a crucial step leading to the ownership of the problem and resulting behavior changes.

A variety of outreach and teaching mechanisms need to be employed in order to reach the diversity of audiences impacted by global change. We need to create new, and utilize existing, informational systems. An example of existing informational systems is the Environmental Protection Agency's world wide web pages on climate change. There are many such governmental agencies, non-profit organizations, and universities that already have existing information; however, accessibility is crucial. Reputable and knowledgeable clearinghouses are needed to find and organize all the diverse sources of information.

* See Appendix V for authors' affiliations and addresses.

Scientists, especially those who are educated to facilitate communication, need to interact more with teachers, the public, and the media. Educators must turn their energies to developing and implementing more authentic learning experiences for students. Outreach specialists need to inform small businesses, farms, and other public sectors of the local and regional impact of global climate change. Finally, the media need to increase their coverage of climate change issues and develop stories that accurately describe the complexity of this topic.

In preparing an information and education effort to address climate change and other global environmental issues, it is crucial to recognize that these issues are long-term, interdisciplinary, and must be understood by a wide range of audiences. As a result, there are no quick, simple, or easy options that can be implemented. The solution requires a long-term investment for the development of a public capable of recognizing and dealing with the complex issues of global environmental change.

SIGNIFICANT FINDINGS

The Information Transfer group recognized certain information dissemination issues that relate to global environmental issues in general and global climate change specifically. The group members also developed a number of recommendations thought of as "actions and opportunities" which are listed at the end of this report.

- Scientists are professionally discouraged from communicating with the general public. This creates an individual hesitancy with regards to sharing data and interpretative information outside of accepted professional channels if one's credibility in the scientific community is to be maintained. We need to create changes in the reward structure for researchers, academics, and scientists.
- People with good information are not always good communicators. Communication training may be a very helpful option. Professionals with a background in science trained in communication and/or educational techniques could bridge the gap between the scientists, the general public and businesses. Examples could include extension educators and specialists, as well as other outreach specialists in governmental and non-governmental organizations.
- The lack of understanding among the public may also be related to the levels of uncertainty reflected in the data on climate change compared to the levels of risk change involves.
- The media needs to be encouraged to report on climate change issues with care, foregoing the sensational and simplistic for proven scientific fact and complexity. Topics of global change, being long-term, are often not a good match with the media requirements for new/late-breaking news, personal interest stories, or dramatic photo opportunities. By the time the drama of a forest die-back occurs, it is too late.
- Doom and gloom sells media stories, however, it is crucially important to provide hopeful, good-news stories that demonstrate appropriate actions to avoid feelings despair and promoting lack of action by the public.
- The classroom educator is already overwhelmed with the amount of material that must be learned by students during the school year. To learn and teach global change issues may not be a priority as a separate subject. However, there are many opportunities in several subject areas such as science and social studies to integrate global change concepts and activities.
- Interest groups and businesses affected by pollution controls frequently implement misinformation campaigns through media editorial campaigns and advertising that further muddy the facts with innuendo and create major obstacles to changing the status quo.
- In many of our discussions we assumed the public *wants* to learn about these global environmental issues; however, it is unclear what percentage of the public is truly interested in learning about these issues. How can we encourage additional interest? How can we support reaching those interested individuals and groups?

THE FOUR QUESTIONS ADDRESSED

The questions given to the various breakout sectors to focus the discussion during the breakout sessions were changed by our group to better address issues of information transfer. Our job is to be able to assimilate information about global change issues and to help others understand this information in a way that informs and empowers them as decision-makers. Information transfer professionals need to know the concerns, problems, and current knowledge held by various stakeholders because of the frequent role that they play as intermediaries between the groups. Therefore, the four guiding questions were transformed.

The Four Original Questions and Transformed Questions

- What are the current concerns and stresses facing regional stakeholders in the Information Transfer sector?

  What are the stresses that impact the information transfer of global change issues?

- How will climate variability and climate change modify the current concerns and stresses of this sector in the region?

  Who is the public we are trying to reach?

- What information and data are needed by information transfer experts to fully understand and address climate-related issues?

  What are some ways to support outreach to the public?

- What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

  Where are the information gaps? What do we need to do better?

From the breakout session notes, themes emerged from the overlap in our rich discussions. Specific suggestions were organized under the description of the four strands, as detailed below.

Four Strands to Global Climate Change Education and Information Transfer

1. Science Literacy

Any long-term education strategy undertaken must include improving science literacy. Science literacy is defined as being made up of at least five components:

1) a vocabulary that includes some basic scientific and technical terms and concepts;
2) an understanding of the scientific method including, for example: the possibilities and limits of scientific investigation;
3) developing an understanding of how scientific consensus is reached;
4) an understanding of the role of uncertainty in science, and options for responding to new scientific claims;
5) the impacts of science and technology on society (what does it mean for me?).

The lack of science literacy in the general public contributes to dismissing the seriousness of global environmental issues, such as global climate change and the likely impacts, for a number of reasons. Scientific literacy can include the need to:

- understand that global change science is a developing science and that the present state of knowledge is changing;
- clarify apparent past scientific non-consensus about global climate change and the confusion that period subsequently engendered;
- understand the reasons for the apparent imprecision in the range of climate model projections or likely impacts for specific regions;
- encourage scientists, who usually do not, and often will not, to make policy even though they are often considered more credible than policy makers;
- understand risk assessment and resulting policy choices.

2. Key Concepts

The confusion experienced by many members of the public when confronted with information related to global environmental issues is common. Part of the confusion relates to the lack of scientific literacy, while another part can be understood due to the complexity of the issue.

The *key concepts,* topics which explain the most important facets of global environmental change issues, need to be developed by experts and disseminated to the many audiences impacted by climate change. Those key concepts need to include brief descriptions, examples, and a glossary including a definition of terms that would clarify the variety of phrases currently in use. For example, global warming, climate change, and climate or natural variability are different concepts that are often (and incorrectly) used interchangeably. All those terms have different meanings, but the public is not aware of the nuances of each term. An effort to cross those language barriers would assist useful interactions related to global environmental issues and the policy options and personal actions undertaken.

Another level of key concept development would be applied to regional and local issues and examples. Personal connections to global environmental change issues are crucial to creating a sense of ownership of the problem and a willingness to undertake the personal responsibility for change.

Some examples of the key concepts in action include:

- Develop a multidisciplinary approach to science learning that addresses the complexity of the interconnections and global nature of the issues under consideration.
- Assist teachers with programs that link required curricula and standards to key concepts about global change issues.
- Connect global change issues to standardized, statewide learning requirements and assessments such as state science assessments (i.e., New Hampshire).
- Encourage the local media to provide information related to the key concepts in several different forms: short television "Did you know" spots, radio announcements, articles in sectorial journals, and inserts in newspapers.

3. Information Availability

The distributed and fragmented nature of the global environmental change information and the resources available, make it extremely difficult for individuals to find pertinent information. One centralized, regional information source would help to solve that problem. Other actions to facilitate information transfer include:

- Address the lack of resources providing information and education to a wide range of audiences.
- Cull, distribute, show how and when to use the fragmented information and resources available to make them available for a variety of user/interest groups.
- Research region-specific examples to explain and encourage adoption of a sense of responsibility. Without local and regional examples it is difficult for people to see the relevance of the issue to themselves.
- Develop an empirical mechanism to see if the information and resources that are being distributed are being used.
- Provide workshop and educational outreach opportunities for the media on climate change issues. A goal of countering incorrect information and de-emphasizing the often-used sensational highlights should be reached. We need to clarify tested observations and understandings to the media by reducing the complexity of climate change science for them.
- Develop relationships with media professionals on local, regional, and national levels to provide the latest emerging data and maintain the media interest for global change issues, which by nature require a long-term focus. Find ways to personalize and localized science stories for media coverage.
- Focus on human actions that positively affect the environment. Doom and gloom sells in the media, however, it is crucially important to provide hope, good-news stories, and appropriate actions to avoid feelings of despair and therefore lack of action by the public.

4. Increased Communications

There are any number of important considerations related to communication efforts. One is the issue of knowledge, accuracy, and credibility. In environmental issues, scientists often have first-hand information and are perceived as more knowledgeable and credible sources than industry, government, or media representatives. Most scientists, however, do not consider direct interaction with the various publics as part of their profession. The Information Transfer working group recognizes this dilemma and suggests the need to widen the job of scientists to include communication. Because of their perceived credibility they might also suggest appropriate actions for individuals and groups to implement. Specific suggestions include:

- Reward scientists for communicating and educating the public.
- Train people with good information to be better communicators and educators to bridge the gap between scientists and the public.
- The transfer of information requires meeting person-to-person with researchers and others outreach specialists.
- Try to find strategies to get non-interested teachers and community members involved.
- Suggest appropriate actions from credible sources for the public to implement to assist in the global change situation.
- Consider using famous personalities as a way to reach various audiences. Suggestions for well-known spokesperson could include: C. Everett Koop, Patrick Stewart, Bill Nye and astronauts such as Sally Ride.

- Combat the misinformation campaigns that are being waged by the potentially affected sectors with well-time, interesting press releases that illustrate the refuting facts.

Recommended Actions and Opportunities

The issues surrounding global environmental change provide windows of opportunity for a variety of actions. Those suggested by the group are listed below, along with a series of crucially important recommended actions needed to support information transfer and education efforts.

- Define "key concepts" that define the most important aspects of significant global environmental change issues to be communicated.
- Develop local, regional, and global examples for use in information transfer activities.
- Recognize science literacy as a major component of a long-term education strategy for global environment issues.
- Encourage an understanding of linkages between global environmental change issues and other stressors on the environment and on the social systems in our communities.
- Recognize that a personal connection to global environmental change issues is crucial to ownership of the problem and resulting behavior changes.
- Understand that these issues are long-term and require a long-term investment to develop a capable public interested in addressing these issues.
- Recognize the variety of audiences that need to be reached and the variety of information sharing mechanisms that need to be employed.
- Utilize existing, and create new and needed, information systems.
- Incorporate media relations as a crucial part of the information transfer process.
- Encourage scientists to interact more with the teachers, the public, and the media.
- Provide opportunities for experiential learning for students and families through programs such as GAIA and GLOBE that encourage people to become scientists in the realm of global change, and students to become involved in the science.
- Train facilitators in communication skills and utilize governmental outreach agents to work with the general public and businesses.
- Reorganize the way science is taught in teacher education programs and undergraduate higher education to be built around an experiential-experimental model instead of lecture-didactic method.
- Create specific learning modules or individual educational activities that teachers can incorporate into existing curriculum.

Natural Resources Sector Report

David Wolfe, Lloyd C. Irland, and Ivan Fernandez*

INTRODUCTION

The Natural Resources working group consisted of 25 participants. The specific number in attendance varied slightly among the three breakout sessions. About half of the participants represented government or non-governmental organizations with interests in natural resources; most of the others were university faculty and staff with expertise in natural resources or agriculture, some of whom have had considerable experience working with related industries. One of the co-chairs and co-authors of this report works as a consultant with the timber industry in New England.

The four questions related to climate change that we were asked to address were the main focal point of discussion in the breakout sessions. We found it necessary to begin by addressing concerns of major industry components (forestry, agriculture, commercial fishing) separately, and then sought common issues of concern and cross-cutting themes. The "Significant Findings" emerged from these discussions. Early drafts of the report were circulated by electronic mail to the participants for their feedback

One point that was raised early on in discussion was that the value of natural resource-based industries, such as timber, agriculture and commercial fishing, to the New England economy (see Natural Resources-Appendix I) is often underestimated, even by residents of the region. A negative climate change impact on New England natural resources could have serious economic consequences. One approach to raising the awareness of this stakeholder group and the general public to climate change issues would be to develop better information on the potential economic impacts specific to key industries and regions. We identified several high priority research and education programs to address this issue.

In addition to the economic value of these natural resource-based industries, the scenic beauty of the region's landscape adds to the quality of life of the residents, and this aesthetic feature itself has a real economic value. One example is when the proximity of forests, waterways, and peaceful rural areas to our urban centers lures professionals and new businesses to establish here. Climate change may alter the landscape, seasonal vegetation patterns, and species composition of wildlife habitats in undesirable ways.

Yet, ecological parameters such as plant growth and vigor are influenced by several abiotic, biotic and human factors simultaneously, and the complexity of these influences is extreme. What this means is that future changes in climate need to be specified in an extraordinary degree of detail to support sound predictions on the impacts to agriculture, forestry and natural systems. A prediction stating that total growing season precipitation will increase by an inch or that season average temperature will rise by so many degrees does not provide enough information to assess impacts to this sector.

Overall, there was a concern that the interaction of multiple stressors resulting from the rise in greenhouse gases and climate change will lead to a destabilization of both managed and natural ecosystems during transition and adaptation to a changing environment. It is during this period of transition when the greatest ecological disruption is likely to occur and have significant economic and political consequences for our region.

SIGNIFICANT FINDINGS

- The timber, agriculture, recreation, tourism, and commercial fishing industries are important components of the economy (see NR-Appendix) and are rich natural resources of the New England region that will be particularly sensitive to changes in climate.
- The supply of clean, safe drinking water for urban population centers within New England is directly dependent on precipitation patterns, streamflow amounts, and the health of watershed ecosystems, all of which could be affected adversely by anticipated changes in the chemical and physical climate.

* See Appendix V for authors' affiliations and addresses.

- The New England region has a unique geography and landuse history that leads to a fragmentation of natural and managed ecosystems. This will make it more difficult for some species to respond to climate change. It also leads to a diversity of those industries dependent on natural resources. Industry diversity can weaken our competitive position when the size of any one component of the industry is not large enough to compete effectively and support an adequate infrastructure. Lack of critical thresholds of infrastructure will be a disadvantage during transition to new climate conditions. On the positive side, a diverse industry will have more options for adaptation to climate change.
- Shifts in species composition, invasion by exotic species, and habitat loss are likely to be exacerbated by climate change, even though productivity of some managed and natural ecosystems may, in the long-term, be unaffected or increase with warmer temperatures and increased CO_2 levels (assuming adequate precipitation during the growing season).
- Atmospheric deposition increases ecosystem productivity on some sites, but could exacerbate other environmental stressors (e.g., by increasing water demand), and lead to nitrogen saturation of the landscape.
- Agricultural productivity of the New England region may survive a climate change (with adequate research and extension support), but there will be significant economic and environmental costs associated with shifts to new varieties and new crops, investment in new infrastructure (such as development of new water supplies for irrigation), and increased pesticide and herbicide use to control more severe insect and weed pressure.
- For some farm families adaptation will not be possible because of lack of capital, lack of available land or other resources, lack of markets for new crops, or environmental constraints. There will be losers as well as winners within the farming community, with some possibility that the New England region will have a disproportionate share of the former.
- Climate change will likely result in more severe infestations of some pests and pathogens in agriculture and forestry, and invasion of undesirable vegetation.
- Regulations and availability of labeled pesticides may constrain the ability of commercial producers to cope with this consequence of climate change.
- It will become more challenging to develop "low input, sustainable" production practices with increased pest and weed pressure. Conflicts between producers and the general public regarding acceptable levels of chemical loading into the environment will undoubtedly be exacerbated by climate change.
- Landuse conflicts are likely to become a major issue with climate change. Pressure for shifts in agricultural zones are likely, and in some cases this may involve decisions regarding migration of agriculture into natural ecosystems. It is possible that there may be pressure to expand agricultural acreage overall in the New England area if agriculture in other regions of the U.S. (e.g., southern plains) is more negatively affected by climate change than our region.
- Despite the fact that natural resource-based industries will be particularly sensitive to climate change, this issue is not currently well understood or appreciated by this stakeholder group. One solution to this is to raise the priority of research and education programs focused on potential impacts at the regional level. Research priorities include the following suggestions.
    1. Improve climate models and their interpretation to indicate likely temperature and precipitation variability scenarios for specific regions within New England. This should include initiatives and supporting research to determine the interactive consequences of these changes in the physical climate with chemical climate factors such as nitrogen deposition or tropospheric ozone. Consider using expert judgement approaches in addition to computer modeling.
    2. Improve our understanding of the impacts of climate change on plant and animal species important to the region. For example, most agricultural research on crop response to climate change and crop modeling efforts have focused on the major world food trade grain crops such as soybeans, wheat and rice. These results are not particularly relevant to assessing impacts on agriculture in our region, where cool season vegetable crops, apples, grapes, and milk production by dairy cattle dominate the economy.
    3. Identify environmental thresholds for climate change impacts on plant and

animal species and ecosystem function within the New England context.

4. Put dollar values (or other quantitative or semi-quantitative values) on and animal species and ecosystem function within the New England context.
5. Put dollar values (or other quantitative or semi-quantitative values) on impacts to natural and managed ecosystems for our region for various climate scenarios (e.g., loss of revenue to state parks, or economic losses to specific components of the agriculture industry such as dairy, cabbage, or apple). This will be essential to increasing the interest of the New England population in the climate change issue.

We identified several research priorities which represent a "win-win" coping strategy in that they would be of immediate benefit as well as help in the long-term adaptation to climate change. Example win-win strategies include:

1. improving our understanding of the response of crop species important to our region (including commercial timber tree species) to biotic and abiotic stresses, and developing crop models for them, would be of great value immediately in integrated pest management (IPM) and other management programs, as well as be useful in projecting climate change impacts;
2. strengthening the diversity of the forest products industry and developing a more flexible marketing strategy less reliant on specific species would be of benefit in the present as well as within the context of climate change;
3. improving our techniques for preserving and improving soil quality in managed forests and farm land will lead to more sustainable production systems regardless of climate change scenario, and will tend to maximize carbon sequestration in the future.

THE FOUR QUESTIONS ADDRESSED

1. What are the current concerns and stresses facing regional stakeholders in the natural resources sector?

There are serious near-term problems, stresses, and concerns that completely occupy the attention of natural resource-based industries in the region. Climate change, because of the long-term nature of the problem, uncertainty and skepticism regarding climate predictions, and lack of information, is not currently "on the radar screens" of most stakeholders in this group. In Question 3 we identify some research, information, and education needs which, if met, would stimulate more interest and concern in the climate change issue.

Below are the current issues of concern identified for each component of the natural resources sector.

Forests

- Plant and animal species composition change (e.g., habitat change, crop tree change, invasion by exotic species)
- Atmospheric deposition (e.g., acid deposition, nitrogen deposition, ozone)
- Public policy/regulation

Others issues included: water quality; water supply; insect pests and pathogens; loss of biodiversity; introduction of new invasive plant species and exotics; forest sustainable productivity; reducing production in this region stresses other regions; rising deer (browser) populations; rising beaver populations; New England forests are old, aging and therefore more sensitive to adverse climate; renewed and increased clear-cutting because forests are aging; non-point source pollution; negative impact of poorly managed recreational use of natural ecosystems; erosion; and weak competitive position of timber industry because of high input costs relative to some other regions.

Agriculture

- Control of insect pests, diseases, and weeds
- Policy/regulation (especially regarding environmental impact of farming such as use of pesticides)
- Soil quality (e.g., loss of organic matter, compaction) and sustainable production
- In some regions of New England, the size of the agriculture industry is not sufficient to support infrastructure such as chemical suppliers, land banks, trucking services, marketing and promotion, etc.

Other issues included: regional competition (e.g., Canadian farmers); loss of good available farm land; loss of small family farms in some areas; weak competitive position of some food processing industries because of tax structure, costs of production; water availability; ozone damage; utility costs; and consumer concerns regarding environmental impact of farming, food safety, use of biotechnology (e.g., animal hormones, genetically engineered plants).

Fisheries/Aquatic Ecosystems

- Overfishing
- Loss of habitat (e.g., riparian zones; aquaculture displacing natural fisheries)
- Invasion of exotics

Other issues included: maintaining fish migratory passageways; toxic contaminants in fish; government regulations on commercial fishing; loss of estuary water quality; non-point source pollution; toxic algal blooms; anoxia-fish kills; and unemployment in commercial fishing industry.

Wetlands

- Loss of habitat
- Toxic contaminants
- Invasive (exotic) plants

Other issues included: eutrophication; atmospheric deposition; motor boat oil contamination; and septic runoff into waterways.

2. How will climate variability and climate change modify the current concerns and stresses of the natural resources sector in the region?

Climate change will likely amplify many current stresses, but could possibly also partially mitigate others. It could raise the priority level of some stresses, and bring new issues onto the agenda.

Forests

- Stresses associated with changes in plant species composition, loss of habitat and invasion by exotic species are likely to become worse with a rapidly changing climate.
- In many cases atmospheric deposition impacts will be negative and make plants more sensitive to climate change. However, in some cases, such as nitrogen deposition on nitrogen-deficient soils, atmospheric deposition may partially compensate for negative climate change impacts.
- Public policy issues are likely to become more complex with climate change, as there may be increased threat to endangered species, and increased pressure for other land uses (e.g., expansion of agriculture).
- New issues or issues that may rise in priority when considering climate change are:
  + timber productivity,
  + water supply and quality problems,
  + pest and disease problems,
  + possible change in fire frequency, and
  + negative impacts on soil biological factors such as beneficial mycorrhizal fungi associations with plant roots.

Agriculture

- Pest, disease, and weed problems are likely to significantly increase with rising CO_2 and increasing temperatures.
- Policy and regulations could constrain farmer adaptation options.
- Climate change could decrease soil quality (loss of organic matter with warmer temperatures; more soil compaction with wetter springs when farm equipment enters the fields). Climate change and increasing CO_2 could, on the other hand, improve soil quality by increasing productivity, including belowground biomass, and thus increase organic matter and carbon sequestration.
- Issues that could become more severe problems with climate change are:
  + water availability,
  + environmental impacts of agriculture (increased use of pesticides, herbicides, resources, expansion of agriculture into natural ecosystems), and
  + lack of sufficient infrastructure (extension personnel, agricultural support businesses, land suitable for agriculture) for farmer adaptation in some regions of New England and upstate New York, where the agriculture industry has lost critical mass.

The New England agricultural competitive position could become better or worse. For example, if the Canadian climate becomes more suitable for some of our important crops, we could lose market share. On the other hand, we may be more competitive with regions south of us for production of other crop species. This is particularly important since this could lead to a shift in the importance of agriculture in the region, reversing the trend of the past century.

Fisheries/Aquatic Ecosystems

- All of original stressors (overfishing, loss of habitat, invading species) could become worse with a climate change and warmer water temperatures with estuaries being the most vulnerable of the water bodies (marine cold water, interior waterways, estuaries).

3. What information and data are needed by the natural resources sector to fully understand and address climate-related issues?

Addressing our highest priority information and research needs in a region-specific manner, will be essential to engaging this stakeholder group and the general public in climate change issues.

Highest Priority

- Developing more accurate climate and atmospheric deposition predictions (i.e., better models) for our region in particular.
- More research on crops important to our region (e.g., cool season vegetable crops, apples, grapes, impact on dairy) to be used in simulation models for projecting climate change impacts. Most current information on crop response to CO_2 and climate is based on research for major world food crops such as wheat, rice, and soybeans that are not important to our region.
- Develop forest and wetland models focused more particularly to species and conditions of our region.
- Identify environmental thresholds (i.e.,, critical changes in temperature, precipitation, etc.) for climate change impacts on species, communities, habitats within the New England context.

Research dollar values (or other quantitative or semi-quantitative values) for impacts to natural resources and agriculture for our region for various climate scenarios (e.g., loss of revenue to state parks, economic losses to specific components of agricultural industry such as dairy, cabbage, or apple). This will be essential to increasing the interest of the New England population in the climate change issue.

Other Important Needs

- Develop detailed historical landcover types and landuse maps for New England (our region is unique in complex history of landuse patterns).
- More research on interactions of multiple stresses is needed (e.g., acid deposition x climate change; CO_2 x environmental stresses on plants).
- Identify components of natural resources that will be most vulnerable to climate change (e.g., estuaries, endangered species, specific agricultural industries such as dairy).
- Conduct region specific policy analysis.
- Re-examine monitoring efforts and modify them to be more useful for climate change impact assessment (e.g., more long-term, focused on particular ecosystems, scales).
- Quantify the level of uncertainty in our models for public education outreach.
- Better characterize potential for sea-level rise and identify coastal areas which are the most vulnerable.
- Assess the vulnerability of ornamental and horticultural landscape components.

4. What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

Forests

Factors affecting forest adaptation to climate change include: age of forests, fragmentation of habitat, rate of land development for other uses (e.g., urbanization, conversion to agriculture), trends in competing regions, rate of climate change, exposure to extremes, and sustainability. Mitigation strategies to be considered:

- More protection for riparian zones
- Protection of coastal areas
- Encouragement of species diversity and age class diversity
- Encourage business diversity
- Reduce fragmentation
- Create ecosystem reservations
- Manage to maintain stand vigor
- Education of land managers
- Implement sequestration strategies

Agriculture

Factors affecting farmer adaptation include: agriculture research and extension support, available capital for new investments and to buffer costs during transition, land and other resource availability, and rate of climate change. Mitigation strategies include:

- Identify availability of new varieties or crops and cultural practices for climate change scenarios.
- More flexible government policies and regulations that will assist farmers in rapid adaptation are needed.

- Increased emphasis on developing regional markets for local agriculture commodities should be considered.

Fisheries/Aquatic Ecosystems

Aquatic mitigation strategies include, but are not limited to:

- Low flow maintenance
- More fish passages
- Better inventory of standing stock and production
- Improved water quality

Examples of Win-win Strategies

- Strengthen the diversity of the forestry industry and develop a more flexible marketing strategy which is less reliant on specific species. This will be of benefit in the present as well as within the context of climate change.
- Improve our understanding of the response of crop species important to our region to biotic and abiotic stresses, and develop crop models. This will be useful immediately in integrated pest management (IPM) programs which reduce pesticide loads, as well as be useful in projecting climate change impacts.
- Improve our techniques for preserving and improving soil quality in managed forests and farming systems. This will be of benefit to the industry by helping to sustain productivity and may improve carbon sequestration by managed and natural ecosystems in the future.

NATURAL RESOURCES—APPENDIX I

Selected Economic Data for Natural Resources Sector

Table 1. Sales value (in $1000) for selected agricultural crops/enterprises (1992 USDA Census of Agriculture)

State	Grains	Silage	Vegetables	Fruit	Nursery	Dairy	Livestock
CT	872	6350	13313	12138	126581	71079	153863
MA	907	9771	26984	118339	88018	60430	95500
ME	4525	9683	12737	49888	20832	89875	214329
NH	16	5591	5249	10399	24069	46861	68346
NY	116924	69261	180861	179251	218241	1428850	1812710
RI	—-	1010	2461	2322	19501	5024	12082
VT	635	11360	4080	9515	9461	328717	37977

Table 2. Selected forest statistics for ME, NH, NY, and VT combined (Northeast Forest Alliance (NEFA) 1990 Report)

Forest-based recreation/tourism jobs: 40,580
Forest-based manufacturing jobs: 86,050
[NOTE: this represents 12%, 11%, 7% and 2% of total employment for ME, VT, NH,and NY, respectively]
Forest-based recreation/tourism payroll dollars: $1.241 billion
Forest-based manufacturing payroll dollars: $2.071 billion
Total forested area for NEFA region: 45.982 million acres
Total timberland area for NEFA region: 42.200 million acres

	$ per forested acre			
	NY	ME	NH	VT
Manufacturing shipments	416	260	302	166
Gross state product	129	90	116	67
Manufacturing payroll	56	34	41	21
Delivered roundwood	24	26	19	21
Tourism spending	180	97	241	213

Recreation and Tourism Sector Report

Gary Lauten and Allan Auclair*

INTRODUCTION

The Recreation/Tourism working group consisted of nine participants during the three sessions—six representatives from various sectors of the industry, two representatives from private environmental organizations, and one representative from a government agency. Drafts of this report have been reviewed and modified by members of the group to reflect all opinions presented.

During the three breakout sessions the group discussed and formulated answers to the four questions that we were asked to address. We began with a shotgun approach in identifying current stresses on the industry and then consolidated these stresses into a manageable list that would then direct our discussions of the other three questions.

We also developed an extensive matrix to show how each stress might affect each individual recreational and tourism activity in the face of climate change (the group used a general warming trend as an entering argument). This was an excellent exercise, since it soon became evident that even though activities were numerous, many were so interrelated that only a few groupings were necessary. We abandoned the matrix once this was realized. The activities fell into two basic categories—warm weather and cold weather activities.

It also became quite evident to us that the cold weather stakeholders had the most to lose in our warming scenario, although freshwater fishing and indirect revenues from fall foliage viewers were certainly in jeopardy as well. Ultimately, we felt that although certain coping strategies could soften the impact of climate change, mitigation was the only long-term solution to the problem.

SIGNIFICANT FINDINGS

- In the northeastern United States, recreation and tourism activities are profoundly affected by climate conditions. The sector is both highly climate-sensitive and a strong contributor to the regional economy.
- Many activities are outdoors and are intimately dependent on the environment (e.g., snow conditions, available fish or wildlife, wind (sail boating), fall foliage coloration).
- Even indoor activities are climate-dependent (i.e., greater response in adverse weather). There are comparatively few indoor facilities/complexes in the Northeast region.
- The concerns are not evenly distributed across all activities. In fact, there is a complex picture with large differences from activity to activity regarding what are the climate sensitivities, which seasons are most involved, and how easily can counter or adaptive measures can be employed (e.g., snow-making on ski slopes), cost/benefit margins, perceptions and other human behaviors.
- There are numerous specific cases and examples of highly adverse impacts on the sector that are climate-related. There is the perception that often the margins of economic viability are narrow, with success or failure dependent on the difference of several days or a few weeks of favorable weather conditions.

Three specific examples, among many, are:

1) bankruptcies for ski operators due to snowless or warm winters in the 1980's and early 1990s;
2) closure of camping and other outdoor facilities due to high incidence of mosquito-borne eastern equine encephalitis; and
3) curtailment of white water/rafting due to dry summer or fall weather.

THE FOUR QUESTIONS ADDRESSED

1. What are the current concerns and stresses facing regional stakeholders in the recreation and tourism sector?

Generic Concerns

- There is no concerted action or infrastructure to deal with the impacts of global climate

* See Appendix V for authors' affiliations and addresses.

changes and its regional impacts in a systematic and strategic way. Approaches have been piece-meal, poorly coordinated and would benefit from better information and strategies to cope and adjust.

- There is the perception that climate-incited impacts have increased in the past 20 to 25 years and have the potential for significant economic disruption.
- There are additional and more immediate and overwhelming concerns than climate and climate change. In particular, the demographic trends toward overuse and urbanization/commercialization are perceived to be large and growing threats.

Specific Concerns

- The ski and snowmobiling industries are in particular jeopardy from any increases in snowless or warm winters.
- Most segments of the industry are vulnerable to decreased air and water quality.
- Warm weather activities would be impacted by an increase in disease and pest outbreaks.

Climate-related Stresses and Other Stresses

- Weather changes in temperature, precipitation, seasonality, cyclical variability, reliability of forecasts, human perception of what the conditions are away from their immediate surroundings.
- Urbanization/commercialization trends.
- Overuse
- Regional infrastructure
- Fuel costs/availability
- Air/water quality
- Invasive plant communities
- Disease/pest outbreaks

2. How will climate variability and climate change modify the current concerns and stresses of the recreation and tourism sector in the region?

- The narrow cost/profit margins and extreme climate-dependency suggest that any adverse climate trends have the potential to drastically affect the sector.
- In some activities of the sector, the present options for alternatives or coping are limited. There is a need to identify cost-effective counter measures and test these out on a case-by-case basis.
- There is a need to "weather-proof" the sector. In some cases this may involve changes in public perception and/or habits. There is a need for all-weather and all-season activity prescriptions for the infrastructure, such as multiple-use facilities. One example given was the access to indoor activities (theater), local traditions (mountain-man lore), and optional outdoor activities (live farm and wildlife animal tours) at ski resorts.
- Climate-induced stresses in the cold and warm weather activities and the direction of impacts are:

  Warm weather

  Generally weather changes would be favorable, but impact on overuse, air/water quality, invasive plant communities, and disease/pest outbreaks would be unfavorable.

  Exceptions to the weather changes being favorable are freshwater fishing and the fall foliage season. The warming of streams could endanger most of the sport fishing population. Warming could cause dulling of the vibrant colors characteristic of the region during fall foliage season, at the very least. It could possibly endanger the species that produce this natural, annual display permanently.

  Cold weather

  Changes to weather, overuse, air/water quality, and disease would have highly unfavorable impacts on these activities.
- The hospitality industry and, to a somewhat lesser extent, the retail industry are strongly impacted by the recreation/tourism industry. The group felt that any impact to tourism would similarly affect these areas.

3. What information and data are needed by the recreation and tourism industry to fully understand and address climate-related issues?

The following four needs were identified:

1. Development of accurate region-level general circulation models.
2. Development of more reliable long-range weather forecasts.
3. Development of reliable 10-20 year climate predictions.

4. Development of reliable early warning systems concerning the potential risk of human disease and pest outbreaks.

4. What types of strategies and approaches are available for coping with, or mitigating, climate change stresses for this sector?

- There was the strong perception that mitigation would prove much more effective than short-term coping strategies. Ultimately, the problem of atmospheric changes will have to be addressed by controls on emissions affecting climate (greenhouse gases) and air quality (ozone, particulates, acidic deposition).
- Stop-gap measures need the attention of both the purveyors and the public but cannot replace or substitute for long-term goals of abating and moderating adverse climate changes.
- There is a need to develop a mechanism and infrastructure for the timely, accurate and easy access to data. It does no good to have wonderful databases of useful information, if the people who have need of these data do not have easy access to them.
- We must create effective programs to educate the hospitality industry. This industry profits the most from the recreation/tourism industry and they need to be made aware that changes in climate that impact unfavorably on tourism will have an unfavorable impact on them as well.
- Hold annual conferences/workshops specifically designed for the recreation and tourism industry to address short-term and long-term issues and actions related to climate change and coping strategies.
- Design tourism publications to educate the public on the issues of climate change, air and water quality protection, and available means of coping, adapting, etc.
- Develop trail systems for non-motorized use.
- Develop community-based, local and regional (i.e., several adjoining towns, etc.) cooperative projects which provide recreational opportunities with multi-seasonal and/or multi-use capabilities. These could draw and accommodate large numbers of visitors in both fair and adverse weather with minimal environmental impact. Some examples include: extensive, non-motorized trail systems for walking, biking, cross-country skiing, etc.; regional arenas or gathering centers available for both indoor and outdoor events (fair, concerts, festivals, etc.).
- Develop strategies for adapting to the change wherever possible, such as smoothing and restructuring ski slopes so less snow is needed to cover the terrain.
- Develop public transportation to the fullest to minimize air quality damage.

APPENDICES

Appendix I

Climate Change and Its Impacts on New England: A White Paper

Shannon Spencer and Barrett Rock [*]

When people think of the climate in New England they think either of crisp, clear fall days enhancing the spectacularly colorful foliage of maple, birch and hickory, sunny summer days and cool starry evenings, or pristine winter snowscapes, with snug cabins and bustling ski slopes. Those of us who live in the New England/upstate New York region, also know that the weather can be highly variable ("...if you don't like the weather, just wait a few minutes...") and unpredictable ("...last year, summer was on July 5th..."). For us, weather (day-to-day factors such as temperature, precipitation and cloud cover) is thought of as highly variable, while climate (the longer-term weather patterns characterizing an area, such as temperate or tropical climates) is considered to be more stable. However, we hear more and more about a changing climate, and most of us are not sure what climate change is or if it is something that we should really be concerned about.

As we begin to look at climate change issues and their potential impacts on the New England and upstate New York region, it is important to note that the term "climate" can refer to both the physical climate and the chemical climate. The physical climate includes variables such as temperature, precipitation patterns, and storm patterns which characterize an area, while the chemical climate includes variations in the chemical make-up of the atmosphere and precipitation. Increasing severity of storms or rising temperatures would be an example of physical climate changes, while increasing levels of ground-level ozone (a form of air pollution or smog) or acidity of rain would be examples of chemical climate changes.

Climate change may be vague and/or misunderstood by residents of the northeast region who are not specialists in this field. A number of reasons for this phenomenon are highlighted below.

- One perception could be that "climate change involves global processes that are poorly understood, and are largely beyond our control, at least at the local or regional level."
- The problems associated with climate change may be seen by the public as somehow involving tropical deforestation or ozone depletion in the Antarctic and Arctic regions, and are not considered as relevant or important to New England. Whereas climate change issues are much broader and more complex than deforestation and ozone depletion. Additionally, climate patterns are affected by the New England region and our actions within this region can have effects on the regional and global climate.
- Climate change problems are seen as very complicated and may be considered to be too difficult to be easily understood by the non-scientist. Northeastern residents, therefore, may not take an interest in the current issues and concerns of climate change.
- It is likely that even if people do recognize the problems associated with climate change that these problems are not of immediate concern. Yet, scientists are already beginning to see the signs of climate change which may be directly affecting our environment and way-of-life. We should look at these issues now and not put them off for future consideration because it may be to late to affect positive mitigation strategies.
- People who observe the reports by scientists on climate change issues may be confused by these reports and adopt a view that climate change specialists can't agree on what is happening. This may send the message that they shouldn't worry about climate change.
- Finally, one of the biggest problems getting people interested and concerned about issues related to climate change may have to deal with the transfer of misinformation on the subject. This is a two-pronged problem which involves the media's portrayal of the issues and scientists' ability to explain to non-scientists their findings. Information in the form of newspaper articles, radio and television coverage, and interpretations of

[*] See Appendix VI for authors' affiliations and addresses.

scientific papers and reports are often incorrect. This misinformation confuses the issues of climate change, making it harder for people to understand the impacts of phenomena such as the greenhouse effect and global warming to the New England/upstate New York region.

This white paper attempts to clarify some of these misunderstandings as well as present a select set of climate change issues which may be important to the New England/upstate New York region. This paper does not attempt to address all of the possible issues. Additionally, it does not contend to answer these complex issues. The idea is to get the reader thinking about these issues and others which may be important from their perspective, in preparation for the September Workshop. One of the goals of the workshop will be to help educate the "stakeholders" on the current understanding of climate change in the northeastern United States. A second goal is to tap into the expertise of stakeholders, in a working group format, in order to help policy makers and scientists determine the importance of climate change issues for our region.

The following discussion addresses some issues and provides examples of potential climate change problems for the region.

IS THE GREENHOUSE EFFECT REAL?

Yes, the greenhouse effect is real, and in fact, essential for life as we know it on our planet. Many of the gases in our atmosphere (including water vapor, ozone, nitrogen and carbon dioxide) allow sunlight to pass through, but once the sunlight interacts with the Earth's surface, the resulting heat released is retained, resulting in a climate conducive to the maintenance of life. The presence of these gases in our atmosphere makes the Earth a living planet. Compare the Earth and its atmosphere with the moon: both are approximately the same distance from the sun, but there the similarity ends. What a difference a few gases make! Human activities, however, have resulted in a significant increase in some of these and other gases in our atmosphere. The growing concern voiced regarding future climate change relates to this ***enhanced*** greenhouse effect.

From the beginning of the Industrial Revolution (in the 1870's), human activities have increased the introduction of greenhouse gases such as carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4), ozone (O_3), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O) into the atmosphere. All of these gases trap heat. The overall increases in CO_2 over

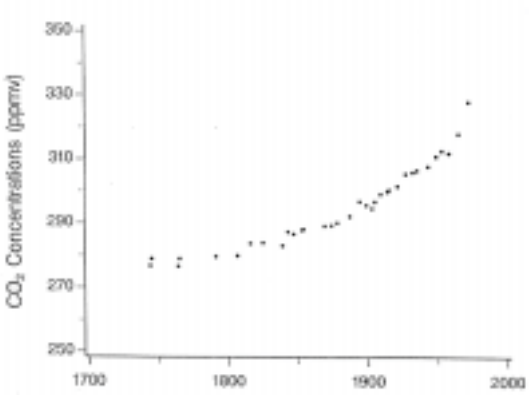


Figure 1. Atmospheric carbon dioxide concentrations derived from ice core data show that this greenhouse gas has steadily increased since the mid-1700s. This phenomenon has been confirmed by independent researchers around the world. And, many of the trends seen in the peaks and valleys of the data can be correlated to specific global or regional events.

time (1750 - present) is shown in Figure 1. The detailed studies of ice core records from glaciers in Greenland and the Antarctic shows that climate change is normal and closely correlated with changes in carbon dioxide and methane in the atmosphere. Dramatic climate change has occurred in the past, even in the absence of human activities, and in all cases, warming is associated with high levels of greenhouse gases, while cooling is characterized by decreased levels of these gases.

A primary question is: how much are humans influencing the climate compared to the natural climate variability? And more importantly, what will this mean for our well being and the well being of the current global ecosystems. Research has shown that the observed increases in greenhouse gas concentrations are human-influenced. The time scale of the human-induced climate change and the magnitude of potential impacts are we should be concerned about.

WHAT ABOUT GLOBAL WARMING?

While large fluctuations in both greenhouse gases in the atmosphere and climate change are clearly normal for our planet, the 1997 levels of atmospheric CO_2 are the highest they have been for the last 160,000 years (based on the ice core record). There is no debate about this! Scientists agree that greenhouse gas levels are increasing in the Earth's atmosphere and there is also consensus among scientists that at least part of this increase is a result of human activity. What is being "hotly" debated at present, is what effect this ***enhanced*** greenhouse effect will have in terms of a warming of the atmosphere.

The ice core records show a direct correlation between CO_2 levels in the atmosphere and global temperature. If the past ice core record is used as an indication of what will happen in the future. If CO_2 levels continue at the present rate of increase, global temperatures can be predicted to rise 2-5ºC (4-9ºF) by 2050. Temperatures in the Arctic are predicted to rise twice as fast—in fact, temperatures there have alread risen by 2ºC in the past 30 years.

In 1995, an international panel of over 2,000 scientists—the Intergovernmental Panel on Climate Change (IPCC)—stated that the observed warming trend seen over the past decade is connected with the increasing levels of greenhouse gases in the atmosphere. This IPCC Report represents the first broad scientific consensus that the ***enhanced*** greenhouse effect has led to increased temperatures over the past century. It is important to note that even if overall warming is seen, the temperature trends observed at the local level will continue to be highly variable. Exactly what this will mean for our region is uncertain and needs more attention.

Doesn't climate change involve global processes that are poorly understood, and largely beyond our control, at least at the local or regional level?

Climate change is a global phenomenon and is based on properties of the atmosphere such as temperature and precipitation. But, climate has many regional action centers. Some are very large such as the El Niño-Southern Oscillation (ENSO) centered in the tropical Pacific which has an impact on climate and weather on a nearly global scale. Another regional climate influence is the North Atlantic Oscillation which can affect storm patterns over New England. We'll return to the ENSO phenomenon shortly.

As we have come to know from watching the evening weather on TV, high and low pressure systems, storms, and associated temperatures and precipitation patterns move rapidly across the United States (as well as the rest of the world) from west to east. Weather affecting the west coast soon affects us. Figure 2 shows that we are in the unenviable position of being down-wind from the rest of the country. Weather and climate are clearly large-scale and global processes. .

Our understanding of how the climate system works, although incomplete, has improved dramatically as a result of our venturing into space. Observing Earth from orbit has significantly improved our ability to predict storms and to monitor pressure systems as they move across the country. Weather satellites are now taken for granted, and our understanding of the processes that result in local weather patterns have greatly improved in the past 25 years.

Even though we have improved our technological capabilities and understanding of the climate system, scientists still cannot predict the weather and its long-term cousin, climate, with much accuracy. Two primary limitations in predicting weather and climate are related to the limited computing power and limited knowledge of regional factors affecting both weather and climate.

Additionally, significant variations in climate can and do occur naturally. Many of the factors affecting climate are beyond our control, such as incoming solar radiation and the relative areas of land and sea surfaces. These factors confound our understanding of human-induced climate change. However, other factors, such as the levels of greenhouse gases in the atmosphere and the amount and health of vegetation on land (and in particu-

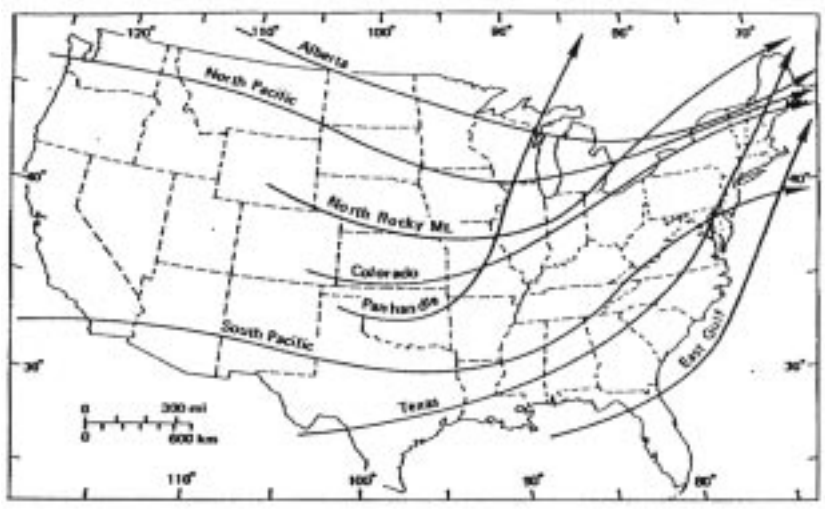


Figure 2. Major storm and airmass patterns for the United States shows that the Northeast's weather is intricately linked to weather phenomena in the rest of the nation and Canada. Additionally, this airmass pattern results in the Northeast receiving high concentrations of chemical airborne pollution from outside the New England region

lar, forest species) are directly related to our activities, and thus within our control.

Along with the oceans, the vegetation acts as a large CO_2 sink, removing CO_2 from the atmosphere as part of the process of photosynthesis. Human activity is destructive to woody vegetation by removal (deforestation) and by pollution-induced forest decline (Camels Hump in Vermont is a well-known example of spruce dieback due to high elevation acid mists). Trees and other vegetation act as CO_2 "sponges," soaking it up from the atmosphere and converting it to plant tissue and wood fiber in the form of cellulose. The large-scale loss of forested and other vegetated areas results in increased levels of CO_2 in the atmosphere.

Does El Niño-Southern Oscillation (ENSO) Affect New England Climate Patterns?

Believe it or not, our climate patterns of droughts and flooding here in New England have their origins in the equatorial Pacific. Scientists studying oceans and sea-surface temperatures have shown a strong linkage between sea-surface temperature patterns associated with the cyclical warming and cooling of waters off the coast of Peru to climatic patterns in North America. Since we are downwind from the rest of the country (Figure 2), what affects climate in North America, affects our region. Climate-related events such as extremely cold winters, summer-time droughts, heat waves and associated crop failures and forest fires, flooding, etc. result in higher heating/ cooling bills and higher food prices. In extreme cases, our homes and livelihoods may be threatened. We need to better understand these linkages, both to make better weather forecasts, and to develop coping strategies.

The El Niño phenomenon was first observed in the 1600s off the coast of Peru by fishermen who noticed a decline in the anchovy population during certain years. On an irregular basis, unusually warm waters off the coast around Christmas time were noted by the Peruvian fishermen. These warm water events were called El Niño (Spanish for "baby boy"), in reference to the Christ child. Only recently have we come to recognize that the development of an El Niño event actually originates in the western Pacific. A relaxation of trade winds in the Pacific results in an eastward movement of ocean currents along the equator, spreading warm sea-surface temperatures eastward toward the South American coast. The resulting El Niño is the warm extreme in year-to-year fluctuation of sea-surface temperature around the Galapagos Islands, while the cold extreme of this irregular cycle is called La Niña ("baby girl"). Together, this shift in winds plus the fluctuation between warm waters and cold waters off the coast of Peru is referred to as the El Niño-Southern Oscillation, or ENSO, for short.

In general, years dominated by an El Niño event will be characterized by hot summers, droughts and forest fires in North American, while La Niña years will typically have cool, wet summers, and spring and/or fall flooding. The ENSO events also may vary with season, so that the timing of specific effects (cold/hot, wet/dry) is more complicated than this simplified explanation. However, this simple explanation does demonstrate how our growing understanding of the connections between sea-surface temperatures in the Pacific and climate patterns in New England. This improved understanding will likely allow us to begin forecasting climate patterns 1-2 seasons in advance.

More specifically, researchers have determined several factors which affect North America and the Northeast due to ENSO. The Jet Steam path and storm fronts have been found to be related to ENSO. La Niña events are associated with chaotic winter weather in the Northeast. Additionally, researchers claim that ENSO is very powerful and can affect human populations around the world. In the Northeast it has been found to result in increased encephalitis outbreaks. Such findings can significantly impact our concern about regional climate variability.

It is interesting to note that hot, dry summers tend to be characterized by elevated levels of certain types of air pollutants, such as low-level ozone (tropospheric O_3) and sulfur dioxide (SO_2), while cool wet summers are characterized by better air quality. In this way, we can clearly see a connection between the physical climate and the chemical climate. Who would have guessed that ocean circulation patterns in the far-off Pacific would have such an impact on us in New England?

Do we have any control over the rates of greenhouse gas emission?

Figure 3 presents an example of how this has already been done. CFCs and other CFC-like compounds are greenhouse gases. They are better known as the major cause for ozone loss in the stratosphere. Figure 3 shows how levels of one specific CFC-like compound—methylchloroform (CH3CCl3)—exhibited significant increases in the atmosphere between 1978 and 1992. The increase of greenhouse gas compounds such as these is a result of their use in manufacturing processes and as refrigerants. The dramatic reversal by 1992 is

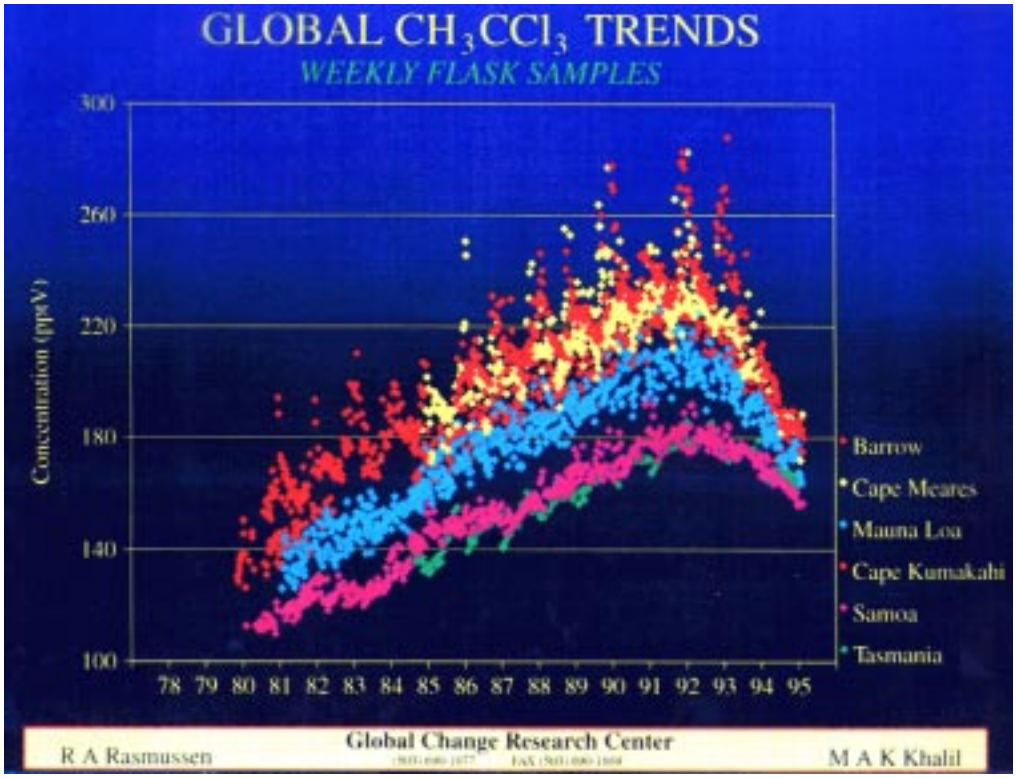


Figure 3. Global concentrations of a Freon-like compound, for selected collection sites from around the world. Increasing concentrations of compounds such as this one have been associated with their increased use in the manufacturing process and as a refrigerant during the 1970s and 80s. The decreasing trend in concentration starting around 1991-2 was measured following the enactment of the Montreal Protocol, which placed limits on the use of these types of compounds

the direct result of the Montreal Protocol initiated in 1987 and ratified by more than 150 countries by 1990. As a result of the Earth Summit held in 1992, the governments of the world agreed to totally phase-out production of this and many other CFC and CFC-like compounds. This dramatic change shows that a cooperative policy decision can have a profound influence on a global-scale problem. We just need to know the facts about an issue to construct a solution.

One way to control greenhouse gas effects is to reduce the amount reaching the upper atmosphere by storing carbon in land-based ecosystems. The change from carbon dioxide into oxygen and stored carbon is part of the photosynthetic process in plants. The forests of New England and New York contain 4.2 billion metric tons of carbon in forest ecosystems, and this amount is increasing at a rate of about 20 million metric tons per year. Annual CO_2 emissions in the United States, primarily from burning fossil fuels for energy, are equivalent to 1.5 billion metric tons of carbon. In the international negotiating arena, the United States is seeking ways to reduce or offset CO_2 emissions by 100 million metric tons, of which about 10 million would come from additional carbon storage in forests. The maturing forests of New York and New England are contributing in a very positive way to offset CO_2 emissions from other sources.

Are climate change issues relevant or important to the New England region?

Often when one thinks of climate change issues, it is easy to assume that these processes occur in distant places. We may think of tropical deforestation in Brazil or the thinning of the ozone layer above Antarctic. These are just examples of extreme events which catch our attention. We need to begin to realize that events in the New England region can both affect the regional and global climate and that the climate can impact the New England region.

According to the *World Almanac and Book of Facts, 1997,* among the largest industries in the New England region are energy, manufacturing and tourism. We need to begin to think about how climate change issues will impact our businesses, our health and our way of life. The following examples of climate change impacts on tourism, coastal/fisheries issues, and human health are meant to give a flavor of how relevant climate

change is to people of New England and upstate New York. These examples represent just the tip of the iceberg, and the workshop in September will focus on these and many more "stakeholder" concerns and issues.

Climate Change Impacts on Tourism in New England

Tourism is one of the largest industries in New England and upstate New York, and for many residents of this region it is a way of life. This multi-billion dollar enterprise is composed of many small businesses and mom-and-pop operations which give the defining character to the New England region. New England is unique in that it offers a wide variety of recreational and leisure activities for a vast population. This region's lakes and rivers, oceans and beaches, mountains, scenic towns, and natural areas are within only a few hours drive of the Boston-New York urban corridor, which hold a substantial percentage of the country's population.

The tourism industry and therefore the character of New England is vulnerable to the impacts of climate change. Weather and climate drive the tourism industry: if it rains during the summer, visitorship is down. If the snows don't fly and the temperatures are too high, the skiers and boarders don't head for the sky! New Hampshire Public Radio reported in June, 1997 that the popular 5-day Biker's Week event in New Hampshire's Lake Region resulted in $65 million in direct sales; that particular week was sunny and warm, with temperatures between 70-80ºF. If the event happened the following week, with the forecasts of rain and thunderstorms, dollar figures could be assured to have been lower. Weather forecasting and predictability are important to the New England tourism industry. If predictability decreases, temperature increases and rain and severe weather events increase, tourism is bound to take a direct hit. Understanding how these climate variables may change is important to our regional economy and well being.

Another issue of concern for tourism and the recreationalists is the chemical climate of New England and upper New York. An interstate panel of pollution and weather experts, headed by the EPA, recently stated that New York and New England are indeed downwind of the smog produced by mid-western states. This smog directly affects the regions prized by outdoor enthusiasts, especially at higher elevations. Air pollution is carried by the prevailing wind patterns until it intercepts forests on mountain sides facing a westerly direction. The haze produced not only affects mountain vistas but is believed to affect the health of people utilizing high elevation areas for recreational purposes. And, the ozone and acid mists impact the health of the forests in these regions as well. If the current trend of increased air pollution continues to occur, human health and the tourism industry will be broadly affected.

New England's fall foliage season is one of the biggest tourist draws to this area by out-of-staters. The beautiful colors associated with fall foliage are created by the unique mixture of tree species found within the Northeastern region, with maple being the most important. Yet, climate change predictions indicate that maple may be an affected species, causing delayed coloration, species collapse, or potential northern migration. Figure 4 shows two different model predictions of the future range of maple, based on a doubling of the current carbon dioxide concentrations. These scenarios predict a different pattern of maple migration, yet both show the northward shift. It is clear that a full understanding is lacking in the effect of climate change on forest migration, but preliminary indications insist that we consider the effects more

Another forest ecotype in jeopardy are the high elevation spruce and fir forests. Because these forests are located at high elevations they are already under several natural stresses in order to survive. Air pollution stresses further aggravate their chances of survival. Many studies have shown that dieback of these forests are related to pollution exposure, winter freeze injury (climate-related), or some combination of the two. Add into this equation climate variability and change and you add insult to injury!

The maple concern and the research documenting spruce/fir decline at high elevations are just two examples which become climate change issues for our region. Understanding climate change and how it will affect our natural areas and the tourism industry is important to protecting New England's heritage.

Allan Auclair and colleagues of the Science and Policy Associates have cited extreme weather events as important mechanisms for causing forest dieback in the Northeast. They predicted, using climate models and forest maturation ages for the Northeast, that major dieback of naturally occurring New England forest species such as birch, maple and spruce are likely to occur in the mid 21st century. This will not only have dramatic impacts on the tourism and forest products indus-

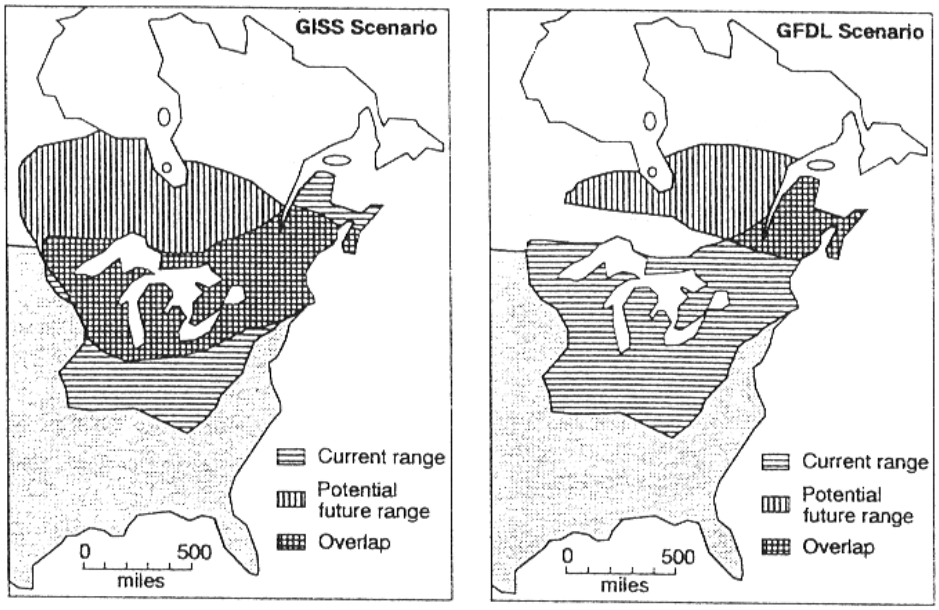


Figure 4. Two different models predict different ranges of sugar maple based on a doubling of atmospheric carbon dioxide concentrations. Yet, both predict a northern migration of the southern extent of maple distribution, with the GFDL model being most extreme.

tries but will mean a significant change in the way of life for children of the next two to three generations.

These issues are just examples of how climate change could affect one of New England's largest industries. The workshop being convened will solicit participant's input on their concerns regarding climate change effects on tourism and other issues. Much is still unknown regarding climate change and the particular effects on New England. Yet, it is important to begin now to address the issue of climate change.

Climate Change and Coastal and Fisheries Issues in New England

The decline of fisheries in the Northeast, where estimates of stocks of cod, haddock and yellowtail flounder are at historically low levels, has been blamed on overexploitation. All along the North Atlantic coast changes in species composition have also occurred, with less desirable species such as dogfish and skates replacing the once abundant groundfish stocks, mainly as a result of over-fishing. It is not clear at present how these declines may be related to climate change.

While there is still uncertainty in the connections between fisheries resources and climate change in the Northeast, researchers have shown that the present distribution of fish populations with water temperature can be used to estimate shifts in fish location resulting from climate change. El Niño-Southern Oscillation events which cause shifts in the ocean temperature have been shown to cause change is fish distribution. Some scientists believed that a change in water temperature kept cod from returning to Newfoundland waters in 1995.

Ocean researchers reported a 1 degree Celsius rise in both the mean and maximum water temperature in August between 1976 and 1996 over Jeffries Ledge, located off Cape Ann, Massachusetts. Increases in ocean temperature can result in northward migration of certain invertebrate species. Species such as the resilient and aggressive starfish (*Asterias forbesii*), found near the Isles of Shoals, off the coast of New Hampshire and Maine, have already been observed to be migrating north.

A recent and unusual outbreak of dense algae (an algal bloom occurred in March, 1997) turned Cape Cod Bay a murky brown, raising concerns about a disruption of the food supplies for the endangered Northern Right whales. This algal bloom appears to have been the cause of the whales abandoning their traditional feeding grounds this year at the earliest date ever recorded. Many of the 325 known remaining right whales, the most endangered of the world's large whales, typically spend the winter and early spring in Cape Cod Bay feeding on crustaceans called copepods. New calves in particular, need the spring copepod harvest to gain weight and strengthen prior to leaving the area. Most years the whales stay in the bay until late May. This year most of the whales were gone by late March.

Scientists know little about how the algae (genus *Phaeocystis*) affect the copepods that the whales eat. However, the coincidence between the algal bloom and the whales' early departure is a source of concern. Perhaps an even greater concern relates to the fact that a decline in copepods may signal a more general alarm for the health of the Cape Cod Bay ecosystem, and an alarm for the larger fish populations in Cape Cod Bay. A current knowledge gap exists in our full understanding of the impact that climate change (warming waters, changing water quality, etc.) will have on New England coastal resources.

Rising ocean temperatures and the accompanying expansion of the water itself contribute to sea level rise, as does more water entering the oceans via the melting of land-bound glaciers and ice sheets. Since the rebound of the earth's surface after the last glacier receded in New England 12,000 years ago has ended, sea level rise is a reality that all low-lying coastal areas must face.

Rising sea levels causes intertidal animals and plants to move to higher elevations. Salt marshes in New England, one of the most productive of the intertidal habitats, are relatively new—only about 4,000 years old. They persist partly due to a balancing act between the rate of sea level rise and the accumulation of sediments and plant material which together form peat on the marsh surface. It is uncertain whether this balance will continue with sea level rising faster in the past fifty years (1.8 mm or 0.07 inches per year) than the rate of rise during the past 2-3,000 years (1 mm or 0.04 inches per year). In addition, man-made structures such as culverts and roads restrict the tidal flow and limit the inland migration of marshes. This results in the replacement salt marsh plants by fresh-water species.

Salt marshes and estuaries provide food and shelter for 70% of the fish and shellfish in the ocean, at some point in their life. A rise in sea level and development-curtailed inland migration of all the intertidal habitats will affect abundance and biodiversity of many plant and animal populations that are essential to food chains that support upper trophic-level animals such as fish.

Storms also have a detrimental effect on some commercially important species. Excessive rainfall such as the 15 inches Great Bay estuary in New Hampshire received in 24 hours last September, caused death and migration of lobsters that traditionally inhabit the Bay, reducing this year's catch.

Economic hardship in coastal communities is beginning to result from climate change. In the past decade, several New England coastal communities have refused shoreline development such as tourist hotels on the basis of predicted increases in sea-level.

As the predicted duration and severity of storms develops, as it now seems to be doing, coastal property owners face increasing economic loses. Coastal New England is continuously exposed to dynamic and corrosive environments whose complexities are exacerbated by harsh winters, severe storms, great tidal ranges from 3 to 50-plus feet and a very irregular coastline. By the year 2010, 70% of New England's population will live within 50 miles of the coast, and more and more people will be directly affected by storm damage to their homes and commercial properties. Development of environmentally-sound technologies for existing and new applications for the New England coast are dependent upon improved ecological knowledge of the environment. Developing a better understanding of how climate change will impact this economically-significant region is most important.

The Impact of Climate Change on Human Health

When most people think of climate change issues and human health, they seldom go beyond the idea that the "ozone hole" allows more dangerous ultraviolet (UV) light to reach the surface of the Earth, and that this increased exposure to UV can cause skin cancer and glaucoma. They also assume that it is a problem for people living in Australia and New Zealand, but not here in New England. Dr. Paul Epstein, Associate Director of the Center for Health and the Global Environment, Harvard Medical School believes differently. He has written many general-purpose articles dealing with health and climate change (for example, the Op-ed article in the Boston Globe, April 10, 1997) and sees the New England area as likely to feel the impact of climate change in many aspects of human health.

Heat-related deaths in cities—which act as heat islands—will be exacerbated by warming, air pollution and smog (ground-level ozone), created both locally and up-wind (see Figure 2) of urban areas. These impacts, particularly with increased cloudiness (associated with the enhanced hydrological cycle), may even act synergistically (e.g., to increase ground-level ozone).

Moreover, the disproportionate rise in minimum temperatures (T_{min} or nighttime and winter temperatures) accompanying climate change means that less nighttime relief during heat waves, espe-

cially when there is a high heat index (a function of temperature and humidity). The humidity traps out-going radiation, decreases nighttime cooling, and exacerbates the impact on mortality.

A warmer atmosphere holds more moisture (6% more for every 1°C); and these changes may, in part, be attributable to the increased hydrological cycle and increasing cloudiness, reducing daytime warming and retarding nighttime cooling. Additionally, the disproportionate rise in T_{min} favors insect overwintering and activity. Researchers report that since 1950, maximum temperatures have risen at a rate of 0.88°C per 100 years, while T_{min} increased at a rate of 1.86°C per 100 years.

Infectious diseases may be increased due to climate change conditions (wetter, warmer summers, less severe winters) that promote tick, mosquito and rodent populations, populations which carry diseases such as Lyme Disease, Ehrlichiosis, Eastern Equine Encephalitis, Hantavirus, etc. Increased run-off of nitrogen and other nutrients into estuaries and bays, coupled with hotter summers (that promotes algal growth and favors the more toxic forms [cyanobacteria and dinoflagellates]) can lead to increased occurrence of red-tides and shellfish poisoning, brown-tides (lowering oxygen levels in water, harming seagrasses and shellfish beds), and can lead to increased diseases of shore birds, sea mammal, and fish.

Food-borne diseases such as toxic E. Coli, Salmonella, Cyclospora and Hepatitis-A may also be enhanced by warmer, moister conditions. Extreme weather events like flooding are particularly associated with outbreaks of Cryptosporidia and Giardia, protozoa that are not sensitive to chlorine.

In addition diseases of terrestrial plants and agricultural crops can be affected. Extreme weather events (flooding and prolonged droughts) increase the susceptibility of forests to infection. Presently, the woolly adalgid presents a threat to hemlock trees in New England; and stressful weather could exacerbate this problem.

Climate extremes are becoming more frequent, and they are also contribute to outbreaks of disease. Floods foster fungal growth and provide new breeding sites for mosquitoes; while droughts concentrate microorganisms, and encourage aphids, locust, whiteflies and—when interrupted by sudden rains—spur explosions of rodent populations. Because of the strong influence of climatic factors prediction of weather patterns based on ENSO and other climatic modes, plus regional patterns, may prove useful for anticipating conditions conducive to such "biological surprises" and epidemics.

These impacts on health could also have substantial economic impacts on our society. These range from the cost of health care to deal with the increased impacts to the costs of prevention measures, such as spraying to control insect populations. Environmental costs would be associated with many of the impacts, as well (consider insect spraying). Outbreaks of diseases can affect humans, agricultural crops and livestock; and their impacts can ripple through economies and cascade through societies. In 1991, for example, the cholera epidemic in Latin American cost Peru over $1 billion in seafood exports and lost tourist revenues. In 1994, the outbreak of plague in India (accompanied by malaria and dengue fever in the wake of widespread flooding) cut tourism precipitously and cost international airline and hotel chains from $2 to 5 billion.

Cruise boats are turning away from islands affected by dengue fever and other insect infestations, and coastal algal blooms along beaches. The consequences could be significant: The tourist industry in the Caribbean generates $12 billion annually and employs over 500,000 people.

The current resurgence of infectious diseases involving food, water, insect and rodent carriers can affect trade, transport, tourism and development. As the headline of Dr. Epstein's article stated: "Warm and wet conditions spell trouble for the world."

Where Do We Go From Here? What Do We Do?

It is easy to respond to the examples presented in this paper with a "gloom and doom" approach, giving a shrug of the shoulder and some nervous laughter. The difficult task at hand is to view these issues as both important and something that we need to know more about. We can't continue to ignore the early-warning signs of what the future will hold if human impacts on the regional and global climate go unchecked. As a people we are conducting a global experiment, the outcome of which we are currently unable to predict. We have records of the past, as well as sophisticated models to attempt projections, but what is currently missing is the local knowledge of the real concerns, perceived vulnerabilities, and the current state of knowledge among a broad range of stakeholders who will be directly impacted by climate change.

Using informed stakeholder input, policy makers and scientists can guide and conduct research

which will help us to understand better the climate change issues and their impacts. We need to also begin to look at the regional climate patterns and predictability in order to separate the natural climate variability from human induced climate changes. Recognizing that we currently lack a full understanding of the complex climate and earth systems, we need to accept the high possibility that our interactions with the environment can negatively impact our lives in the near and/or long-term future. By accepting this possibility we can begin to adapt some of our actions and policies in order to mitigate the magnitude of the potential impacts.

Awareness of the climate change issues is an important aspect to reducing the impacts of climate change in the future. We need to properly educate the people of our region on the current understanding of climate change and offer positive and active solutions to the problems. Ensuring that people of the New England/upstate New York region receive accurate information from the on going research and know how to process that information to increase their knowledge of the issues is fundamental. Developing educational outreach programs that engage citizens of all ages in a wide spectrum of thought, activities, and action in school programs, public forums, teacher education workshops, and the media are important for developing the kind of ethos and knowledge required to meet the challenge that climate change presents to our region.

The New England Regional Workshop will provide an ideal environment by beginning to develop an open dialogue among stakeholders, policymakers and research scientists. The U.S. Global Change Research Program needs your input. Please join us at the New England Climate Change Impacts Workshop, to be held at the University of New Hampshire from September 3-5, 1997.

The White Paper was developed for the New England Regional Climate Change Impacts Workshop, held at the New England Center on the University of New Hampshire campus, September 3-5, 1997. The White Paper was compiled and edited by Shannon Spencer and Barrett Rock, with contributions from members of the Steering Committee.

Appendix II

New England Regional Climate Change Impacts Workshop

Final Agenda

September 3-4, 1997

Day 1: Wednesday, September 3

7:00 Media Breakfast - *New England Center - Mansfield Room*

7:30 Registration & Continental Breakfast - *New England Center - Great Bay Foyer*

8:15 Welcome - *Great Bay Room*
Berrien Moore III, Director, Institute for the Study of Earth, Oceans, and Space (EOS) at the University of New Hampshire
Joan Leitzel, President, University of New Hampshire (UNH)

Introductory Remarks:
Robert Corell, Assistant Director for Geosciences, National Science Foundation
Norman Willard, Climate Change Coordinator, Environmental Protection Agency, Region I

8:45 *"Working Towards a National Assessment: Common Goals for the Regional Workshops"*
Jerry Melillo, Co-Director and Senior Scientist Ecosystems Center, Marine Biological Laboratory

9:00 Panel Discussion on Stakeholder Perspectives of Regional Vulnerabilities
Moderator: **Steven Hamburg**, Associate Professor, Brown University

Natural Resources (Agriculture, Forestry, Fisheries) - **Lloyd Irland**, Irland Group

Human Health - **Paul Epstein**, Associate Director, Center for Health and the Global Environment, Harvard Medical School
Amy Langston, Disease Database Coordinator, Harvard University

Insurance - **James Russell**, Vice President, Institute for Business & Home Safety

BREAK

Energy/Utilities - **James Platts**, Senior Engineer, Northeast Utilities

Government/Resource Management - **Robert Brower**, Director of Cayuga County Planning

Recreation/Tourism - **Ken Kimball**, Director of Research, Appalachian Mountain Club

12:00 Luncheon - *New England Center Dining Room*
Luncheon Address (1:00 PM) - **Daniel S. Goldin**, Administrator, National Aeronautics and Space Administration - *Great Bay Room*

1:45 Regional Weather/Climate - **Norman J. MacDonald**, Meteorologist - *Great Bay Room*

2:00 *"Climate Change Lessons from the Past: A Key to Prediction"* - **Paul Mayewski**, Director, Climate Change Research Center, UNH

2:30 Break Out Sessions: Stakeholder Issues
Moderator, **Barry Rock**, Director, Complex Systems Research Center, UNH

Natural Resources (Agriculture, Forestry, Fisheries)
Human Health
Insurance/Business and Industries
Energy and Utilities
Government and Resource Management
Recreation and Tourism
Information Transfer and Public Awareness (Media, Education)

4:30 Plenary: Presentation of Findings by Session Chairs
Moderator, **Berrien Moore III**

5:30 Reception - *Gallery - New England Center*
Demonstrations of Geographic Information Systems Capabilities

Day 2: Thursday, September 4

7:30 Continental Breakfast - *New England Center - Great Bay Foyer*

8:00 Panel Discussion on Climate Change Issues
Moderator: **John Aber**, Professor, Complex Systems Research Center, UNH

Climate Change and Ecosystems - **Ivan Fernandez**, Professor, Soil Sciences
University of Maine at Orono
Climate Change and Weather Variability/Predictability - **Barry Keim**, New Hampshire State Climatologist, UNH
Climate Change and Air Quality - **Allan Auclair**, Senior Scientist
Science and Policy Associates, Inc.
Climate Change and Coastal Shoreline Issues - **Graham Giese**, Research Specialist,
Woods Hole Oceanographic Institute
Climate Change and Agricultural Impacts - **David Wolfe**, Associate Professor Cornell University

10:00 BREAK

10:15 *"Visible Climate Change Effects: The Alaskan Experience"*
Glenn Juday, Associate Professor Forest Ecology, University of Alaska

10:45 Break Out Sessions: Regional Climate Change Issues
Moderator, **Barry Rock**
Identifying vulnerabilities, how will climate variability and climate change amplify stake holder concerns and issues?

12:00 Luncheon - *New England Center Dining Room*

1:15 Introduction to Afternoon Session - **Barry Rock** - *Great Bay Room*

1:20 *"Global Environmental Change: Modifying Human Contributions through Education"*
Lynne Carter, Visiting Scientist, University of Rhode Island (*Great Bay Room)*

1:40 *"Federal Programs to Meet Implementation Needs"*
Norman Willard, Climate Change Coordinator, Environmental Protection Agency, Region I

2:00 *"Knowledge Gaps, Research Needs, and Integrated Assessment Challenges: What is really needed?"*
Ronald Prinn, Professor, Massachusetts Institute of Technology

2:30 Break Out Sessions: Working with the Issues
Moderator, **Barry Rock**
Focus on coping, mitigation strategies and identifying knowledge gaps, research needs

4:30 Plenary Discussion on Findings: Presentations by Session Chairs
Moderator, **Berrien Moore III**

5:30 Closing Remarks
Berrien Moore III
Tom Baerwald, Deputy Assistant Director for Geoscience, National Science Foundation

6:00 Adjourn

Day 3: Friday, September 5 - Writing Group - *NEC Great Bay Room*

A smaller group of identified participants and presenters remained to write the draft version of the Workshop Summary Report for the U.S. Climate Forum held Washington, DC, November 12-13.

9:00 Writing Assignments/Tasks

12:00 Working Lunch

1:30 Convene to assemble the pieces

3:00 Adjourn

Appendix III

Distribution of Participants New England Regional Climate Change Impacts Workshop

State	Local Gov.	Federal Agency	Energy / Utility	Business / Industry	NGOs	Education / Outreach	Scientists / Researcher	Total by State
AK							1	1
CAN	1							1
CT			1	1				2
DC		3					1	4
MA	2	7		1	5	3	5	23
ME	1		1	2		1	1	6
MD		2					1	3
NH	7	2	2	3	6	11	29	59
NY	1			1	1		3	6
PA		1						1
RI				1		2	4	7
VA		2						2
VT	3						3	6
Total	15	17	4	9	12	17	48	122

Appendix IV

Steering Committee NE Regional Climate Change Impacts Workshop

David Bartlett
Associate Director
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-0322
Fax: (603) 862-1915
E-mail: dbartlet@bigred.sr.unh.edu

Thomas Baerwald
Program Director
Geology and Regional Science
National Science Foundation
1800 G Street, NW
Washington, DC 20550
Phone: (703) 306-1502
Fax: (703) 306-0372
E-mail: tbaerwald@nsf.gov

Richard Birdsey
Program Manager
USDA Forest Service
100 Matsonford Road
5 Radnor Corp Ctr Ste 200
Radnor, PA 19087-4585
Phone: (610) 975-4092
Fax: (610) 975-4095
E-mail: rbirdsey@lunar.nena.org

Robert Brower
Director of Planning
Cayuga County Planning Department
County Office Building - 5th Floor
160 Genesee Street
Auburn, NY 13021
Phone: (315) 253-1276
Fax: (315) 253-1586
E-mail: brower@sycayva.cayuga-cc.edu

Ann Bucklin
Director — NH-ME Sea Grant
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-3505
Fax: (603) 862-0243
E-mail: acb@kepler.unh.edu

Paul R. Epstein
Associate Director
Center for Health & Global Environment
Harvard Medical School
260 Longwood Society
Boston, MA 02115
Tel: (617) 432-0493
Fax: (617) 432-2595
E-mail: pepstein@igc.org

Kate Hartnett
Executive Director
New Hampshire Comparative Risk Project
18 Low Avenue
Concord, NH 03301
Phone: (603) 226-1009
Fax: (603) 226-0042
E-mail: katehart@tiac.net

Wanda Haxton
Policy Analyst
Climate Policy & Assessment Division
Mail Code 2174
Washington, DC 20460
Phone: (202) 260-2709
Fax: (202) 260-6405
E-mail: haxton.wanda@epamail.epa.gov

Clara Kustra
Public Relations Coordinator
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-3484
Fax: (603) 862-1915
E-mail: clara.kustra@unh.edu

Paul Mayewski
Professor
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525

Phone: (603) 862-3146
E-mail: p_mayewski@unh.edu

Berrien Moore III
Director
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-1766
Fax: (603) 862-1915
E-mail: b.moore@unh.edu

Barry Rock
Director
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-1792
Fax: (603) 862-0188
E-mail: barry.rock@unh.edu

Fay Rubin
Director - GRANIT
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-1792
Fax: (603) 862-0188
E-mail: fay.rubin@unh.edu

Shannon Spencer
Research Scientist
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Phone: (603) 862-1792
Fax: (603) 862-0188
E:mail: shannon.spencer@unh.edu

APPENDIX V

New England Regional Workshop Participants List

John Aber
Professor
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-3045
Fax: (603) 862-0188
E-mail: john.aber@unh.edu

Jim Abraham
Manager of Atmospheric Science
Environmental Canada
Atlantic Region
1496 Bedford Highway
Bedford, NS B4A1E5
CANADA
Tel: (902) 426-9134
Fax: (902) 426-9158
E-mail: jim.abraham@ec.gc.ca

Eleanor Abrams
Assistant Professor
Department of Education
University of New Hampshire
Morrill Hall
Durham, NH 03824
Tel: (603) 862-2990
Fax: (603) 862-2174
E-mail: eda@christa.unh.edu

Samuel S. Adams
President
Loon Mountain Recreation Corporation
PO Box 697
Lincoln, NH 03251
Tel: (603) 745-6281 ext. 5511
Fax: (603) 745-8214
E-mail: info@loonmtn.com

Donald L. Anderson
Environmental Specialist
Maine DEP -BAQC, DEP
17 State House Station
Augusta, ME 04333-0017
Tel: (207) 287-2437
Fax: (207) 287-7641
E-mail: don.anderson@state.me.us

Allan Auclair
Senior Scientist
Science & Policy Associates, Inc.
West Tower, Suite 400
1333 H Street, N.W.
Washington, DC 20005
Tel: (202) 789-1201 x28
Fax: (202) 789-1206
E-mail: auclair@rff.org

Thomas J. Baerwald
Deputy Assistant Director for Geosciences
National Science Foundation
4201 Wilson Boulevard, Suite 705
Arlington, VA 22230
Tel: (703) 306-1502
Fax: (703) 306-0372
E-mail: tbaerwald@nsf.gov

Marian Baker
AirNET Director
Harris Center
341 King's Highway
Hancock, NH 03449
(603) 525-3394

Patrick J.Barosh
Consultant
P.J. Barosh and Associates
35 Potter Street
Concord, MA 01742
(508) 369-1906
(508) 369-1906

David Bartlett
Associate Director
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0322
Fax: (603) 862-1915
E-mail: dbartlet@bigred.sr.unh.edu

Howard B. Bernstein
Senior Policy Analyst
MA Division of Energy Resources
100 Cambridge Street, Room 1500
Boston, MA 02202
Tel: (617) 727-4732
Fax: (617) 727-0030
E-mail: howard.bernstein@state.ma.us

Richard Birdsey
Program Manager
USDA Forest Service
5 Radnor Corp. Center, Suite 200
Radnor, PA 19087-4585
Tel: (610) 975-4092
Fax: (610) 975-4095
E-mail: rbirdsey@lunar.nena.org

Doug Bogen
NH Program Coordinator
Clean Water Action
163 Court Street
Portsmouth, NH 03801
Tel: (603) 430-9565
Fax: (603) 430-9708

Robert Brower
Director of Planning
Cayuga County Planning Department
County Office Building - 5th Floor
160 Genesee Street
Auburn, NY 13021
Tel: (315) 253-1276
Fax: (315) 253-1586
E-mail: bbrower@relex.com

Deirdre Buckley
Assistant Director
Air Policy & Planning
100 Cambridge Street, 20th Floor
Boston, MA 02202
Tel: (617) 727-9800 ext. 233
Fax: (617) 727-1598
E-mail: deirdre.buckley@state.ma.us

Ann Bucklin
Director - NH-ME Sea Grant
Research Associate Professor
Ocean Process Analysis Laboratory
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603)862-3505
Fax: (603) 862-0243
E-mail: acb@kepler.unh.edu

Karen Burnett-Kurie
Project Manager for WhaleNet
Wheelock College
4 Pendexter Road
Durham, NH 03824
E-mail: kburnett@whale.wheelock.edu

Lynne M. Carter
Visiting Scientist
Department of Oceanography
University of Rhode Island
P.O. Box 21
Narragansett, RI 02882
Tel: (401) 874-6211
E-mail: lcarter@gsosun1.gso.uri.edu

David W. Cash
Center for Science & International Affairs
John F. Kennedy School of Government
79 John F. Kennedy Street
Cambridge, MA 02138
Tel: (617) 496-9330
Fax: (617) 495-8963
E-mail: cashdav@ksg.harvard.edu

Michael A. Charpentier
GIS Analyst
US EPA, Region 1
JFK Federal Building - MIR
Boston, MA 02203-0001
Tel: (617) 565-4156
Fax: (617) 565-3736
E-mail: mike@tweety.r01.epa.gov

Michael Cline
Licensed Forester
147 Raymond Cape Road
Timber & Habitat Company
147 Raymond Cape Road
Raymond, ME 04071
Tel: (207) 655-4074

Kenneth A. Colburn
Director
Air Resources Division
NH DES
64 North Main Street, PO Box 2033
Concord, NH 03302-0233
Tel: (603) 271-1380
Fax: (603) 271-1381
E-mail: k_colburn@des.state.nh.us

Nancy Cole
Project Manager
Sound Science Initiative
Union of Concerned Scientists
2 Brattle Square
Cambridge, MA 02140
Tel: (617) 547-5552
Fax: (617) 864-9405
E-mail: ncole@ucsusa.org

Priscilla Cookson
Educational Chair
NH Sierra Club
191 A York Woods Road
South Berwick, ME 03908
E-mail: desrtfox@nh.ultranet.com

Robert W. Corell
Assistant Director for Geosciences
National Science Foundation
4201 Wilson Boulevard, Suite 705N
Arlington, VA 22230
Tel: (703) 306-1500
Fax: (703) 306-0372
E-mail: rcorell@nsf.gov

Michael Disharoon
Environmental Engineer
Wyeth - Ayerst Research
Chemical Development
Rouses Point, NY 12979
Tel: (518) 297-8920
Fax: (518) 297-8116
E-mail: disharm@war.wyeth.com

Claudette M. Donnelly
RI Environmental Education Assoc.
170 Plum Point Road
Saunderstown, RI 02874-2706
Tel: (401) 294-4055
Fax: (401) 294-4055
E-mail: RFDonnelly@aol.com

Richard F. Donnelly
Board of Directors
RI Environmental Education Assoc.
170 Plum Point Road
Saunderstown, RI 02874-2706
Tel: (401) 294-4055
Fax: (401) 294-4055
E-mail: RFDonnelly@aol.com

Lesley-Ann Dupigny-Giroux
Assistant Director
Department of Geography
University of Vermont
PO Box 54170
Old Mill Building
Burlington, VT 05405-4170
Tel: (802) 656-2146
Fax: (802) 656-3042
E-mail: ldupigny@zoo.uvm.edu

Petya Entcheva
Graduate Student
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0048
E-mail: petya@garnet.sr.unh.edu

Paul R. Epstein
Associate Director
Center for Health & Global Environment
Harvard Medical School
260 Longwood Society
Boston, MA 02115
Tel: (617) 432-0493
Fax: (617) 432-2595
E-mail: pepstein@igc.org

Ivan Fernandez
Professor, Soil Sciences
University of Maine
Orono, ME 04469
Tel: (207) 581-2932
Fax: (207) 581-2999
E-mail: ivanjf@maine.maine.edu

Douglas P. Forbes
Chief of Staff
MA Emergency Management Agency
Box 1496
Framingham, MA 01701
Tel: (508) 820-2040
Fax: (508) 820-2030

Tim Foresman
Director, Spatial Analysis Laboratory
Baltimore-Washington Regional Collaboratory
University of Maryland - Baltimore Co.
Dept. of Geography
1000 Hilltop Circle
Baltimore, MD 21250
Tel: (410) 455-3149
Fax: (410) 455-1056
foresman@mbc.edu

Fred Friedman
Head, Research Library for RCRA
US EPA, Region 1
JFK Federal Building - SPP
Boston, MA 02203
Tel: (617) 565-3282
Fax: (617) 565-4939
E-mail: friedman.fred@epamail.epa.gov

Harold Garabedian
Assistant Director
VT Air Pollution Control Program
103 South Main Street
Building 3 South
Waterbury, VT 05671-0402
Tel: (802) 241-3849
Fax: (802) 241-2590
E-mail: haroldg@qtm.anr.state.vt.us

Patrick Garner
President
Association of Massachusetts
Wetland Scientists
109 Whitney Street
Northboro, MA 01532
Tel: (508) 393-3200
Fax: (508) 393-3200
E-mail: pcgarner@sprintmail.com

Graham Giese
Research Specialist
Department of Geology & Geophysics
Woods Hole Oceanographic Institute
Woods Hole, MA 02543
Tel: (508) 289-2297
E-mail: ggiese@whoi.edu

Lewis E. Gilbert
Director for Interdisciplinary Programs
Columbia University
405 Law Library
New York, NY 10027
Tel: (212) 854-4830
Fax: (212) 854-6309
E-mail: gel@ldeo.columbia.edu

Daniel S. Goldin
Administrator
NASA Headquarters
Code A
Washington, DC 20546-0001
Tel: (202) 358-1010
Fax: (202) 358-2810
E-mail: dgoldin@mail.hq.nasa.gov

Joel N. Gordes
President
Environmental Energy Solutions
97 End Hill Road
Winsted, CT 06098
Tel: (860) 379-2430
Fax: (860) 379-2430
E-mail: jgordes@snet.net

Cynthia Greene
Environmental Scientist
US EPA, Region 1
JFK Federal Building - SPP
Boston, MA 02203
Tel: (617) 565-3165
Fax: (617) 565-4939
E-mail: greene.cynthia@epamail.epa.gov

Timothy L. Gubbels
Senior Scientist
NASA ECS Project
Hughes Applied Information Systems
1616 McCormick Drive
Landover, MD 20785-5372
Tel: (301) 925-0452
Fax: (301) 925-0321
E-mail: tgubbels@eos.hitc.com

Perry Hagenstein
Chairman
New England Natural Resources Center
Box 44
Wayland, MA 01778
Tel: (508) 358-2261
Fax: (508) 358-2261
hagenstein@aol.com

Stephen R. Hale
Graduate Student
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-4758
Fax: (603) 862-0188
E-mail: steve.hale@unh.edu

Steven P. Hamburg
Associate Professor
Center for Environmental Studies
Brown University
Box 1943
Providence, RI 02912-1943
Tel: (401) 863-3449
E-mail: Steven.Hamburg@Brown.EDU

Kate Hartnett
Executive Director
New Hampshire Comparative Risk Project
18 Low Avenue
Concord, NH 03301
Tel: (603) 226-1009
Fax: (603) 226-0042
E-mail: katehart@tiac.net

Paul G. Harris
Research Director
Orion Worldwide Research
17 Greenwich Park, Suite 3
Boston, MA 02118
Tel: (617) 262-4877
E-mail: pgharris@ix.netcom.com

Denise Hart
Media Coordinator
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0322
Fax: (603) 862-1915
E-mail: dlhart@christa.unh.edu

Brenda Hausauer
Consultant
VT Department of Public Service
10 Laugdon Street, Apartment 12
Montpelier, VT 05602
Tel: (802) 223-7018
E-mail: WCJG18C@prodigy.com

James D. Hawk
Graduate Student in Oceanography
University of Rhode Island
81 Wampum Road, Apartment B
Narragansett, RI 02882
Tel: (401) 792-0062
Fax: (401) 874-6613
E-mail: jhawk@gsosun1.gso.uri.edu

Wanda Haxton
Policy Analyst
Climate Policy & Assessment Division
Mail Code 2174
Washington, DC 20460
Tel: (202) 260-2709
Fax: (202) 260-6405

Douglas Hill
President
Douglas Hill, P.E., P.C.
15 Anthony Court
Huntington, NY 11743
Tel: (516) 421-5544
Fax: (516) 421-2999
E-mail: dhill@ccmail.sunysb.edu

Lloyd C. Irland
President
Irland Group
RFD #2, Box 9200
Winthrop, ME 04364
Tel: (207) 395-2185
Fax: (207) 395-2188
E-mail: irland@aol.com

Glenn Juday
Associate Professor
Forest Sciences Department
University of Alaska, Fairbanks
182D AHRB
Fairbanks, AK 99775
Tel: (907) 474-6717
E-mail: gjuday@gis.lter.alaska.edu

Representative Naida Kaen
New Hampshire House of Representatives
22 Toon Lane
Lee, NH 03824
Tel: (603) 659-2205
E-mail: kaen@nh.ultranet.com

Barry Keim
NH State Climatologist
University of New Hampshire
James Hall
Durham, NH 03824
Tel: (603) 862-3136
E-mail: bdk@hopper.unh.edu

Thomas Kelly
Director, Sustainability Programs
University of New Hampshire
Nesmith Hall
Durham, NH 03824-3587
Tel: (603) 862-2640
Fax: (603) 862-0785
E-mail: thkelly@hopper.unh.edu

John Kermond
NOAA Office of Global Programs
Silver Springs, MD 20910
Tel: (301) 427-2089
E-mail: kermond@ogp.noaa.gov

Ken Kimball
Director of Research
Appalachian Mountain Club
Pinkham Notch
Gorham, NH 03581
Tel: (603) 466-2721 ext 199
E-mail: kkimball@amcinfo.org

Karl Kreutz
Graduate Student
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0266
Fax: (603) 862-2124
E-mail: karl.kreutz@unh.edu

Clara Kustra
Workshop Coordinator
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0322
Fax: (603) 862-1915
E-mail: clara.kustra@unh.edu

Amy Langston
Disease Database Coordinator
Engineering Sciences Laboratory
Harvard University
40 Oxford Street, Room 328
Cambridge, MA 02138
Tel: (617) 496-8128
Fax: (617) 495-5672
E-mail: alangston@igc.org

Don LaTourette
Greenhouse Gas Specialist
NH DES Air Resources Division
64 North Main Street
Concord, NH 03302-2033
Tel: (603) 271-5552
Fax: (603) 271-1381
E-mail: tec@des.state.nh.us

Gary Lauten
Research Scientist
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-4187
Fax: (603) 862-0188
E-mail: gary.lauten@unh.edu

Rob Leatherbee
Senior Engineer
Public Service of New Hampshire
PO Box 350
Manchester, NH 03105
Tel: (603) 634-2458
Fax: (603) 634-2449
E-mail: leathrs@nu.com

Stuart M. Leiderman
Doctoral Student
Natural Resources Department
University of New Hampshire
James Hall
Durham, NH 03824
Tel: (603) 862-0280
Fax: (603) 862-4976
E-mail: leidermn@christa.unh.edu

Michael MacCracken
Director
USGCRP Office
400 Virginia Avenue, Suite 750
Washington, DC 20024
Tel: (202) 314-2220
Fax: (202) 488-8679
E-mail: mmaccrac@usgcrp.gov

Norman J. MacDonald
Meterologist
Brave Boat Harbor Road
York, ME 03909
Tel: (207) 363-1877

Representative Jeffrey MacGillivray
Science, Technology & Energy Committee
New Hampshire House of Representatives
256 Timbertop Road
New Ipswich, NH 03071-3018
Tel: (603) 878-4251
Fax: (603) 878-1000

Paul Mayewski
Director
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-3146
Fax: (603) 862-2124
E-mail: p_mayewski@unh.edu

Sharon Meeker
Extension Educator
NH - ME Sea Grant
University of New Hampshire
Kingman Farm
Durham, NH 03824
(603) 749-1565
E-mail: bsm@christa.unh.edu

David Meeker
Professor of Mathematics
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-3157
Fax: (603) 862-2124
E-mail: ldm@math.unh.edu

Jerry Melillo
Co-Director
Senior Scientist
Ecosystems Center
Marine Biological Laborabory
Woods Hole, MA 02543
Tel: (508) 548-3705 ext. 494
Fax: (508) 457-1548
E-mail: jmelillo@lupine.mbl.edu

Eric Meyerson
Graduate Student
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-4046
Fax: (603) 862-2124
E-mail: eric.meyerson@grg.sr.unh.edu

Rakesh Minocha
Research Biochemist
USDA Forest Service
271 Mast Road, PO Box 640
Durham, NH 03824
Tel: (603) 868-7622
Fax: (603) 868-7604
E-mail: rminocha@hopper.unh.edu

Berrien Moore III
Director
Institute for the Study of EOS
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-1766
Fax: (603) 862-1915
E-mail: b.moore@unh.edu

David M. Moss
Instructor, Department of Education
University of New Hampshire
Morrill Hall
Durham, NH 03824
Tel: (603) 862-2310
Fax: (603) 862-0188
E-mail: dave.moss.unh.edu

Representative George T. Musler
Chair, Environment & Agriculture
New Hampshire House of Representatives
449 Route 9
Barrington, NH 03825
Tel: (603) 664-2877

Scott W. Nixon
Director of RI Sea Grant
Graduate School of Oceanography
University of Rhode Island
South Ferry Road
Narragansett, RI 02882-1197
Tel: (401) 874-6800
Fax: (401) 789-8340
E-mail: snixon@gso.uri.edu

Alan Nogee
Senior Energy Analyst
Union of Concerned Scientists
2 Brattle Square
Cambridge, MA 02238
Tel: (617) 547-5552
Fax: (617) 864-9405
E-mail: anogee@ucsusa.org

Ellen O'Donnell
Environmental Analyst
Public Service of New Hampshire
1000 Elm Street, PO Box 330
Manchester, NH 03101
Tel: (603) 634-2331
Fax: (603) 634-2597
E-mail: odonnee@nu.com

Mila Paul
9 Evans Road
Madbury, NH 03820
E-mail: mcpaul@hopper

Iqbal Pittalwala
Research Scientist
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0663
Fax: (603) 862-2124
E-mail: ip@breeze.sr.unh.edu

James Platts
Senior Engineer
Northeast Utilities
107 Selden Street
Berlin, CT 06037
Tel: (860) 665-5643
Fax: (860) 665-3777
E-mail: plattje@nu.com

Ronald G. Prinn
Director
Center for Global Change Science
Massachusetts Institute of Technology
Building 54-1312
Cambridge, MA 02139-4307
Tel: (617) 253-2452
Fax: (617) 253-0354
E-mail: rprinn@mit.edu

David B. Reusch
Graduate Student
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-4046
Fax: (603) 862-2124
E-mail: dave.reusch@unh.edu

Mary K. Reynolds
Urban Forester
NH Division of Forests & Lands
PO Box 1856
Concord, NH 03302-1856
Tel: (603) 271-2214
Fax: (603) 271-2629
E-mail: m_reynolds@dred.state.nh.us

Barry Rock
Director
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-2949
Fax: (603) 862-0188
E-mail: barry.rock@unh.edu

Fay Rubin
NH Grant Director
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-1792
Fax: (603) 862-0188
E-mail: fay.rubin@unh.edu

James W. Russell
Vice President
Institute for Business & Home Safety
73 Tremon Street, Suite 510
Boston, MA 02108-3910
Tel: (617) 722-0200
Fax: (617) 722-0202
E-mail: jrussell@ibhs.org

Larry Ryan
Senior Scientific Data Analyst
Ocean Process Analysis Laboratory
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0195
Fax: (603) 862-0243
E-mail: ryan@ekman.unh.edu

William Salas
Research Scientist
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824
Tel: (603) 862-1792
Fax: (603) 862-0188
E-mail: bill@japura.unh.edu

Tim Scherbatskoy
Assistant Professor
School of Natural Resources
University of Vermont
Burlington, VT 05405
Tel: (802) 656-8336
Fax: (802) 656-8683
E-mail: tscherba@zoo.uvm.edu

Nancy Sherman
Policy & Planning Analyst
VT Department of Public Service
112 State Street
Montpelier, VT 05620
Tel: (802) 828-4081
Fax: (802) 828-2342
E-mail: shermann@psd.state.vt.us

Frederick Short
Associate Estuarine Professor
Jackson Estuarine Laboratory
University of New Hampshire
Durham, NH 03824
Tel: (603) 862-2175
Fax: (603) 862-1101
E-mail: fred.short@unh.edu

John Slater
Graduate Student
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-4046
Fax: (603) 862-2124
E-mail: john.slater@grg.sr.unh.edu

Molly Smith
Environmental Defense Fund
257 Park Avenue South
New York, NY 10010
Tel: (212) 505-0606 ext. 373
Fax: (212) 505-0892
E-mail: molly_smith@edf.org

Elske Smith
68 Old Stockbridge Road
Lenox, MA 01240
Tel: (413) 637-2106
E-mail: elskesmith@compuserve.com

Leo Spencer
Chocorua Camping Village
86 Stepping Stone Road
Lee, NH 03824
Tel: (603) 659-8312
Fax: (603) 659-8405
info@bahamasvacations.com

Shannon Spencer
Research Assistant
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-4311
Fax: (603) 862-0188
E-mail: shannon.spencer@unh.edu

Daniel A. Sundquist
Science Director
Society for Protection of NH Forests
54 Portsmouth Street
Concord, NH 03221
Tel: (603) 224-9945
Fax: (603) 228-0423
E-mail: dsund@spnhf.org

Jennifer Supple
Environmental Science Teacher
Kennett High School
Box 372
Freedom, NH 03836
Tel: (603) 539-8356
Fax: (603) 356-5394
E-mail: JenSupple@aol.com

Marika Tatsutani
Policy Analyst
NESCAUM
19 Portland Street
Boston, MA 02114
Tel: (617) 367-8540
Fax: (617) 742-9162
E-mail: mtatsutani@nescaum.org

Mary Tebo
Community Forestry Coordinator
Cooperative Extension
University of New Hampshire
Pettee Hall
Durham, NH 03824
Tel: (603) 624-9481
Fax: (603) 624-9469
E-mail: mary.tebo@unh.edu

Marc J. Tremblay
Manager
Water Resources
552 Academy Avenue
Providence, RI 02908
Tel: (401) 828-1660
Fax: (401) 828-7780

Mark Twickler
Associate Director
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-1991
Fax: (603) 862-2124
E-mail: mark.twickler@unh.edu

Representative Thomas A. Varrell
Lieutenant USN Retired
New Hampshire House of Representatives
PO Box 193
235 Long Pond Road
Danville, NH 03819
Tel: (603) 642-3823

Henry Veilleux
Vice President
Business & Industry Association of NH
122 North Main Street
Concord, NH 03301
Tel: (603) 224-5388
Fax: (603) 224-2872
E-mail: hveilleux@aol.com

Eric VonMagnus
Analyst
Maine Public Utilities Commission
18 State House Station
Augusta, ME 04333
Tel: (207) 287-3831
Fax: (207) 287-1039
E-mail: eric.vonmagnus@state.me.us

Cameron Wake
Research Assistant Professor
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-2329
Fax: (603) 862-2124
E-mail: cameron.wake@unh.edu

Margaret Weeks
Forest Health Monitoring
USDA Forest Service
PO Box 640
Durham, NH 03824
Tel: (603) 868-7712
Fax: (603) 868-7604
E-mail: mweeks@hpl.nena.org

Tom Wessels
Director of Environmental Biology
Antioch New England Graduate School
Keene, NH 03431
Tel: (603) 357-3122 ext. 277
Fax: (603) 357-0718
E-mail: twessels@antiochne.edu

Bruce Westcott
Executive Director
VT Center for Geographic Information, Inc.
University of Vermont
206 Morrill Hall
Burlington, VT 05405-0106
Tel: (802) 656-4277
Fax: (802) 656-0776
E-mail: brucew@vcgi.uvm.edu

Norman Willard
Climate Change Coordinator
US EPA, Region 1
JFK Federal Building
Boston, MA 02203
Tel: (617) 565-3702
Fax: (617) 565-4939
E-mail: willard.norman@epamail.epa.gov

Steven Winnett
Watershed Specialist
US EPA, Region 1
JFK Federal Building - CCT
Boston, MA 02203
Tel: (617) 565-3570
Fax: (617) 565-4940
E-mail: winnett.steven@epamail.epa.gov

David W. Wolfe
Associate Professor
Cornell University
168 Plant Science Building
Ithaca, NY 14853
Tel: (607) 255-7888
Fax: (607) 255-0599
E-mail: dww5@cornell.edu

Christian Zdanowicz
Graduate Student
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-0286
Fax: (603) 862-2124
E-mail: cmz@kepler.unh.edu

Julian Zelazny
Environmental Policy Director
Audubon Society of New Hampshire
3 Silk Farm Road
Concord, NH 03301
Tel: (603) 224-9909
Fax: (603) 226-0902
E-mail: bosko@cyberportal.net

Greg Zielinski
Research Associate Professor
Climate Change Research Center
University of New Hampshire
Morse Hall
Durham, NH 03824-3525
Tel: (603) 862-1012
Fax: (603) 862-2124
E-mail: greg.zielinski@unh.edu

Appendix VI

Invited Speaker Papers

Potential Impacts of Climate Change on Forest Resources in New England

Richard Birdsey
USDA Forest Service*

Forest resources in New England are intensively utilized for many different purposes. Population density is high, and because New England also has the highest proportion of forested land in the Nation, there is an intimate association of people and forests. Both large and small municipalities rely on forested watersheds for water supplies. Local economies are strongly tied to forest resources for uses such as outdoor recreation, hunting, maple syrup production, wood and fiber production, and aesthetic values.

Increasing atmospheric CO_2 (and other trace gases) causes enhanced greenhouse warming and has a direct effect on tree physiology and growth. Along with these changes, air pollution and acidic deposition exert strong influences on forest ecosystems in New England. Climate and pollution stresses, and their interactions with pests and intensive land uses, are likely to cause unprecedented and unanticipated changes in forest productivity and composition. The fragmentation of Northern forests due to urbanization, recreation, and agricultural use affects species habitats and the ability of some species to adapt to climatic change.

Research in New England has begun to unravel some key questions about how environmental changes will impact the productivity and health of forest ecosystems, species distributions and abundance, and associations of people and forests. However, just as we cannot predict with much certainty how climate in New England will change, we cannot yet predict how a given climate change scenario might impact different forest types or species. Nevertheless, some interesting information is becoming available and we should be aware of the possible consequences of climate change, and how climate change may interact with other factors to shape our future forests. Because of these potential changes, there is a need to develop adaptive management practices to protect forest health and productivity on both public and private lands.

New England Forests in a National and Global Context

The dense forests of New England and New York contain 4.2 billion metric tons of carbon in forest ecosystems, and this amount is increasing at a rate of about 20 million metric tons per year. Annual CO_2 emissions in the United States, primarily from burning fossil fuels for energy, are equivalent to 1.5 billion metric tons of carbon. In the international negotiating arena, the President is seeking ways to reduce or offset CO_2 emissions by 100 million metric tons, of which about 10 million would come from additional carbon storage in forests. The maturing forests of New York and New England are contributing in a very positive way to offset CO_2 emissions from other sources.

The rate of increase in forest carbon will not last. Growth is slowing as the forests mature, and harvest levels remain steady. Thus the inventory of forest carbon will level off in future years, and the U.S. will have to seek other ways besides forest offsets to control CO_2 emissions. Threats to the forests could reverse the trend and reduce the amount of carbon storage by causing declines and diebacks. On the other hand, increasing atmospheric CO_2 and nitrogen deposition may increase growth rates for many species, which would increase the amount of carbon in forest ecosystems. We are monitoring the exchange of CO_2 between forests and the atmosphere at research sites in Maine and Massachusetts so that we may understand better how forests are changing now and prospectively.

Which Forests and Species are Vulnerable to Climate Change?

Although we cannot yet identify which specific forest ecosystems and resources are most vulnerable to rapid climate change, some general characteristics of vulnerable forest ecosystems have been identified. These include: (1) forests and trees growing at or near their ecological limits of survival; (2) forests and trees already undergoing stress of some kind; (3) isolated populations or populations growing where barriers would pre-

* See Appendix V for authors' affiliations and addresses.

vent successful migration; and (4) forests and trees with limited adaptive capability.

In general, forests at climatic extremes, ecotones or transition areas, and forest areas limited by a barrier such as a mountain top or unfavorable site condition are often considered at greatest risk. Forests that are already stressed by other biotic or abiotic factors are also at high risk.

Some examples of vulnerable forests in New England include:

1) High-elevation red spruce, which is already stressed by acid deposition and winter injury.
2) Aging hardwood forests, which may be limited in adaptive capability.
3) Aspen-birch, which reaches its southern limit in Northern New England.

Some Tree Species May Adapt Quickly to Environmental Stress

Some tree species are well adapted to extreme environmental conditions. Under a changing environment, adaptation may be a significant alternative survival strategy to migration for some species. Successful adaptation or migration, or both, of a species may depend on how rapidly environmental conditions change.

Investigations on larch show how rapidly conifers can change their genetic makeup in response to changes in the environment. Genetic maps of the DNA from larch seeds grown under two temperature conditions show a strong segregation in certain marker locations, and show different growth responses, indicating selection for alternative traits under differing growth environments. The environment induces selection of different alleles in genetically identical populations of trees.

Eventually, identified genetic markers can be correlated with tree stress responses. This correlation would allow managers to select and propagate trees with adaptive traits for changing climatic conditions. A better understanding of the effect of breeding environment on plant performance may allow managers to select seed sources tailored to the expected environment in which a tree will grow over a long rotation.

Acid Deposition is Linked to Increased Winter Injury in Red Spruce

Damage to the foliage of red spruce during the winter is observed periodically in New England. Reports of winter injury have increased since 1960. Several studies have shown that exposure to acid mist, common at high elevations in New England, reduces the cold tolerance of red spruce foliage, predisposing it to winter injury. In experiments with simulated acid cloud water, exposing plants to acid mist at pH 5.6 and pH 3.2 reduced their cold tolerance by 3 to 5°C.

Midwinter dehardening followed by extreme cold or rapid freezing (rather than reduced tolerance to cold temperature) may also cause winter injury. In laboratory experiments and field studies, rapid freezing causes the same damage symptoms as observed in the field after winter injury events. There were strong elevation and aspect patterns to damaged trees after severe injury during the winter of 1992-93, suggesting that solar radiation plays a role in rapid temperature changes.

Foliage exposed to acid mist has lower amounts of calcium (Ca) in the tissue. There is some disagreement concerning the role of Ca in the sensitivity of tissue to cold. Attempts to mediate reductions in cold tolerance by adding Ca to the soil in short-term experiments have not been successful. There is some uncertainty regarding the role of older, weathered soils that have depleted levels of Ca vs. newer glaciated soils that have abundant available Ca.

Although the link between acid deposition and increased winter injury has been demonstrated in experiments, the impact on red spruce at different field sites is still under study. Effective management practices have yet to be identified.

Warmer Temperatures Affect C and N Dynamics in New England Forest Soils

Climate—particularly temperature and precipitation—affects the rate at which organic matter decays and is broken down into its mineral components. This has led to much debate about the potential effects of global warming on northern temperate and boreal forest soils, especially since soils are major reservoirs for C, N, and other nutrients necessary for forest growth and productivity. Air pollution, particularly acid deposition, may also affect the availability of certain nutrients such as calcium and magnesium.

The response of a commercial spruce-fir forest soil to a warmer climate was investigated by increasing the forest floor thermal regime by 5°C with the use of buried heating cables. This experiment has shown that fine root growth, litter decay, and CO_2 emissions are greater in the heated plots than the unheated plots. It is likely that increased microbial decomposition and root respiration caused these changes. A similar soil heating study in a northern

hardwood forest produced similar results: increases in CO_2 flux, litter decomposition, and N mineralization. Germination of white pine seeds increased but there was no change in germination of eastern hemlock seeds in response to heating. In another study using sample plots along a series of short climate gradients in Maine, investigators concluded that temperature is a strong predictor of soil respiration and net N mineralization, though there are regional differences in the derived relationships.

These studies suggest that global warming would affect forest productivity, species composition, and carbon sequestration in forests of New England. Such experiments help answer some key questions about CO_2 flux and nutrient availability under a changing climate, and provide data to use in predictive models of the effects of regional climate change.

Nitrogen Deposition Is Retained and Sulphur Deposition Exported in Northeastern Study Sites

Continuous, long-term measurements of climate variables, atmospheric deposition, throughfall chemistry, and soil solution chemistry provide a basis for evaluating changes in chemical deposition and effects on forest processes. Nitrogen deposition is of particular importance in the Northeast. Although most temperate forests are considered N limited, there is a growing concern that chronic N deposition can lead to the contrasting condition of excess N or N saturation. Excess N interferes with normal soil processes and can reduce productivity, and may also be exported from the forest in streams and rivers, with undesirable effects on water quality. Sulphur (S) affects vegetation in the Northeast primarily as sulfuric acid, a major component of acid deposition.

At a commercial spruce-fir forest site in Howland, Maine, S deposition has decreased over a 6-year period while N deposition has remained relatively steady. There was a net retention of N in the soils, attributable to N-deficiency in the ecosystem. Outputs of S in streamwater decreased in proportion to decreasing atmospheric inputs.

The effects of elevation on deposition and nutrient cycling were studied over an 8-year period at a high-elevation spruce-fir forest on Whiteface Mountain, New York. There are large (four- to fivefold) differences in deposition of S and N over an elevational range of 600 to 1275 m. The differences are attributed to higher levels of cloud water deposition at higher elevations. Most of the N is retained in the ecosystem, except a small amount is exported in streamwater. This may signal the early stages of N saturation. Sulphur output varies with the level of S input, similar to observations at Howland.

These long-term observations of chemical inputs, transformations, and outputs in forest ecosystems allow us to analyze changes that result from the recent revision of the Clean Air Act. They also facilitate understanding of the critical role of N in ecosystem productivity, interactions with other stresses such as increasing CO_2 and O_3, and the role of N fertilization in the global C cycle. Of particular importance are prospects for N saturation and eventual export of nitrate, a significant pollutant of drinking water and marine systems, from northeastern watersheds.

Nutrient Concentrations Are Declining in Areas Sensitive to Acid Deposition

Several long-term studies in the Adirondack Mountains of New York and the White Mountains of New Hampshire documented a substantial decline since 1950 in Ca and Mg in the organic soil layers of red spruce forests. Evidence of changing Ca and Mg availability is also present in wood. Chemical analysis of wood cores from the northeastern United States has documented trends in Ca and Mg concentrations that are consistent with changes measured in the soil. There is a strong correlation between these changes in the forest and historical changes in acid deposition, which increased substantially about 1950.

It has been suggested that reduced availability of Ca and Mg could cause decreased productivity and decline/dieback of red spruce in the Northeast, especially on calcium-deficient soils. Chemical analyses from the 12 research sites in New England and New York have documented increased leaching of Ca and Mg from the soil, a decreased amount of Ca and Mg available to tree roots, and corresponding changes in Ca in wood. These changes are initiated by acid deposition. Acid deposition leaches Ca from the soil, and can cause aluminum (Al) to become soluble. Soluble Al may be brought to the surface soil and the rooting zone of red spruce by upward water movement. Elevated concentrations of Al inhibit the uptake of Ca and Mg by the roots, and can be toxic if concentration becomes too high.

Decreased availability of Ca and Mg and increased availability of Al cause stress in red spruce and make the trees more vulnerable to winter injury, defoliators, and root rot. High elevation spruce-fir sites have shown the greatest impact, and although lowland spruce-fir forests have been less

obviously impacted, the same chemical processes are occurring and there is reason to expect that impacts may become more apparent over time.

Scientists are seeking to discover early indicators of stress in red spruce trees so that managers have an early warning of impending decline/dieback. They are also evaluating possible mitigating effects of additions of Ca. Results of this research will assist land managers in maintaining healthy forests over a large area of red spruce forest in the Northeast.

Can We Predict or Detect Species Migrations?

Predictions of the effects of global warming on the ranges of individual tree species indicate northward shifts of up to 800 km. Estimates of the maximum rate of tree migration from historical records (15-50 km per century) suggest that most species could not keep pace with the predicted rate of climate change. Keeping pace would require a migration rate of more than 10 times the past rates. Following this logic, many have speculated that rapid climate change could cause tree species to grow under environmental conditions that are not optimal for growth during transition to a new climate (a transient response), which could cause growth reductions, declines in tree health, or abnormal rates of tree mortality.

Historical rates of distribution shifts may be misleading because human land use has fragmented most landscapes, making it even more difficult for many species to move into new areas. On the other hand, humans have unprecedented capability to assist in the process of species establishment and so could substantially increase the natural rate of seed dispersal.

We have remeasured long-term, permanent sample plots with the objective of detecting changes in species composition associated with disturbance, acid deposition, and climate change. Establishment of sample plots along an elevation gradient in New Hampshire, and remeasurment of forest inventory plots over a 24-year period in Maine, show that species composition changes are strongly associated with past land use changes, obscuring any signal of changing composition associated with climate. A separate study covering a 60-year period on the Bartlett Experimental Forest in New Hampshire showed that the primary factor affecting species composition was natural succession, followed by management activities and wind damage.

These and other studies highlight the difficulty of attributing observed changes in forest composition to specific causes when there are many factors simultaneously influencing the systems. Natural succession, disturbance and drought, and past and present human activities seem to be dominant factors affecting forests in the Northeast. Detection of changes in species composition as a consequence of warming or other environmental change would require intensive monitoring of sites that would be most sensitive to small perturbations.

Ozone May Reduce Regional Ecosystem Productivity

We are synthesizing, on a regional basis, the different responses of trees, stands, and landscapes to multiple environmental stresses. We developed or studied a number of models with the goal of integrating a cluster of biological models operating at various spatial and temporal scales with models of physical and social systems.

In one study we adapted a well-known ecosystem process model, PnET-II, to estimate the effects of O_3 on forest productivity over the northeastern United States. The productivity model is applied to regional data bases within a geographic information system. The model simulates physiological processes at the ecosystem scale and applies the predicted changes to landscapes composed of a grid of cells classified by vegetation attributes, climate parameters, pollution exposure, and so on.

We assumed that the only effect of elevated O_3 was a reduction in photosynthesis. Using average O_3 exposures from 1987-92, we estimated that annual Net Primary Productivity (NPP) was reduced from 2 to17 percent, with the greatest reductions in southern New York and New England where O_3 levels and potential photosynthesis were greatest.

No Evidence of Decline in Productivity of Sugar Maple

Since the 1980's, some stands of sugar maple have declined in New England and Canada. Extensive monitoring has failed to substantiate reports of widespread decline, yet the issue continues to surface because maple is so important in many ways: wood, maple syrup, aesthetics, and wildlife.

In 1991 we recovered records of research plots measured in the late 1950's in northern hardwood stands of Vermont's Green Mountains. The purpose of the original study was to examine relationships between site index and site characteristics. It was hypothesized that remeasurement of these

same plots and replication of the original analyses would uncover any significant changes in productivity that might have occurred over the 33-year period. About half of the plots had been harvested, allowing tests of additional hypotheses about the effects of disturbance.

The investigators found current growth to be equal to or better than growth 33 years ago, with shade tolerant species such as sugar maple increasing to a greater degree than shade intolerant species. This is consistent with expected stand dynamics. In the undisturbed plots, stands grew essentially as predicted from the 1957-59 data. For a given d.b.h., sugar maple was slightly (but not significantly) taller in 1990-92 than in 1957-59 (Figure 11). For maple stands that were harvested, there was apparently no effect on total carbon stored in the soil.

Conclusions Prospective Effects of Global Change On New England Forests

While we cannot predict the future with great certainty, research and monitoring are highlighting some important trends in forest ecosystems of New England and New York:

1) Carbon storage in Northeastern forests is increasing at a decreasing rate. The rate of change is affected by maturing forests and harvesting activity, increasing atmospheric CO_2, air pollution, and acid deposition.
2) High-elevation red spruce, aging hardwood forests, and aspen-birch forests are examples of forest types at risk from climate change.
3) Species composition is likely to change due to variability in adaptation and migration between species.
4) Increased winter injury of red spruce is likely as a consequence of acid deposition and extreme weather events.
5) Warmer temperatures have strong effects on soil processes. Nutrient availability and CO_2 flux will be affected, as will productivity and forest growth.
6) Nitrogen deposition remains high and sulphur deposition is declining. These chemical inputs affect productivity and forest growth.
7) Calcium and magnesium, important forest nutrients, are declining in calcium-deficient soils and may cause decreased productivity and decline/dieback of red spruce.
8) Because of the many factors affecting forests in New England and New York, it will be very difficult to identify the effect of climate change alone. Natural succession, disturbance, and drought seem to be the dominant factors affecting forests at the current time.
9) There is evidence that ground-level ozone may reduce ecosystem productivity in New England and New York, in areas where exposure is highest.
10) There is no evidence of widespread decline of sugar maple in New England and New York. In Vermont, sugar maple is growing as good or better than 3 decades ago.

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

Janine Bloomfield[1] and Steven Hamburg[*]

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-

[*] See Appendix V for authors' affiliations and addresses.

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.

SOURCES

Allen DC, Bauce E, and Barnett CJ (1992). Sugar Maple Declines: Causes, Effects and Recommendations. In Forest Decline Concepts (Eds. PD Manion and D Lachance) APS Press, St. Paul MN.

Callaway M, Smith J, and Keefe S (1995). The Economic Effects of Climate Change on US Forests. RCG/Hagler Bailly, Boulder CO, Prepared for Adaptation Branch, Climate Change Division, Office of Policy, Planning and Evaluation, US EPA, Washington DC Contract No. 68-W2-0018.

Dr. Laurence Goss, personal communication, Institute for New Hampshire Studies, Plymouth State College.

Hill LB, Allen GA, and Carlson J (1995). Characterization of Ozone in the Great Gulf and Presidential/Dry River Class-I Airsheds, White Mountain National Forest, New Hampshire. Appalachian Mountain Club Technical Report 95-1.

Institute of New Hampshire Studies, Plymouth College (1993). The New Hampshire Ski Industry, 1992-1993: It's Contribution to the State's Economy. Prepared for the NH Department of Resources and Economic Development in cooperation with Ski New Hampshire, Inc. and the U.S. Forest Service, WMNF.

Intergovernmental Panel on Climate Change (1996, volume I) Climate Change 1995: The Science of Climate Change. Eds. JT Houghton, LG Meira Filho, BA Calander, N Harris, A Kattenberg and K Maskell. Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (1996, volume II) Climate Change 1995: Impacts, Adaptation and Mitigation of Climate Change. Eds. RT Wilson, MC Zinyowera, and RH Moss, Cambridge University Press, Cambridge.

Kattenberg A, Giorgi F, Grassel H, Meehl GA, Mitchell JFB, Stouffer RJ, Tokioka T, Weaver AJ, and Wigley TML (1995). Climate Models Projections of Climate Change, in IPCC 1996, volume I.

Kirschbaum MUF, Fischlin A et al., (1995). Climate Change Impacts on Forests, in IPCC 1996, volume II.

Kozlowski TT, Kramer PJ, and Pallardy SG (1991). The Physiological Ecology of Woody Plants, Academic Press, New York.

Kukla G and Kar TR (1993). Nighttime warming and the greenhouse effect. Environment, Science and Technology, 27(8):1469-1474.

McBoyle G and Wall G (1987). The impact of CO_2-induced warming on downhill skiing in the Laurentians. Cahiers de Géographie due Québec, 31:39-50.

Morselli M (1988). Environmental stresses on the Sugar Maple by the year 2000 may affect sap biochemistry, hence syrup grades. Maple Syrup Digest 28(1):24-28.

Tyree MT (1983). Maple sap uptake, exudation and pressure changes associated with freezing exotherms and thawing endotherms. Plant Physiology, 73:277-285.

U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census (1993). 1991 National Survey of Fishing, Hunting and Wildlife-Associated Recreation.

U.S. Environmental Protection Agency (1995). Ecological Impacts for Climate Change: An Economic Analysis of Freshwater Recreational Fishing, EPA-230-R-95-004

Wilmont TR, Brett PW, MT Tyree (1995). Vigor and nutrition vs. sap sugar concentrations in sugar maples. Northern Journal of Applied Forestry, 12(4):156-162.

Global Environmental Change: Modifying Human Contributions Through Education

Lynne M. Carter, Ph.D., Visiting Scientist
Graduate School of Oceanography, University of Rhode Island*

BACKGROUND

The latest Intergovernmental Panel on Climate Change (IPCC, 1996) report on the Science of Climate Change concludes that the evidence now available "points toward a discernible human influence on global climate" (p. 439) and that ". . . if the current rate of increase of anthropogenic emissions is maintained . . . it should become increasingly easy to eliminate natural variability and other natural external forcings as causes for most of the observed changes" (p. 438). The anthropogenic activities contributing to emissions that are important to climate changes are undertaken by all members of the human population. Reductions in those emissions will require changes in human behavior.

Human behavior is complex in that it can be influenced by both psychological or internal factors as well as social or external factors. According to Simon (1992) and others (e.g., Bandura 1991), an individual's goals are important directives for behavior along with their values, attitudes, circumstances, knowledge, skills, experiences, and social contexts. Knowledge, generally gained through education, is an important moderator for environmental behavior and choice (Arcury, 1990; Hungerford and Volk, 1990; Stern, 1976). Environmental knowledge is very low in the United States (Maloney and Ward, 1973; Miller, 1991; Arcury, 1990) and particularly lacking and confused related to global environmental issues (Kempton, 1991; Read et al., 1994; Bostrom et al., 1994). This is especially so in terms of understanding the anthropogenic activities that enhance natural cycles and the environmental consequences of those activities for both humans and the natural world over both the short and long term.

While there seems to be a great deal of expressed concern about environmental degradation, nationally and globally (Krause, 1993; Kempton et al., 1995; Dunlap et al., 1992), most individuals see the responsibility for changing environmentally destructive behaviors belonging to technological development and industrial practices rather than to changing their personal behaviors (Dunlap et al., 1992). The international agreements developed to reduce human interference with the Earth's atmospheric systems, the *Montreal Protocol on Substances that Deplete the Ozone Layer* and the *United Nations Framework Convention on Climate Change*, recognize the environmental consequences of human activities and look to both societal and personal behavior changes to reduce environmental destruction. Both agreements call upon educational programs to assist in moving human behavior in a sustainable direction. Sustainability is used here as it is in Our Common Future (1987):

> Sustainab[ility] . . . is . . . meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs (p.43).

The traditional success noted in behavioral research occurs when participants change their behavior during some type of intervention period. Unfortunately, that immediate behavior change is often externally derived and not durable (DeYoung, 1993). Long term change seems to be related to less quantifiable, internally derived attributes identified by many researchers as personal insight, intrinsic satisfaction, care and concern, compassion, commitment, an internal locus of control, confidence, a sense of environmental ethics, morals, personal responsibility, environmental sensitivity, or a more spiritual or traditional approach to nature (e.g., DeYoung, 1993; Geller, 1995; Milbrath, 1989; Bowers, 1995, Hines et al., 1986-87, Hungerford and Volk, 1990; Bandura, 1991). These internally derived attributes can be supported through gaining more tangible and concrete information and knowledge about an issue of importance, such as, in this case, global environmental change.

THE STUDY

To support the importance of education as a serious and durable influence on environmentally responsible behavior, this study focused on assessing the relationship between global environmental change issues and human behavior in an educational context. The study assessed a two-and-one-

* See Appendix V for authors' affiliations and addresses.

half day National Informal Educators Workshop and Videoconference held November 14-16, 1994. The workshops were located in seven down-link sites around the continental U.S. and Hawaii and were each under the direction of a Sea Grant Regional Coordinator. The program utilized a variety of pedagogical techniques during both the national portions of the program–five hours of live and pre-recorded satellite programming with national expertise on global change topics (natural variability, greenhouse effect, ozone depletion, ecosystem response, and population and resource distribution)–and the regional workshops portion that applied the newly offered information through hands-on activities and discussion with local experts on related regional issues. The question addressed was whether conference/workshop participants would change their personal and professional behavior as a consequence of learning new information about global environmental change issues. Also of interest was whether participants would gain and retain topic specific information and if so, would that information be reflected in increased participation in responsible environmental behaviors.

Pilot Survey

A pilot survey was developed and administered to each of the 315 participants nationwide prior to the beginning of the conference, at the conclusion of each satellite session, and at the conclusion of the conference. The pilot utilized open-ended questions to encourage the participants to reflect on their: learning expectations; learning results; the scientific content; applications of this information to real-life choices and behavior (behavior alert); and the use of the technology in the learning process. Three sections of the pilot surveys (learning expectations, learning results, process) were analyzed to provide direction for the final questionnaire.

Sample

Informal and formal educators from around the U.S. and Canada, including the U.S.–affiliated Pacific island entities were participants in this educational video conference. They were the focus for many reasons, two of which are: environmental educators are believed to embody the crucial (considered prerequisite to responsible environmental behavior) entry level variables identified by Hungerford and Volk (1990) of environmental sensitivity, knowedge of ecology, psychological androgny, and attitudes toward pollution, technology, and economics; and most have the ability to reach many members of the public through their work. Of the 315 participants nationwide, 79 responded to the follow-up/final questionnaire and became the study sample. Demographic characteristics of the sample include: age (29-72 years); income (less than $20,000 to over $60,000 per year [U.S. dollars]); gender (twice as many women as men); education (from high school graduates to Ph.D.); region (Northeast, Mid Atlantic, Gulf Coast, Mid Continent, Pacific, Great Lakes, Hawaii and the Islands); affiliation (government, nonprofit agencies, and educational institutions); and educational background (mostly science–75% and education–39% = more than 100% because participants could have both types of backgrounds).

Final Survey

The results of the final questionnaire, administered eight months after the program, are reported in four sections. In the first section the participants' responses to the survey questionnaire are reported using descriptive statistics such as percentages, means, and standard deviations. In the second section three personal and three professional behavior change scales are created. Scale construction was undertaken to simplify the data resulting in new factors that represent groupings of interrelated variables used to describe the personal and professional behavior changes implemented. Scale creation was accomplished by logically grouping items and then testing the scales for internal consistency reliability. The statistic to test internal consistency was Cronbach's Alpha (Nunnally, 1978). High alphas are generally 0.7 or above. Four of the six behavior change scale alphas were above 0.7; one was very close at 0.68, and only one scale had a low alpha of 0.58.

On the personal behavior change list activities fell into three groupings, the first is the Use of Fewer Resources which included both using less (e.g., drive less) and using an alternative more (e.g., recycle more). Both forms of activities represent a change in normal social behavior that results in using fewer resources and is often under personal, volitional control. Looking ahead to more long-term decisions resulted in the second category: Purchasing Choices/Options and incorporated looking for or choosing autos and appliances that either utilized an alternative energy source (e.g., natural gas over coal or oil) or utilized less energy (e.g., more efficient appliances). The final personal category had to do with broadening one's awareness and influence related to applying global environmental change issues and became Increased Awareness and Discussion.

The professional behavior change scales incorporated items that also grouped into three categories. The first is Curriculum Development and includes items that relate to changes in planned or offered programs including revisions to programs either as an individual or as a member of a team and utilizing teaching techniques and materials gained from participation in the video conference. The second category of Networking could include networking either regionally or nationally. The third professional behavior change scale was made up of items representing changes in Office Procedures that included energy efficiency concerns in equipment purchasing review.

In the third section the relationships between the demographics and behavior change scales are explored. If the demographic variable was continuos (e.g., age), the Pearson product-moment correlation was computed. If the demographic was categorical with two categories (e.g., gender), the student t-test was employed. If the demographic characteristic had three or more categories (e.g., region or income level) an F-test was used. A further refinement was that if the demographic variable with three or more categories was also ordered (e.g., level of income, level of education), the F-test for linear trend was utilized. If the demographic was non-ordered (e.g., region), the ordinary F was calculated. The fourth section, which examined the relationship between non-demographic response to the questionnaire and the behavior change scales, used Pearson correlations because the non-demographic variables were Likert items, which could be treated as continuos variables. All the statistical analyses were done using the SAS statistical package.

SUMMARY OF RESULTS

Section One: Direct Questionnaire Responses

- Many participants reported making personal (65% recycle more) and professional (56% utilized some or all of the resource materials provided) behavior changes.
- Respondents indicated meaningful increases in substantive and specific knowledge in all five content areas (60% and greater).
- 95% of participants reported feeling more confident in talking about global change issues while another 90% reported feeling more confident in approaching additional content material.
- More than three quarters (78%) of respondents expressed a new sense of urgency in passing on global change knowledge.
- The scientific content was extremely or quite important to 91% of respondents and 82% were extremely or quite interested in receiving teaching techniques and resources to assist in passing-on this information to others.
- Information in all five content areas (natural variability, greenhouse gases, ozone depletion, ecosystem response, and population and resource distribution) was extremely or quite important to more than 50% of individuals' environmental actions.
- National and regional components of the program, as well as content instruction and teaching techniques, were extremely or quite important to more than 80% of the respondents in ranking overall success of the program.
- Participants showed a high degree of satisfaction with participation in the program (8.2 on a 10 point scale).
- Participants rated Global Environmental Change issues as extremely important (9.5 on a 10 point scale).

Section Two: Behavior Change Scales

Personal Behavior Change Scale	Item	Internal Consistency Reliability Coefficient Alpha
Use of Fewer Resources		**.74**
1. Drive less		
2. Walk or ride bike more		
3. Use less water		
4. Use less electricity		
5. Recycle more		
6. Use fewer disposables		
Purchasing Choices/Options		**.77**
1. Look for/choose natural gas over coal or oil		
2. Look for/purchase auto with higher mpg		
3. Look for/purchase more efficient appliances		
4. Look for/purchase appliance and auto w/no CFCs		
Increased Awareness and Discussion		**.58**
1. Discuss environmental issues with family and friends more often		
2. Notice waste		

N=79

Professional Behavior Change Scale	Internal Consistency Reliability Item Coefficient Alpha
Curriculum Development	**.78**
1. Developed/offered new programs/curricula	
2. Revised programs/curricula to include new information	
3. Developed/offered new programs/curricula-disciplinary lines	
4. Developed/offered new programs/curricula interdisciplinarily	
5. Worked with a team on new programs	
6. Developed/offered new programs alone	
7. Utilized some or all teaching techniques	
8. Utilized some or all resource materials	
9. Have planned/offered a video conference	
Networking	**.74**
1. Utilized network developed through video conference	
2. Have collaborated with colleagues from video conference	
Office Procedures	**.68**
1. Instituted changes in office procedure	
2. Included energy efficiency in equipment purchase review	

N=7

Sections Three and Four: Significant Relationships between Demographic Characteristics and Descriptive Reports and the Personal and Professional Behavior Change Scales

Personal

- Those from the Pacific and the Northeast Regions made greater changes in using Fewer Resources than those from other regions.
- Those with an Education background indicated a statistically significant relationship with Increased Awareness and Discussion of Global Environmental Issues.
- Those who gained confidence in talking about Global Change issues also made statistically significant gains in Increased Awareness and Discussion of Global Change Issues.
- Those who increased their confidence in approaching additional content material made statistically significant gains in all three of the personal behavior change scales.
- Those who expressed a new sense of urgency in passing-on this information made statistically significant gains in all three of the personal behavior change scales.
- Of the five topics, greenhouse gases, ozone depletion, and ecosystem response were the most important in participants' gains in the personal behavior change scale of Increased Awareness and Discussion.
- Learning the science content related to greenhouse gases and ozone depletion supported the Use of Fewer Resources.
- Gains in the personal behavior change scales were most closely related to a number of national program components and to one regional component, the workshops (overall).

Professional

- Those who gained confidence in talking about global change issues and in approaching additional content material made statistically significant changes in Curriculum Development.
- Of the five topics, natural variability, greenhouse gases, and population and resource distribution were most important to changes in Curriculum Development.
- The professional behavior change scale of Curriculum Development was most closely related to program components that focused on teaching techniques and content, both regionally and nationally.
- Those who were more satisfied with their participation in the program tended to make more Curriculum Development changes and to participate in Networking more than those less satisfied with the program.
- Those with higher incomes Networked more than those with lower incomes.
- The professional behavior change scale of Networking was closely related to the program component of regional networking.
- Those from the Northeast made more changes in Office Procedures than other regions.
- Those with affiliations with Non-Profit Agencies made more changes in Office Procedures than those without such an affiliation.
- Those affiliated with Educational Institutions implemented more changes in Office Procedures than those without such an affiliation.
- The topic of natural variability contributed most to changes in Office Procedures.

DISCUSSION

This video conference and regional workshops was an educational program not directly aimed at encouraging behavior change, yet participants implemented many behavior changes, both personal and professional, as a result of their partici-

pation. The following discussion is focused on the two themes of personal and professional behavior change.

Personal Behavior Change

Of the twelve personal behavior changes, more than 50% of the participants implemented five changes and four of those five could be thought of more as "cures" and were ". . . acts of everyday life" (Sjorberg, 1989, p. 415), fairly easily implemented, and generally under personal volitional control. One such example is reducing resource use. On the other end of the spectrum, and implemented by fewer respondents (22% to 47%), were activities that were less frequent, more difficult to implement, often not totally under the volitional control of the respondent (e.g., family decisions) and that could be referred to as "prevention" (Sjorberg, 1989, p. 415). A decision that could be termed "preventive" would be one where the decision would have a significant environmental effect over the lifetime of that decision, e.g., a major purchase. While major purchases (automobiles, appliances, and heating systems) are not everyday occurrences, those who made them were positively influenced toward an environmentally friendly direction by participation in the Video conference. Every personal behavior change measured, no matter how difficult or rare an occurrence, was implemented by at least 22%, nearly one quarter, of the participants.

There are *four themes* that emerge from the relationships between the demographic characteristics and descriptive reports and the personal behavior change scales.

Personalizing Environmental Issues

The *first theme* echoes what other researchers have found, that making the environmental issue personal, whether in the form of perceived threat or ownership of the issue (e.g., Baldassare and Katz, 1992; Hungerford and Volk, 1990), encourages behavior change. Those who expressed a new sense of urgency in passing on this information made statistically significant gains in all the personal behavior change scales. But, American adults have a growing number of choices about where to expend their energy and focus to make an issue personal (Miller, 1991). There are increasing numbers of public causes and special interests that solicit both time and money (Thomashow, 1995). Many are two-job families, with responsibility to children and extended families and leisure time options are innumerable. So a choice is in order, since few individuals follow and participate in more than two or three of the major issue areas that are available to them (Miller, 1991) and they expend little effort on activities of little value to them (Bandura, 1991).

Knowledge Acquisition

The *second theme* related to knowledge acquisition. It was found that acquiring specific content knowledge related to emerging scientific information was very important to personal behavior change. Participants with an education background made statistically significant gains in increasing their awareness and discussion of global change issues. The clear, understandable presentation of information on topics that had been confusing to the participants, such as, the greenhouse effect and ozone depletion, (Read et al., 1994; Kempton et al., 1995), as well as learning about already measurable impacts on the ecosystem were statistically significantly related to respondent gains on all three personal behavior change scales. These findings support the important role of knowledge and education in behavior change and the likelihood that people without science backgrounds (a majority of the American public) have the most to learn. This finding also supports the theories of other researchers (e.g., Kempton et al., 1995) that clear, concise, global environmental change knowledge can lead to an increased concern about the environment and appropriate, responsible behavior change.

Increases in Confidence

The *third theme* that emerged was an increase in confidence related to both an understanding of the complexity of global change issues and in approaching additional content information. Along with those increases in confidence came significant changes in all the personal behavior change scales. Neither intention nor desire will result in responsible behavior change if individuals do not have confidence in their ability to choose appropriate actions. "Among the mechanisms of personal agency, none is more central or pervasive than people's own beliefs about their capabilities to exercise control over their own level of functioning and over events that effect their lives" (Bandura, 1991, p. 257). Increased confidence results in participants' determination to triumph over obstacles blocking achievement of their goals rather than being dissuaded by failures or difficulties (Bandura, 1991). This also applies to identifying ways to have some amount of control over one's behavior even in "environments containing limited opportunities and many constraints" (Bandura, 1991, p. 269). This is particularly important in the concept of learning to live sustainably since there are no clear directives on how to ac-

complish that goal. We all need to continue to learn and find ways to live more lightly on the earth and confidence encourages ingenuity and "figuring it out" (Bandura, 1991, p. 269; Walsh, 1991). The behaviors that made-up the personal behavior change scales were not explicitly recommended behaviors but were the result of self-reflection on the content information and its application to personal behavior. Self-reflection is the first step to behavior change, but without knowledge and the confidence that knowledge engenders there is little basis for self-directed change. Much of the scientific content information is still considered *science-in-the-making*, however, providing a solid foundation and a broad understanding of the complexity of the issue from which to proceed encouraged participants to attempt to grasp and apply information that was previously too formidable to them.

National Perspective

Finally, gains in the personal behavior change scales were related to many of the program components that were National in scale. It seemed important to the participants that they were involved in a program of national scale and that they were able to interact nationally, that they all received the same content information, and that they all were exposed to the same national demonstrations and teaching techniques. All these program components statistically significantly influenced the use of fewer resources and an increase in the awareness and discussion of global environmental change issues. Knowing that a national network of interested others was developing was also important in encouraging increases in awareness and discussion of global change issues. Being part of a large, national program seemed to bring a seriousness and importance to the issue that enhanced the participants' sense of self-esteem and worth. According to Bandura (1982), there are two sources of futility for people: one relates to the individual's abilities and the other relates to their inability to produce results because of an unresponsive environment. Societal codes and sanctions influence social conduct. Personal confidence was increased through increased knowledge, while the national perspective encouraged people to feel that the social environment was becoming responsive in encouraging and supporting environmentally responsible behavior changes. That national level of concern is implemented regionally, influences each region uniquely, and was expressed through the Pacific and Northeast regions making significantly more changes in the use of fewer resources. In the words of one respondent "being invited gave us credibility–this year we are able to function because of being involved last year" (MC-4). Increases in ownership variables, particularly, content knowledge, self-esteem, worth and credibility support increases in empowerment variables, such as confidence and self-efficacy, which in turn lead to action (Hungerford and Volk, 1990). Also, according to Prochaska and DiClemente (1992), if the new behavior does not continue to be valued (in this case by society as well as the individual) then the behavior is likely to revert back or be difficult to maintain. The recognition of these issues as of national and global importance helps to support and maintain behavior change.

Professional Behavior Change

Of the professional behavior changes measured, more than half (56%) the respondents utilized some or all of the resource materials provided through the program and one third to nearly half the respondents developed and offered new programs or revised programs or curricula to include information from the Video conference. Again, regardless of difficulty, every measurable professional behavior change activity was implemented by at least 5% of the respondents. The themes that emerged related to professional behavior changes can be characterized by the three professional behavior change scales: curriculum development, networking, and office procedures.

Curriculum Development

Three factors seemed to influence the professional behavior change scale of curriculum development: confidence, content knowledge, and satisfaction. Development of confidence in talking about global environmental change issues and in approaching additional content materials was extremely important in encouraging changes in curriculum development. It is the rare person who is willing to teach something about which they have little confidence in their level of knowledge. "People avoid activities that they believe exceed their coping capabilities, but they undertake and perform assuredly those that they judge themselves capable of managing" (Bandura, 1982, p. 123). The previous discussion related to confidence also applies here.

Content information, particularly in three of the five topical areas (natural variability, greenhouse effect, and population/resource distribution), was important to changes in curriculum development. An understanding of the topic of natural variability is at the heart of the global environmental change issue. A major focus of both national and international global change research programs is

to clarify natural from anthropogenic influences on the Earth's climate system (Our Changing Planet, 1995). The greenhouse effect issue is one that promotes misunderstanding (e.g., Read et al., 1994) so that the incorporation of clear, concise content information into curriculum development in this and other areas could be helpful in answering many questions posed by students and the public. The issues of population and resource distribution help to clarify the causes of anthropogenic influences on the climate system. These three topical areas make the crucial connection between scientific knowledge and the environmental effects and consequences of human activities that are important to society. Many authors and reports (e.g., National Research Council, 1994; Costa, 1995) in the educational arena, have called for clarifying these connections. Relating cause and effect is important in helping people take ownership of their personal decisions and ultimately to make environmentally responsible behavior changes.

The respondents who were more satisfied with what they learned at the National Informal Educators Video conference made more changes in curriculum development than those who were less satisfied with the program. Satisfaction implies setting and attaining some valued personal standard. An overwhelming majority of participants indicated in the pilot survey that they were looking to attain both scientific (content) knowledge and an increased understanding of the complexity of these global environmental issues from this conference. Attainment of some level of their goal generated self-satisfaction and self-motivation to pass-on what had been learned and to continue the process of understanding and learning.

Networking

Three factors statistically significantly influenced the professional behavior change scale of networking: income, satisfaction with the learning that occurred from participation in the video conference, and the program component of regional networking. While other researchers have stated that behavior change, knowledge, and income are not positively related (Thompson and Stoutmeyer, 1991), increased income was found to be related to the professional behavior change scale of networking in this study. This is likely more related to professional seniority than to income per se. There is a certain professional level that must be attained before one can actually participate and benefit from networking. The authority to make decisions and the ability to develop and implement new programs comes with experience and so does income. Respondents who were more satisfied with what they learned from participation in the program increased their networking more than those who were not as satisfied. Again, satisfaction implies gaining something valued, in this case, global environmental change knowledge which in turn spurred a sense of personal responsibility to get this information out. Networking with interested others is a useful way to try out new teaching ideas, to glean information on what others have tried and their resulting levels of success, and to continue learning.

Office Procedures

Three factors significantly influenced changes in office procedures, a professional behavior change scale: affiliation, the scientific content related to the topic of natural variability, and region. Those subjects affiliated with Educational Institutions or with Non-profit Agencies made more changes in office procedures than those without such affiliation. The affiliations of the respondents fell into three major groups: non-profit, education, and government. Of those three groups, presumably, the most institutionalized would be government, followed by education and finally non-profit agencies. It appears that the most changes were implemented in the least institutionalized of the affiliations which were, it is assumed, easiest to change. Content information in the topic of natural variability was significantly correlated with changes in office procedures. It could be that an increase in clarifying the roles of natural variability and anthropogenic activities in enhancing global environmental changes increased the understanding of the importance of applying this knowledge to making additional professional changes. (This topic was important in increasing curriculum development as well.) Inappropriate behavior, in general, can be encouraged when any of the following are in effect: responsibility for the behavior lies elsewhere (i.e., with the institution); collective responsibility (everyone is responsible while no one is held responsible); when it is the norm (activities harmful to others occur because of social inducements); and when the recipients of the behavior are impersonal, strangers, or different (e.g., other living beings, the next generation, or those from developing countries) (Bandura, 1991, p. 281). Scientific information gained through program components of this conference effectively disengaged those inducements to inappropriate environmental behaviors by: personalizing the responsibility; and encouraging self-recognition of the environmental consequences of normative behavior. By moving responsibility from the collective and impersonal institution to the self, changes in office procedures were encouraged and

implemented where possible. The Northeast region participants implemented statistically significantly more changes in Office procedures than the other regions. There was a higher percentage of non-profit agency participants from the Northeast (>56%) than from other regions which could support the affiliation finding.

Crucial Elements

The methods used in this educational program and the findings from this study should be applicable to many developing global change education programs. There are four crucial aspects of this educational program that should be staples for any global environmental change education effort. The first must include an interdisciplinary perspective. Interdisciplinary perspectives are crucial to help individuals recognize that global environmental changes can be studied and understood from many disciplines, thereby increasing the approachability of the topic to a wide variety of individuals of varying educational backgrounds and levels.

The second important aspect to any global change education program relates to both a national and a regional dimension. The national dimension requires national participation and support and at the same time provides a broad social comparison for people to recognize their role in an important issue. The regional dimension brings the issues to a personal level, considered crucial to action.

The third important aspect is providing knowledge through understandable scientific content. Knowledge builds confidence that encourages risk taking in the form of environmentally responsible behaviors but must include clear connections to social impacts. For many, science and society have no connections. Those interactions must become explicit and thereby guide appropriate environmentally responsible behavior and policy choices.

Finally, using a multimodal approach with a variety of teaching techniques and demonstrations, including lectures, visuals, discussions, and hands-on activities, reaches a wide range of learners and models successful teaching strategies useful to a broad spectrum of educators.

Concluding Comments

This research inevitably suffers from the weaknesses inherent in mail response surveys. While there were 315 registered participants only 79 took the time to respond to the follow-up questionnaire, even with prompting. That number of respondents limited the sophistication of the statistical analyses that could be performed on the data. Also, those who participated were self-selected through an application process which makes the participants biased toward those already interested in such environmental issues rather than representative of the general public. However, the exploratory nature of the study has allowed a preliminary assessment of outcomes on important components of the program. The behavior changes implemented by respondents as a result of participation in the subject education program were internally derived, self directed, and effective many months after the program, which leads one to suspect that they may be durable. This finding is very encouraging and supports DeYoung (1993), Hungerford and Volk (1990), and the IPCC Response Strategies Working Group, among others, that suggest that providing specific environmental issue knowledge can lead to personal insight with environmentally responsible behavior changes as an outcome. However, the environmental challenges that face us are on long time scales, decades to centuries, and environmentally responsible behaviors must remain and continue to increase in frequency and complexity. Further work on whether these behaviors are transmitted to others and if so, how, would be important.

Humans do not live socially isolated and many of the environmental challenges and difficulties that we face into the future reflect group problems and will require sustained collective efforts to produce significant change. "The strength of groups, organizations, and even nations, lies partly in people's sense of collective efficacy that they can solve their problems and improve their lives through concerted effort. Perceived collective efficacy will influence what people choose to do as a group, how much effort they put into it, and their staying power when group efforts fail to produce results" (Bandura, 1982, p. 143). Building confident, self-efficacious individuals is a crucial step in collective efficacy. "Inveterate self-doubters are not easily forged into a collectively efficacious force" (Bandura, 1982, p. 143). Kempton et al., (1995) showed that environmental values were already integrated into core American views (p. 214) but that inappropriate behavior and policy choices were often made because what was lacking was the in-depth knowledge and understanding of consequences of those choices. This program presented up-to-date scientific information in a concise, understandable way that resulted in more appropriate choices for responsible environmental behavior.

Humans have spent most of their history living harmoniously with other species and with nature and the behaviors that are wreaking havoc on the

planet and that we are working to change are relatively new. We must find ways to rethink our present activities and societal structures that support unbridled growth that results in unsustainable behavior. Interest or concern alone are not enough. Knowledge alone is not enough. Confidence alone is not enough. But, provide concerned and interested individuals with informative and applicable global environmental change education programs that build confidence and the result is responsible environmental behavior and choices. In the words of Baba Dioum (a Senegalese conservationist):

> We will conserve only what we love;
> We will love only what we understand; and
> We will understand only what we are taught.

ACKNOWLEDGMENTS

I would like to thank the U.S. Subcommittee on Global Change Research, NOAA Office of Global Programs, and U. S. Department of Agriculture for funding the Informal Educators Videoconference and Workshops that were the basis for this assessment. The Sea Grant Global Change Regional Coordinators also deserve my thanks for assistance and support in distribution and collection of the pilot surveys and for their mailing lists for the final surveys. They are a dedicated group of individuals who believe as I do that an understanding of global environmental issues is crucial to living sustainably on the Earth. One final sincere thank you to Dr. Gary Evans, U.S. Department of Agriculture, formerly of the Global Change Office, for funding this study.

REFERENCES

Arcury, T. (1990). Environmental Attitude and Environmental Knowledge. *Human Organization* 49 (4): 300-304.

Baldassare, M. and C. Katz. (1992). The Personal Threat of Environmental Problems as Predictor of Environmental Practices. *Environment and Behavior* 24 (5): 602-616.

Bandura, A. (1982). Self-Efficacy Mechanism in Human Agency. *American Psychologist* 37 (2): 122-147.

Bandura, A. (1991). Social Cognitive Theory of Self-Regulation. *Organizational Behavior and Human Decision Processes* 50: 248-287.

Bostrom, A., M. G. Morgan, B. Fischhoff, and D. Read. (1994). What do people know about global climate change? 1. Mental Models. *Risk Analysis* 14 (6): 959-970.

Bowers, C.A. (1995). Educating for an Ecologically Sustainable Culture, State University of New York Press; Albany, NY 12246.

Costa, V.B. (1995). When Science is "Another World": Relationships between Worlds of Family, Friends, School, and Science. *Science Education* 79 (3): 313-333.

DeYoung, R. (1993). Changing Behavior and Making It Stick. *Environment and Behavior* 25 (4): 485-505.

Dunlap, R.E., G.H. Gallup, Jr., and A.M. Gallup. (1992). Health of the Planet: A George H. Gallup Memorial Survey. Princeton, New Jersey: Gallup International Institute.

Geller, E.S. (1995). Actively Caring for the Environment: An Integration of Behaviorism and Humanism. *Environment and Behavior* 27 (2): 184-195.

Hines, J.M., H.R. Hungerford, and A.N. Tomera. (1986-87). Analysis and synthesis of research on responsible environmental behavior: A meta-analysis. *Journal of Environmental Education* 18: 1-18.

Hungerford, H.R. and T.L. Volk. (1990). Changing learner behavior through environmental education. *Journal of Environmental Education* 21: 8-21.

Intergovernmental Panel on Climate Change (IPCC), Response Strategies Working Group [RSWG]. (1990). "Public Education and Information Implementation Measures." In: Climate Change: The IPCC Response Strategies, WMO, UNEP, Island Press, Washington, DC: 209-219.

Intergovernmental Panel on Climate Change (IPCC). (1996). Climate Change 1995 The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, eds Houghton, J.J., L.G. Meiro Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, Cambridge University Press.

Kempton, W. (1991). Lay Perspectives on Global Climate Change. *Global Environmental Change* June: 183-208.

Kempton, W., J. S. Boster, and J. A. Hartley. (1995). Environmental Values in American Culture. MIT Press, Cambridge, Massachusetts.

Krause, D. (1993). Environmental Consciousness: An Empirical Study. *Environment and Behavior* 25 (1): 126-142.

Maloney, M.P. and M.P. Ward. (1973). Ecology: Let's Hear from the People. *American Psychologist* 28: 583-586.

Milbrath, L.W. (1989). Envisioning a Sustainable Society, Albany, NY: State University of New York Press.

Milbrath, L. W. (1993). "The World is Relearning its Story about How the World Works," In: Environmental Politics in the International Arena, S. Kamieniecki (ed.), Albany, New York: State University of New York Press: 21-40.

Miller, J.D. (1991). The Public Understanding of Science and Technology in the United States, 1990: A Report to the National Science Foundation, Public Opinion Laboratory, Northern Illinois University, DeKalb, Illinois.

National Research Council. (1994). National Science Education Standards. Washington, DC, National Academy of Sciences.

Nunnally, J.C. (1978) Psychometric Theory, Second Edition, New York: McGraw Hill Book Co.

Our Changing Planet: The FY 1995 U.S. Global Change Research Program. (OCP) A Report by the Subcommittee on Global Change Research, Committee on Environment and Natural Resources Research of the National Science and Technology Council. A Supplement to the President's Fiscal Year 1995 Budget.

Prochaska, J.O. and C. C. DiClemente. (1992). Stages of Change in the Modification of Problem Behaviors. *Progress in Behavior Modification* 28: 183-218.

Read, D., A. Bostrom, M. G. Morgan, B. Fischhoff, T. Smuts. (1994). "What do people know about global climate change? 2. Survey studies of educated laypeople," *Risk Analysis* 14 (6): 971-982 .

Schmookler, A.B. (1993). The Illusion of Choice, How the Market Economy Shapes Our Destiny. Albany, New York: State University of New York Press.

Simon, H.A. (1992). What is an "Explanation" of Behavior? *Psychological Science* 3 (3): 151-161.

Sjoberg, L. (1989). Global Change and Human Action: Psychological Perspectives. *International Social Science Journal* 41: 413-32.

Stern, P.C. (1976). Effects of Incentives and Education on Resource Conservation Decisions in a Simulated Commons Dilemma. *Journal of Personality and Social Psychology* (34) 6: 1285-1292.

Thomashow, M. (1995). Ecological Identity: Becoming a Reflective Environmentalist. Cambridge, Massachusetts: MIT Press.

Thompson, S.C. and K. Stoutmeyer. (1991). Water Use as a Commons Dilemma: The Effects of Education that Focuses on Long-term Consequences and Individual Action. *Environment and Behavior* 23 (3): 314-333.

Walsh, R. (1991). Toward a Psychology of Sustainability. *ReVision* 14 (2): 61-66.

World Commission on Environment and Development. (1987). Our Common Future. Oxford, New York: Oxford University Press.

The Impact of Climate Change on Human Health in New England[3]

Paul R. Epstein, Associate Director
Center for Health and the Global Environment, Harvard Medical School*

In the summer of 1997 **skunks** emerged as a problem in many areas of the Northeast. A mild winter, plus habitat loss, plus the die-off of raccoons in previous years due to rabies combined to produce this proliferation. (The skunks replaced the raccoon niche.) Climate, ecological change and disease all interacted to increase the populations of a 'generalist' species that has become a pest. Mild winters are one feature of climate change, and ecological transformations can increase the vulnerability to changes in weather patterns and in the timing of seasons.

Global warming is not a pleasant, nor an easy subject to address. While our understanding of the dynamics of our global systems increases, the uncertainty about it's course and consequences grows. But some changes may already be underway.

Changes in atmospheric chemistry are now altering global physics (i.e., the heat budget). Together with changes in ocean chemistry, biological systems are being affected. Many of the driving forces lie within human social systems, and social policy must reflect the magnitude of the risks.

SEASONAL CHANGE AND EXTREME WEATHER EVENTS

Spring now comes early to New England; there are now 11 more frost-free days than there were two decades ago.** Recent weather in New England demonstrates how disruptive a more variable and unstable climate—and the associated extreme weather events—can be to biological systems. The prolonged drought in June and July of 1997 was harmful to grasslands, forests and cranberry crops. Rains in August precipitated new crops of mosquitoes, raising the spectra of Eastern equine encephalitis in Massachusetts and Rhode Island.

Elsewhere in the world, Europe experienced its most severe floods in half a century, as North Atlantic sea surface temperatures turned warmer. And North Korea and China were plagued by prolonged drought, spreading famine and infectious diseases. The large El Niño event now evolving in the Pacific portends more severe weather for the coming year.

A WORD ABOUT EL NIÑO AND GLOBAL WARMING

Several models suggest that El Niño events will increase with global warming (Zebiak & Cane, 1991; Manabe & Stouffer, 1993; Meehl & Washington, 1993; Bengtsson et al., 1993).

Since 1877, El Niño events have occurred on average every 4.2 years. But beginning in the mid 1970s, El Niño-Southern Oscillation (ENSO) events have come more often and persisted longer than in any previous period since 1877 (Trenberth & Hoar, 1996). The 1982/83 El Niño was the largest of the century so far. In March of this year the Southern Oscillation (sea surface pressures) turned negative; and by June, sea surface temperatures (SSTs) along the American coast had developed a 6 degree Centigrade warm anomaly, initiating a strong El Niño for 1997. The increase in El Niño events is consistent with the model projections concerning the effects of climate change on the oceans.

EMERGING DISEASES

Worldwide there is an emergence of new infectious diseases, a resurgence of old diseases and a redistribution of old diseases, that began in the 1980s and is accelerating in the 1990s. According to The World Health Report 1996: Fighting Disease, Fostering Development of the World Health Organization, 30 new diseases have emerged in the past two decades. There have been other periods in history when infectious diseases have resurged and spread. Often these are periods of accelerated social and environmental change, when growth has outstripped infrastructure.

OVERHEAD 1 - World Distribution of EIDs

As you look over this overhead, some diseases - like diphtheria—are transmitted person-to-person. Outbreaks of these diseases primarily reflect changes in social systems and public health infra-

* See Appendix V for authors' affiliations and addresses.

[3] Note: references to Overheads are made but not included here.

structure. Outbreaks of diseases that involve mosquitoes, ticks and rodents will reflect environmental and climatic factors as well.

Some of the diseases are already appearing at high altitudes, in areas of the world where mountain glaciers are melting at accelerating rates, and where plants are migrating upward. Recent data indicates that freezing levels in the mountains has shifted upward 500 feet or almost 2 degrees Fahrenheit since 1970 (Diaz and Graham, 1996).

NEW ENGLAND

In New England, several infectious disease are of concern, as ecological and climate change can affect their impact. Eastern equine encephalitis (EEE) involves a complex cycle of mosquitoes, birds, humans and horses. But warm and wet winters, combined with warm and wet summers (or drought punctuated by heavy rains in August) can stimulate mosquito breeding and biting.

OVERHEAD 2 - EEE risk factors

Note the key climatic issues: mild winters and wet springs (Edman et al., 1993).

OVERHEAD 3 - Distribution of some Aedes spp. in the U.S.

Not shown are the Aedes spp. That carry EEE, that are ubiquitous in the continental US. These include Aedes vexans and Aedes sollicitans - the salt marsh mosquito, named for the lawyers on Nantucket that reported it.

Increased surveillance and early warning can reduce the need for extensive spraying of pesticides, harmful to pollinating bees, predator insects and humans.

Another disease of concern in Lyme Disease. The incidence last year was over 16, 000 cases, and increase of 37% over the year before. An estimate 3,500 people on Cape Cod have been infected. Ticks in this region also carry babesiosis (animal malaria), erhlichiosis (a treatable bacterial disease) and a virus (that can cause encephalitis).

The life cycle of ticks is also complex, and involves mice, acorns, deer and humans. But climate plays a role. Unpublished work in Sweden demonstrates that warm, wet winters are associated with heavy crops of ticks two years later, given the two-year development of ticks (Elizabet Lindgren, unpublished data submitted for publication, 1997). (Prolonged droughts, like that of June and July, 1997, can certainly negate this.) If climate change involves warmer winters, in general, more ticks may result; though the increased variability also associated makes linear predictions impossible.

A WORD ABOUT WINTER AND NIGHTTIME TEMPERATURES

The disproportionate rise in minimum temperatures (winter and nighttime and temperatures or TMINs) (Karl et al., 1993) accompanying climate change is directly bad for human health (e.g., during heatwaves), and favors insect overwintering and activity. Recently, Easterling et al., (1997) report that since 1950, maximum temperatures have risen at a rate of 0.88°C per 100 years, while TMINs increased at a rate of 1.86°C per 100 years. In both hemispheres TMINs increased abruptly in the late 1970s.

Heat-related deaths in cities—which act as heat islands—will be exacerbated by warming. Air pollution and photochemical smog (ground-level ozone) is created both locally and up-wind of urban areas. These impacts, particularly with increased cloudiness, may even act synergistically (e.g., to increases ground-level ozone).

A warmer atmosphere holds more moisture (6% more for every 1°C) (Karl, 1997); and these changes may, in part, be attributable to the increased hydrological cycle (IPCC, 1996; Graham, 1995) and increasing cloudiness, reducing daytime warming and retarding nighttime cooling.

Moreover, the disproportionate rise in minimum temperatures (TMINs or nighttime and winter temperatures) (Karl et al., 1993) accompanying climate change means that less nighttime relief during heat waves, especially when there is a high heat index (a function of temperature and humidity). The humidity traps out-going radiation, decreases nighttime cooling, and exacerbates the impact on mortality.

Infectious diseases may be increased due to climate change conditions (wetter, warmer summers, less severe winters) that promote tick, mosquito and rodent populations, populations which carry diseases such as Lyme Disease, ehrlichiosis, Eastern equine encephalitis, hantavirus, etc.

HARMFUL ALGAL BLOOMS

Increased run-off of nitrogen and other nutrients into estuaries and bays (from sewage, fertilizers and aerosolized from fossil fuel burning), plus removal of filtering wetlands and reductions in fish that consume algae are all encouraging algal blooms along our coasts. But warm waters and

heavy rains (flushing in nutrients) are climatic factors that also promote algal growth.

OVERHEAD 4—Coastal zone Perturbations

Note the multiple factors contributing to the reported global increase in the incidence, intensity and persistence of noxious coastal algal blooms.

Hotter summers increase photosynthesis and metabolism of algae, and also favor the more toxic forms—cyanobacteria and dinoflagellates. Thus excess nutrients and warming can lead to increased occurrence of red-tides and shellfish poisoning. Additionally, it can lead to the persistence of brown-tides that lower oxygen levels in water, harm seagrasses and thus shellfish beds. Those off Long Island have crippled the scallop industry. Finally, the affects can cascade through ecosystems and lead to increased diseases of shore birds, sea mammal, fish and humans.

OVERHEAD 5 - Remote Sensing Image

SeaWiFs and other remote sensing instruments can now be used to track algal blooms, and help target sampling for toxic species and bacteria - like cholera - that are harbored in the plankton.

OVERHEAD 6 - Harmful Algal Blooms along the U.S. East Coast

Data taken from a GIS-based project that can be located on the world wide web at heed.harvard.edu.

OVERHEAD 7 - Shellfish Toxicity Data in New England States

A time series of toxic phytoplankton-related events in New England.

FOOD-BORNE DISEASES

Food-borne diseases such as toxic E. coli, Salmonella, Cyclospora and Hepatitis-A may also be enhanced by warmer, moister conditions. Extreme weather events like flooding are particularly associated with outbreaks of Cryptosporidia and Giardia, protozoa that are not sensitive to chlorine; as flooding flushes these parasite contaminants into clean water systems.

In addition diseases of terrestrial plants and agricultural crops can be affected (Dahlstein & Garcia, 1989; Sutherst, 1990). Extreme weather events (flooding and prolonged droughts) increase the susceptibility of forests to infection. Presently, the woolly adalgid presents a threat to hemlock trees in New England; and stressful weather could exacerbate this problem.

CLIMATE EXTREMES

Climate extremes are becoming more frequent (Karl et al., 1995), and they are also contribute to outbreaks of disease. Floods foster fungal growth and provide new breeding sites for mosquitoes; while droughts concentrate microorganisms, and encourage aphids, locust, whiteflies and - when interrupted by sudden rains—spur explosions of rodent populations (Epstein & Chikwenhere, 1994). Because of the strong influence of climatic factors prediction of weather patterns based on ENSO and other climatic modes, plus regional patterns, may prove useful for anticipating conditions conducive to such "biological surprises" and epidemics (Bouma et al., 1994; Epstein et al., 1995; Hales et al., 1996).

Does instability indicate increased sensitivity to change, from a further perturbation? Records from this century indicate that periods of warming (from 1900 to 1940, and from mid-1970s to present) were associated with greater variability in heat-degree days, than was the interim period cooling period (1940 to mid 1970s). First, do these multi-decadal shifts follow multi-decadal patterns of convective changes in the oceans (Latif, Barnett, CLIVAR)? Secondly, ice core records indicate enhanced variability may have heralded the state change from the Last Glacial Maximum to the Younger Dryas. Does greater variability, mean greater instability and increased vulnerability to sudden state change—be it to warmer or cooler climate, with smaller or larger polar ice caps?

The oceans are the primary memory for the climate system, absorbing heat and circulating it both laterally and vertically. There is some evidence suggesting that deep ocean warming may be occurring.

Deep ocean warming has been reported from subtropical transects in the Atlantic (Parilla et al., 1994), Pacific Thwaites, 1994) and Indian Oceans (Bindoff and Church, 1992), in the Arctic Tundra and near the poles (Travis, 1994; Regaldo, 1995).

COSTS

Outbreaks of diseases can affect humans, agricultural crops and livestock; and their impacts can ripple through economies and cascade through societies. In 1991, for example, the cholera epidemic in Latin American cost Peru over $1 billion in seafood exports and lost tourist revenues. In 1994, the outbreak of plague in India (accompanied by malaria and dengue fever in the wake of widespread flooding) cut tourism precipitously

and cost international airline and hotel chains from $2 to 5 billion.

Cruise boats are turning away from islands affected by dengue fever and other insect infestations, and coastal algal blooms along beaches. The consequences could be significant: The tourist industry in the Caribbean generates $12 billion annually and employs over 500,000 people.

The current resurgence of infectious diseases involving food, water, insect and rodent carriers can affect trade, transport, tourism and development.

CONCLUSION

The resurgence of infectious disease in the latter part of the twentieth century may be viewed as symptoms of widespread ecological change. If climate continues to change, its influence on the distribution of infectious diseases may grow. Prudent climate change policies must take into account the magnitude of risk to food security, water security and biological security.

REFERENCES

Bouma, M.J., Sondorp, H.E., and J.H. van der Kaay, 1994: Climate change and periodic epidemic malaria. Lancet, 343, 1440.

Diaz, H.F., and N.E. Graham, 1996; Recent changes in tropical freezing heights and the role of sea surface temperature. Nature 383,152-5.

Easterling, D.R., Horton, B., Jones, P.D., Peterson, T.C., Karl, T.R., Parker, D.E., Salinger, M.J., Razuvayev, V., Plummer, N., Jamason, P., and C.K. Folland, 1997: Maximum and minimum temperature trends for the globe. Science 277,363-67.

Edman,J.D., Timperi, R., and B. Warner, 1993: Epidemiology of Eastern equine encephalitis in Massachusetts. J Fla Mosquito Control Assoc, 64,84-96.

Epstein, P.R., and G.P. Chikwenhere, 1994: Biodiversity questions (Ltr). Science;, 265,1510-1511.

Epstein, P.R., Pena, O.C., and J. B. Racedo, 1995: Climate and disease in Colombia. Lancet 346,1243.

Hales, S., Weinstein, P., and A. Woodward, 1996: Dengue fever in the South Pacific: driven by El Niño Southern Oscillation? Lancet 348,1664-65.

Graham, N.E., 1995: Simulation of recent global temperature trends. Science 267,666-71.

Intergovernmental Panel on Climate Change (IPCC), 1996: Climate Change '95: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the IPCC. Houghton, J.T., Meiro Filho, L.G., Callandar, B.A., Harris, N., Kattenberg, A., and K. Maskell (Eds.). Chapter 3, p149 and Chapter 7, pp370-374, Cambridge University Press, Cambridge, UK.

Karl, T.R., Knight, R.W., Easterling, D.R., and R.G. Quayle, 1995. Trends in U.S. climate during the twentieth century. Consequences 1,3-12.

Karl, T.R., Knight, R.W., and N. Plummer, 1995: Trends in high-frequency climate variability in the twentieth century. Nature 377,217-220.

Karl, T.R., Nicholls, N., and J.Gregory, 1997: The coming climate. Scientific American, May, pp78-83.

Climate Change and Forest Ecosystems

Ivan J. Fernandez
Professor of Soil Science
University of Maine*

DEFINING "CLIMATE CHANGE"

I was requested to provide comments on the implications of modern climate change on forested ecosystems in the northeastern US. I provide this perspective as a soil scientist working on environmental stressors in forested ecosystems, and focusing on the biogeochemical responses of these ecosystems over varying spatial and temporal scales.

How will climate change influence northeastern US forests? First, we need to determine what changes in climate will be expected. This is likely the subject of numerous other comments during these meetings. Second, we need to define climate change. Indeed, I view "climate" as a term defining the sum total of both the *chemical* and *physical* climate. While it may facilitate our discussions of modern stressors on forests, or the development of national programs of research, to separate the components of our chemical and physical environment, forested ecosystems reflect an integrated response to the sum of these components.

Therefore, "climate" change can be defined as changes over time that include responses to:

- Acid rain
- Tropospheric ozone
- Nitrogen deposition
- Metal deposition
- Atmospheric carbon dioxide
- UV-B radiation
- Temperature
- Moisture

WHAT DO WE KNOW?

We know that forest environments have been exposed to modern inputs of acidifying substances (primarily sulfur and nitrogen) from the combustion of fossil fuels. We know that soil solutions throughout the Northeast have a unique signal of sulfate concentrations reflecting these pollutant exposures, and while the potential for acidification remains, the rates of sulfur deposition appear to be on the decline. There remains concern for long-term acidification of vulnerable surface waters, and there exists a scientific debate over evidence for base cation depletion in forest soils throughout the region as to its cause and consequence.

Nitrogen is part of the acid deposition mix, but is usually retained by forested landscapes because of the typical deficiency of nitrogen for tree nutrient requirements. However, modern evidence exist for some ecosystems becoming "saturated" in the region with nitrogen, the phenomenon of "Nitrogen Saturation" widely prevalent in Europe and of some concern in the northeastern US. Nitrogen not only contributes to acidification and potential Nitrogen Saturation concerns, but is also a precursor to the formation of tropospheric ozone. Nitrogen deposition does not appear to be declining in the region.

Others are better qualified to describe the current status of tropospheric ozone exposure to both forests and humans. However, I believe it has been demonstrated that relatively high levels of this ozone can develop even in areas remote from major pollution sources. Additionally, research has shown that significant losses occur in agriculture annually due to tropospheric ozone and studies indicate that even forests may be negatively influenced by current ozone exposures. In most instances when ambient levels of ozone are removed from the atmosphere, all plants grow better.

Trace metals such as lead are also released by fossil fuel combustion and other processes, are transported long distances in the atmosphere, and can be deposited on forested landscapes. Indeed, numerous studies in the northeastern US in the early 1980's documented the accumulation of these metals in the forest floor throughout the region. The evidence also suggests that drastic reductions in the emission and deposition of these metals has resulted in a positive response in forest soil burdens, and that some evidence indicates a more rapid recovery is possible than previously suspected. One exception to this relatively positive outlook for trace metal trends has been mercury, where relatively high concentrations have been found in fish and the environment in remote

* See Appendix V for authors' affiliations and addresses.

forested regions without a clear cause of these exposures.

There is little question that the concentration of atmospheric carbon dioxide is increasing. It is well established that most plants will grow faster, if all other factors are adequate, under increased atmospheric concentrations of carbon dioxide. It is generally accepted, I believe, that increasing concentrations of atmospheric carbon dioxide can essentially "fertilize" forests, much like atmospherically derived nitrogen, and promote increased growth. Numerous other physiological and ecological changes would likely also occur, but these are poorly understood. Most plants increase their water use efficiency under increased carbon dioxide, thus leading to better use of water resources even if they are getting more scarce under a warming climate. One of the many interesting but complex interactions among these factors.

Very little is known about the direct and indirect consequences of UV-B radiation on forest ecosystems, except that increasing exposure will logically lead to a magnification of potential negative consequences and potentially greater interactive stress with other factors described here.

Both temperature and moisture are environmental factors that clearly influence forest condition, and both are predicted to change with changing climate. A warming climate can be expected to warm both the atmosphere bathing forest canopies and the soil supporting root systems. Both biological and chemical reactions speed up with warming, and we expect these effects to result in shifts in forest condition. Whether soil moisture becomes more or less available is a critical unknown in predicting the response of individual ecosystems. Likewise shifting species composition and litter quality can play a key role in governing the response of forests to climate change. We know that increasing soil temperature will increase the rate of nutrient cycling and organic matter decomposition. This could lead to another source of increased available nitrogen further promoting plant growth. We know that increases in the most limiting growth factor cause forest productivity to increase, but result in subsequent stress due to secondary limiting factors such as other nutrients. One example could be increased forest growth due to warming, carbon dioxide, and nitrogen resulting in forest health concerns due to increased demand for calcium (a base cation) possibly being depleted due to chronic acidification.

We know that climate plays a critical role in the distribution of forest species across the landscape, and a warming climate is expected to promote the northward migration of boundaries between major forest types or species distributions. This change then becomes good or bad depending on the human value assigned to the end result.

WHAT WE DO NOT KNOW?

Certainly in science we recognize that what we do not know far exceeds what we know, and so it is with the broadly defined issue of climate change. At present, to my knowledge, we do not know precisely how the climate of the northeastern US will change in the next century, nor do we know how forests will respond to these undefined changes. We know some mechanisms of response, a few briefly mentioned above. Broader issues of "unknowns" might be summarized as the implications of:

- Interactions among stressors (e.g., nitrogen deposition, warming)
- Episodic processes (e.g., fire, pest/pathogen outbreaks, wind)
- Pattern of changes in temperature *and* moisture
- Mechanisms of *recovery* to one or more stressors
- The human response through management

MANAGEMENT CONSIDERATIONS?

Significant energy has been spent, and will be spent, in determining the implications of various potential changes in forest ecosystems on forest ecosystem management. This brief discussion has tended to focus on traditional forest productivity issues, but issues of surface water supply and quality, biodiversity, and recreation can be equally or even more important under certain scenarios. It can be instructive to include in this discussion some possible consequences of climate change that ultimately contribute to the scenarios of change over time. These could include:

1. Cutting practices as related to the size, method and pattern of harvesting.
2. Stand regeneration considerations given a potential shifting competitive advantage among species.
3. Simple growth rates as they effect the production of raw materials for the forest products industry.

4. Managing in consideration of changing risks for certain insect and disease concerns.
5. Pesticide use in response to shifting risks of insects and disease, and in response to the encroachment of species ranges.
6. Altered product quality (i.e., wood quality) due to changing growth rates.
7. Increased risk of wildfire and perhaps costs of fire suppression, and possible increased use of prescribed fire in management scenarios.
8. Need for forest fertilization due to alterations in forest ecosystems, that may result in added costs (e.g., commercial fertilizer) and opportunities (e.g., ash/sludge utilization).

CLOSING COMMENTS

There appears to be significant evidence to suggest that forest ecosystems as we know them today will change in response to long-term alterations in the chemical and physical climate. These changes may be the result of both positive and negative impacts on tree growth and other forest values. Interactions among primary factors, and with secondary factors, will play a turnkey role in the ultimate response of forest ecosystems from the tree to the landscape scale. Particularly noteworthy seems to be the growth promoting effects of (a) increased atmospheric carbon dioxide, (b) increased bioavailability of nitrogen due to several factors, and (c) increased warming of the soil and atmosphere. While these suggest better growth conditions, they may also promote forest susceptibility to other factors, thus resulting in changes that occur slowly or as events. Assigning "good" or "bad" labels to these changes is typically then a product of human judgement.

Potential Impacts of Sea-Level Rise in Massachusetts

Graham S. Giese
Woods Hole Oceanographic Institution*

INTRODUCTION

The contrasting features of the Massachusetts coast are often depicted in vacation brochures and photographs: the north shore with its rocky coasts and isolated barrier beaches, the south shore boasting sandy beaches and offshore shoals such as Georges Bank and Nantucket Shoals, and Cape Cod and the islands of Martha's Vineyard and Nantucket offering a combination of sea cliffs, sandy beaches, and barrier beaches.

These coastal features result, primarily, from submergence produced by Holocene relative sea-level rise, and secondarily, from wind-generated waves and tides that erode, transport and deposit coastal sediment.

The way the New England coast responded to the encroaching Holocene sea was dependent upon the postglacial characteristics left by the Pleistocene glaciation: While some parts of the northern Massachusetts coast had been stripped of sediment, the retreating glacier left isolated deposits of till—frequently with drumlins—or hummocky, stratified glacial drift in other areas. Submergence of the northern Massachusetts coast produced drowned bays with drumlin islands, flooded valleys with salt marshes, rocky headlands, and isolated barrier beaches.

Much of the southern Massachusetts coast had been overlain with thick glacial deposits in the form of outwash plains and moraines. Typically, this terrain had low slopes and consisted of easily erodable, unconsolidated sediment. The advancing seas submerged vast portions of it, producing large, offshore shoal areas such as George's Bank and Nantucket Shoals. Steeper regions, such as the eastern coast of Cape Cod, were eroded by a combination of wave action and sea-level rise to produce coastal sea cliffs with broad offshore wave-cut platforms. Sediment that eroded from these shores produced sandy beaches fronting the sea cliffs and barrier beaches downdrift from them. Behind the barrier beaches extensive salt marshes developed in the protected lagoons and bays.

PRESENT IMPACTS OF SEA LEVEL RISE

Today, relative sea level is rising in Massachusetts, as it has been for thousands of years. An overall value of 3 mm/yr (0.01 ft/yr) is frequently used as an estimate of the "present" relative sea-level rise rate throughout the state. As in the past, the primary result of this rise is submergence of the coastal upland. Of course, the rate of upland submergence depends upon regional topography and, in general, is considerably higher along the outwash plains of the south than along the rocky shores of the north. Giese, Aubrey, and Zeeb (1986) have calculated upland loss due to submergence for each of the 72 coastal towns of Massachusetts and found that the state as a whole loses an average of 26.5 hectares (65 acres) of upland each year due to this process. Half of this total is lost by only 10 towns, all but one of which are along the south coast. It is likely that a large percentage of this submerged upland is converted to fringing marshland. Such areas of new marsh development along the inner marsh margin tend to offset losses due to erosion at the outer marsh boundary and to overwash deposition at the marsh/barrier beach boundary.

Relative sea-level rise in Massachusetts also contributes to upland loss through active coastal erosion of Pleistocene glacial deposits along exposed sea cliffs. These losses are particularly large along the open-sea facing cliffs of outer Cape Cod, Martha's Vineyard and Nantucket, where the long-term cliff retreat is frequently on the order of 1 m/yr and in some locations exceeds that rate. Despite the dramatic appearance of wave-eroded cliffs throughout Massachusetts, upland loss due to active erosion is considerably less than that due to passive submergence. As an example, it has been estimated that of the total of approximately 13.3 hectares (33 acres) of upland lost each year on Cape Cod, 9.7 hectares, or 73 percent, is the result of passive submergence, and only 3.6 hectares (27 percent) results from active erosion.

Wave erosion of upland material is the only significant source of sediment for the beaches and

* See Appendix V for authors' affiliations and addresses.

barrier beaches of Massachusetts. As has been widely reported for this area and many other parts of the world, Massachusetts' barrier beaches maintain themselves in the face of rising relative sea level by "rolling-over" themselves, i.e., by migrating landward through a combination of dune movement, storm wave overwash and tidal inlet deposition. Present barrier beach migration rates vary from very little to as much as several meters per year (in long-term average) at some locations such as along sections of Cape Cod's Nauset Beach system.

POTENTIAL IMPACTS OF SEA LEVEL RISE

How will the Massachusetts coast respond to different rates of relative sea-level rise in the future? In particular, how would the coast respond to increasing sea-level rise rates?

To answer these questions, it is important to understand that relative sea-level rise has two components: one due to global, or "eustatic," sea-level rise, and the other due to local crustal subsidence. Considering the present relative sea-level rise rate in Massachusetts of approximately 3 mm/yr, we will assume that half of that rate, or 1.5 mm/yr, is the result of eustatic sea-level rise, and that the other half results from crustal subsidence. Global climate changes, of course, affect only the eustatic component. Therefore, in order to achieve a doubling of the relative sea-level rise rate from 3 mm/yr to 6 mm/yr, eustatic sea level must triple (increasing 1.5 mm/yr to 3.5 mm/yr). Hence the ratio of future rates of submergence to present rates would approximately equal the ratio of future relative sea level rise rates to present relative sea-level rise rates.

In the case of unconsolidated cliff retreat (active erosion) and barrier beach retreat, we assume a similar linear increase in retreat rate with respect to increases in relative sea level rise depending on sediment dynamics.

Total salt marsh area probably would not be significantly reduced by increased relative sea-level rise. New marsh would form at the marsh/upland boundary, even as existing areas would be lost at the outer margins of the marshes. This assumes that new marsh growth would be able to keep pace with sea-level rise because, in Massachusetts, marsh development depends primarily on sediment supply. This is an area of much uncertainty and it is the subject of intensive research at the present time.

The projections presented above have not taken into account the critical factor of societal responses to future sea-level rise. While we do not know what those responses will be, present practices in Massachusetts give cause for concern. The state's coastal wetlands regulations make it possible for coastal property owners—especially those whose homes predate the 1978 enactment of the regulations—to construct sea walls on actively eroding cliffs. In addition, there are presently no regulations prohibiting barriers to the encroachment of fringing salt marsh on low-lying inner upland slopes.

The long-term cumulate impact of these practices, together with the impacts of existing jetties and groins in reducing the alongshore movement of sediment, could be devastating for the Massachusetts coast. By preventing cliff erosion, sea walls reduce the supply of sediment to beaches. This leads to the reduction of alongshore movement of beach sand. Jetties and groins similarly "starve" beaches downdrift of them: These structures disrupt the stability of beaches and barrier beaches by decreasing the sediment supply. They also destabilize the shore by preventing it from adjusting its form to long-term changes of wave exposure. Finally, marsh development is threatened by these structures since new marsh areas are produced by coastal submergence. New marsh area tends to balance areas lost at outer marsh boundaries. Interference with their development would be expected to lead to overall long-term salt marsh loss.

SUMMARY/CONCLUSIONS

Along the Massachusetts coast:

1. Relative sea level has risen, is rising, and probably will continue to rise.
2. As a result, coastal upland has been, is being, and probably will continue to be submerged.
3. At the present rate of relative sea-level rise (c. 3 mm/yr), about 26.5 hectares (65 acres) of upland are lost each year due to submergence.
4. Geographically, the rate of upland submergence depends upon local topography, and therefore upon local geological history.
5. Ten towns account for 50% of annual upland submergence. Nine of the 10 are on southeastern outwash plains.
6. Much of the submerged upland is converted to upland-fringing salt marsh.
7. This new marsh serves to offset seaward salt marsh losses due to erosion and barrier beach roll-over.

8. Along exposed sandy coasts, storm waves erode upland. On Cape Cod, about 1/4 of total upland loss is due to active erosion, 3/4 to passive submergence.
9. Upland erosion provides sand for beaches and barrier beaches which, in turn, moderate the erosion process and provide storm and flood protection for associated upland.
10. Coastal engineering structures designed to control shore submergence and erosion at specific sites are having a detrimental effect on the shoreline as a whole.
11. As a result of such efforts to reduce the impacts of relative sea-level rise, Massachusetts is now experiencing:
    a. Loss of salt marsh due to engineering structures designed to control upland submergence, and
    b. Loss of beaches and barrier beaches due to engineering structures designed to control upland erosion or alongshore sediment transport. It is likely that these adverse impacts will continue to occur in the future, perhaps at an increased rate.

ACKNOWLEDGMENTS

This work is the result of research sponsored by NOAA National Sea Grant College Program Office, Department of Commerce, under Grant No. NA90-AA-D-SG480, Woods Hole Oceanographic Institution Sea Grant Project No. M/O-2.

REFERENCES

Emery, K.O. and D.G. Aubrey. 1991. Sea Levels, Land Levels, and Tide Gauges. Springer-Verlag, New York, 237 pp.

Giese, G.S., D.G. Aubrey, and P. Zeeb. 1986. Passive Retreat of Massachusetts Coastal Upland Due to Relative Sea-Level Rise. Massachusetts Office of Coastal Zone Management, Boston, 17 pp. and 155 pp. appen.

Oldale, R.N. 1992. Cape Cod and the Islands: The Geologic Story. Parnassus Imprints, East Orleans, MA, 208 pp.

Stakeholder Perceptions and Concerns Northeastern Forest Owners and Industry

Report for New England Regional Climate Change Impacts Workshop

Lloyd C. Irland
The Irland Group*

Forests cover the bulk of the land area of the New York/Northern New England region (Table 1). These lands are owned by hundreds of thousands of individuals and companies, in ownerships ranging from a few acres to the paper company tracts in Maine exceeding a million acres.

Table 1: Land Uses, Rural Land, 1987

	All Land			
State	Cropland	Pasture	Forest	(MMA)
	PERCENT			
Maine	5	2	89	19.8
New Hampshire	4	2	88	5.7
Vermont	12	7	78	5.9
New York	21	14	61	30.2

Source: USDA-SCS, 1989; and Powell, 1993.

In terms of landowners, wood using plants depending on the forest, local governments, recreation visitors, and other interests, the number and complexity of stakeholders in the region's forests is mind-numbing.

My task today is to comment only on landowners and wood using industries. Lacking the resources for an actual research project, I have fallen back on interviews and general familiarity with the region's forests, its industries, and its forest policies. Hence, these observations are preliminary and informal and would be debated by some observers. In no sense do I claim to speak as a spokesperson for these groups. Further, it is not my purpose today to critique or evaluate those perceptions and concerns, only to report them as I have come to perceive them myself.

THE FOREST AND THE REGIONAL ECONOMY

The region's forests support timber production, recreation, and water supplies that are important to the economies of local communities and to the region's quality of life (USDA Forest Service, 1990; Dobbs and Ober, 1994). Land uses and management practices on these lands are the subject of ongoing and at times intense controversy. Scientists tell us that future climate change could have significant impacts on these forests. Yet those effects have not been assessed in detail and clearly presented to stakeholders within the region. Many important effects are subject to debate (see, e.g., Birdsey, n.d.; Loehle and LeBlanc, 1996; Foster, et al., 1997; Aber, et al., 1995). As a result, stakeholder perceptions and concerns about the issue and its impacts are diverse and not always in tune with contemporary science.

The forest-based economy of rural parts of this region is based on several market levels of economic activity:

- Land management.
- Logging and trucking of wood.
- Primary conversion, sawmills and veneer plants.
- Secondary manufacturing, producing industrial components and consumer goods.
- Distribution: Marketing and delivery to end users.

Future climate changes, and climate change polices could affect firms differently at different levels of the market.

Forest harvesting affects between two and four percent of the land area, varying around the region. This has several implications. First, in the short run, the near-term harvest of wood is not controlled by the total standing inventory. Second, forest practices can only affect a tiny portion of the forest—even in a decade. Any management actions suggested to adapt to climate changes can only affect a significant portion of the landscape over a very long period of time.

Intensity of use of the forest varies around the region. Forests in New York gained volume dramatically in recent years, while in Maine, spruce-fir volumes declined due to the budworm outbreak and heavy harvesting levels (Irland, 1996b).

* See Appendix V for authors' affiliations and addresses.

There is some interest in the potential role of active forest management and recycling in managing the carbon cycle in this region. A project now underway by the Conference of Northeastern Governors is reviewing the possibilities for possible inclusion in state-level Climate Action Plans (see, e.g., Sedjo, et al., 1995; Heath and Birdsey, 1993).

STYLIZED FACTS ABOUT THE INDUSTRY

The region's wood products industry is as diverse as any found in North America. In solid products, it covers primary plants ranging from spruce-fir stud mills to hardwood sawmills, birch toothpick and dowel plants and hardwood plywood plants. Because of its large population and proximity of low-cost Canadian sources, the Northeast depends heavily on lumber and plywood from other regions (Irland, 1982).

Secondary plants include those fabricating trusses or making furniture, and a few lobster trap plants. Each of these industries has its own material needs, markets, domestic and foreign competitors, and market trends. Hence, generalizations about economic outlooks and policy issues are elusive at best.

The region is the historic home of the nation's paper industry, and has a significant market share in some paper grades (Irland, 1996a). Yet its mostly old mills are under competitive pressures from many competing producing regions. In many lines, the northeastern industry is at the high end of the cost spectrum within North America and at times the world. For complex reasons, in rural areas the industries have a strong primary orientation, while much of the value added activity, for wood and paper, is in the nearby cities. In New York City alone there are probably 10,000 value added wood industry jobs.

Both the lumber business and the paper business face highly volatile prices and operating conditions, as well as intense international competition. They must deal with near-term risks and adverse developments on a yearly basis. Among the smaller firms, the business is often more a way of life than it is a financial enterprise. Family ownership is common. As a result, capital may be limited, but tenacity in the face of adversity is often remarkable.

PERCEPTIONS AND CONCERNS

On many important policy issues, there exists no uniformity of view within the landowner community or the forest-based industries. On the contrary, there are often sharp differences, illustrated most recently in the Maine clearcutting controversy (Lansky, Irland, Hancock, 1996). The landowner community varies from suburbanites who own a condo or summer place in New Hampshire or the Adirondacks, to local farmers with a woodlot out back, and again to multinational corporations.

It would be fair to say that the forest landowner and industry community in this region are not thinking in any detail about the climate change issue. This would apply to any very clear views as to the long-term outlook, the short-term implications for them, and any sense of urgency about responding to it. Individual technical staff members and managers do follow the issue, however.

As many of these stakeholders see it, much of the advocacy about the climate change issue is coming from organizations and leaders of low credibility, and who do not understand or care much about the region's and the industry's problems. The ways that climate change could affect the region's forests are often described in very general terms, for extremely long time horizons. Scientists apparently can model future forest conditions, but not the transition from present conditions. Significant effects are in the distant future. Climate change effects are being discussed by scientists on time scales longer than the planned rotations of trees than a paper company is now planting. As a result, many in the region's landowner and forest industry community are often inclined to accept the more skeptical views about the reality of the climate change outlook.

As the debate leading up to Kyoto became more intense and polarized, forest owners and industry people in this region have not felt that their concerns and perceptions have been heard by analysts or by policymakers. Many of these groups seem to be leaving climate policy to their "Beltway" representatives and trade organizations, and even at that to largely ignore what those groups are doing.

The paper industry is capital intensive, subject to global competition. Despite making major reductions in its energy intensity in recent decades, and increasing its recycling rate significantly, it is a leading energy user. As a major energy user, the industry would be affected in complex ways by efforts to reduce the carbon intensity of the U.S. economy.

Policies designed to reduce carbon emissions, if effective, will affect businesses now. The types of polices that will be applied and how they will actually work is as yet uncertain. Certainly the program announced by President Clinton in Fall

1996 does not seem threatening. But the Kyoto commitments to reductions from 1990 emissions levels would require serious policy measures to bring them about. It is no wonder that energy intensive industries, and their unions, are concerned.

Measures to adapt to and offset future climate change effects may be less threatening, but in the presence of so many uncertainties about those effects, it is difficult for land managers and manufacturers to develop much motivation to pursue them.

Based on concerns like these, the America Forest and Paper Association, a major trade group of lumber and paper producers, offers a short list of criteria for climate treaties (Table 2). In particular, these acknowledge a need for more research, and emphasize the potential for artificially placing U.S. industries at a competitive disadvantage if other nations are exempted from emission limits.

Table 2: American Forest and Paper Association Views

No targets/timetables until more research
Equal treatment of developing countries
Sequestration should be recognized
— forest
— products
Biomass energy should be treated as net-zero emitter
Develop cheaper means of controlling emissions

Source: Moore, 1997.

SUMMARY

On the basis of a few observations, it seems to me that among the climate science community, and portions of the press, persons who question the consensus represented by the latest IPCC Assessment are considered to be outside the "politically correct" science community. They are treated accordingly. This does not seem to be the best intellectual atmosphere in which to conduct a debate over many facts which are still contested. As one observer from a paper industry group noted, "Respected authorities who note weaknesses and uncertainties in "consensus" views are dismissed as being outside the scientific mainstream... Many in the climate change research and policy establishment seem to be aggressively intolerant of criticism..." (Lucier, 1996). This statement also indicates a perception on the part of this stakeholder group that its concerns are not being heard.

Near-term problems dominate the agenda of these groups. As long as climate change effects are so distant in the future, and so highly uncertain as to the details, it is going to be difficult to engage them in serious consideration of scenarios about the future impacts. It is likely that the forest products industry's concern as an energy user will dominate any concerns it may have as a landowner.

Paper companies are especially concerned about policies that would exempt other nations from carbon control commitments, and thereby enhance the competitive advantage of locations like Indonesia and Brazil, which have formidable advantages in forest growth rates and energy costs already.

There is a mismatch in time between the likely effects of carbon emissions control policies, which are immediate and perceived to be adverse, and effects of future climate change, which are highly uncertain and distant in the future.

Given the relatively early stage of the discussion on this issue in the Northeast, it would be desirable to improve the reporting of assessments of climate change in terms meaningful to regional stakeholder groups, and to engage in a sincere process of dialogue on the issues, the uncertainties, and the costs and benefits of policies for emission reduction and for adaptation.

REFERENCES

Aber, J. A., et al., 1995. Predicting the effects of climate changes on water yield and forest production in the northeastern United States. Climate Research 5; 207-222.

Birdsey, R. A. 1997. NE climate change workshop: potential impacts of climate change on forest resources in New England. Unpub. paper. USDA Forest Service, NEFES, Radnor, PA. 8 pp. (web: www.necci.sr.unh.edu/forestry.htm)

Dobbs, D., and R. Ober. 1994. The Northern Forest. White River Junction: Chelsea Green Press.

Foster, D. R., et al., 1997. Forest response to disturbance and anthropogenic stress. BioScience 47(7): 437-445.

Heath. L. S., and R. A. Birdsey. 1993. Impacts of alternative forest policies on carbon sequestration on U.S. timberlands. World Resource Review 5(2): 171-179.

Irland, L. C. 1982. Wildlands and woodlots. Univ. Press of New England. 192 pp.

Irland, L. C. 1996a. Better markets, management can benefit frostbelt's timber resource. Pulp and Paper. November. p. 85-88.

Irland, L. C. 1996b. Land, timber and recreation in Maine's Northwoods. Maine Agr. and For. Exp. Sta., Misc. Pub. 730. 81 pp.

Lansky, M., L. C. Irland, and K. Hancock. 1996. Commentaries on Maine forestry referendum. Maine Policy Review. 5(3): 81-90.

Loehle, C., and D. LeBlanc. 1996. Model-based assessment of climate-change effects on forests: a critical review. Ecological Modeling 90: 1-36.

Lucier, A. 1996. Overview of the global climate issue and its implications for the forest products industry. NCASI Forestry Environmental Program News. 8(21): 1-2, Dec. 11.

Moore, W. H. 1997. Kellogg graduate school of management climate change dialogue. Northwestern University. July 1, 1997. Washington: AFPA. 11 pp.

Sedjo, R. A., et al., 1994. Managing carbon via forestry: assessment of some economic studies. Washington: Resources for the Future. Disc. Pap. 95-06. 40 pp.

USDA Forest Service. 1990. Northern forest lands study. Rutland: Green Mountain National Forest. 260 pp.

Assessment of Actual and Potential Global Warming Effects on Forests of Alaska

Glenn Patrick Juday, Robert A. Ott,
David W. Valentine, and Valerie A. Barber*

INTRODUCTION: EXTENT AND SIGNIFICANCE OF ALASKA FORESTS

There are 2 major types of forest in Alaska (1) the boreal forest or taiga of southcentral and interior Alaska, and (2) the coastal temperate rainforest of southeast and southcentral Alaska. The boreal forest covers the larger area by far, about 46.2 million ha (114 million ac) versus 5 million ha (12.3 million ac) for the coastal forest (Labau and Van Hess, 1990).

Coastal Forest

Worldwide, the cool temperate rainforest is confined to narrow coastal strips in Chile, New Zealand, Australia, northwest Europe, and northwestern North America, including southeast and southcentral Alaska. It is not naturally abundant on the earth, and a large proportion of the remaining unlogged share of this forest type is found in Alaska. Alaska contains 19% of world total of 26.6 million ha (65.7 million ac) of temperate rainforest, and 38% of the total unlogged area (11.6 million ha) (Ecotrust et al., 1995).

Boreal Forest

The world boreal forest zone makes up about 17% of the earth's land surface area (Bonan, 1992) and increasingly it is being used as a source area for the world timber trade. Of all the major forest regions of the world, the boreal zone supports the lowest density of settled human populations. Only about 12% of the Alaska boreal forest is sufficiently productive to meet the definition of commercial forest land (Labau and Van Hess, 1990). However, the total productive Alaska boreal forest area of about 5.5 million ha (13.5 million ac) is greater than the productive forest land base of many states.

The boreal forest is an important component of the Earth climate system. The stored pools of carbon in boreal forest trees and soils represent a significant share of the total terrestrial carbon reservoir. The release of this carbon to the atmosphere as carbon dioxide or methane as the result of climate warming could be a major positive feedback loop in future climate warming. The Alaska boreal forest is one of the most intact natural ecosystem regions in the world; nearly all of the Alaska boreal forest still supports most of its native wildlife including free-ranging large predators. Alaska hosts a huge influx of migratory birds that depend on summer breeding grounds in its boreal forests. Many prime wilderness areas are attracting increasing numbers of visitors and their impacts. Large-scale fire management takes place when human habitation or commercially valuable timber is threatened. The Alaska boreal forest supports a small-scale local industry.

CLIMATE TRENDS IN ALASKA

Recently a substantial amount of evidence has begun to accumulate that climate change in Alaska's forest regions has surpassed the range of background variability and is changing systematically in ways that are posing significant challenges to several Alaska forest resources.

Coastal Forest

Mean annual temperature at coastal stations shows a strong cycling trend with a period of about 19 years between peaks (Juday, 1984; Royer, 1993). In the mid 1970s temperatures in Alaska coastal stations increased abruptly to the highest level of the 20th century; even the low period in the temperature cycle that followed was markedly warmer than any similar period in the instrument based record.

Changes in Snow Patterns

In southeast Alaska, the frequency of snow avalanches at low and moderate elevations has declined since the late 1970s in response to climatic warming (more of the winter precipitation falling as rain and less as snow). The result is that mountain hemlock trees are currently colonizing alpine tundra in the region, and the shrub salmonberry (*Rubus spectabilis*) is invading meadows dominated by heather (*Cassiope*)—or sedge (*Carex*) (Veblen

* See Appendix V for authors' affiliations and addresses.

and Alaback, 1996). A decline in the frequency of severe snow accumulation at low elevations in southeast Alaska has allowed Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) better access to critical winter forage plants. A series of winters with low snowfall is partly responsible for higher winter survival and increased overall population levels of deer. One result may be reduced tree regeneration of the Alaska yellow-cedar (*Chamaecyparis nootkatensis*), a preferred browse species of deer (Hennon, 1992).

Wind Disturbance and Abiotic Stress

Coastal forests of Alaska respond not only to temperature and precipitaion, but to wind as well. Wind is the primary disturbance agent in these forests (Veblen and Alaback, 1996). Coastal forests are highly susceptible to wind damage (Harris 1989) due to the combination of shallow root systems, poorly drained soils, and high winds—usually during peak rain intensity (Alaback, 1990). Wind disturbance events typically are small-scaled and involve single trees or small groups of trees—termed canopy gaps (Alaback, 1990; Ott, 1997). However, large-scale tree blowdowns do occur, especially along exposed coastlines (Veblen and Alaback,, 1996). The storms that deliver damaging winds to coastal Alaska are produced by the mixing of cold polar air with the warmer air of the North Pacific. A warmer sea surface intensifies the storm system produced (Salmon ,1992). During a period of moderate cooling from 1953-1979 the number of days per year with the fastest mile wind speed >31 mph (moderate gale or stronger) gradually decreased at both Annette Island and Yakutat in southeast Alaska. Since the late 1970s, a period of strong warming in southcentral and southeast coastal Alaska, the number of days with gale winds increased dramatically.

Forest Insects

Biological disturbance agents of coastal forests respond to climate. The western black-headed budworm (*Acleris gloverana*) feeds primarily on western hemlock buds and current year's needles. This insect periodically defoliates large areas of western hemlock-Sitka spruce forest; it causes reduced tree growth, tree top-kill, and some whole-tree mortality (Hard, 1974). Past black-headed budworm outbreaks affected trees over hundreds of thousands of hectares in southeast and southcentral Alaska, where it is one of the most damaging species present (Holsten et. al 1985). Growing season temperature appears to be a major factor controlling this insect's populations in coastal Alaska (Hard 1974). Large outbreaks are triggered by warm, dry summers (Furniss and Carolyn 1977).

Boreal Forest

Significant climate warming, and drying in certain localities, has been observed in interior Alaska over the last 20 years. For example, the mean daily maximum temperature in the warm season at Fairbanks has been rising sharply (over 3 °C per century) since 1949. Perhaps equally significant, the number of days with the warmest extreme of temperatures, 80º F or warmer, has increased substantially from just over a week in the early 1950s to nearly 3 weeks in the 1990s. The extremes of warm temperatures in the boreal forest are associated with rapid maturation of insects and their population buildups and with moisture stress to trees.

Warm early spring and summer weather is apparently a necessary trigger factor in the production of the infrequent excellent white spruce cone and seed crops (Alden 1985, Zasada et al 1992). Until recently the occurrence of a high number of days with warm temperatures in the early summer would be followed predictably the following year by a white spruce cone crop, unless a crop was already being produced in the trigger year. In the last decade or more, greater numbers of warm days than ever have occurred but crops are not being formed.

A comparison of growing degree days from the most recent (1973-96) 24 years of he Fairbanks Airport climate data compared to the previous 24 years (1949-72) shows a pattern of warmer and extended growing seasons. The average annual total of growing degree days is 10% greater in the most recent half of the Fairbanks record than in the first half. A study of the period 1981 to 1991 claims that an increase in growing season length is detectable from satellite data in the northern hemisphere, concentrated in the area between 45° N and 70° N (Myneni et al 1997).

Moisture Stress

Both annual precipitation and summer precipitation have decreased during the entire 81-year (1906-96) period of record in Fairbanks. Summer precipitation, already marginal for forest growth across much of low elevation interior Alaska, has decreased at rate of 17% per century at Fairbanks. White spruce growth is positively related to precipitation (greater in wet years) and negatively related to temperature (greater in cool years). Since the late 1970s both the precipitation and

temperature index values are moving strongly in an unfavorable direction, warming and drying, for white spruce growth. Trees that are stressed produce more of each annual ring as dense latewood. Figure 16 shows how the density of white spruce latewood closely matches the temperature at the beginning and the end of the growing season. Because recent climate warming has started the growing season earlier and extended growth later, white spruce on productive sites near Fairbanks have become moisture stressed.

The combination of warming and drying are producing severe stress and decreased productivity in boreal forest trees unprecedented in the 20th century (Barber et al., 1997). Elsewhere in Alaska treeline trees (growing at the tree limit along the margin of tundra) that were previously limited only by warmth, are now limited by moisture stress (Jacoby and D'Arrigo, 1995).

Forest Insects

The 1996 aerial survey of areas of major forest damage in Alaska identified 1.0 million ha (2.4 million ac) affected by insects (Holsten and Burnside, 1997). Alaska contains 49.6 million ha (119 million ac) of forest land, of which about 24% is commercial forest land. Roughly speaking then, an area equivalent to about 2% of all forest in Alaska and over 10% of commercial forest displays current or recent significant forest damage. This is an exceptional, if not historically unprecedented, level of forest damage. The ongoing mortality of spruce in southcentral and interior Alaska caused by bark beetles, currently involving 0.46 million ha (1.1 million ac), is the largest forest insect epidemic in North America (Werner 1996).

The widespread outbreak of tree mortality in Alaska from stress-related insects[8] is also coincident in time with the onset of climate stress (Juday and Marler 1997). In the Bonanza Creek Long-Term Ecological Research (LTER) site in central interior Alaska, the tree-ring growth reduction caused by a 1993-95 spruce budworm (*Choristoneura* spp.) outbreak is unique in the 200-year record, supporting the view that outbreak levels of this insect are a new phenomenon caused by recent climate warming. In the LTER stands monitored snow breakage events in 1989 and 1990-91 triggered bark beetle (*Dendroctonus rufipennis*) attacks that occurred as tree growth was slowing markedly due to warming and drying. This suggests that climate change effects may be multiplicative, as one change (tree breakage from heavy snowfalls) sets the stage for another (insect outbreaks from damaged trees spread to undamaged stands because of warm weather).

Wildland Fire

Fire is the major natural disturbance agent in the boreal forest. Large scale insect outbreaks can weaken or kill trees over vast areas, often leading to forest fires. Most of the area burned (about 90%) in the Alaskan boreal forest is the result of natural ignition caused by lightning. Figure 18 shows the annual area burned in Alaska. In years with prolonged hot and dry periods of summer weather, Alaska experiences millions of hectares burned, mostly in a few very large fires. Peaks in area burned appear about every 10 years, typically with very little area burned between peak years. The trend in annual area burned in Alaska is related to summer warmth. If the record is analyzed for the period 1955 to 1996 the overall trend represents a moderate decline (34%) of average annual area burned. A portion of the decline possibly may be accounted for by the maximum fire suppression effort in the 1960 and early 1970s. Since the mid 1980s about 80% of Alaska has been zoned for limited or no wildland fire suppression. However, because of the highly cyclic nature of the record of area burned evident in the Alaska record, care should be taken to compare intervals that start and stop at equivalent positions on the approximate 10-year cycle. If estimated fire acreage values typical of the Alaska fire cycle are supplied for 1997-99, then a trend of nearly 100% increase in average annual area burned would appear.

Several factors operating together suggest that a substantial area should burn in Alaska in the next 1 to 4 years. These include: (1) anticipated greater number of periods of warm and dry weather, (2) a cumulative fuel/soil moisture deficit that has developed in the mid 1990s, and (3) extensive areas of dead vegetation. The relative proportion of area burned as a result of human-caused fire is gradually increasing in Alaska as population and developed area increase. A combination of increased human ignition sources, extensive penetration of forest land by suburban and intensified rural development, and prolonged warmer and drier weather set the stage for the highly destructive wildland-urban interface fires. The Miller's Reach-Big Lake fire of 1996 destroyed the largest number of structures by fire in the history of Alaska.

[8] Insects that either cause stress to trees by their attacks or insects that concentrate their attacks on already stressed trees.

FUTURE CHANGES IN A WARMING CLIMATE

Coastal Forest

Much of the risk to Alaska coastal forest from climate change scenarios associated with global warming involve (1) destructive winds, (2) tree mortality from insect outbreaks, and (3) changes in forest hydrology.

The recent dramatic increase in gale winds in coastal Alaska suggests that the risk of windthrow of trees would be much greater. To date there has not been an apparent increase in the rate of formation of large-scale blowdowns in southeast Alaska corresponding to increased days with storm winds. However, it is possible that canopy gap formation or expansion rates have increased as the number of days with storm winds increased. Trees along clearcut edges in productive, low-elevation forests are more susceptible to wind disturbance, compared to trees in closed canopy forest, for 10 to 15 years following timber harvest. To date, the relationship between the latter 2 types of disturbance and increased days with storm winds has not been documented.

As climate warming occurs, insect populations that were previously restrained by marginal climatic conditions can increase rapidly (Fleming and Volney 1995). Insects can increase much more rapidly than the forest can respond, for example by adjusting the age or species distribution of trees. A transition period of increased tree mortality from insect outbreaks in coastal forest of Alaska would be probable in a warming climate.

Most of the forest streams of coastal Alaska have short and steep watersheds because of the strong, recent geologic uplift that characterizes most of the area. Precipitation has been so abundant and reliable that many streams with small watershed areas are important salmon producers or municipal or industrial water supplies. As the climate warms the forest demands and removes more soil moisture into the atmosphere, reducing groundwater storage available for stream flows. An increase in the number of warm, dry weather intervals under a warming climate would make even more acute the problems from recent low stream flows, such as blockages of spawning fish and lack of municipal water supply.

Ultimately, a number of positive effects on the coastal forest could be associated with a warmer climate. These involve increased average tree growth and other forms of forest productivity, increased species diversity, and expansion of forest following glacial retreat and colonization of tundra. These adjustments characteristically take some time, but the degree of intactness of the Alaska coastal forest ecosystem insures a high probability of success as long as the magnitude of change does not exceed the degree of adaptability of the organisms, especially of the vegetation. However, if the climate change is of such a magnitude as to allow or require species not currently in or immediately adjacent to the region, then the survival challenge is considerably more severe. A warming of the mean annual temperature that was typical of Anchorage in the 20th century by the amount specified in Weller et al., (1995) would result in a climate that was no longer boreal forest, but a transition type between boreal and temperate hardwood forest. The nearest source areas for seeds and spores to establish such a vegetation type are located over half a continent away in the northcentral U.S. That would be far too distant to make any practical contribution to establishing elements of the temperate forest in Alaska.

Boreal Forest

Much of the risk to Alaska boreal forest from climate change scenarios associated with global warming involve (1) decreases in effective moisture sufficient for forest growth, (2) tree mortality from insect outbreaks, (3) probability of a transition period of large fires, (4) interference with reproduction of white spruce, and (5) changes caused by thawing of permafrost.

The effects of a projected warming of 4° C in summer and 5° C in the winter for interior Alaska (Weller et al., 1995) would depend critically on accompanying changes in precipitation, if any. Warming of the interior Alaska climate without a sufficient increase in precipitation that was effective in supplying water to the forest in the driest part of the year (mid and late summer) would probably transform large areas of productive lowland boreal forest in Alaska and western Canada (Hogg and Hurdle, 1995) to aspen parkland. In aspen parkland conifers are absent and aspen is restricted to stunted patches within a grassland. Aspen parkland occurs in the interior Alaska landscape today as a narrow zone separating steep south bluff grasslands and boreal forest.

One of the characteristic features of the boreal forest is that insect outbreaks are a dominant disturbance factor and that during outbreaks they can cause tree death over vast areas (Juday, 1996; Fleming and Volney, 1995). The risk from future global change to the Alaska boreal forest includes

both (1) increased damage from defoliators and tree-boring insects that have appeared in outbreaks to date, and (2) damage from outbreaks of insect species that have not been observed to produce landscape-level effects on Alaska's forests in the recent past.

The probability of a transition period of large fires in the Alaskan boreal forest is substantial, largely because (A) overall area burned is well correlated with the average summer temperature, and (B) large areas of standing dead forest represent a fuel source that would be difficult to keep from burning once ignited. Fire is an important disturbance agent in the boreal forest and most of the Alaska boreal forest system displays adaptations to it. Fire removes organic accumulations that would otherwise depress site productivity, prepares seedbeds, and renews early successional vegetation important as browse species for many harvested animal species. The main global change issues associated with fire in the boreal forest are the scale, timing, pattern, and intensity of fire. Any of those fire disturbance characteristics could pose unique problems with significant consequences to the forest. Less certain is the fire potential following a transition period of large fires. The new landscape probably would support a significantly lower proportion of conifers and instead large areas of relatively pure hardwood stands that would be relatively fire-resistant. However, a warmer and drier climate might still cause a significant amount of burning in the new landscape.

The disruption of white spruce reproduction in a warmer and more stressful climate would have both significant biological and economic effects on the Alaskan boreal forest. Even the uncertainty over this potential becomes an forest management issue because forests are managed over the relatively long lifespans of the trees. If reproduction of the desired species is not certain in the future, forest management plans may need to be adjusted today. To some degree artificial tree regeneration can mitigate this problem, but then issues of costs and other land management objectives must be addressed.

Changes to the Alaskan boreal forest that would be caused by thawing of permafrost are potentially so extensive and so profound that it is difficult to summarize them. The major pathways of change would involve an unstable transition when surface subsidence from the melting of the ground ice content would alter ground contours and collect, reroute, and alter water. Once the thawing had taken place the site productivity should increase substantially, but the vegetation community that would develop would probably not be similar that which grew on permafrost (although there is little to base a prediction on). The disappearance of a impervious frozen layer would allow precipitation to infiltrate the ground much more effectively compared to the tendency of permafrost to shed rain immediately. The hydrology of streams and rivers would be considerably different.

LITERATURE CITED

Alden, J. 1985. Biology and management of white spruce seed crops for reforestation in subarctic taiga forests. AFES. School of Agriculture and Land Resources Management. Univ. of Alaska. Fairbanks, AK. Bulletin 69. 51p.

Alaback, P. 1990. Dynamics of old-growth temperate rainforests in southeast Alaska. Proceedings. Glacier Bay Science Symposium 2: 150-153.

Barber, V. A., G. P. Juday and B. P. Finney. 1997. Stable isotope and wood density evidence of upland white spruce growth in Bonanza Creek LTER in central Alaska consistent with increased climatic stress. Bulletin of the Ecological Society of America (Supplement Annual Meeting Abstracts) 78(4): 50.

Bonan, G. 1990. A simulation analysis of environmental factors and ecological processes in North American boreal forests. Pages in H.H. Shugart, R. Leemans, G.B. Bonan eds. A systems analysis of the global boreal forest. Cambridge University Press, New York, NY.

Ecotrust, Pacific GIS, and Conservation International. 1995. The rain forests of home: an atlas of people and place. Part 1: natural forests and native languages of the coastal temperate rainforest. Portland, OR.

Fleming, R.A., and J.A. Volney. 1995. Effects of climate change on insect defoliator population processes in Canada's boreal forest: some plausible scenarios. Water, Air and Soil Pollution 82: 445-454.

Furniss, R.L., and V.M. Carolin. 1977. Western Forest Insects. USDA Forest Service, Miscellaneous Publication Number 1339. Washington, D.C.

Hard, J. S. 1974. Budworm in coastal Alaska. Journal of Forestry 72: 26-31.

Harris, A. S. 1989. Wind in the forests of southeast Alaska and guides for reducing damage. USDA Forest Service General Technical Report PNW-GTR-244. 63 pp.

Hennon, P. E. 1992. Current knowledge of ecology and silviculture of yellow-cedar in southeast Alaska: information exchanged at Sitka, Alaska,

November 1991. USDA Forest Service General Technical Report R10-TP-24. 31 pp.

Hogg, E.H., and P.A. Hurdle. 1995. The aspen parkland in western Canada: a dry-climate analogue for the future boreal forest? Water, Air and Soil Pollution 82: 391-400.

Holsten, E., and R. Burnside. 1997. Forest Health in Alaska: An Update. Western Forester 42(4):8-9.

Holsten, E.H., P.E. Hennon, and R.A. Werner. 1985. Insects and Diseases of Alaska Forests. USDA Forest Service, Forest Pest Management and State and Private Forestry. Alaska Region Report Number 181, Revised October 1985. Anchorage, AK.

Jacoby, G.C., and R.D. D'Arrigo. 1995. Tree ring width and density evidence of climatic and potential forest change in Alaska. Global Biogeochemical Cycles 9(2):227-234.

Jacoby, G.C., and R.D. D'Arrigo. 1989. Reconstructed northern hemisphere annual temperature since 1671 based on high-latitude tree-ring data from North America. Climatic Change 14:39-59.

Juday, Glenn Patrick. 1996 (on-line version issued Jan. 1996). Boreal Forests (Taiga) In: The Biosphere and Concepts of Ecology. Volume 14 Encyclopedia Britannica, 15th edition. pp. 1210-1216. [hardcopy 1997]

Juday, Glenn Patrick. 1984. Temperature Trends in the Alaska Climate Record. Proceedings of the Conference on the Potential Effects of Carbon Dioxide-Induced Climatic Changes in Alaska. Ag. Exp. Sta. Miscellaneous Publication 83-1. Univ. of Alaska. pp 76 88.

Juday, G. P. and S.A. Marler. 1997. Tree-ring evidence of climatic warming stress in Alaska: variation and stand history context. Bulletin of the Ecological Society of America (Supplement Annual Meeting Abstracts) 78(4): 119.

Labau, V. J., and W. Van Hess. 1990. An inventory of Alaska's boreal forests: their extent, condition, and potential use. In: Proceedings of the International Symposium Boreal Forests: Condition, Dynamics, Anthropogenic Effects. 16-26 July, 1990, Archangel, Russia. State Committee of USSR on Forests. Moscow.

Lamas, T. and C. Fries. 1995. Emergence of a Biodiversity Concept in Swedish Forest Policy. Water, Air, and Soil Pollution 82: 57-66.

Myneni, R.B., Keeling, C.D., Tucker, C.J., Asrar, G., and R.R. Nemani. 1997. Increased plant growth in the northern high latitudes from 1981 to 1991. Nature 386: 698-702.

Ott, R. A. 1997. Natural disturbance at the site and landscape levels in temperate rainforests of southeast Alaska. Ph.D. Thesis, University of Alaska Fairbanks. Fairbanks, Alaska. 169 pp. + 2 maps.

Royer, T.C. 1993. High-latitude oceanic variability associated with the 18.6-year nodal tide. Journal of Geophysical Research 98: 4639-4644.

Salmon, David K. 1992. On Interannual Variability and Climate Change in the North Pacific. Ph.D. Thesis, University of Alaska Fairbanks. Fairbanks, Alaska. 219 pp.

Veblen, T. T., and P. B. Alaback. 1996. A comparative review of forest dynamics and disturbance in the temperate rainforests of North and South America. Pages 173-213 in R. G. Lawford, P. B. Alaback, and E. Fuentes, eds. High-latitude rainforests and associated ecosystems of the west coast of the Americas: climate, hydrology, ecology, and conservation. Springer, New York.

Weller, G., A. Lynch, T. Osterkamp, and G. Wendler. 1995. Climate Change and its Effects on the Physical Environment of Alaska. Pages 5-13 In: P. Anderson and G. Weller (editors). 1995. Preparing for an Uncertain Future: Impacts of Short- and Long-Term Climate Change on Alaska. Proceedings of a Workshop held during the Arctic Science Conference, Fairbanks, Alaska, September, 1995. The Center for Global Change and Arctic System Research, University of Alaska Fairbanks.

Werner, R.A. 1996. Forest health in boreal ecosystems of Alaska. The Forestry Chronicle 72(1) 43-46.

Zasada, J.C., Sharik, T.L., and M. Nygren. 1992. The reproductive process in boreal forest trees. *In* H. Shugart, R. Leemans, and G. Bonan (eds). A system analysis of the global boreal forest. Cambridge Univ. Press, Cambridge, UK.

Implications of Climate Change on New England Extreme Weather Events

Barry D. Keim
New Hampshire State Climatologist
Department of Geography, University of New Hampshire*

In recent years, it appears that extreme events have been ubiquitous in the United States, particularly in the Northeast. At the national level, we have experienced:

- flooding in Washington and Oregon (December, 1996-January, 1997)
- The Ohio River Valley Flood (Spring, 1997)
- Northern Great Plains Flooding (Spring, 1997)
- Over 30 inches of rainfall in Alabama resulting from Hurricane Danny (July, 1997)

And in the Northeast:

- Region-wide blizzard with storm snowfall totals in excess of 30 inches (January, 1996)
- Coastal New England Rainstorm producing over 19 inches of rainfall (October, 1996)
- Warmest single-day February temperature record in Seacoast of New Hampshire (1997)
- Boston's new 24-hour snowfall record broken (April, 1997).

Other evidence of increasing extremes is provided by Changnon et al., (1997) in the form of increasing trends in weather-related insurance claims and by Karl et al., (1996) who show that the proportion of annual rainfall contributed by 1-day extremes appears to have increased in the United States over the past century. Regarding the insurance claims, one difficulty in assessing whether extremes are temporally increasing is that population is also increasing. In addition, society is developing land in vulnerable locations like the coastal zone (which is susceptible to hurricanes), and floodplains (which are vulnerable to river-basin floods) leaving more people impacted by these events when they occur.

Predicting future extreme events in a changing climate has proven to be a difficult task. Most of what is known about future climates is derived from general circulation models (GCMs). The various GCMs (e.g., Goddard Institute for Space Studies, Geophysical Fluid Dynamics Laboratory, National Center for Atmospheric Research, Oregon State University, United Kingdom Meteorological Office) generally agree that global temperature and precipitation should increase as concentrations of atmospheric greenhouse gases increase, but regional impacts remain unclear. Furthermore, most extreme events (e.g., intense precipitation events, tornadoes, hurricanes, high winds, etc.) are too small in scale for GCM recognition and therefore the GCMs are of limited value in predicting extremes.

Though the GCMS are of little assistance in directly projecting future extremes, global warming has implications on future events, although with mixed possibilities. First, global warming would likely translate into warmer global sea surface temperatures (SSTs). It was found that warmer SSTs are strongly correlated with increases in tropical storm frequencies, at least in the north Atlantic Basin (Wendland, 1977), which impacts storm frequencies in the eastern United States. Similarly, Emanual (1987) reports that hurricane intensity is likely to increase under warmer conditions globally. However, time series of annual hurricane frequencies over the past 100+ years do not show any trend toward increasing frequencies. Furthermore, hurricane intensities do not appear to be increasing either as evidenced by the most powerful storms to strike the eastern United States over the past century. These hurricanes occurred in the following years in decending order; 1935, 1969, 1992, 1919, 1928, 1960, 1900, 1909, 1915, and 1961. A second implication of global warming is based on the spatial dimensions of the warming. Most GCMs are predicting that higher latitudes will warm to a much larger extent than lower latitudes. As a result, there would be a reduction in the temperature gradient between the tropics and poles. It is this gradient, however, that drives most of the severe weather in the mid-latitudes and a gradient reduction may lead to a reduction in atmospheric mixing, thereby reducing severe weather.

Predicting extremes in New England and New York is particularly difficult because of the region's geographic location. It is positioned roughly halfway between the equator and the North Pole and is exposed to both cold and dry airstreams from the north and warm and moist

* See Appendix V for authors' affiliations and addresses.

airstreams from the south. The interaction between these opposing airmasses often leads to turbulent weather across the region. Also, because of the propensity of storm tracks to move across this region, the jet stream is frequently positioned overhead. The complicating factor here is that very small shifts in storm tracks and jet stream location lead to highly differing weather conditions region-wide. Currently, GCMs do not have the capability to predict how these storm tracks, nor jet stream locations, may shift in a warmer climate. Regarding extremes of the past in this region, cursory examination suggests slightly warmer extreme cold conditions in southern New Hampshire, and perhaps an increase in the frequency of extreme precipitation events in southern New England. Both of these are in general agreement with increases in annual temperature and precipitation found across the region (Karl et al., 1994a; Karl et al 1994b). In addition, Davis and Dolan (1993) report that over the past 50 years, the total number of East Coast nor'easters appears to be decreasing, but that the most powerful ones seem to be increasing in frequency.

In conclusion, little is really know about the response of extreme events in a changing climate. There is limited evidence that extremes have been on the rise, but this is somewhat muddled by increasing population and changing zoning practices. Furthermore, climate models are not yet sensitive enough to yield reliable information at a scale associated with most extreme events. At this point, we clearly need more time and research to assess the true impacts of a changing climate on extreme weather phenomena.

REFERENCES

Changnon, S.A., Changnon, D., Fosse, E.R., Hoganson, D.C., Roth, Sr. R.J., Totsch, M. 1997: Effects of Recent Weather Extremes on the Insurance Industry; Major Implications for the Atmospheric Sciences. Bulletin of the American Meteorology Society 78:425-435.

Davis, R.E., Dolan, R. 1993. Nor'easters. American Scientist 81:428-439.

Emanuel, K.A. 1987. The Dependence of Hurricane Intensity on Climate. Nature 326:483-485.

Karl, T.R., Easterling, D.R., Knight, R.W., Hughes, P.Y. 1994a. U.S National and Regional Temperature Anomalies. In: T.A. Boden, D.P. Kaiser, R.J Sepanski, and F.W. Stoss (eds.), Trends 93: A Compendium of Data on Global Change. ORNL/CDIAC-65, pp. 686-736. Carbon Dioxide Information and Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN.

Karl, T.R. Easterling, D.R., Groisman, P.Ya. 1994b. United States Historical Climatology Network-National and Regional Estimates of Monthly and Annual Precipitation. In: T.A. Boden, D.P. Kaiser, R.J Sepanski, and F.W. Stoss (eds.), Trends 93: A Compendium of Data on Global Change. ORNL/CDIAC-65, pp. 830-905. Carbon Dioxide Information and Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN.

Karl, T.R., Knight, R.W., Easterling, D.R., Quayle, R.G. 1996: Indices of Climate Change for the United States. Bulletin of the American Meteorology Society 77:279-292.

Wendland, W. 1977. Tropical Storm Frequencies Related to Sea Surface Temperatures. Journal of Applied Meteorology 16:477-481.

New England Regional Climate Change Impacts on Recreation and Tourism

Dr. Kenneth D. Kimball
Director of Research, Appalachian Mountain Club*

Recreation and tourism is a major part of New England's economy. Using New Hampshire as an example, this sector of the economy resulted in $2.5 billion dollars in direct spending and 1.5 billion in indirect spending in 1994, which represented 9.5% of the gross state product. Outdoor recreation is a very significant part of this business. The 28 New Hampshire alpine and nordic ski areas resulted in $190 million in direct spending, $18 million in tax revenues, and another $319 million and $48 million in secondary spending and taxes, respectively. The Appalachian Mountain Club (AMC) operates a series of backcountry huts and facilities and cooperatively maintains hiking trails within the White Mountain National Forest, NH. A 1995 report indicated that AMC's activities alone resulted in some 662,746 visitor days, generating nearly $63 million in economic activity.

For perspective, tourism ranks third behind manufacturing and retail in terms of bringing money into NH, accounting for 12% of the total employment and 7% of the state's taxroll. Within region's of the state, such as the White Mountain's, tourism is the most important export industry. In this area tourism will continue to increase in importance with the decline of the major manufacturing jobs in the paper and wood industry that once dominated northern NH. Visitor days to the White Mountain National Forest in NH have grown from 2.8 million visitor days in 1975 to an estimated 7 million in 1995. These trends are not unique and mirror themselves in the neighboring states of Maine, Vermont and New York.

The recreation and tourism business in New England is highly dependent on several factors including the weather, the health of the region's ecosystems and the economy. Climate change can impact this industry in both obvious and more subtle ways. Alteration of the physical climate such as temperature, precipitation and storm patterns greatly influence the willingness of people to take a vacation and the length of that vacation. Snowless winters in much of the region can set the mood for the large skiing population in the southern part of the region to not venture north. It also greatly increases the cost of snowmaking which can exceed $750,000 per year for a major ski area. Cross-country skiing and snowmobiling, other important components of the winter tourist economy, become almost non-existent during low snow winters such as occurred in the early 1980s. Similarly the very hot and smoggy summer of 1998 saw fewer people venturing into the mountains due to the uncomfortable heat and humidity and poor visibility.

Changes in the physical environment may also negatively impact the ecosystems which draw people to a region to recreate. Unique natural resources are a particularly strong draw for tourists, such as the alpine areas for their unobstructed views and relatively uncommon vegetation communities. In what is one of the most populated regions of the US, today there are only about 13 square miles of alpine habitat in the eastern US all remnants of the glacial era of years bygone. The largest alpine ecosystem is the Presidential Range in the White Mountain National Forest that includes Mount Washington, followed by Mt. Katahdin in Maine and much smaller units in the Green and Adirondack Mountains. It is estimated that some 250,000 people annually ascend Mount Washington, the region's highest mountain. Unfortunately the northeast's alpine ecosystems are some of the most threatened by climatic change, they are relatively small and isolated meaning natural processes for recolonization would be extremely slow.

Moderate warming can result in the of migration of plant species. Alpine species in high mountains can be pushed upwards in elevation and be eliminated if already at mountain summits. During this century warming trends in western Austria and Switzerland are correlated with the displacement of alpine plants at the rate of about 3 13 feet elevation per decade. Most at risk in New England would be the smaller alpine areas all those in the Adirondack and Green Mountains and, excluding Mount Washington and Katahdin, all others in NH and ME. Monitoring the treeline alpine ecotone

* See Appendix V for authors' affiliations and addresses.

boundary may serve as one of the best indicators of plant community response to climatic change. The AMC has begun a monitoring program to measure alpine vegetation shifts on Mount Washington and the Presidential Range, NH.

Alteration of the chemical climate, that is variations in the chemical composition of the atmosphere and precipitation, also have direct impacts on recreation and tourism. Ozone, though a natural and needed chemical in the atmosphere's upper stratosphere, is a manmade pollutant in the lower troposphere with serious global warming, ecological and health implications. Ozone, a primary ingredient in urban smog, is four times more effective as a greenhouse gas than carbon dioxide, is now increasing in the atmosphere at the same annual rate as carbon dioxide, and currently is estimated to contribute about 8% to global warming. Ozone smog formation is not only enhanced by warmer, sunnier conditions, but it also can travel long distances from urban into rural areas.

Ozone has serious health implications particularly for the young and those with asthma or heart problems. Eastern mountain summits and the coastal regions such as Bar Harbor, Maine, some of the most important tourist regions in New England, are particularly prone to and now commonly experience long-distance ozone transport episodes. AMC has monitored ozone on Mount Washington's summit for over a decade, where values commonly surpass those in the surrounding lowlands and have exceeded national health standards. Preliminary results from a study by the AMC, Brigham and Women's Hospital and the Harvard School of Public Health (currently being peer-reviewed for publication) suggest that prolonged outdoor exercise by hikers exposed to low-levels of ozone, fine particle (PM 2.5) and strong aerosol acidity is associated with significant effects on lung function among adults. On Mount Washington and its surrounding peaks it is estimated that some 60,000 people hike. Studies like these only add to the reason for smog alerts and warnings that people should not exercise outdoors on certain days, particularly on warmer summer days. In summary many rural tourist destination areas are no longer exempt from smog impacts, in fact ozone advisories have been expanded from urban weather forecasts to some eastern National Parks as well. The impacts of these evolving chemical climatic conditions are not selling points for a tourist region's brochure or its economy.

Suspended particles and droplets in the atmosphere may counter some effects of global warming, by reflecting sunlight back into space. But they add little to New England's health or tourist business, with the exception of giving prettier sunsets. In the northeast many of these fine mass particles are anthropogenic in origin, can stay suspended for lengthy periods and have a large fraction containing sulfates or acid aerosols. These fine mass particles contribute to acid rain and cloud events.

Given the abundance of scenic vistas, visibility is important to the White Mountains and many other tourist regions. Ongoing studies by AMC, the White Mountain National Forest and the Harvard School of Public Health link visibility impairment with fine mass particles in the White Mountains. Preliminary results from a 1996 study indicate that forest users can consistently perceive changes in visibility reduction related to fine particle concentrations in the atmosphere.

In an earlier 1988 AMC survey, respondents were asked to look at pictures depicting different visibility conditions in the White Mountains that were selected from clear to hazy conditions caused by fine mass particle pollution. Sightseers indicated that as visibility impairment increased, almost 53% would curtail their activities. 86% of the respondents found the transition in visibility from unpolluted to polluted to be undesirable. Much of the public incorrectly attributed hazy, low visibility conditions to humidity and not fine mass particles. An ongoing study by AMC and a UNH Ph.D. candidate is now focused on the economic value individuals place on visibility in the White Mountains.

Clearly there are numerous other implications of how changes in the physical and chemical climate can influence the region's tourism and recreation. The fall foliage season is one of the region's biggest seasonal draws, attracting visitors from around the world. This colorful display and the related tourist business is highly susceptible to changes in annual weather patterns. The survival and range of the tree species which make New England's colors some of the most dramatic in the world, particularly sugar maples, are dependent on climatic conditions.

Similarly, fishing is a cornerstone and very important economic part of the outdoor recreation industry in New England. For the region, some 2 million people devoted 24 million days to fishing and spent an estimated $1.3 billion in 1991, many coming from out of state. The fisheries is susceptible to not only chemical changes as acid rain, which can eliminate species, but also changes in water temperature. In central and northern New

England fishing for species dependent on colder waters such as trout and salmon is one of the largest economic segments of this recreational industry. Alterations in streams chemistry or the warming of pond, lake and stream temperatures could greatly reduce habitat available for the region's economically important and very sensitive cold water fisheries.

Upwind sources of emissions are a very important factor impacting the quality of New England tourism and indirectly its climate. But the recreation and tourism industry in New England is also very dependent on a highly mobile public using the automobile as its primary source of transportation to travel long distances. Automobiles are a significant source of the chemical precursors that form ozone; their combustion of fossil fuels also makes major contributions to increased carbon dioxide levels. In searching for solutions, the recreation and tourism industry needs to actively seek ways to reduce its contribution to the climate change problem, not just look for scapegoats.

Climate Change Lessons from the Past: A Key to Prediction

Paul A. Mayewski
Climate Change Reseacher Center
University of New Hampshire*

Since ancient times humans have modified their local and regional environment, but only since the Industrial Revolution has human activity had a significant measured effect at the planetary scale. Human impact on the composition of the global atmosphere is now without question. Human disturbance of biogeochemical cycles may now be approaching a critical level. Over the past few decades concentrations of atmospheric gases (eg., CO_2, CH_4, N_2O) have been increasing dramatically and have moved into a range unprecedented for the past million years. This increase has produced serious concern regarding the heat balance of the global atmosphere. Greenhouse gases are, however, only part of the human problem. For example, sulfur gases and dusts can reinforce or counteract greenhouse gas effects on local to regional scales. While remarkable efforts are underway to resolve the history and significance of the human influences on climate, pollution and resource depletion, our understanding of climate change is still hampered by a lack of knowledge of the processes which underlie natural climate variations.

The task of understanding climate change and predicting future climate change would be complex enough if only natural forcing mechanisms were involved. It is significantly more daunting due to the introduction of anthropogenic forcing and even more so considering the limitations in available records. Earth history provides a unique opportunity to: (a) assess the temporal and spatial characteristics of climate variability prior to any anthropogenic forcing, (b) assess the natural rates of change associated with the evolution of the Earth system, (c) understand how physical and biospheric systems interact across multiple time and space scales, (c) define the nature of the sensitivity of the Earth's climate and biosphere to a large number of forcing factors, (d) examine the integrated climatic, chemical and biological response of the Earth system to a variety of perturbations, and (e) to test the predictions of numerical models for conditions significantly different from the present day. In effect, the paleoclimate record provides a series of cases and lessons upon which our understanding of climate change can be constructed and tested.

The paleo perspective has provided some significant surprises concerning climate change, changes in atmospheric chemistry and the response of natural systems to climate change. The most recent dramatic new discovery is the verification that rapid and massive reorganizations in the ocean-atmosphere system, rapid climate change events, occur at frequent intervals throughout at least the last glacial cycle (the last ~130,000 years). The largest of these events are characterized by changes in climate that are close to the order of glacial/interglacial cycles. Perhaps most surprising is the demonstration that these rapid climate change events turn on and off in decades or less and may last centuries to millennia. Further these events are globally distributed and found in a variety of paleoenvironments (ocean, atmosphere and land). Several potential causes for these events have been proposed, but without a more detailed understanding of the relative phasing of these events from region to region, definitive causal mechanisms cannot be constructed.

Of greatest consequence to humans is the fact that subdued versions of these events are documented during our current interglacial (the Holocene; which began ~11,500 years ago). While subdued relative to earlier events, they are still sufficient to significantly perturb natural systems and still operate at rapid rates (years to decades). Thus one of the most important tasks for paleoclimatologists is improving our understanding of Holocene climate, for it is within the Holocene that the boundary conditions for modern natural climate variability can be identified and from which the relative importance of natural versus anthropogenic climate forcing can be assessed.

Regular patterns in climate variability can be identified on the decadal to millennial scale. This finding is particularly encouraging since one of the end goals of climate change research is predictability. However, deconvolving predictable patterns at the regional scale and determining the temporal baseline from which predictably can be assessed will require more dense spacing of paleodata.

* See Appendix V for authors' affiliations and addresses.

Few instrumental records precede the era of anthropogenic involvement; thus it is necessary to supplement and hindcast this data with paleoclimate records. Fortunately, many paleodata series afford detailed views of pertinent climate indicators (eg., temperature, precipitation, ENSO, monsoon). On the other hand, since there are no true analogs in the paleoclimate record for modern or future climate it is essential to utilize both modern observational and paleoclimate records to solve this complex problem.

New advances in paleoclimate research reaffirm the necessity to: (1) view climate change over varying time scales; (2) utilize a variety of globally distributed paleoclimate records that monitor change throughout the earth system and; (3) focus attention on well-dated, highly resolved multivariate paleoclimate records. This paleodata is essential for understanding global environmental change and its potential impact on humans, assessing human influence on the global environment and for the evaluation of predictive climate models.

ABOUT PAUL MAYEWSKI

Paul A. Mayewski was born in Edinburgh, Scotland and attended school in the United States, receiving a PhD from the Institute of Polar Studies, Ohio State University, in 1973.

He is Director of the Climate Change Research Center (CCRC) and Professor in the Institute for the Study of Earth, Oceans and Space and Department of Earth Sciences at the University of New Hampshire. He has been the leader of more than twenty-five scientific expeditions to the Antarctic, the Arctic and the Himalayas. He has published in excess of 150 papers in peer-reviewed journals such as *Nature* and *Science* and chairs several national and international scientific committees. His papers have been instrumental in understanding a wide range of scientific problems including, for example: the chemistry of the remote atmosphere, acid rain, the ozone hole, the global distribution of the Chernobyl nuclear accident, identification of massive and rapid change in climate, controls on climate change, histories of volcanic activity, biomass burning, aridity events, storm activity, sea ice extent and glacier fluctuations. He has developed collaborative scientific programs with several countries (eg., India, China, Iceland, France, Denmark, Nepal).

His expeditionary and scientific achievements have been highlighted in numerous articles and interviews including, for example: *Discover*, *Harper's Magazine*, *The New York Times*, *Good Morning America*, several BBC/PBS film series, and National Public Radio's *Fresh Air*.

Dr. Mayewski has served for eight years as Chief Scientist for the Greenland Ice Sheet Project Two (GISP2), a multi-institutional National Science Foundation project that has revolutionized our understanding of climate change. Currently he and his colleagues at CCRC are organizing several multi-disciplinary, multi-institutional research efforts dedicated to understanding climate change on global to regional scales, such as: ITASE (the International Trans-Antarctic Scientific Expedition), HIPP (the Himalayan Paleoclimate Program) and NECC (the New England Climate Consortium).

He has been accorded several honors, such as: the naming of an Antarctic mountain peak, inclusion in Sigma Xi and Phi Kappa Phi, the 1995 Citation of Merit from the Explorers Club, a French Senior Research Fellowship (CNRS), and as a guest of the Chinese Academy of Sciences in 1996 he was given a personal audience with scientific officials in the Forbidden City, Beijing.

Utilities Response to Climate Change

James E. Platts
Northeast Utilities*

For presentation at the New England Regional Climate Change Impacts Workshop, Durham, NH, September 3, 1997

A serious discussion of climate change must include the contribution that electric utilities make to greenhouse gas emissions (GHG). In the U.S. the utilities contribute about one-third of the total man-made CO_2 emissions. On a worldwide basis the utilities contribution is a somewhat lower percentage but certainly significant. The contribution is the direct result of the burning of fossil fuels (coal, oil and gas) in boilers. Industrial and commercial entities who burn these fuels also add to the CO_2 emitted.

To begin to understand how utility CO_2 emissions can be reduced, it is useful to look at the energy sources used to produce electricity. Figure 1 shows that in 1995 about three-fourths of U.S. electricity came from fossil fuels, 40 percent of which was from coal, the highest CO_2 emitter of the three fossil fuels. Most of the remaining one-fourth came from energy sources with zero emissions, hydro and nuclear, in other words good resources from a climate change viewpoint.

If we look at how New England obtained its electricity in 1995 only about 55 percent came from fossil resources, and one-third of that was from coal. Our region did a little better than the U.S. with its 25 percent contribution from nuclear energy versus 13 percent for the U.S., but only 5 percent from hydro versus 13 percent from the U.S. The other 15 percent came from power purchased from other utilities or independent power producers. Some of the purchased power came from hydro and other renewables. So, overall, our region is ahead of the U.S. in lower CO_2 emissions per kWh.

We can get a sharper picture of this comparison and also include just Northeast Utilities (NU) looking at Figure 2. Here we see the lbs of CO_2 emitted for each kWh produced for the Midwest, where we know most of the coal burning takes place, for the total U.S. For NU, and for the rest of New England. This shows a definite improvement in the reduction of CO_2 per kWh for all categories. NU has the lowest level of CO_2 per kWh shown, or about half that compared to the others. The graph is for a normal nuclear operating year when we expect about 50% or more of our electricity to be generated by nuclear energy.

But this doesn't tell the whole story or the problem we face relative to climate challenge. Electricity growth continues and is forecasted to growth at about one percent per year for our company while other regions will have higher growth rates. The key question is how will they add the resources needed to serve this growth while trying to reduce their overall CO_2 emissions? The U.S. utility CO_2 emissions are about 700 MTCE and will likely grow. But the industry is responding to help curb this growth. As a benchmark New England utilities emitted about 54 million (short) tons of CO_2 in 1990, the year which is being used as a baseline year for climate change policy planning. While the region's CO_2 emissions are down from that level in this decade, they are expected to rise above it under normal growth scenarios shortly after 2000. But before we discuss what is being done specifically to mitigate this growth, let's consider some electric utility industry trends that maybe helping or hurting this growth from a climate change viewpoint. These trends are shown in Table 1.

Table 1. Electric Energy Trends

- Restructuring the electric utility industry
- Smaller unit sizes
- Increased need for power quality
- Increased attention to environmental performance
- Increased use of natural gas
- Increased use of renewable technologies, DSM and conservation

Probably the trend with most uncertainty is the restructuring of the electric industry. For example as power plants become spun off under unregulated subsidiaries, what will be their inclination to reduce CO_2 when they are trying to compete at the lowest busbar cost? The last three trends are of more direct interest to us. Attention to environmental performance may bring about standards

* See Appendix V for authors' affiliations and addresses.

that require a certain emissions level for CO_2 per kWh. One of the biggest contributors to lowering CO_2 is the increased use of natural gas. Not only is it the lowest CO_2 emitting fossil fuel, but the combined cycle plants that are being built today are using new combustion turbine designs that achieve a total plant efficiency of over 40 percent, well above today's typical fossil steam plant, and they are going higher. As these replace older existing plants burning oil and coal in the dispatch we are reducing the CO_2 per kWh. Finally, there is an growing interest in using renewable technologies with zero CO_2 emissions and doing more conservation. Renewables will help, but they are not liking to have the biggest impact for some time given their high cost. A great example of where using renewables is appropriate is some new entrepreneurial firms are marketing 50 watt photovoltaic standalone solar panels to third world villagers for lighting and cooking. The solar energy will replace their use of kerosene and wood and reduce CO_2 while improving their standard of living.

With this brief background let us look at some policy options that are being considered by the U.S. Government and at other international groups involved in climate change policy discussions. These are listed in Table 2.

Emission caps or budgets along with credit trading have been the basis to use market forces to help achieve lower SO_2 and NO_x emissions from utility power plants in the U.S. These have been by and large successful. Fuel subsidies and taxes are very political and are being considered. along with generation performance standards especially related to older plants.

Table 2. Some Policy Options to Reduce CO_2

- Set CO_2 targets: emission caps or budgets, % reductions
- Recognize voluntary early reductions
- Reduce subsidies or establish taxes
- Set generation performance standards, renewable portfolios
- Establish CO_2 credit trading

What have been some of the lessons learned from SO_2 and NO_x regulations? First, while there are other large sources for both SO_2 and NO_x emissions, utilities have been the bigger focus for developing regulations to reduce these emissions. Second, the cost for utilities to comply has often been less than originally projected or claimed, especially, by those opposing the regulations. Third, other factors can help reduce emissions: fuel switching, plant retirements, etc. So while we the utility industry will continue to be a major target for reductions, the pain should not be as great as we might first think, especially if we integrate our responses with other advantageous steps we take in the deregulated market. One such step is to respond to a certain portion of the electric consumers who are willing to pay for "Green Power". This can help drive our use of renewable resources.

You may have gotten some idea already of how can we produce less CO_2 from electricity. Table 3 shows general directions that may have been obvious from the earlier discussion.

Table 3. How to produce less CO_2 from electricity?

- Use less energy, i.e. conservation
- Use sources that produce less CO_2/kWh
  - $\Rightarrow$ Fossil fuel with lower CO_2 emissions
  - $\Rightarrow$ Higher efficiency technologies
  - $\Rightarrow$ Zero emitting sources: solar, wind, hydro, nuclear

Certainly it makes common sense to use less energy to do a given task. Electricity can help here. For example, faxing a 20-page document across country versus mailing it has been estimated to save 2 lbs of CO_2 emissions. The best approach for reducing CO_2 is to use the fossil fuels with lower emissions of CO_2 i.e. natural gas, and this is a trend we have seen. Higher efficiency generation technologies are entering the marketplace with combined cycle plants above 40 percent and fuel cells that, in conjunction with microturbines, can ultimately reach over 60 percent. These fuel cells are some years away though from being commercial. Finally, there are the zero emitting technologies: solar, wind, hydro and let's not overlook the big benefit nuclear brings to reducing CO_2. Despite all of its other problems, with new developments and growing climate change concerns in the next century there may be a role nuclear can continue to play here.

Let's now turn to what is being done by the electric utility industry to respond to the need for GHG reductions. As part of the President's Climate Change Action Plan issued 1993 the DOE worked in conjunction with the electric utility industry trade groups to develop a program that would encourage and recognize voluntary actions by individual utilities to reduce or avoid GHG emissions. The progress that has been made with

this program is summarized in Table 4. What is important is the level of participation that is encompassed by these agreements as well as the variety of approaches being used to make the reductions: system reductions of CO_2 emissions, improved use of nuclear plants, conservation, efficiency improvements in the generation of electricity, management of forests and many more. The tracking of the progress of these commitments is done through annual filings under the 1605b Voluntary Reporting of Greenhouse Gas Emissions, set up by the National Energy Policy Act of 1992. A key policy element for the utility industry is to be sure that the agreements coming out of Kyoto in December recognize early voluntary reductions. The U.S. position currently does not.

Table 4: Utility Responses to DOE Climate Challenge

- Memo of Understanding in April 1994
- Voluntary agreements between utilities and DOE
- 120 agreements signed, 636 individual utilities have made pledges
- Total reductions promised by 2000: 44 MTCE

What may be of more interest for this audience is what has NU done under this program? Figure 3 shows the NU commitment made under its Climate Challenge Agreement is a one million ton reduction from the NU baseline emissions (average of 1987-1990) by the year 2000. It also includes a cumulative reduction of three million tons from 1995 to 2000. These are in short tons. The figure shows the actual emissions to date being well below our yearly targets. This is in spite of our two recent bad nuclear operating years. Hopefully, the margin by which we meet our pledge will increase as our nuclear plants come back on line in 1998.

Let's also look at two renewable energy projects that contribute to GHG reductions, but for which NU is not taking any credit in its Climate Challenge pledge. One involves fuel cells and the other wind power. NU is operating a 200 kW fuel cell at a landfill in Groton, CT using about one fifth of the available landfill gas being collected. Prior to the fuel cell being installed, the landfill was flaring the gas which burned the methane component yielding CO_2 a much less potent GHG than the methane being released. The fuel cell improves this by converting the methane after some cleanup into electricity, CO_2 and water. What is of more interest is that we plan to install a 3 to 4 acre hydroponic greenhouse to grow vegetables year around. This greenhouse would use the electricity from the fuel cell plus some electricity from the grid, and the CO_2 along with some additional heat. A conceptual view of this is shown in Figure 4. The idea behind turning the wastes from the landfill into useful products is industrial ecology. NU has been awarded DOE rebates for 10 more of these 200 kW fuel cells and we hope to replicate this idea at one or more landfill sites in Connecticut. We have calculated that about 11,000 tons per year MCTE would be reduced by this project at Groton when fully developed. We have also received a letter of intent from a group of Canadian industries to purchase 1000 tons of these reductions as credits for 10 ten years. We believe this purchase could demonstrate a first international commercial transaction of carbon credits, and would be an important step toward establishing a carbon credit trading mechanism.

The second renewable energy area, wind power, includes two efforts: one is a 20 MW operating wind farm in Costa Rica with the NU's subsidiary Charter Oak Energy as the principal owner. The farm has 55 wind turbines operating a one of the world's best wind sites. It is expected to yield about 260,000 MTCE by the year 2000 by avoiding the Costa Rican electric system's fossil emissions that would otherwise be produced.

The second wind effort about to get underway should be of particular interest here in New Hampshire. It is a three-year wind assessment which includes two years of detailed measurements at wind sites yet to be selected. NU is sponsoring this research project jointly with the NH Governor's Office and we expect to announce the contract award later this month. The results of this research project can provide a solid basis to plan wind power projects at the selected sites. We are also finishing up a similar project in Massachusetts with UMASS as the contractor. Such projects would of course reduce GHG emissions similar to the Costa Rica project. Last month Green Mountain Power dedicated the largest wind project in the East at Searsburg in southern Vermont. It is a 11 turbine 6 MW installation and expects to save over 11,000 (short) tons of CO_2 emissions.

One last important area to touch on is Joint Implementation (JI) or also called Activities Implemented Jointly or AJI. This is a U.S. Pilot Program Initiative that seeks to do projects cooperatively in two or more countries that reduce GHG. These JI projects are voluntary and to date 26 have been recognized by the U.S. committee overseeing this Program. Our Costa Rica wind farm was among the first recognized in this program. There is not yet international consensus for JI in the climate change discussions. But the U.S. through this pilot

program hopes to set an example that can be the basis for international projects that can provide reductions and marketable credits to the countries and entities involved.

Finally I want to end offering a list of issues that are important to utilities in the outcome of both deregulation and the climate change negotiations. This are listed in Table 5. These are not meant to be inclusive but ones which stand out to us at NU as key issues to resolve.

Table 5: Issues for Utilities on Climate

- ChangeContinue investing in and promoting more efficient energy use and conversion processes
- Plan transition toward zero emitting energy sources and technologies
- How to recover costs of CO_2 reductions in a competitive generation market
- Remain a major player in climate change policy discussions
- Promote JI projects and GHG credit trading system

Figure 1.

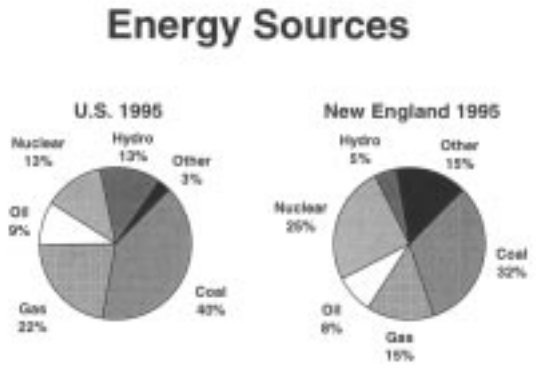


Figure 2.

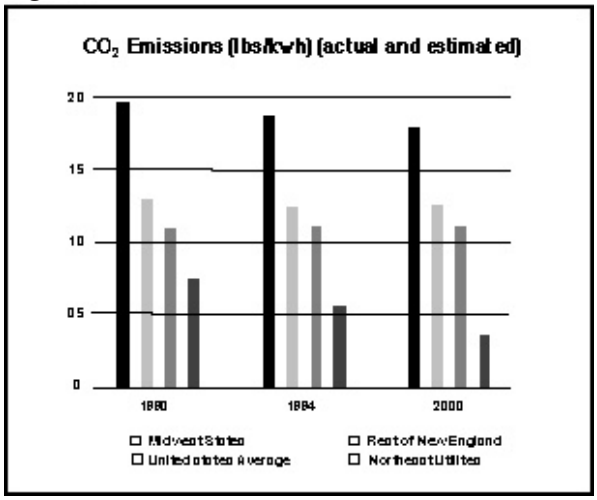


Figure 3.

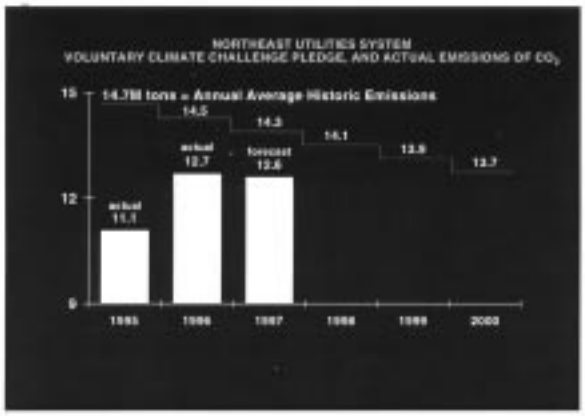
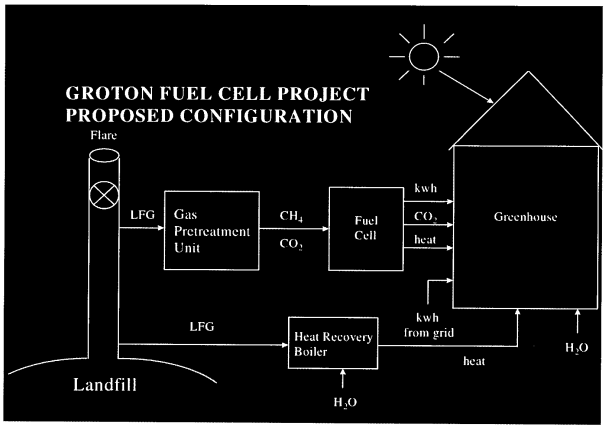


Figure 4.



An Insurance Industry Perspective On Climate Change

James Russell
Vice President, Institute for Business and Home Safety*

I am pleased to participate in this meeting regarding Global Warming, bringing to reality a needed dialogue about Climate Change and its effects on insurers. These discussions serve a number of worthwhile purposes. They prompt us to ponder and weigh issues we might otherwise choose to ignore. They confront us with points of view we might not otherwise investigate. This Conference provides an excellent stepping-off point, for the parties to build bridges of confidence and trust, upon which understandings can be formulated and future actions initiated.

Let me tell you where I'm coming from in all this. I am with the Institute for Business and Home Safety in Boston. We are an initiative of the insurance industry to reduce deaths, injuries, property damage, economic losses and human suffering caused by natural disasters. The "natural hazards" I am referring to are the windstorms, including hurricanes, earthquakes, floods, hailstorms and wildfires that cause untold damage, harm so many people and place economic burdens on all segments or society. In New England and northern New York, we face all of these perils.

We at the Institute are trying to take the losses—the claims—out of the insurance system in advance of a catastrophe. Why and how do we do that?

Because of the growing number of people living in harms way; that is, along the Atlantic, Gulf and Pacific Coasts; along the Nation's river; over fault lines; in the path of tornadoes, the potential for deaths and injuries is greatly increased. Further, the value of the commercial and residential structures needed to accommodate the people and businesses already in harm's way has grown in leaps and bounds.

Current estimates are that approximately one-half of the nation's population lives in coastal counties. Of particular concern are, according to a 1994 Report of the U.S. Bureau of the Census, the increasing population in those counties located in hurricane-prone areas. Projections indicate that by the year 2010, more than 73 million people will live in these areas. In the 1970's and 1980's, almost half of all new construction in the country took place in coastal areas (includes coast of the Great Lakes). There have been more expensive properties put in the paths of perils.

The dollar value of residential and commercial structures in the first tier of coastal counties along the Atlantic and Gulf Coasts, a band of real estate approximately fifty miles wide, as of 1993 was $3.15 trillion. And that represented an increase of 69% over 1988.

Adding to the woes of insurers is the storm surge exposure which places inhabitants and properties at greater risk. Consider that the highest point in Florida is only 53 feet above sea level and all of the Florida Keys are less than 10 feet above sea level. Further, New Orleans is below sea level and the barrier islands off the Texas and North Carolina Coasts are highly vulnerable to the ravages of the ocean and storm surge. In Rhode Island and southeastern Massachusetts, the shoreline erodes with severe storm surge.

It should be apparent that in a society which views insurance as an entitlement and virtually mandates coverage for all, that lacking rate adequacy, and in the presence of the extreme event, insurers teeter at the edge of financial collapse. By removing the losses from the system, the insurer's risk of insolvency is reduced, policyholders are indemnified and the government and taxpayers are spared the burdens that would accompany uncovered and uninsured losses. Simply stated, we have a win-win-win situation for all through mitigation!

How do we (IBHS) do that? We do it by vigorously working in the following five areas:

1. Public Outreach
2. Community Land Use
3. Construction of New Buildings
4. Retrofitting of Existing Structures
5. Collection, Analysis and Dissemination of Information

By working to reach out to the public, we ensure that all stakeholders are aware of natural hazards, understand the associated risks, know how to

* See Appendix V for authors' affiliations and addresses.

reduce these risks, and take action to mitigate the level of risk to which they are exposed. The major components of this program are public relations, education and articulation of response and recovery issues.

By working with community land use, we will encourage responsible decisions about the density, type, and location of structures and create incentives to reduce development in high risk areas subject to natural hazards.

By working for stronger building codes we assist in ensuring that all new structures will be designed, engineered and constructed using up-to-date techniques, and materials.

In its efforts to secure stronger structural building codes, IBHS will, where practical, lend its support to energy efficiency in the building codes as a part of its ongoing efforts to construct lower-risk buildings. We also believe that energy efficiency in building codes is cost-effective in its own right. That means that even if climate change does not prove to be as great a risk as some predict, homeowners and the economy will be better off with improved building codes.

By promoting the retrofitting of existing structures we will participate in the reduction of potential deaths, injuries and property damage.

We work at mitigating losses because, as previously stated, it is the only way the private insurance system can remain viable and sound over the long term. Insurers do not have bottomless pockets to pay unlimited claims caused by natural hazards year after year. growing world population and expanding economies.

Data compiled for 1996 by Munich Reinsurance discloses that the drum beat of natural catastrophes and the accompanying financial drain continues. According to Munich Re, in America, there were: 195 (earthquake, windstorm, flooding and other type) events. 0r 32% of the events worldwide $21.3 billion in economic loss, 35% of the economic loss worldwide; and $7.5 billion in insured loss, or 81% of the worldwide insured loss. This data clearly reveals why U.S. insurers have a "stake" in the solution to the problems under discussion. We cannot get the job done by acting alone. We have to work with all the other stakeholders. That is essential.

The issues being discussed are of importance to all of us. Climate and climate change are issues that touch all of us. Insurers do not have the scientific knowledge and/or resources to address them and must leave this study and research to meteorologists and climatologists. Further, since insurers deal with the **effects** of weather events, they are of the opinion that the activities initiated by IBHS and described earlier in this presentation are, at this juncture, adequate to reduce potential deaths, injuries, economic loss and property damage.

In the remainder of this paper, I will offer, for your consideration, some specific thoughts regarding insurers and climate change.

Some would ask: "Why aren't property-casualty insurers more interested in climate changes?" **They are interested!** Insurers recognize that they cannot eliminate the adverse weather. The real question therefore becomes "**What can be done to lessen the number of deaths, injuries, property damage and economic loss which these natural hazard events may cause?"**

As a matter of course, insurers must respond to these factors regardless of the magnitude of the uncertainty. Why? Because of **vulnerability**. Further, insurers must make prudent judgments regarding the probability of future events and their financial consequences such that the system can compensate policy-holders, adapt, and endure.

Insurers recognize another impact factor–climate change. To be sure, there is a degree of uncertainty associated with climate change. Yet, they are concerned by the mounting evidence which suggests that a change in the world climate is occurring and that perhaps this change may be affected by human behavior and they take note of research which suggests an increase in the frequency and intensity of severe weather. They also are attentive to the accompanying predictions of sea level rise and the impact this would have on business written in and for properties in coastal counties.

We in the insurance sector must become more knowledgeable about, and inquisitive of, climate issues. Insurance practitioners must become more knowledgeable about atmospheric science so that they effectively discharge their responsibilities; so that they raise pertinent questions; so that they know when loss attributable to climate is a certainty.

At the same time, insurers also acknowledge the pervasiveness of the scientific uncertainty surrounding climate change. This uncertainty, however, does not relieve them of their responsibility to continue to protect people and their possessions. Nor does it preclude this complex system from positioning itself better to cope with the broad range of possible changes and mitigate potentially devastating outcomes. They must continue to make prudent judgments in order to miti-

gate future potential loss and to do so, they must incorporate climate change as an impact factor.

Insurers' responsibilities do not oblige them to engage in the scientific debates, as they are ill-equipped to do so. The decision not to engage in the debate over scientific issues is based on the fact that insurers are not technically equipped to enter into those types of discussions or the controversial causation issues swirling about those subjects. They view the pursuit of good science and the advancement of their understanding of climate change as a critical ingredient to their success in coping with this important issue as a society.

To quote the President of the Reinsurance Association of America,

> "If the scientific community becomes increasingly confident in its assessment of global warming and the consequences for that with respect to insured natural events like hurricanes, then I think the industry will accept the science."

As a whole, insurers are an important stakeholder in ensuring society's well-being. Thus, they must be aware of vexing issues such as climate change and must actively engage in the problem solving process.

THANK YOU!

EPA National & Region I Initiatives to Reduce Greenhouse Gas Emissions

Norman Willard, Climate Change Coordinator
U.S. Environmental Protection Agency Region I - New England*

U.S. CLIMATE CHANGE ACTION PLAN

Altogether there are nearly 50 programs and initiatives that comprise the U.S. Climate Action Plan to reduce greenhouse gas emissions. These are often referred to as the "CCAP" programs. Most are voluntary and non-regulatory. The U.S. EPA and the U.S. Department of Energy are responsible for implementing the lion's share of these programs, but other agencies have programs too. Federal agencies provide free technical assistance and support. This paper will focus on some of EPA's programs to reduce greenhouse gases.

EPA's climate action programs and initiatives are based simple propositions

Carbon dioxide represents the largest share of U.S. greenhouse gas (ghg) emissions. By far, most U.S. carbon dioxide emissions come from the combustion of fossil fuels: coal, oil and gas. Carbon dioxide is a by-product of fossil fuel combustion. To the extent that we can reduce the combustion of fossil fuels, we can reduce U.S. carbon dioxide emissions.

KEY GREENHOUSE GAS SECTORS: TRANSPORTATION AND ENERGY PRODUCTION AND USE

Fossil fuels are combusted to move people and goods around–"trains, planes, automobiles". And boats. And trucks. And SUV's. The transportation sector in this country is based on the internal combustion engine burning fossil fuels. As a source of greenhouse gas emissions, the transportation sector is a critical one because it accounts for about 30 percent of total U.S. ghg emissions. The energy sector—that of energy production and energy use—is the other critical sector.

The U.S. economy is highly dependent on electricity to meet our enormous (and growing) energy needs. Today, most of our electricity comes from generating plants that burn fossil fuels: coal, oil and natural gas. Coal and oil release more CO_2 per unit of energy (Btu) than natural gas.

Electricity production and use constitutes the principal source of U.S. greenhouse gas emissions. By generating less electricity and by using cleaner fuels, we will reduce ghg emissions. By using more efficient generating technologies, we will reduce ghg emissions. By generating less electricity—by reducing demand for electricity—we will reduce ghg emissions. By being more energy efficiency and using more end-use energy efficient technologies, we will reduce our ghg emissions.

The majority of EPA's Climate Action Plan programs—"CCAP" programs—focus on energy efficient technologies. These technologies are "off the shelf" and available now. They are not science fiction technologies or years out from development.

EPA's EnergyStar and Green Lights programs—U.S. CCAP flagship programs—promote energy efficient technologies. They are based on profitability and on free technical support from EPA.

Participants are asked to undertake, for example, a lighting upgrade, where it is profitable, using energy efficient lighting technologies. In the case of Green Lights, a participant—a Partner—is asked to upgrade facility lighting where there will be an internal rate of return greater than 20 percent (before any rebates—to the extent that rebates still exist). This is a great return on investment, when you compare it to the stock market historically. Except for the 80's and, it seems, the last year or so, the stock market over its history has shown about a 10-12 percent annual investment return.

In the Green Lights program, which has been going for about 6 years, Partners on average have seen a 47 percent reduction annually in their electricity use and in their bills for lighting using available technology. Because the technology is efficient, it means less electricity in needed to perform the same lighting work. This means less electricity has to be generated. And this means, in turn, less carbon dioxide—the greenhouse gas—is emitted from the generating plant.

Equate efficiency with less waste, and with saving money. Through efficiency, the less you waste CO_2, kilowatt hours and dollars, the more you have: clean air and more money for reinvestment. Some

* See Appendix V for authors' affiliations and addresses.

have said that energy efficiency is a "win-win" proposition. They have likened it to picking up twenty dollar bills on the street. There are "no regrets." It makes sense to do it in any case. The investment in energy efficiency and clean air—reduced CO_2 (and SO_2, NO_x, particulates, heavy metals) emissions—is profitable!

TRANSFORMING THE MARKET

Another benefit of EPA CCAP programs is market transformation. As more companies, colleges and universities, hospitals and schools, municipalities and states and federal agencies participating in the programs upgrade their facilities with energy efficient technologies, the price of the equipment comes down, the quality improves and more efficient technologies are produced because of the increased demand.

The national EPA CCAP market transformation programs—"pushes" and "pulls"— promote technology advancements that strengthen the economy and create jobs, while saving everyone money—and helping the environment.

SAVING MONEY, REDUCING ENERGY USE *AND* PREVENTING POLLUTION— GREEN LIGHTS

Today, there are on the order of 2,600 participants in the EPA's Green Lights program, representing more than 6 billion square feet of space—about 1/10 of all the office space in the country. Green Lights Partners are saving more than 4.6 billion kilowatts per year of electricity from their completed upgrades. This equates to $340 million a year, money that would otherwise be simply wasted, into the air—on inefficient, outdated technology. All the while these Green Lights Partners, are helping to reduce greenhouse gas emissions–some 6.4 billion lbs. of CO_2 a year. This is the equivalent to taking 644,000 cars off the road. Or planting 880,000 thousand trees.

Twenty four states have joined the Green Lights program and are upgrading all state-owned buildings and facilities. In this region, Maine and Massachusetts have joined Green Lights. We encourage all states in our region and elsewhere to join the Green Lights and EnergyStar programs.

EPA'S ENERGYSTAR PROGRAMS

EPA's EnergyStar Buildings program builds on the lighting program. It, too, is based on profitability. It, too, is voluntary. U.S. businesses spend $100 billion on energy each year to operate commercial and industrial buildings. By using energy efficient products and operational procedures recommended in this program, organizations could reduce their energy use by 35 percent or $ 35 billion nationally.

Participants begin by installing energy efficient lighting, because lighting affects a building's heating and cooling needs. A comprehensive, staged, energy efficiency upgrade is done of the entire building and its energy load. Where it is profitable–a greater than 20 percent internal rate of return–participants are asked to upgrade one-half of their building square footage over a 7 year period.

EPA has also designed an EnergyStar Homes program. New EnergyStar homes save owners a lot on their electricity consumption. At the same time they help reduce ghg's by lowering energy demand; they have a small energy footprint. We are working with the lending community and looking to save people on mortgage rates since efficient technologies represent such a good investment. We are working with the home renovation trade groups, too, to promote the installation of EnergyStar technologies when homes are renovated. Energy used in homes accounts for over 20 percent of all air pollution emissions in the country.

We are working to make the EnergyStar label–now commonly found on computers and other office equipment—familiar to everyone as a "sure sign" of efficacy and energy efficiency. We have entered into agreements with hundreds of equipment manufactures producing thousands of products–office equipment—computers, printers, copiers, fax machines, scanners—and other products—heating and cooling equipment, exit signs, heat pumps, geo-thermal systems, building insulation, windows, and many other products—to bring to market more energy efficient products. In return for meeting EPA voluntary efficiency performance standards, manufacturers of products may display the EnergyStar logo. This helps manufacturers and retailers to differentiate their products. The label and logo will help consumers make the energy-correct decision by showing them which products are the most energy efficient, and, therefore, which represent a good energy investment for the dollar. And which represent an investment in the planet by reducing greenhouse gas emissions.

We have developed an EnergyStar Small Business program that provides free assistance to the owners of facilities having less than 100,000 square feet of space. Since more than 99 percent of the approximately 22 million non-farm businesses in this country are small businesses according to the Small Business Administration, there is enormous potential for energy savings and cost savings for business owners–and for ghg reductions. Small businesses participating in this program can expect to cut energy costs by 35 percent. EPA is working with the lending community to develop loan programs that support small business energy efficiency.

We are working states and local governments (and encouraging companies, schools and other large purchasers) to encourage bulk purchases of EnergyStar equipment by means of the EnergyStar State and Local Government Procurement Challenge program. The power of the "procurement purse" will bring prices down, send efficiency up, lower electricity bills, and reduce emissions—when EnergyStar products are specified.

AN EPA CLIMATE CHANGE ACTION PLAN FOR NEW ENGLAND

At a June 26th conference on "Global Warming: What Does It Mean for New England?", EPA Regional Administrator John DeVillars announced an aggressive plan to reduce greenhouse gas emissions in New England and to increase public understanding of the issue—a climate action plan (CCAP) for New England.

1. Expand Participation in EPA's Voluntary Programs for GHG Reductions

EPA Region I will add 50 million square feet of new participant facilities in the EnergyStar/Green Lights programs by the end of 1998, reducing CO_2 emission in New England by an additional 73 million pounds per year. As of July, 1997, more than 200 participants in the region were reducing regional CO_2 emission by 417 million pounds a year. We would especially welcome the participation of states and municipalities in these programs to save taxpayers money and to show leadership in energy efficiency and true commitment to reducing their contributions of greenhouse gases.

In the same time period, EPA will increase by 50 percent—to almost 200—the number of New England business participant in EPA's flagship solid waste source reduction and recycling program, WasteWi$e. This program reduces placement of solid waste into landfills, thereby reducing the formation of the harmful greenhouse gas, methane produced by landfills.

In addition, our expanded source reduction and recycling programs with the Northeast Recycling Council to expand office paper recycling, and a new food waste composting program with the Center for Ecological Technology will eliminate an additional 10,000 metric tons carbon equivalent (MTCE) by the end of 1999.

2. Education and Information to Effect Change

We will make available to every student, teacher, and parent in New England clear, concise and easy-to-understand educational materials on global warming. These materials will be easily accessible on the Internet and in every public library in New England by December, 1997.

The environmental agency in each New England state will be furnished with clear, concise information on global warming—educational videos, print materials, and slide shows—to facilitate outreach to stakeholders and the public.

The EPA Region I - New England website will contain more information about EPA's climate change activities. It will include a bibliography of New England-related climate change materials comprising a Region I—New England clearinghouse on climate change, a list of climate change-related Internet links, information on what individuals can do about climate change, state-specific climate change impacts fact sheets, and other resources. Go to **www.epa.gov/region01**.

3. A Federal Response: Getting Our House in Order

In the summer of 1997, the U.S. General Services Administration issued a request for proposals (rfp) to purchase power in bulk for New England's federal facilities. At EPA's urging, the rfp includes a "clean power" choice–4 percent of the electricity supplied will be from renewable, climate-friendly resources, thereby creating significant new demand for "green power" in New England. This rfp will leverage the government's buying power to bring state-of-the-art renewable energy resources and efficiency strategies to our buildings.

We encourage states, municipalities, companies large and small, institutions, cooperatives and other large buying entities to make the "climate-friendly" power choice, too, when open retail energy/electricity choice becomes available across

the region as electric industry restructuring unfolds in New England. Residential customers, too, should consider "clean power."

4. Federal Vehicle Fleets Helping the Climate

By 1999, 50 percent of new fleet vehicles purchases will have the capacity to run on alternative fuels. EPA will assist and encourage all federal agencies in the region to purchase and use clean fuel vehicles.

5. Transportation

Through its Clean Air Partners program, EPA is helping to make Logan International Airport in Boston a world model for the use of clean fuel vehicles—for both passenger transportation and for airplane service vehicles.

Building on the success at Logan over the next year, we will expand the use of clean fuel vehicles in Portland, Maine, including:

- Developing legislative incentives to facilitate increased use of clean alternative fuels, including electric, natural gas and propane vehicles
- Introducing up to 10 propane-powered vehicles to private companies with fleets in greater Portland

And at the Foxwoods Casino and Resort in Ledyard, Connecticut we will:

- Establish a refueling infrastructure for compressed natural gas (CNG)
- Introduce four CNG passenger shuttle buses

6. Promoting Collaboration Among the New England States

EPA has launched a New England Global Warming Network (a collaboration of EPA, DOE, and state environmental, energy, public utility, planning and transportation agency officials). By June, 1998, we plan that each of the six New England states will have created a comprehensive greenhouse gas emissions inventory. Further, by the end of 1998, the Network will identify a comprehensive set of strategies to stabilize greenhouse gas emissions.

By September, 1998, each New England state will have measures in place to ensure that methane from all large landfills is either flared or recovered for energy production, thereby reducing atmospheric releases of this potent greenhouse gas.

CONCLUSION

As citizens of a shrinking and interdependent world, as Americans, and as New Englanders, must find ways to reduce our greenhouse gas emissions. To succeed, we must pursue our reduction goals vigorously and in the most cost-effective ways we can devise. It will take a strong collective will and major commitment at all levels—in all sectors. We will all be participants in the coming years and decades.

Potential Climate Change Impacts on New England Agriculture

David W. Wolfe
Cornell University*

Prepared for and presented at the New England Regional Climate Change Impacts Workshop, September 3-5, 1997, University of New Hampshire, Durham, NH.

ABSTRACT

The New England area is an important contributor to the national supply of dairy products and food crops such as apples, grapes, potatoes, sweet corn, onions, cabbage, and maple syrup. In upstate New York alone the cash receipts from the sale of farm products approach $3 billion on an annual basis. The agriculture sector of the New England economy will be particularly sensitive to climate change, and there will be both winners and losers within the farming community. The social and political consequences of this will reach well beyond the farm gate because of the impact on supply and price of agricultural commodities, and the impact on local economies and land use.

Some crops, and the New England farmers producing them, will benefit from warmer temperatures, longer growing seasons, and the positive direct effect of increased atmospheric carbon dioxide on yield. In contrast, the competitive position of those farmers producing crops well-adapted to the existing climate could be weakened, or their enterprises may completely collapse, if their crops do not respond well to shifts in climate, and adaptation strategies fail. The dairy industry is likely to suffer adverse consequences from warmer summer temperatures because milk production by dairy cattle is very sensitive to heat stress.

Reaping the potential benefits while minimizing the potential negative consequences of climate change will require diversion of agricultural research dollars to climate change issues, shifts in crops and varieties grown, and increases in water, fertilizer, pesticides, and other farm inputs. In some cases, substantial capital investment by farmers, and taxpayer investment in regional infrastructure (e.g., development of water resources for irrigation) may be necessary just to maintain the status quo.

Assuming a best-case climate change scenario—a "benign" warming, with no major shifts in precipitation patterns or increase in catastrophic weather events—the agricultural industry in New England should be able to adapt, but the transition during the next century could be very stressful both economically and politically for the region.

INTRODUCTION

The economic value of agriculture in New England is often underestimated, even by many residents of the region who are not directly involved with this industry. In upstate New York alone the total farm cash receipts approach $3 billion on an annual basis. Many are surprised to learn that New York ranks within the top three in the nation for production of apples, grapes, sweet corn, snap beans, cabbage, milk, cottage cheese, and several other commodities. Maine has long had important potato, egg production, and other agriculture-related industries. The Vermont maple syrup industry is internationally recognized. The New England area as a whole provides a significant proportion of the total U.S. supply of dairy and maple syrup products. In addition, small family farms throughout New England are vital to the economy of rural areas, and they fill an important market niche for fresh, high quality, affordable local produce.

Key questions regarding New England agriculture and climate change are:

- Could the beneficial effects of increasing atmospheric carbon dioxide (CO_2) on plants (the so-called "CO_2 fertilization effect") counteract some of the negative effects of climate change?
- What types of adaptations and policies will be necessary to take advantage of the opportunities and minimize the negative impacts of climate change on New England agriculture?
- What will the cost of these adaptations and policies be?

* See Appendix V for authors' affiliations and addresses.

- Who will be the likely winners and losers within our region?
- What will be the likely impact of climate change on New England agriculture relative to other areas?
- Will climate change help or hinder our efforts to maintain an affordable food supply for the region, the nation, and for an increasing world population?

To date, there has been no comprehensive quantitative analysis of potential climate change impacts on New England agriculture. However, some findings from studies focused on impacts at the national and international scale are relevant here. Also, basic information on the regional agricultural economy, and information on crop and livestock responses to temperature and greenhouse gases, can be utilized in developing a qualitative assessment for the New England area. We will first review some fundamental aspects of what we know and don't know about how crops respond to temperature and increases in atmospheric carbon dioxide (CO_2).

TEMPERATURE EFFECTS ON CROPS

Most plant processes related to growth and yield are highly temperature dependent. We can identify an optimum temperature range for maximum yield for any one crop. Crop species are often classified as warm- or cool-season types. Most of the crops for which the New England area currently holds a strong competitive market position at the national level are cool-season species well adapted to our mild summers and cool spring and fall temperatures.

The optimum growth temperature frequently corresponds to the optimum temperature for photosynthesis , the process by which plants absorb CO_2 from the atmosphere and convert it to sugars used for energy and growth. Temperature also affects the rate of plant development. Higher temperatures speed annual crops through their developmental phases. This shortens the life cycle of determinate species like grain crops, which only set seed once and then stop producing. For a variety currently being grown in a climate near its optimum, a temperature increase of several degrees could reduce photosynthesis and shorten the growing period. Both of these effects will tend to reduce yields. Brief high temperature events at critical stages can severely reduce the quality of some cool season vegetable and fruit crops, and thereby reduce marketable yields even when total productivity is not affected.

The particular crop varieties currently being grown in major production areas are usually those best-adapted to the current climate. A significant increase in growing season temperatures will require shifts to new varieties that are more heat tolerant, do not mature too quickly, and have a higher temperature optimum for photosynthesis. Developing such varieties should be possible for many crop species, but there are limits to what can be accomplished through plant breeding and modern genetic engineering approaches. In many cases traditional crops will have to be abandoned for new crops better suited to the new environment. On the positive side, for farmers in cool regions such as New England, a "benign" warming (no major shifts in precipitation patterns and no increase in frequency of catastrophic weather events) will lengthen the growing season and should expand the list of crop species and varieties that can be grown successfully.

TEMPERATURE EFFECTS ON LIVESTOCK

Farm animals are directly affected by temperature and vary in their optimum temperature range. Dairy cattle perform best in cool climates (temperatures between 40 and 75 °F), and are particularly sensitive to heat stress (Bray and Bucklin 1996). High relative humidity (RH) exacerbates the negative effect from high temperatures. For example, at 80% RH heat stress in dairy cattle can begin at temperatures as low as 73 °F and stress becomes severe at 93 °F. Heat stress can have a carryover effect on milk production and reproduction for up to 150 days. Renovation or new construction of controlled environment facilities to house farm animals is costly and will not be a viable option for many New England dairy farmers. Climate change will also affect livestock production indirectly by its impact on the availability and price of animal feed, such as corn silage.

CARBON DIOXIDE (CO_2) EFFECTS ON PLANTS

The debate over whether CO_2 and other greenhouse gases are warming the planet continues, but few question the fact that atmospheric CO_2 is increasing exponentially and will likely double (to 700 parts per million (ppm)) within the next century. We can be relatively certain that agriculture in the future will be affected by the direct effects of

CO_2 on crops and weed species, whether or not we have a concomitant change in climate. Elevated CO_2 levels have a potential beneficial effect on the Earth's plant life because plants take up CO_2 via photosynthesis and use it to produce sugars and grow. The magnitude of this "CO_2 fertilization effect" varies with crop species and other environmental conditions such as temperature and availability of water and plant nutrients (see reviews: Wolfe 1994; Wolfe and Erickson 1993).

Most of our information regarding the yield response to CO_2 is based on experiments where plants were well supplied with water and nutrients, temperatures were near optimum, and pressure from weeds, disease and insect pests were nonexistent. Under such optimum conditions, a doubling of CO_2 (e.g., from 350 to 700 ppm) typically increases the yield of most crops by 20 - 35% (Kimball, 1983). While this describes the average, there are reports in the literature of lower yield responses in some slow-growing winter vegetables such as cabbage, and reports of higher yield responses in some fast-growing indeterminate species such as cotton and citrus.

Corn, an important crop in New England, is somewhat unique in that it shows very little growth stimulation with a doubling of CO_2 concentration even under optimum conditions. This is because it has a rather unique mechanism of photosynthesis. Some pasture grasses, weed species, and a small number of other crop plants (sorghum, millet, sugarcane) are similar to corn in their photosynthetic biochemistry, and so also do not benefit much from elevated CO_2.

It is possible that the beneficial effects from elevated CO_2 may compensate in some cases for negative yield responses to increasing temperatures. However, New England farmers in this situation could still be out-competed by farmers in more northern, cooler regions whose crops get the full benefit from higher CO_2 without the negative effects from high temperature stress.

Within the non-stress temperature range, the beneficial effects from elevated CO_2 tend to increase as temperatures increase. However, when temperatures become so high as to adversely affect flowering and pollination (e.g., >100 °F) the CO_2 benefits on yield become negligible.

Plant response to CO_2 at low temperatures will have important implications for high latitude regions such as New England where, even with a global warming, plants will be subjected to suboptimal temperatures during early and late portions of the growing season. The specific low temperature threshold for realization of a positive CO_2 effect varies, but for most crops the beneficial effects on photosynthesis become minimal at temperatures below about 55 °F. A recent study (Boese et al., 1997) found that for some selected crop species, such as beans and cucumber, elevated CO_2 provides some protection from chilling injury at temperatures between 40 and 45 °F.

Obtaining maximum benefit from an increase in atmospheric CO_2 is likely to require an increase in chemical inputs by farmers. Weed species can benefit just as much as cash crops from the CO_2 fertilization effect, and therefore growers may need to use more herbicides to control weeds in the future. Warmer temperatures in high latitude areas such as New England may allow more insects to overwinter in these areas, leading to greater pest pressure in the spring and increased pesticide use. Plants grown at high CO_2 tend to use water and nitrogen fertilizer more efficiently on a per unit leaf area basis, but when the increase in plant size due to high CO_2 is greater than the increase in efficiency, more water and fertilizer may be necessary.

MODEL PROJECTIONS OF CLIMATE CHANGE IMPACT ON AGRICULTURE

Scientists have attempted to address the issue of climate change impact on agriculture by linking together climate, crop growth, and economic-food trade computer models. These multi-layered models are extremely complex and contain numerous assumptions about the physical, biological, and socioeconomic systems they attempt to simulate. Nevertheless, they represent the most comprehensive analyses we have at present. They can be useful to policymakers at both the regional and national level provided there is an educated appreciation for the level of uncertainty inherent in their projections.

A comparison of impacts on U.S. agriculture for selected regions, based on a simulation analysis by Adams et al. (1995), is shown in Table 1. They considered climate uncertainties by comparing results from three different general circulation models (GCMs), those from the NASA Goddard Institute for Space Studies (GISS), the Geophysical Fluid Dynamics Laboratory (GDFL) and the UK Meteorological Office (UKMO). These GCMs vary in the severity and spatial distribution of their predicted changes in temperature and precipitation. The UKMO model predicts the greatest increases in temperature and, not surprisingly, the greatest effect on regional economic welfare.

The results in Table 1 indicate that the greatest negative effects on economic welfare tend to occur in southern, warm regions of the U.S. In general these negative effects are small relative to the base economy, but it should be noted that the yield forecasts used to create Table 1 are optimistic in that they assume a substantial CO_2 fertilization effect. The model is quite sensitive to this CO_2 effect assumption. For example, in simulations for the Northeast where no benefit from CO_2 was assumed, the negative impact from climate change more than doubled, with a percent change in economic welfare of -1.67, -2.91, and -14.86% for the GISS, GDFL, and UKMO models, respectively.

Table 1. Model projections of climate change effects on regional economic welfare (percent change from base) assuming current (1990) technology and positive CO_2 fertilization effects on yield. From Adams et al. (1995).

	Climate Model		
Geographic Region	GISS	GFDL-QFlux	UKMO
Mountain	+16.27	+1.18	+44.83
Northern Plains	+2.38	+10.32	+7.11
Pacific	+1.94	+1.57	-2.15
Lake States	+0.89	+3.23	-4.11
Northeast	-0.45	-0.35	-5.05
Southeast	-0.61	-0.70	-5.08
Appalachian	-0.69	-0.81	-5.21
Corn Belt	-0.90	-0.38	-3.50
Delta	-0.93	-0.44	-2.38
Southern Plains	-1.14	-0.63	-4.94

Although these computer projections can be a useful tool for policymakers, it is important that the results of such simulations not be take too literally. For example, the data for the Northeast region in Table 1 may not be particularly relevant to the situation for New England for several reasons. First, "Northeast" as defined by Adams et al. (1995) included Pennsylvania and New Jersey, as well as all of New York and the rest of New England. Second, the yield simulations are based entirely on crop models for wheat, maize (field corn), and soybeans. It is questionable whether these results have relevance for horticultural crops such as apples, grapes, potatoes, and cabbage that dominate the New England agricultural economy. The lack of reliable crop models for many important high value crops is a shortcoming of our current knowledge base. Finally, heat stress effects on milk production by dairy cattle, a very important consideration for the New England area, is not quantified in data in Table 1.

CAN FARMERS ADAPT TO CLIMATE CHANGE?

The U.S. and many other developed nations have a strong agricultural research base, abundant natural resources for flexibility in cropping patterns, and capital available to pay for adaptations and buffer negative economic effects during transition. For this reason many are optimistic that farmers in regions such as New England will be able to take advantage of opportunities and minimize negative effects associated with climate change.

Adapting to climate change will be costly, however. Costs at the farm level will include such things as increased use of water, fertilizer and pesticides to maximize beneficial effects of higher CO_2, and investment in new farm equipment and storage facilities as shifts are made to new crop varieties and new crops. (Imagine the costs, for example, for an apple grower to change varieties, or for a dairy farmer to switch to tomato production). Costs at the regional and national level will include substantial diversion of agricultural research dollars to climate change issues, and major infrastructure investments, such as construction of new dams and reservoirs to meet increased crop water requirements. Environmental costs associated with agricultural expansion into some regions could include increased soil erosion, increased risk of ground and surface water pollution, depletion of water resources, and loss of wildlife habitat.

Developed as well as developing nations must be prepared to deal with the citizens in those regions negatively impacted by climate change. Regardless of capital availability, agricultural economies in some areas will collapse due to factors such as excessively high temperatures, severe pest pressure, lack of locally adapted varieties, or poor markets for adapted crops. As climatic zones shift, there will be some cases where those zones with the best climate for crops will not have good soils or available water.

It would be wise to begin examining national policies for their ability to handle these climate change issues. The Council for Agricultural Science and Technology report on preparing the U.S. for climate change (CAST, 1992) emphasized the need for climate change-related agricultural research, and suggested modifying existing policies to encourage more flexible land use, more prudent use of water resources, and freer trade.

CONCLUDING REMARKS

The three major uncertainties regarding impacts of climate change on agriculture are: (1) the magnitude of regional changes in temperature and precipitation; (2) the magnitude of the beneficial effects of higher CO_2 on crop yields; and (3) the ability of farmers to adapt to climate change. If we lean toward the optimistic in our assumptions regarding all three of these uncertainties (e.g., a "benign warming", significant yield increases with a CO_2 doubling for most crops, and considerable capacity for adaptation by farmers), the New England agriculture industry should be able to survive a climate change, and may even benefit relative to some other regions of the U.S.. However, even with an optimistic set of assumptions, we can be relatively certain that the transition will be very stressful both economically and politically for the region. While some components of the agriculture industry will benefit, others will lose. Some farm families may go completely out of business when adaptation strategies fail. There could also be environmental costs associated with adaptation such as expansion of agriculture into fragile ecosystems, the need to develop new water resources, and increased use of chemical inputs by farmers.

Adapting to climate change with minimal economic, social, and political upheaval will require a coordinated effort at regional, national, and international levels to deal with the many serious consequences of climate change on agriculture.

REFERENCES

Adams, RM, RA Fleming, C-C Chang, B.A. McCarl and C Rosenzweig. 1995. A reassessment of the economic effects of global climate change on U.S. agriculture. Climatic Change 30:147-167.

Boese, SR, DW Wolfe and J Melkonian. 1997. Elevated CO_2 mitigates chilling-induced water stress and photosynthetic reduction during chilling. Plant, Cell and Environ. 20:625-632.

Bray, DR and R Bucklin. 1996. Recommendations for Cooling Systems for Dairy Cattle. Univ. of Florida Coop. Ext. Fact Sheet DS-29.

Council for Agricultural Science and Technology (CAST). 1992. Preparing U.S. Agriculture for Global Climate Change. Task Force Report No. 119. CAST, Ames, Iowa. 96 pp.

Kimball, BA. 1983. Carbon dioxide and crop yield: An assemblage and analysis of 430 prior observations. Agron. J. 75:779-787.

Wolfe, DW 1994. Physiological and growth responses to atmospheric carbon dioxide. In: Handbook of Plant and Crop Physiology. M Pessarakli (ed.) Marcel Dekker, Inc., New York. pp. 223-242.

Wolfe, DW and JD Erickson. 1993. Carbon dioxide effects on plants: uncertainties and implications for modeling crop response to climate change. In: Agricultural Dimensions of Global Climate Change., HM Kaiser and TE Drennen (eds.). St. Lucie Press, Delray Beach, FL, pp. 153-178.