

# CLIMATE SECTOR REPORT

*Session Chairs: Kenneth Kunkel and Julie Winkler*  
*Rapporteur: Michael Crimmins*

## OVERVIEW

The Climate breakout group included participants from various universities and research facilities from around the Upper Great Lakes region. The overall strength of the group was its knowledge of climate modeling and regional climatology. Participants with expertise in paleoclimate reconstruction, mesoscale modeling, and hydrology further extended the knowledge base of the group. This diverse and comprehensive background of the participants made for very insightful and productive discussions concerning the monitoring of climate variability, assessing potential climatic change, and evaluating the resulting environmental impacts for the Upper Great Lakes region.

Because the set of questions that most of the other sectors addressed was not applicable, a different set of overarching questions (listed in the next section) was devised to guide the breakout discussions. Each of the four breakout sessions was further guided with specific questions (also listed below) that related to the general overarching themes. In addition, each session began with a short presentation by one of the group participants. These presentations provided a “jumping off” point for the discussion.

A major theme of the breakout discussions was the assessment of the natural variability of the regional climate. Understanding the short-term and long-term natural variability is important both for understanding the behavior of the regional climate and for assessing the performance of General Circulation Model (GCM) simulations for the region. The breakout group emphasized the importance of a quality

observational record for evaluating climate variability and discussed the many limitations of the available historical climatological record. Alternative means for enhancing and extending the climatological record, such as the use of proxy data, were also discussed.

A second major theme was the role of GCMs in impacts analysis. The breakout group acknowledged that the limitations of the current family of models make assessing regional climate change difficult. Regional climate models and statistical downscaling were advocated as ways to provide greater spatial detail and richness to climate scenarios. The breakout group emphasized that the unique meteorology of the Great Lakes region needs to be carefully considered in model simulations and in any impacts analysis.

General recommendations of the breakout group were that more research is needed to better understand past and current climate variability in the Upper Great Lakes region. More research is needed to evaluate the behavior of GCMs at different levels of greenhouse gas forcing. Also, a better understanding of the interaction between the large water bodies of the Great Lakes and the regional climate is necessary before long term climate impacts can be adequately assessed. More specific recommendations, along with the background for these recommendations, are provided below.

## DISCUSSION QUESTIONS FOR THE CLIMATE BREAKOUT GROUP

### Overarching Questions

The following overarching questions were addressed by the Climate Breakout Group:

1. **Scenarios.** What are the important characteristics that climate change scenarios should possess if they are to be used for impacts assessment in the Upper Great Lakes region?

2. **GCMs.** How can the important climate and weather characteristics be incorporated into GCM-based scenarios?
3. **Research.** What new directions of research should be pursued to reduce uncertainties in scenarios?
4. **Uncertainties.** What uncertainties exist regarding current and past climate of the Upper Great Lakes region?
5. **Baseline data.** What research still remains to be conducted to provide an adequate baseline climatology for the region?
6. **Monitoring.** What (e.g. tools, knowledge, data) is required for adequate climate monitoring in the future?

### Specific Questions

The specific questions discussed in the breakout sessions were as follows:

- **Scenario development.** What is the nature of historical variability of climate in this region, particularly with regard to impacts-relevant characteristics, such as water supplies and extreme events? What range of conditions should be incorporated into scenarios? What are the limitations in using GCM-based scenarios? Will GCM-based scenarios provide unrealistic ranges of future conditions?
- **Spatial Variability.** How do climate fluctuations and trends vary spatially across this region? Will GCM-based scenarios produce unrealistic spatial patterns? What methods are available to produce realistic spatial patterns?
- **Local influences.** How are local and regional features of the climate (e.g., lake effect snowstorms, lake breezes and near-shore modification of temperature) related to large-scale variability and change? How can such features be incorporated into GCM-based scenarios? Will

such scenarios provide a realistic range of future conditions?

- **Land Surface.** How important are land-surface feedbacks in modifying the climate of the region? How likely is it that these feedbacks will change in response to anthropogenic influences? Is it important that GCM-based scenarios incorporate a range of land-surface feedbacks?
- **Future research.** What are the major recommendations of the group related to the overarching questions? What new research should be pursued to reduce uncertainties in scenarios of future change?

### RECOMMENDATIONS

- **Scenario length.** The historical climate record exhibits temporal variability over a range of time scales. Of particular interest are multi-decadal periods with climate conditions significantly different than the long-term mean. Such long-term variability is likely to be a feature of any future climate regime. Some impacts will be sensitive to variability on long time scales. In order to accurately assess such impacts, it is necessary to have scenarios of great length.

#### *Recommendation #1:*

We recommend that scenarios used for climate assessments be of an appropriate length. A minimum length of 100 years is recommended for examining important long-term variability within the Upper Great Lakes region.

- **Scenario detail.** Many impacts are directly caused by short-term and/or extreme weather events. In order to assess such impacts, scenarios rich in detail are required. Weather events that need to be specified in order to assess certain impacts of climate change include: thunderstorm (wind, hail, tornadoes, etc.) frequency, winter storms (wind, snow, etc.), critical

temperature threshold exceedances, freeze dates, clouds/fog, length of wet/dry periods, and heavy precipitation amounts and intensities.

### **Recommendation #2:**

We recommend that scenarios have, at a minimum, a daily resolution in order to assess event-influenced impacts and be rich in climatic detail, including the variables listed above to the extent practical.

- **Derived climate variables.** Related to *Recommendation #2* is the use of “integrative” or “derived” variables rather than “standard” climate variables in impacts analysis. Integrative and/or derived variables may include ice-on and ice-off dates, bore-hole temperatures, evapotranspiration, soil moisture balance, and length of time above a threshold temperature, among other possibilities. An advantage of employing integrative and/or derived variables is that these variables represent more closely the concerns of stakeholders. Another advantage is that some of the integrative variables (ice on/ice off, for example) have long records and can be used to supplement standard climatological records. Disadvantages of integrative and/or derived variables are that they often require careful interpretation and that they may be hard to produce from model output.

### **Recommendation #3:**

We recommend that analysts consider integrative and/or derived climate variables when developing climate impacts assessments. However, they should bear in mind that the choice of an integrative or derived variable is likely specific to the impact under investigation. Climatologists, impact analysts, and stakeholders should work jointly in defining appropriate integrative and/or derived variables.

- **Model assessment.** General circulation models incorporate a variety of simple param-

eterizations to simulate boundary layer processes, convection, and radiation, to name a few. These parameterizations lead to uncertainties in certain aspects of the GCM-based climate projections. Some aspects, such as mean annual temperature, may be associated with a relatively smaller level of uncertainty than others. Also, these uncertainties may vary from one region to another. For example, uncertainties may be greater for high-latitude locations compared to low-latitude locations. An excellent starting point for assessing the uncertainty of a future climate projection is to evaluate how well GCMs simulate the current or control climate. This type of evaluation can be useful for identifying “uncertainty boundaries” for perturbed simulations.

### **Recommendation #4:**

We recommend that uncertainties in model climatologies of impacts-relevant variables be assessed and documented at the regional scale. This assessment should encompass not only mean temperature and precipitation, but also other impacts-relevant variables, such as those listed in the “scenario detail” section under Recommendation #1.

- **Downscaling.** We recognize that many of the weather phenomena listed in the “scenario detail” item are not resolvable in the current generation of GCMs. Thus, the richness called for in Recommendation #2 is often not directly achievable from GCM output. However, there are downscaling methods that can contribute to the desired richness.

### **Recommendation #5:**

We recommend that available contemporary downscaling techniques be applied to GCM scenarios in order to maximize the climate detail available for impacts assessment, to the extent that the current state of science allows.

- **Mesoscale features.** A unique feature of the Upper Great Lakes region is the modification of the climate by the Great Lakes. Features such as lake-effect snow and near-shore modification of temperature have a multitude of impacts. These are mesoscale features, unresolved by most GCMs. Accurate estimates of future changes in these features will require downscaling. This is a problem that is ideally suited to the use of Regional Climate Models (RCMs) embedded within GCMs. A possible short-term solution, as regional models are developed further, is the use of statistical downscaling and analogue models.

**Recommendation #6.1:**

We recommend that statistical downscaling and analogue techniques be developed specifically for the assessment of near-shore lake modification features.

**Recommendation #6.2:**

We recommend the continued support for the development of RCMs with a resolution that is capable of simulating lake effects. It is important that they eventually incorporate a lake model in order to assess the timing of any overturning of the lakes in a perturbed climate. It is not sufficient for them to incorporate the lakes as a simple water surface.

- **Multiple scenarios.** It is important that impacts researchers appropriately convey the uncertainty of climate scenarios to stakeholders. One method of conveying uncertainty is to employ an ensemble of climate scenarios that span a range of plausible outcomes. However, in order for this to be possible, impacts analysts must have ready access to simulations from a large number of GCMs and RCMs.

**Recommendation # 7:**

We recommend that analysts routinely employ an ensemble of scenarios for impacts research. In order to facilitate analysts' access to climate simulations, we recommend that a central "clearing house", perhaps at the National Center for Atmospheric Research, be established where model developers can archive detailed output from recent model simulations.

- **Spatial variability.** The spatial variability of severe climatic anomalies plays a key role in the management of Great Lakes water supplies. Specifically, Lake Superior is used as a storage basin to minimize fluctuations in the levels of the lower lakes. This management strategy is of limited effectiveness when anomalies are in phase between Lake Superior and the rest of the basin. The outcome of an impacts assessment will depend on the nature of this spatial variability.

**Recommendation #8:**

We recommend that the spatial variability of climatic anomalies simulated in GCM and RCM scenarios be documented to assist in the interpretation of the outcomes of impacts assessments. Of particular interest is the frequency of in-phase and out-of-phase patterns of anomalous temperature and precipitation conditions, both in control and perturbed climate simulations.

- **Proxy data.** As stated under Recommendation #1, large variability at low frequencies (periods of years to several decades) is evident in the Upper Great Lakes region. Such variability can both ameliorate and exacerbate greenhouse gas-induced change. Our understanding of the magnitude and nature of this variability is incomplete, particularly with regard to very long period variations. Proxy data (e.g., sediment analysis, isotope analysis, ice on/ice off and tree ring data) may allow us to extend the climate

record back several hundred years in this area. In addition, the joint use of proxy data and paleoclimatic simulations helps to validate GCMs and RCMs.

***Recommendation #9:***

We recommend further support for the collection and examination of proxy data to extend the climatic record and for the validation of climate models.

- ***Vegetation.*** The synergistic effects of climate on vegetation are of great interest to climatologists and ecologists. The human-induced deforestation of the Upper Great Lakes region in the mid-to-late 1800s and the subsequent reforestation in the early 1900s is likely more extreme than land cover changes expected under climate change. The impacts of this deforestation/reforestation on the climate record, however, is unclear.

***Recommendation #10:***

We recommend that long-term climate records, including proxy records, be carefully examined to determine whether a signal reflecting past large-scale changes in vegetation can be identified.

- ***Land-surface interactions.*** Land-surface feedbacks are important when examining impacts at fine spatial and temporal scales. These feedbacks include both natural surface changes (e.g., changes in lake ice cover) and anthropogenic changes (e.g., increased urbanization/suburbanization, or wetland removal).

***Recommendation #11:***

We recommend that developers of GCMs and RCMs continue to work toward the inclusion of land-surface feedbacks in climate models, such as the inclusion of interactive biosphere models.

- ***Monitoring.*** A quality observational network with fine temporal and spatial resolution is absolutely essential to: 1) understand the current baseline climatology, and 2) to identify and evaluate changes in short and long term climate variability. Recent changes in climate observing practices in the United States raise concerns about the long-term health of our current network. In addition, recent improvements in remotely-sensed observations of atmospheric variables provide unprecedented opportunities for a more detailed and sophisticated monitoring of our climate.

***Recommendation #12:***

We recommend that, at a minimum, the current observational record be retained and, preferably, that the observational network be improved. In addition, we support the improvement and use of remotely-sensed observations of atmospheric variables.



# WATER ECOLOGY SECTOR REPORT

*Session Chairs: Arthur Brooks and John Magnuson*  
*Rapporteur: Kimberly Hall*

## INTRODUCTION

The Water Ecology breakout group included participants from academia, federal environmental agencies, the National Wildlife Federation and the Mille Lacs Band of Ojibwe Tribe.

The discussion group was asked to interpret the four questions broadly to reduce the chance that significant issues would be overlooked. Because this was an initial effort, failing to include potentially critical issues was considered a greater mistake than including issues that, upon further study, turn out to be relatively unimportant. The participants were not asked to make quantitative assessments of the impacts that they discussed.

## THE 4 QUESTIONS ADDRESSED

### 1. What are the current concerns?

- **Land-use.** The most important source of impacts on aquatic systems in the Upper Great Lakes region was thought to be land-use – specifically agriculture and urbanization (including industrial uses). These types of land-use changes can lead to direct loss or degradation of aquatic systems (e.g. filling of wetlands for agriculture and siltation of streams due to runoff from agriculture).
- **Agriculture.** Fertilizer and pesticide runoff produce widespread and detrimental impacts on aquatic ecosystems. In addition to these well known concerns, questions were raised about industrial farms and how they handle animal wastes. On one hand, manure was described as having a potentially large impact on phospho-

rus and ammonia levels in aquatic systems. On the other hand, European studies show that manure can be an important source of nutrients when spread across the landscape.

- **Urbanization.** A study linking increasing urbanization with decreasing scores on a biotic index was discussed. The aspect of climate change that may prove to be most important in terms of aquatic ecosystem health is how land-use patterns (e.g. urbanization or sprawl) change as a result of climate change and climate change mitigation policies.
- **“Leap-frogging.”** Aquatic systems are particularly vulnerable to “leap-frogging” (i.e., building vacation homes in remote areas causes degradation “leaps” from cities to more rural areas), especially groundwater systems (resulting from more well drilling and waste disposal in previously unimpacted areas).
- **Population growth.** Land-use issues are closely tied to population growth, which was identified as an important stressor.
- **Pollution.** Important concerns included mercury deposition (leading to reproductive and potentially fatal, developmental impairments in aquatic life); eutrophication (leading to reduced dissolved oxygen and potential species loss) and acid rain (impairing and potentially killing fish and plant life). Other sources of point and non-point source pollution and existing contaminant loads in aquatic sediments and biota were also important concerns.
- **Additional stresses.** The alteration of lake levels in the Great Lakes, the shoreline modification (related to human settlement along shores), the loss of Great Lakes coastal wetlands (related to the alteration of lake levels and shoreline modification), and the invasion of exotic species were all discussed as areas of importance. The current concerns are summarized in Figure 1.

AQUATIC ECOSYSTEMS				
STRESSOR	GREAT LAKES	INLAND LAKES	WETLANDS	RIVERS & STREAMS
Agriculture	○	●	●	●
Urbanization	○	○	○	●
Forestry Recreation	●	●	○	●
Shoreline Modification	●	●	○	●
Dams & Hydrologic Manipulation	○	○	●	●
Eutrophication		●		
Toxics & Contaminants	●	●		●
Exotic Species	●	●	○	●

Figure 1: Major stressors on aquatic ecosystems in the Upper Great Lakes region.

- Strongly impact ecosystem
- Very strongly impact ecosystem
- Likely to interact with or be further impacted as a result of climate change
- Likely to strongly interact with and be impacted by climate change

AQUATIC ECOSYSTEMS				
CLIMATE VARIABLE	GREAT LAKES	INLAND LAKES	WETLANDS	RIVERS & STREAMS
Mean Temperature	○	●	●	○
Seasonality (temp. & precipitation)	○	●	●	●
Weather extremes	○	●	○	●
Water level	●	●	●	●
Runoff	●	●	○	●
Wind	●	●		
Cloud Cover	●	●	●	○

Figure 2. Climate factors that affect the structure and function of aquatic ecosystems in the Upper Great Lakes region. All of these climate factors are likely to be affected by global climate change.

- Important impacts
- Very important impacts

## 2. How may climate change impact our lives?

It was recognized that any changes in climate could have strong and hard-to-predict impacts on aquatic systems. Examples that were discussed included:

- **Water temperature increase.** Potential effects of a temperature increase on deep inland lakes could lengthen the period of thermal stratification and decrease the volume of the layer of water beneath the thermocline. This could lead to a decrease in dissolved oxygen, decrease in primary productivity, and a decrease in cold water fish populations.
- **Decrease in ice cover.** A decrease in ice cover could reduce winter kills (i.e. fish that die because of insufficient dissolved oxygen in the water under the ice). An overall change in the seasonal patterns of freezing and thawing could interfere with aspects of fish (and other species) life histories, such as the timing of reproduction.

- **Decrease net water basin supply.** Decreased rates of supply, coupled with increased rates of evaporation, could lead to decreased lake levels and the widespread loss of wetlands.

A summary of the discussed impacts on various water bodies from changes in climate factors is presented in Figure 2. Interactions among the climate factors shown in the table were thought to be highly likely but beyond the scope of the discussion.

## 3. What additional information do we need?

The discussion in this section fell into three categories: better understanding, better model development and implementation, and better general information and better data.

### *Better understanding*

Improved regional climate models are needed that incorporate feedbacks between climate and ecological aspects of the Great Lakes. The group discussed several issues related to modeling.

- **Recharge mechanisms.** A main informational need with respect to groundwater models is an understanding of recharge mechanisms on the larger scale. The focus of most groundwater models is shallow system aquifers. Some work has been done to estimate flow to and from the lakes and the flow of groundwater. Groundwater exchanges with the lakes are highly variable by area because of soil type and underlying geology.

- **Runoff.** Another informational need is a better understanding of runoff. Better parameterization of runoff in GCMs and RCMs is important because incorrect treatment of runoff can cause errors in surface fluxes. To develop improved parameterizations, there is some question as to whether runoff data and recharge data are both needed, because the processes tend to cancel to a large degree. The degree of cancellation depends on the scale of the model being used and the spatial patterns of the aquatic systems in the model. Currently there are no projects at the U.S. Geological Survey (USGS) to link runoff to these models.

### *Better model implementation*

- **Linkage.** Models for groundwater, river flow, runoff, and wetlands need to be linked together. This linkage will require the development of models for wetlands (currently there are no generic wetland ecosystem model of which the group was aware). It appears that there are currently models under development that are likely to be useful – it was mentioned that NCAR has a version of VEMAP (Vegetation/Ecosystem Modeling and Analysis Project) that

models the effects of current and doubled CO<sub>2</sub> at 50 km resolution that includes the Great Lakes. The USGS also has models of groundwater flow that are at a small scale (RASAS studies – watershed scale) that could potentially be linked to produce a regional model.

- **Calibration.** Existing groundwater models need to be calibrated using data from periods of major hydrologic stress. Currently there is not sufficient information available.

- **Integrated databases.** There is potential to link three existing groundwater models for different parts of the region and then tie in runoff. It may be useful to get NOAA and the Army Corps of Engineers involved. It was also suggested that there is a lot of information available on lake levels and stream flow that could be linked with existing forest, agriculture, wetland distribution, and groundwater databases. A major effort should be put into integration of the existing databases and models to improve understanding. The focus of these integrated groundwater models should be on hydrologic balance at a landscape scale. Future links envisioned by the group would be to tie in urbanization and other types of land-use change. The group agreed that land-use changes are going to be a key factors determining the fate of aquatic systems. Finally, the integrated groundwater and runoff models should be linked to GCMs and RCMs.

- **Spatial Scale.** Broad-based models for the Great Lakes or wetlands are not likely to be useful because effects related to climate change are likely to be very site-specific. It is possible to get (opposite) effects due to some climatic change in adjacent sites – the results have to do with the water budget for each water body. Local flow paths dominate small-scale effects. As a result, predictions need to be presented carefully and with respect to specific sites; general broad scale predictions will be incorrect and inappropriate.

- **Temporal scale.** Another problem with current models is the assumption that the Great Lakes area has remained unchanged over time. Data from several centuries needs to be examined in order to better understand the effects of changing climate. We are currently in a period of declining lake levels. Lake levels also show strong periodicities at various time scales that are likely to be climate-driven. Both of these would not be clear without the long-term data sets that are available. There are likely to be strong parallels between the inland lakes and the Great Lakes that may be identifiable through paleoecological studies.

#### *Better general information and better data*

- **How climate shapes ecosystems.** Research should address the question of “How does climate shape aquatic ecosystems?” Climate change is likely to lead to a wide variety of ecosystem feedbacks. As described above, effects are likely to differ – even in systems that appear similar – due to differences in water regime, soil/parent material, and location on the landscape.
- **Exotic species.** The habitat needs and ecological requirements for a whole collection of species remain unknown and must be studied. This is especially true for those that are likely to invade and possibly dominate aquatic systems. The forces and factors that are currently restricting ranges (including climate factors) must be understood to make better predictions about what will happen in the future. The population ecology of many species could be dramatically altered by changes in climate.
- **Air quality.** Information is needed to link nitrogen deposition patterns and the impacts on levels in ecosystems. The Great Lakes are probably not nitrogen limited, although this may vary seasonally. In wetlands, nitrogen can be a key limiting nutrient. Peatlands may be particularly

at risk because *Sphagnum* species are killed by high nitrogen levels. Mercury deposition is also important to examine.

- **New data.** Information gathering should focus on key stressors identified in Figure 1, especially those that are susceptible to climate change impacts. One important data need relates to the natural fluctuations in groundwater level – most data currently reflects water levels in pumped systems (i.e. systems in which the water level is at least in part determined by human activity). Good data on sunlight, especially in remote areas like the centers of each of the Great Lakes is also needed. These data would help in the estimation of primary productivity in aquatic systems.
- **Long-term lake levels.** The relationships between long-term lake level data and other long term climate data (i.e., CO<sub>2</sub> from ice cores) should be investigated.

#### *Organizing research and impact assessments*

From the previous list it is clear that additional research is needed. The following specific tasks and general guidelines resulted from a discussion of the need for further research.

#### **Specific tasks**

1. Develop better proxies for assessing the effects of climate change in the past (in addition to the records that already exist from long term Great Lakes water level studies).
2. Develop an understanding of the connection between aquatic ecosystems, the watershed, and local and regional hydrology.
3. Develop basic ecosystem models for wetlands.
4. Develop and integrate regional models of climate, landscapes, hydrology, and terrestrial and aquatic ecosystems.

5. Improve the understanding of climate as a basic structuring principle of aquatic ecosystems.
6. Obtain more information about the key stressors identified in Figure 1.

#### General guidelines

1. Develop location-specific studies. An overall feeling was that the heterogeneity and interconnectedness of aquatic systems makes any sort of generalization about stressors or effects of climate change very difficult.
2. In terms of discussing impacts, it may be useful to divide aquatic systems into those *directly and indirectly* influenced by the Great Lakes.
3. Streams, groundwater-fed systems and storm-responsive systems should be examined separately. Alternatively, streams and rivers could be divided into those that are *high and low* in the landscape.
4. Wetlands should be assessed on a gradient from lake-influenced to non-lake influenced.

#### 4. How do we cope with climate change?

This session was short and focused on the development of the summary list below.

1. **Data usage.** Maximize and integrate current data sets and models. This will increase the usefulness of currently available information and predictive ability.
2. **Economics assessment.** Promote consideration of environmental costs (externalities) in cost/benefit assessments of various planning and mitigation strategies. Unless this is done, economic and policy decisions intended to increase the value of our world in future years will fail to promote healthy ecosystems.

3. **Comprehensive studies.** Incorporate climate change-related variables into ongoing studies of other stressors of aquatic systems. This is essential to determining the extent and type of aquatic system vulnerability.
4. **Outreach.** Increase efforts at public outreach and education about potential effects of climate change on aquatic ecosystems. Until the public is informed they will not support enlightened policies.
5. **Land-use strategies.** Promote land-use planning that will minimize potential impacts of extreme events. Land-use patterns can either increase or decrease the vulnerability of ecosystems.
6. **Restoration.** Encourage development of adequate restoration techniques for aquatic systems. It is not enough to decide to restore and promote healthy aquatic systems, one must know how to implement these goals.



# LAND ECOLOGY SECTOR REPORT

*Session Chair: Daniel G. Brown*

*Rapporteur: Sheila Ruth Burris*

## INTRODUCTION

The Land Ecology breakout group included participants from universities, federal agencies, and private industry. Several issues particular to the Upper Great Lakes region were discussed. Detailed results from the discussion are included as the main content of this report. Concise results of this discussion are included in tabular form at the end of this report.

## THE 4 QUESTIONS ADDRESSED

### 1. What are the current concerns?

The session began by considering maps of land-use and land cover (USGS), eco-regions, and locations of public lands in the Upper Great Lakes region. The natural ecosystems of the region occur along a north-south transition from prairie to forest in the west, and from eastern deciduous forests to northern mixed hardwood forests in the east. This transition corresponds to climatic and soil gradients, and is reflected in a steep south-north land-use gradient from predominantly agriculture to predominantly forest. The region is at the southern margin of the boreal forest and has a large number of inland lakes and wetlands, including the prairie potholes in the western portion of the region.

Without ever achieving a fully satisfactory definition of what qualifies as a “stress”, the group focused initial discussions on identifying the current “stresses” on the ecosystems of the region. The effects of human and natural disturbances on the landscape are numerous. Important bio-indicators such as deformed frogs in

Minnesota may be indicative of air, land, and water quality problems. During the discussion, one overarching theme emerged as central to current and future land ecology concerns – namely, **ecological disturbances**. These include both anthropogenic (e.g. human population patterns, land-use practices, forest management, and agricultural pressures) and natural disturbances (e.g., fires, pests, and extreme weather and climate events). Additionally, the group considered the importance of extreme climatic events for ecosystem functioning. The frequency, intensity, duration, and location of climatic extremes may be influenced by human activity but the group considered them to be fundamentally natural factors.

### *Anthropogenic disturbances.*

- **Human Population.** Through extensive logging, mining, urban and dispersed-rural development, and agricultural activities, the human population in the Upper Great Lakes region has had a significant impact on the ecological patterns and processes in the region. Ongoing changes in the numbers and distribution of population are likely to result in further impacts. Despite these land-use changes, the amount of forested land in all three states (MI, MN, and WI) has increased over the last decade.
- **Rural development.** In rural areas, settlement is consuming more land, increasing commuting distances, and increasing rural infrastructure demands. Although some attempts at policy remedies have been made, the demand for some rural land continues to rise, and a strong home-rule tradition has limited effectiveness of statewide controls. For example, in Michigan, the Subdivision Control Act was designed to reduce these problems by requiring land to be sold in larger lots (i.e., greater than 10 acres). But it also increased the effects of dispersed development by increasing the number of these now-larger lots that are sold. The

result is an increase in the rate at which farm land and natural ecosystems are being lost.

- **Urban development.** Several impacts of urban development on natural ecosystems were discussed, including forest fragmentation (which limits the ability of ecosystems to respond to pressure by migrating); impervious surfaces (which increasing runoff and erosion); increased fire suppression (occasional fire is a natural part of the Great Lakes ecosystem), and air pollution (e.g., nitrates and ozone).
- **Retirement.** Population growth and redistribution are being compounded by the fact that people are living longer. Retirement-related development has had a profound impact on rural land-uses in the region.
- **Recreation and Tourism.** Another aspect of the complex urban expansion is tourism. One estimate puts the recreation and tourism industry in the region at \$9 billion per year. Michigan is second in the U.S. only to Florida in the percentage of homes that are used only seasonally and first in the in the U.S. in the number of registered boaters.
- **Demographic Changes.** The strongest drivers of land-use change in the region within the last several decades have been the changes in human demographics and economics (e.g., a more affluent, older, less agrarian, and globalized society with net migration from urban to rural areas). These drivers are likely to continue and to interact with climate forcing. It is not clear that climate forcing will dominate the land-use changes. Possible economic impacts include increases in energy consumption and tourism in the region.
- **Agricultural land-use.** In the western portion of the region, intensification of agriculture is a concern. Feedlots and hog farms, which confine huge numbers of animals to small spaces, have proliferated in recent years. Also,

the combination of abandonment of marginal farmland and conversion of other farmland to urban-type development has reduced the available productive farmland in the region.

- **Pest management.** Reactions to pests, such as spraying pesticides, can have serious negative consequences for ecosystems unless management efforts are designed to minimize them.
- **Mining.** Another land-use practice in the region affecting ecosystem health is *mining*, which includes the extraction of oil, gas, metals, minerals, and peat.
- **Air pollution.** Atmospheric deposition of ammonium and other sources of nitrogen from agricultural regions to the west and increasing amounts of tropospheric ozone due to urbanization can place stresses on natural ecosystems.
- **Loss of habitat.** In the southern portion of the region, where agriculture and urban development are extensive, there is clearly evidence of loss of habitat. This is especially true in the Maple/Basswood Forests of Southern Michigan, which exist mostly as small wood lots scattered amongst agricultural fields. Other sensitive habitats experiencing loss and fragmentation include prairie within forested areas. This loss has had negative implications for threatened or endangered species (TES), like Pitcher's Thistle and Karner Blue Butterflies. Other TES in the area include Kirtland's Warbler, which has also suffered loss of habitat through fire suppression.
- **Stresses on Native Peoples.** Many indigenous cultures that depend on water resources and species in fragile habitat for maintenance of their traditional lifestyles have experienced intense pressure. For example fire suppression has altered traditional burial grounds. The deterioration in water quality has had a great impact on many groups of Native Americans as they rely on water resources for their livelihoods (fishing, etc.). Most Native Americans are uni-

versally aligned against mining because of its affect on water quality through ground water.

- **Exotic Species.** The advance of exotic species, (that were introduced by people) like buckthorn and honeysuckle, also represents a major cause for concern. Exotics can spread rapidly and push out native species.

### *Natural disturbances*

- **Pests and diseases.** Natural ecosystems are subject to the impacts of pests and diseases resulting in significant and sometimes devastating results.

- **Fire.** Fire has always been an important process to which many of the ecosystems in the region have adapted. Dramatic alterations in fire regimes, through suppression, have led to similarly dramatic changes in ecosystem composition and structure. Encroachment of forests into prairie openings was noted as a particularly important example of these changes.

- **Wind.** The atmosphere is an important factor to consider because it can alleviate or intensify existing problems. Wind-throw acts as a direct disturbance in forested ecosystems.

- **Precipitation and temperature extremes.** The flora and fauna of the region are dependent on climatic moderation. Periodic extreme droughts, flooding, late-spring or early-autumn frost, low minimum and high maximum temperatures punctuate the climatic variability of the region. Any consideration of the interaction between climate and land ecosystems must account for the magnitude, frequency, and duration of these events.

## **2. How may climate change impact our lives?**

Some analyses of temperature and precipitation trends and predictions for the Upper Great Lakes region reveal a climate that is getting warmer and wetter. There is significant uncertainty in

both the historical trends and the future projections at the regional scale. Therefore, the discussion tended to focus on identifying the sensitivities of the region's ecosystems to change, rather than predicting the future.

In order to address the question of impacts, it was clear to the group that average climatic conditions would not be the only, or even the dominant, climate-change related effects on terrestrial ecosystems. Other potential changes (e.g., changes in extreme events) are even less well understood than average conditions. Three general areas in which climate change is likely to impact terrestrial ecosystems were identified in the breakout group:

Land-use Issues

Disturbances and Extreme Events

Species Adaptation and Migration

### *Land-use Issues*

- **Agricultural productivity.** A changing climate may have direct impacts on agricultural productivity in the region. Because farming tends to occur at the margins of profitability, some climate change scenarios could favor significant increases in agricultural productivity. Furthermore, declining productivity in other regions may encourage agricultural intensification in the Upper Great Lakes region. This intensification would likely result in drained wetlands and other consequences in the region. Uncertainties in such a scenario, however, are large.

- **Agriculture and climate variability.** One confounding factor is the influence of climate variability, which currently directly affects agricultural productivity. Increases in the occurrence of extreme events may limit real gains in productivity.

- **Pests and diseases.** The interactions of pests and disease with climatic variability are unclear

but are likely to confound analysis of how natural ecosystems will respond to climate change. Although they might be managed through integrated pest management, pest increases could mean an increase in the use of pesticides and herbicides. Reactions to pests can have serious negative consequences for ecosystems unless management efforts are designed to minimize them.

- **Soil-imposed limits to land-use.** A significant cause of uncertainty is the degree to which land-use is limited by soil type. In addition to climate, the land-use gradient from agricultural production in the south, to forest and recreation in the north, is controlled to some extent by soils (i.e., sandier and/or more acidic soils to the north).

- **Trees.** Forest productivity may also be affected by climate change. There are implications for both the forest products industry and the amount of carbon sequestration accounted for in the forests. Like agricultural systems, forested ecosystems are complicated by many interacting effects. The combined effects of climate change, changes in disturbance regimes, nitrogen deposition, CO<sub>2</sub> fertilization, and increasing ozone levels are not yet known.

### ***Disturbances and Extreme Events***

Changes in natural disturbance regimes caused by climate change are critical to the future functioning of the ecosystems. Climate change will likely have effects on insect populations, fire regimes, extreme temperatures, precipitation, wind events, and tropospheric ozone. There has already been tree damage due to increased ozone concentrations throughout the rural Upper Great Lakes region.

- **Pests and diseases.** The populations of forest pathogens may increase. For example, Beech bark disease and the Woolly Adelgid, currently in the eastern U.S., might affect for-

ests in the Upper Great Lakes region. Because of a warmer winter and spring in 1998, there were predictions of a 40% increase in gypsy moths, black flies, and mosquitoes for that summer. Indeed, gypsy moth populations were substantially larger in the summer of 1998 than in the previous two years.

- **Climate variability.** Changing climatic variability is critical to understanding ecosystem responses. Understanding changes in patterns of events (e.g., more frequent periods of extended drought, timing of last frost) may be more important than understanding changes in climate means.

- **Fire.** The peak fire season in the Upper Great Lakes region is May. For this reason, changes in late winter snow cover and early spring precipitation will be strong determinants of fire frequency and severity. In addition, fire management practices have important indirect effects on increased fire potential. The more fires are controlled, the higher the probability will be of a catastrophic fire – unless management includes prescribed burns.

### ***Species Adaptation and Migration***

- **Change and the rate of change.** Shifting ecological zones and interactions with soils have serious implications for the natural ecosystems and for biodiversity in the region. The rate of climate change is expected to be more rapid than anything experienced in the historical record. There is some question as to whether plant species will be able to migrate and/or adapt sufficiently fast.

- **Forest adaptation.** Trees with wind-dispersed seeds will have more trouble, especially if they need special habitats or if their habitats are fragmented. There is some potential for migration and replacement, such as the hemlock migration evidenced by paleoecological records.

- **Limits to migration.** The Great Lakes themselves and expanses of agricultural land-use in the southern part of the region will likely act as barriers for species migration.
- **Atmospheric chemistry.** It is difficult to assess the changes of CO<sub>2</sub> fertilization on community composition, since it will improve the growth of some species but not others. It will be hard to isolate the effects of CO<sub>2</sub> fertilization from those of climate change. Nitrogen deposition may cause only small changes in prairie communities because of the small size and fragmentation of prairie reserves. However, nitrogen deposition will likely affect forests more significantly, especially those with deciduous trees.
- **Temperature.** Physical ecosystem properties (e.g. temperature) are tied to ecosystem diversity. The group discussed recent results from the Linkages Model, which illustrates the temperature effects on forest structure and, subsequently, on avian diversity.
- **Intraspecies genetic diversity.** An important determinant of the ability of populations to adapt to climate change is their genetic diversity. So far, there has been very little direct research on genetic diversity and its effects on adaptation through evolution. As regional climate change continues, some genotypes and local phenotypes will likely become much more abundant at the expense of more narrowly adapted species. An example is Trembling Aspen, a species with one of the broadest tolerance limits and adaptation to fire.
- **Species distribution and sprawl.** There will be interactions due to changing human settlement patterns. Several different types of examples include sprawl, leading to urban-dwelling deer in the Twin Cities; the escape into forest habitats of exotic, ornamental plants; and the spread of bovine tuberculosis from domestic to wildlife populations.

### 3. What additional information do we need?

The monitoring of ecosystem status and trends, and the acquisition of scientific knowledge about the functioning of ecosystems form the core of information needs in the region. With these in mind, more information is needed in the following areas (discussed in detail below):

Land-use Options/Scenarios

Disturbance Trends/Patterns

Determinants of Species Patterns

Other Data/Issues

#### *Land-Use Options/Scenarios*

Ultimately, the development of land-use scenarios under various assumptions of climate change would be a valuable tool for evaluating possible land policy responses in the region. To develop such scenarios, additional data, scientific investigations, and models are needed to understand the interactions among climate, land-use, demographics, economics, soils, and other factors.

- **Monitoring data.** The information needs include a better attempt to monitor ongoing changes in land-use and land cover. Monitoring data will help identify future ecosystem impacts as well as provide data for scenario development.
- **Carbon budget data.** Concurrently, more information is needed on the changes in the amount of forest cover and the rate of carbon sequestration in the forested lands. This information will help improve quantification of the regional, national, and global carbon budgets.
- **Economic modeling.** A better understanding is needed of the settings under which expansion or intensification of agriculture in the region makes sense economically. Agricultural practices have significant impacts on ecosystems.

- **Competing uses.** Ecosystem models should account for competition for land among various sectors and should attempt to evaluate how the competitive advantages in the region shift under various climate scenarios.

### *Disturbance Trends/Patterns*

- **Historical disturbances.** Information is needed on the historical and long-term trends in the regimes of various disturbances (including fire, pests, disease, and extreme climatic events). Data that can be used to address this gap include long term proxy records and historical records. Research is needed to interpret the data in ecologically meaningful terms.
- **Improved monitoring.** Monitoring of ecologically significant climatic extreme events (e.g. frost, drought) needs to be in place. In addition, improved data collection and monitoring systems regarding all ecosystem disturbances should be established.
- **Modeling.** The following factors need to be modelled: a) The responses of ecosystems to current stresses, b) How those responses are affected by climate change, and c) The interactions between the responses and other ecosystem stress factors. Such comprehensive, interactive models might allow better prediction of ecosystem responses to stresses that are part of climatic change.
- **Regional climate models.** As regionally specific climate modeling improves, it is hoped that extreme events and climate variability might be better predicted.

### *Determinants of Species Patterns*

Better knowledge of the elements that are required by species for survival, such as the relationships between habitat patterns and species abundance, is needed. This knowledge should come from both the compilations of data sets,

for example on the current distributions of different species, and the scientific investigations of the relationships between the species and their environment.

- **Interdependence data.** More information is needed regarding the interacting processes affecting species distributions, e.g., the interacting effects of climate, nitrogen deposition, CO<sub>2</sub> fertilization, and migration mechanisms on intraspecies competition. More stand-level investigations of species response are needed in attempts to account for these interactions.
- **Migration studies.** A better understanding is needed, perhaps through better modeling, of the ability of species with various dispersal mechanisms, to migrate through fragmented landscapes.
- **Robustness and adaptability.** Better knowledge of the responses of species to interannual variability in climate is needed. For example, species react very differently to a single severe drought year than to several drought years in a row. Furthermore, the equilibrium state of species with respect to climate, needs to be known. The rate of change now is greater than ever recorded before. It is necessary to know what to measure in order to be able to determine the robustness of the system, i.e., whether or not the system can quickly adapt to changes.

### *Other Data/Issues*

- **Data existence.** A variety of good data on species distributions exists, but many are not easy to access. A good example is the data on tree distributions held in the General Land Office survey records. In Minnesota, the Department of Natural Resources has compiled a digital database from the survey records. Every state has a national heritage program, which is doing something similar, but the efforts are inconsistent. In Michigan, for example, the decision was made not to compile the data in a digital

database. Some forms of data will be more helpful than others. For instance, palynological records cannot be used to distinguish between red and white oak pollen and yet the species have very different interactions with wildlife (e.g., deer).

- **Data availability.** Many data on ecosystems in all regions of the country reside within various federal and state agencies, as well as with many various scientific investigators. It is often difficult to know what data are, in fact, available. The breakout group agreed that some effort to catalogue, or create a meta-database on biological and ecosystem data would be valuable. Such “data about data” would serve to minimize the duplicate collection of data.

- **Remote sensing.** It was also felt that, given improvements in the spatial, spectral, and temporal resolutions of satellite remote sensing instruments, the ecosystem research and management communities should be able to make more effective and efficient use of remote sensing. Land-use and land cover changes, at the very least, can be monitored with remote sensing. There was some hope that remote sensing could be used to improve both the thematic content of existing data (e.g., by giving species-level distributions) as well as the temporal frequency, to improve interannual investigations. An example of the latter is a current prototype use of remote sensing to potentially increase the temporal frequency of the Forest Inventory and Analysis (FIA) program at the USDA Forest Service.

- **Public education.** Another major information issue is education. Providing the public with a regional scale prediction of changes in their area might help personalize the issue of climate change for people and get them involved with the changes that are likely to occur. People will not react to global change until they can be told specifically how it will affect them.

#### 4. How do we cope with climate change?

The discussion of this last question was abbreviated because many in the group were unable to attend the discussion. The remaining members of the group discussed several possible coping strategies to encourage sustainability of the terrestrial ecosystems in the region under changing climatic conditions.

- **Zoning reform.** Land-use conflicts may occur as a more dispersed settlement pattern develops and as competition among various land-uses changes with changing climate. Policies, such as land-use planning and/or “sprawl” taxes, might be used to minimize land-use conflicts. However, it must first be understood how and why the current strategies are failing. For example, attempts to minimize sprawl (e.g., Subdivision Control Act, zoning) in the past have not met with great success. The political costs of abridging land ownership rights in the region could be high.

- **Facilitate adaptation.** The migrations of plant species with the shifting of ecological zones should be facilitated where possible. The establishment of migration corridors was suggested as a possible mechanism to reduce the effects of fragmentation. However, maintaining a corridor may not be successful if flowering is limited due to climatic changes. For certain birds and for wolves, preservation corridors are working, but they may not work for some plant species. Following harvest, tree species that are better suited to a changed climate might be planted to encourage adaptation of the ecosystem. Species and genetic diversity should also be encouraged to improve natural adaptive capacity.

- **Genetic manipulation.** In some industries, selective breeding and/or genetic engineering may provide an option to improve adaptation. These strategies are probably more likely to be successful in high-value agriculture crops (e.g.,

fruit production in Michigan) than in the forestry industry.

- **Management.** Existing fire and pest management strategies may need to be reevaluated for a changing climate. Incorporation of integrated pest management and prescribed burning may reduce the indirect effects of these disturbances with a changing climate.

- **Education.** Finally, and most importantly, a public education program regarding the potential risks and consequences associated with rapid changes in climate should be in place. For example, the potential for increasing fire danger associated with warmer and drier conditions should be communicated to homeowners in high fire-risk ecosystems. The increased potential for flooding with an increase in the frequency of heavy rain events should be communicated to flood plain landowners. With better information, the residents of the region will be better prepared to respond to a more variable and less certain climate.

# AGRICULTURE SECTOR REPORT

*Session Chairs: Jeff Andresen and H. H. Cheng  
Rapporteur: Colleen Garritty*

## INTRODUCTION

The Agriculture breakout group included participants from academia, state and federal government, and agribusiness. The results of discussions, centered around the U.S. Global Change Research Program Level 1 assessment framework, are summarized below. The group considered the dependence of regional agriculture on climate and the potential impacts caused by climate change, assuming a warmer climate than that currently, and with both increasing and decreasing levels of precipitation and degrees of climatological variability. In general, the potential impacts of a changing climate on agricultural activities in the region are viewed as potentially serious in the long term (i.e. decadal time scale), but at least partially manageable through technological adaptations, and, in general, of lesser importance than the economic and regulatory pressures, which the sector currently faces.

The discussion group was expected to interpret the four questions broadly in an effort to reduce the chance that significant issues would be overlooked. Because this was an initial effort, failing to include potentially critical issues was considered a greater mistake than including issues that, upon further study, turn out to be relatively unimportant. The participants were not asked to make quantitative assessments of the impacts that they discussed.

## THE 4 QUESTIONS ADDRESSED

### 1. What are the current concerns?

Of the many concerns identified by the working group, first and foremost was the problem of economic viability, based heavily on issues such as low commodity prices, high input prices, and domestic/ international competition. Major concerns were categorized as economic, environmental, regulatory, and societal, which are listed below. Specific climatological concerns were considered separately.

#### *Economic Concerns*

The most important economic concerns that were identified included:

- ***Low commodity prices and high price volatility.*** In recent times, prices for many commodities have been near or below the costs of production. In addition, commodity price swings and market volatility have made it difficult for producers to market their products and to plan for the future. For some crops, the profit that a producer may make one year has to last five more years before there is another profitable year.
- ***Difficulty of producers obtaining finance capital.*** Without finance, in the form of loans, there is no way to physically produce the product in a capital-intensive production system such as ours.
- ***Domestic/international competition.*** Products from other regions in the U.S. and from other countries are sold in the region at a lower price, which reflects an abundance of cheaper labor and overall lower production costs than are possible in the U.S.
- ***High farm labor costs/labor availability.*** In labor-intensive production, such as that for fruits and vegetables, producers face prohibitively high labor costs and a short supply of labor.
- ***Loss of industry infrastructure.*** The loss of infrastructure is especially true for the produc-

tion of specialized agricultural crops. If there are no processing facilities and other necessary infrastructure for a product in a region, then the cost of production increases by an amount proportional to the distance to the nearest processing plant.

- **Economics of scale and corporate farming.** There has been a significant loss of small and medium size farming operations because large corporate farms are able to produce at a lower cost than are small-to-medium-sized producers. Those with higher costs of production are often squeezed out of the market.

### *Environmental Concerns*

The most important environmental factors that were identified included:

- **Soil degradation, erosion.** After being in production for decades, soils are often degraded by water and wind erosion, necessitating more fertilizers to retain their productive capacity and reducing the value of the soil for agriculture.
- **Livestock waste management.** As livestock production becomes more geographically concentrated, waste management concerns grow. Ecosystems usually are not capable of accommodating the large amounts of livestock waste that are produced in feedlots or confinement operations. The application of a large amount of waste to a small area can lead to surface and groundwater contamination.
- **Insect, disease, and weed pressure.** Pests and plant diseases threaten the health of crops in the field, while weeds compete with crops for soil nutrients, sunlight, and water resources. Often, insects, disease, and weeds are controlled by applications of pesticides and herbicides.
- **Pesticides and fertilizers use.** Application of pesticides and fertilizers is often the most economical way to deal with pest pressures and

increase crop production. These pesticides and fertilizers, when lost due to runoff or when leached out of the soil, can contaminate surface and groundwater resources and threaten human and ecosystem health.

### *Regulatory Concerns*

The most important regulatory concerns that were identified included:

- **Federal and state regulations.** These regulations change the standards and alter the economics of the production system (e.g. Food Quality Protection Act). For example, a pesticide banned for regulatory reasons may be a grower's only line of defense against a pest. When new pesticides (or other control methodologies) are not immediately available, the crops cannot be grown economically or to the standards expected by consumers.

### *Societal Concerns*

- **Land-use change.** Loss of farmland, increasing land values, property taxes due to population shifts to rural areas, home construction, and suburban sprawl. This reduces the viability of agricultural practices in a region, both directly by purchasing tillable acreage for housing and indirectly by driving up property values so that farmers can no longer afford property tax payments.
- **Increasing median age of farmers.** Fewer young people are entering into the business of family-owned farming. The increasing median age of farmers raises concerns about the future of food production in the U.S. as well as the value of farming as part of our national heritage.
- **Sustainability/Balance.** One major concern, which integrates a number of the categories, is the balance between economic viability, environmental constraints, and government

regulation. This balance determines the long term sustainability of the system.

Finally, the group considered the specific climatological concerns associated with agriculture in the region.

### *Climatological Concerns*

The most important climatological concerns that were identified included:

- ***Precipitation extremes (drought, flooding).*** Water, much of it in the form of naturally occurring precipitation, is the most important single climatological variable that determines a region's agricultural production. Crops cannot achieve their potential when they are under stress from too little or too much water.

- ***Temperature extremes.*** Agricultural productivity potential can be reduced dramatically by the occurrence of just one extreme temperature event.

- ***Insufficient growing season length.*** Short growing seasons limit the amount of time that crops can produce biomass, thereby reducing potential crop yields. An anomalously cold summer coupled with a late spring and/or an early fall can have a disastrous effect on regional agriculture.

- ***Frequency of severe storms.*** Severe storms with damaging winds and hail can cause major crop catastrophes. More frequent occurrences of these storms render agricultural operations even riskier.

- ***Excessive cloudiness.*** Many plants are most productive at high levels of sunlight. As cloudiness increases, the potential rate of photosynthesis and the productivity of the crop also generally decrease.

- ***Changes in variability of all of the above.*** Increased variability of climatic parameters sig-

nificantly increases production risks to farmers. Agricultural technology can generally adapt to shifts in the means of climatological elements, but not nearly as well to increases in variability of the elements (e.g. late spring freezes, growing season droughts).

## **2. How may climate change impact our lives?**

Weather and climate remain among the most important uncontrollable variables involved in agricultural production systems. Future stresses will likely be largely dependent on the nature of climatic trends, especially with respect to variability. The group discussed some recent climate trends for the region and considered their recent effects on agriculture.

Climatologically, the most significant observed trend in the Great Lakes region during the past century is an increase in precipitation, especially during the summer and fall months (Boden et al., 1994). This increase is associated with significant increases in the number of wet days, multiple wet day events, and a general increase in cloudiness.

Mean temperatures in the region have also changed, increasing somewhat during the past 20 years, but increases remain within the observed variations of the past century.

Assuming a warmer and wetter climate, some potential direct and indirect impacts discussed by the group are as follows:

### *Direct impacts*

- ***Carbon dioxide enrichment.*** For crops that benefit from carbon dioxide enrichment, the increasing atmospheric concentrations of carbon dioxide will lead to an increase in biomass accumulation and in water use efficiency, ultimately leading to higher yields and potential productivity.

- **Soil limitations.** Expansion of agricultural activities northward with a warming climate will be limited by soils that are unsuitable for agriculture.
- **Water regulation.** If evapotranspiration rates increase significantly in a warmer climate, then the Great Lakes could become a major source of irrigation water, which would also likely necessitate regulations dealing with water rights and usage.
- **Climate variability.** If future changes in climate are characterized by gradual changes in the means, then there is a good chance that changes in agricultural technology could keep pace. However, if the changes are accompanied by increases in variability such as the frequency of extreme events, then it would likely be much more difficult to adapt to the impacts.

### **Indirect Impacts**

- **Dairy.** Expected changes could lead to less production per cow because of a longer season for forage production, lower forage nutrient quality, greater potential for herd sickness/disease, more pest pressure for forages, and significant economic investment for modification or reconstruction of dairy barns (necessitated by a changing warm season climate).
- **Field crops.** With a longer frost free growing season, potential crop productivity should in general be higher. There will also likely be greater pest/weed/disease pressure, some possibly caused by organisms that are not currently problems in the region. Combined, these trends suggest an overall increase in potential productivity for most crops, with reductions in water stress playing a major role.

### **3. What additional information do we need?**

This group discussed a wide range of information needs, from better climate models, to more

collaborative research, to improved farming practices. Some of the highest priority needs included:

- **Improved General Circulation Models.** Given the current problems with General Circulation Model (GCM) performance at the regional level, The Upper Great Lakes region could experience changes that differ significantly from GCM predictions. The need to improve GCM climate modeling capabilities, especially at the regional level, is a high priority. Because of their importance in describing the present day climate, the Great Lakes need to be included in the models (i.e. parameterized as large bodies of water).
- **Improved agricultural production models.** Characterization and realistic simulation of agricultural production systems, from the production level to the market level, are needed. These activities would help facilitate research on farm/agricultural management in the context of climate change and help identify technological/management options for the producer (e.g. diversification, new crops).
- **More collaborative research.** Trans-disciplinary research is needed to investigate production practices and policies that are ecologically sensible/congruent with environmental goals (e.g. “agro-eco-region management”). This type of research may also help determine the potential impacts of environmental and/or other regulations before they are implemented.
- **More education.** Exchange of information about climate change should take place between different agricultural sectors. Many people in the industry do not even believe that climate change is a real possibility.
- **Improved farming techniques.** Research in no-till farming practices, aimed at carbon sequestration, is needed.

- **Maintaining the cooperative observer network.** Agriculture, as an economic pillar of the American landscape, is dependent on weather events and requires a significant commitment by the government to maintain and enhance weather- and climate-monitoring capabilities. Serious concerns were expressed about the degradation of the nation's Cooperative Climatological Network, which is an integral part of the monitoring and understanding of long term climate change. Environmental monitoring of other climate related variables is also essential.

#### 4. How do we cope with climate change?

The ability to adapt to any future changes in climate will strongly depend on the nature of the change. Should future changes in climate be characterized by gradual shifts of the means, there is the likelihood that changes in agricultural technology could keep pace. However, changes such as increases in variability pose many potential problems for agriculture. Among the possible adaptations that were discussed are:

- **Diversification.** The ability for any one farmer to grow a variety of crops will be beneficial for sustaining farmers through dry/wet/hot years.
- **Increasing use of irrigation.** A warmer growing season combined with irrigation would increase potential productivity.
- **New policies.** Government policy could help facilitate adaptation to climate change. Producers will need assistance as climate changes occur, and tax policy and incentives for crop insurance may need to be implemented to get farmers through difficult years and to ensure continuity of the industry. The government could also underwrite the higher risks involved in climate change by subsidizing crop insurance.

- **Flexible infrastructure.** An agricultural infrastructure flexible enough to adapt to shifting crop regions would facilitate coping with climate change.

- **Education.** Education is vital for understanding the effects of climate change on agriculture and for solving current and future problems in our food production systems. The Cooperative Extension Service can and must play an integral role in this effort.

- **Reduce tillage.** Depending on the type of tillage practice, organic matter in the soil may become either a source of carbon dioxide or a sink. Increased use of reduced tillage systems across this region could provide the potential for significant carbon sequestration as well as the benefits of improved tillth, soil fertility, and water holding capacity.



# INFRASTRUCTURE SECTOR REPORT

*Session Chairs: George Albercook and Werner Braun  
Rapporteur: Diana Stralberg*

## INTRODUCTION

The Infrastructure breakout group included participants from industry (i.e. chemical manufacturing, automobile and electric utilities), academia (i.e. atmospheric sciences and social sciences), environmental organizations, and Native American groups. The group met four times during the workshop to discuss the potential impacts of climate change and climate variability on various infrastructure components in the Upper Great Lakes region.

The group interpreted infrastructure components to mean primarily fixed, durable goods with long lifetimes that are important in maintaining a functioning society. Other non-fixed distribution networks were also considered. Several infrastructure sectors were identified:

- **Energy** – including the generation, transmission, and distribution of oil, gas, and electric power
- **Transportation** – including primary and secondary roads, bridges, rail lines, managed waterways, and airports
- **Telecommunication** – including cable and satellite transmission of information
- **Buildings** – including commercial, industrial, and residential structures
- **Waste management** – including sewer and storm drain systems, landfills, and other disposal facilities
- **Food** – storage and distribution
- **Health** – delivery systems

Due to their mobility, motor vehicles, although important to many of the above-listed sectors, were only tangentially considered by this workgroup. It was assumed that climate change impacts related to motor vehicles were adequately addressed by the Industry workgroup.

## SIGNIFICANT FINDINGS

The following ideas and themes emerged as significant overall findings of our breakout sessions.

- **Limits of current infrastructure.** Current infrastructure systems are large, rigid, and largely based on 19th century engineering and scientific understanding. They were constructed under certain assumptions about climate that now appear to be changing. Many of these systems are not designed to withstand extreme events, and their failure or malfunction could actually amplify the impacts of climate change and variability on humans.
- **Climate extremes.** In terms of impacts on infrastructure, changes in climate extremes are likely to be more important than changes in climate means.
- **Inefficiencies.** Current inefficiencies in energy generation and consumption represent a potential for capturing lost (e.g., waste) heat and alternative forms of generating energy (e.g., water, wind, and solar).
- **Policy matters.** Power generation is extremely sensitive to policy changes, especially under deregulation scenarios. Economic incentives can change quickly, and aren't necessarily related to the true costs (i.e. impact) of production.
- **Small vs. Large.** Large infrastructure projects, with large capital costs and long payback times, may be a thing of the past. Efficiency and flexibility should be important

considerations for new infrastructure projects. Several smaller energy projects (e.g., small hydropower, photovoltaics, and gas turbines) provide more flexibility and adaptability to climate change.

- **Globalization.** Increasingly integrated economies, globalization of trade, and deregulation of energy markets may help or hinder our ability to mitigate and adapt to climate change.
- **“No regrets” strategies.** The uncertainty and variability of climate change impacts supports the implementation of “no regrets” policies (e.g., increased energy and material efficiency) that make sense under any climate change scenario.
- **Life-cycle analysis.** In order to efficiently and effectively achieve reductions in greenhouse gas emissions, life-cycle analyses must be conducted, and produced goods must be reassessed in terms of desired *services* (e.g. warm, well-lit houses), rather than desired *products* (e.g. electricity and gas).
- **Better metrics.** Economic indicators must become more sophisticated than Gross Domestic Product (GDP), so that costs may be assigned to environmental degradation, health effects, quality of life, and other values that are not traditionally quantified. Value should be placed on consuming *better* rather than consuming *more*.

## THE 4 QUESTIONS

### 1. What are the current concerns? & 2. How may climate change impact our lives?

The first two questions were addressed simultaneously over two breakout sessions. Current regional concerns were discussed, potential climate change scenarios, direct impacts and indirect impacts, such as policy and market responses to climate change and variability. The direct climate change influences that were

considered included increased mean temperatures, increased frequency of temperature extremes, extreme weather events, water level changes, and altered freeze/thaw cycles. The indirect influences that were considered included the effects of energy conservation and efficiency measures, and increased costs and regulations in each of the infrastructure sectors.

For each sector, both the *sensitivity* and *adaptability* of various infrastructure components were considered. Most of the infrastructure sectors were deemed more sensitive to changes in climate *extremes* than to changes in *means*. Although adaptability was considered to be primarily determined by cost, it was concluded that the costs of adaptation depend on the types of policies instituted and how they are implemented (including the rate and predictability of policy changes). It was also acknowledged that public perceptions about climate change maybe just as important as actual changes in determining private and public sector responses and in turn the rate and hence the cost of those changes.

### Direct impacts

#### Energy

- **Peak Loads.** Extreme high temperatures create increases in peak power loads. It is expected that climate change will result in more extremely hot days and greater peak loads.
- **Power line damage.** Snow, ice, frost, and temperature extremes all place an undue stress on power lines (e.g., the recent ice storm in the northeast). It is expected that climate change will result in greater weather extremes, both warm and cold, which will likely increase damage to power lines.

#### Transportation

- **Lake levels.** Low water levels on the Great Lakes require ships to transport lighter loads or increased dredging of harbors and channels. It

is expected that climate change will lead to higher temperatures, increased evaporation, decreased lake levels, and a greater stress on shipping on the Great Lakes.

- **Road damage.** Freeze/thaw cycles reek havoc with paved roads, rail lines, and bridges. It is expected that climate change will result in increased interannual variability and greater weather extremes, which will increase the stress on maintaining smoothly paved or railed surfaces.

- **Erosion and mudslides.** Heavy precipitation (flash floods) and freeze/thaw cycles accelerate deterioration of roads, rail lines, bridges and lakeshore property. It is expected that climate change will result in increased interannual variability and greater weather extremes, which will increase erosion.

- **Corrosion.** Heavy snow events are typically treated with copious amounts of salt that corrode bridges and other elements of the infrastructure. It is expected that climate change will result in decreased snowfall that would decrease salt use and hence corrosion.

- **Air travel.** Fog, ice storms, heavy snow, and thunderstorms can all disrupt airline schedules. It is expected that climate change will result in more frequent and more intense weather extremes, which would increase these disruptions.

### Telecommunication

- **Damage.** Ice storms and other extreme weather events can cause significant damage to power and communication equipment. It is expected that climate change will result in more frequent and more intense weather extremes, which would increase the likelihood of damage.

### Buildings

- **Flooding.** Existing structures in proximity of flood plains are susceptible to flooding from heavy precipitation events. It is expected that climate change will result in more frequent and more intense weather extremes, which would increase the likelihood of flooding.

- **Fire.** Existing structures in proximity of fire-prone areas are susceptible to damage from fires that develop from drought and/or lightning strikes. It is expected that climate change will result in more dry periods followed by more intense convective precipitation events, which may increase the likelihood of lightning strikes and fires.

### Waste Management

- **Sewage.** Heavy rains can cause overflows of combined storm and sewage drain systems, resulting in releases of untreated sewage into waterways. It is expected that climate change will result in more frequent and more intense heavy precipitation events, which would increase the likelihood of sewage overflows.

- **Landfill leakage.** Areas near landfills that are close to the water table are at risk for leaking. It is expected that climate change will result in increased precipitation, which may increase the likelihood of landfill leakage.

### Food

- **Storage and distribution.** Greater agricultural yields require more storage. It is expected that climate change will result in warmer conditions, which could result in larger harvests and increased problems with storage and distribution of these larger harvests.

- **Pests.** Warm conditions tend to support larger (agricultural) pest populations. It is expected that climate change will result in warmer conditions, which could result in larger populations of agricultural pests.

## Health

- **Medical facilities.** Hot conditions and other extreme conditions are a stress to the medical infrastructure. It is expected that climate change will result in more frequent and more intense heat waves and other weather extremes, along with the possibility of increased vector-borne diseases, which would increase the stress on the existing medical infrastructure.

### *Indirect impacts*

Unlike direct costs, indirect costs are mitigated by societal actions. These include tax and regulatory decisions to deal with both prevention and adaptation. Behaviors like consumption patterns and fears about the future may also have indirect impacts.

Possible consequences of energy conservation and efficiency measures:

- **Energy taxes.** Several policy strategies to reduce the amount of CO<sub>2</sub> released into the atmosphere have already been proposed, including taxes on the amount of carbon released.
- **Increased energy costs related to infrastructure changes.** Switching to less vulnerable systems or systems that produce less carbon requires the expenditure of money and possibly the retirement of capital equipment before the end of its useful lifetime.
- **Shifts in economy affecting energy-intensive industries.** Full-cost accounting, tax shifting, or other methods that attempt to incorporate the impacts of producing a product or service into the price of that product or service will put enormous pressure on energy intensive industries.
- **Trade-offs between reliable and inexpensive.** Consumers may be able, as they are now in some pilot programs, to choose less reliable power in return for a lower cost.

- **Increases in building energy efficient measures.** Part of a portfolio of energy options may include increased efficiency in the heating, cooling, and lighting of buildings. The payoffs from these types of improvements are equivalent to finding an alternative energy source that releases no CO<sub>2</sub>.

- **Increased localization of energy production.** Gas turbine and fuel cell technologies both provide cogeneration options. This provides tremendous reduction in the total carbon released.

- **Pressure to aggregate energy supply/purchase.** Consumers may form buying cooperatives to make bulk energy purchases.

- **Selling energy back to the grid.** Increases in the amount of electricity generated by consumers through alternative energy sources like fuel cells, solar roofs, and combined heat and power will lead to increases in the amount of electricity sold back to the power grid.

Possible consequences of infrastructure adaptations and regulations:

- **Increased capital investment in new infrastructure:** It may be necessary to build new infrastructure or to repair existing components more frequently.
- **Increased inspection and maintenance costs.** Enforcing regulations and market-driven certifications (e.g. the ISO 9000 standard) cost time and money.
- **Higher insurance costs / inability to get insurance.** If climate change is gradual, then it will probably be possible to get insurance to protect property. But if patterns and predictions worsen, then insurance may increase in cost or even cease to be available in some cases.
- **Decreased convenience and predictability** (e.g. easily disrupted transportation schedules).

### 3. What additional information do we need?

Based on questions and uncertainties raised in the previous breakout sessions, the group easily identified several priority data needs, which are summarized below:

- **Better extreme event data.** There has been some debate regarding whether the frequency of extreme events has increased recently. A better database and an analysis of that database is needed.
- **Better accounting.** The GDP overlooks external costs of environmental degradation, health impacts, etc. Full-cost accounting / credible quantification of externalities are needed to more accurately reflect the impacts of weather and climate on various infrastructure components.
- **Better documentation.** Currently there is no consolidated, integrated information on infrastructure characteristics. A systematic, integrated GIS database on infrastructure characteristics is needed.
- **Better climate models.** Current climate models are inadequate in terms of their physical parameterizations and resolutions. Some models do not even include the Great Lakes because they are so coarse. Better General Circulation Models (GCMs) and (nested) regional climate models (RCMs) are needed.
- **Better urban data.** Much about cities is unknown. For the most part, records of human population, employment, movement of goods, water usage, etc. are of poor quality. Concrete measurements of fundamental human systems and their sustainability are needed.
- **Better risk analysis.** Climate change impacts are uncertain, but they are likely to include increased variability in many systems. More

in-depth strategic, acute and chronic risk analysis; and sensitivity analysis are needed.

- **Better understanding of climate interactions.** Climate change will likely involve synergistic effects, and nonlinear / threshold events. More research on the effects of interacting factors (e.g. UVB, SO<sub>2</sub>, ozone, precipitation, nitrogen fertilization, habitat fragmentation) is needed.
- **Better understanding of the rate of climate change.** Industry operates with set timelines. The timelines for climate change is not necessarily known, so the timing of appropriate action is hard to gauge. A better understanding of how rapidly climate change will occur is needed.
- **Better life-cycle analysis.** The (long-term) impacts of many products and chemicals are unknown. A better understanding of these impacts (e.g., a better life-cycle analysis) is needed.
- **Better demographic information.** Population is stratified with respect to infrastructure use and vulnerability to climate change. Better information about infrastructure use by various population segments is needed.
- **Better cost/benefit analyses.** There are two types of infrastructure: public and private. More appropriate cost/benefit analyses of the different policy options for each of these types is needed.

### 4. How do we cope with climate change?

In addressing this question, coping was interpreted to mean prevention and mitigation of climate change, as well as adaptation and response to climate change. With respect to prevention and mitigation, the primary focus was on energy conservation and efficiency measures that may help slow global warming by reducing greenhouse gas emissions. The listings of appropriate adaptations and responses addressed

both direct and indirect consequences of climate change. Many of the recommendations for energy conservation and efficiency were technology-based or policy-based.

### ***Technology-Based***

- ***Increasing use of cogeneration technologies.*** In cogeneration, electricity and heat are produced in the location where they are needed. Transmission losses are eliminated and heat, which is otherwise wasted, is utilized.
- ***Improved power plant efficiency.*** Cleaner burning coal- and oil-fired power plants will go a long way towards reducing carbon emissions in the region.
- ***Improved vehicle technology.*** More efficient cars, alternate fuel cars, and GPS navigation systems are just some examples of how automobiles can be designed so that less carbon is put into the atmosphere in going from point A to B.
- ***Increased use of mobile energy sources.*** Such energy sources could effectively power transportation vehicles, for example. A fuel cell in a car can be recharged at home during night and at work during the day.
- ***Increased telecommuting.*** Working from home via computer not only saves employees from lengthy commutes, but also saves fuel and reduces carbon emissions.
- ***Technology-assisted home energy audits.*** This could include the use of integrated energy and climate databases to find inefficient homes, as well as technology to find wasted heat energy.
- ***Adopting existing energy technology.*** Looking to other (e.g. warmer, drier) regions for existing energy-efficient technologies will go a long way towards reducing the amount

of carbon that the many coal- and oil-fired power plants in the region now produce.

### ***Policy-Based***

- ***Investing in latest technology.*** Investing in “leap frog”, rather than incremental technology advances (e.g., much of the world is “leap-frogging” right past land-based telecommunication systems to cellular systems) will be more beneficial in the long run.
- ***Investing in mass transportation.*** Greater use of mass transportation systems – not necessarily conventional public transportation systems like busses, trolleys, and subways; but, on a less massive scale, car sharing, large taxis and public bicycles – will reduce carbon emissions.
- ***Investing in alternate energy.*** Implementing alternate-energy power plants and developing alternate-fuel automobiles are just two examples of how alternative energy use could reduce carbon emissions.
- ***Improved product labeling.*** More stringent labeling requirements and global product standards (e.g., standardized full-cost accounting could lead to labels that include the amount of carbon released by the manufacture of the item) would facilitate full-cost accounting efforts.
- ***More energy conservation incentives.*** Providing rate-based incentives for the public and for industry to shift energy use to off-peak hours would help to alleviate power overloads – especially during heavy-use situations.
- ***More tax incentives.*** Providing incentives in the form of reduced taxes or tax rebates for energy conservation may motivate people to use less energy and to reduce carbon emissions.

The general consensus, however, was that major lifestyle changes and paradigm shifts would be necessary to significantly alter the current

global warming trajectory. Some examples included:

- **Reductions in energy consumption.** People need to learn how to live using less energy.
- **Reduced suburban sprawl.** Changes in human settlement patterns (e.g. densification, cluster development) to retard suburban sprawl could lead to reduced commuting, reduced traffic congestion, and reduced pollution.
- **Increased use of mass transit.** Changes in commuting and driving patterns (e.g., greater reliance on public transportation) would lead to fewer driven miles and reduced traffic congestion and pollution.
- **Better-designed power plants.** If the energy generation infrastructure were designed to supply the average need, then it might be much more efficient but it would not be able to handle large peak loads.
- **Better lake-ice forecasts.** Improved forecasting and monitoring of lake-ice (e.g., sophisticated docks) would allow shipping schedules to be more efficient.
- **Increased use of high speed rail systems.** Airports have become increasingly congested. Providing another high-speed alternative will help to reduce the travel burdens from airports.
- **Switching to electronic communication media.** Increased use of email and electronic video conferencing, for example, will also help to reduce the burden on the transportation and shipping infrastructure segments.
- **Interruptible power supplies during peak load hours.** During peak demand on hot days, customers allow the power company to shut off their air conditioning in return for lower rates.

- **Separation of storm and sewer systems.** This separation will help to reduce contamination during heavy rain or melting events.

Some general suggestions for coping with climate change impacts on infrastructure systems included:

- **Assessing existing (old) infrastructure elements.** Improved assessment of and attention to old infrastructure elements will help people to decide more carefully whether replacement or repair is a better option.
- **Increased maintenance of infrastructure systems.** Better monitoring and maintenance of existing infrastructure elements

Finally, the breakout group recognized that a host of external factors may complicate the implementation of recommended coping strategies. The following key issues should be considered:

- **Barriers.** Legislative, regulatory and political barriers impede the implementation of climate change coping strategies. Interest groups and government institutions may be resistant to change.
- **Scale.** Other significant barriers to change include the longevity and size of most infrastructure components. The magnitude of investment needed to overcome these barriers is significant.
- **Interactions.** In responding to climate change, the interactions between climate change and other human-induced factors, including increases in UVB, sulfur dioxide, nitrogen, ozone, and precipitation, as well as population growth, urbanization and habitat fragmentation, must be considered.

- **Global scope.** Due to increasing globalization of economies and markets, climate change impacts of other regions of the U.S., as well as in other countries, will indirectly affect the Upper Great Lakes region. These impacts need additional attention.
- **Deregulation.** The deregulation of electric utilities and other energy sectors is already occurring, resulting in greater individual purchasing control but less central control of energy generation, transmission and distribution. It is unclear what interaction will occur between deregulation and climate change.
- **Better measures.** Our current national accounting system (GDP) does not incorporate the external costs of degrading the environment, human health, quality of life, etc., that are difficult to quantify. More sophisticated economic indicators are needed to provide market incentives for energy conservation.

# ECONOMY SECTOR REPORT

*Session Chairs: George Kuper and Karel Rogers  
Rapporteur: Bruce L. Dinda II*

## INTRODUCTION

The Economic breakout group included participants from the Council of Great Lakes Industries, General Motors, Global R & D Operations, Port of Milwaukee, Environmental Research Institute of Michigan, and several sectors of the scientific community.

The Great Lakes region is one of the most intensive industrial regions in the United States today. Less than 1.5% of earned income derives from agricultural services, forestry, and fisheries, whereas 25-39% derives from construction and manufacturing. Industry is the third largest employer in the Great Lakes States (behind services and wholesale and retail).

Participants agreed that, except for tourism and agriculture, industry/manufacturing in the Great Lakes region is not vulnerable to the direct effects of the predicted changes in temperature, precipitation, or weather variability associated with climate change. Nevertheless, the economy and commerce of the region are highly vulnerable to the secondary effects of climate change. That is, public opinion has the potential to vastly change markets and altered governmental policies have the potential, if not carefully designed, to devastate Great Lakes industries.

Industries in the Great Lakes region have the potential to address greenhouse gas emissions and other environmental concerns in a timely way if the transition from new technologies and techniques is done in a careful manner that provides a predictable environment in which

businesses can plan for the future. A key to effective and swift change is propagation of technologies/techniques that serve a dual role of addressing the threat of climate change while simultaneously improving efficiency and profit margins. In addition, the timing of transitions must be staged to allow a return on investment of current capital stock while stimulating investment in innovative technologies that are ready for market.

## THE 4 QUESTIONS ADDRESSED

### 1. What are the current concerns?

The stresses on the economy that are secondarily related to climate change were divided into three groups: the historical tensions between economy and environment, economic realities that exist for business, and the impacts of social factors.

- ***Historical tensions between economy and environment.*** Federal regulation of industrial pollution was almost nonexistent until the US Congress passed the National Environmental Policy Act of 1969, which committed government to take an active role in protecting the environment. The next year, the Environmental Protection Agency (EPA) was established to coordinate and oversee this effort. A series of federal acts following that one progressively placed increasingly stringent restrictions on industrial and commercial activities that might result in the pollution, degradation, or contamination of land, air, water, food, and the workplace. The main mechanism for control was a top-down regulatory paradigm that ignored the possibility of cooperation and collaboration of industrial leaders to achieve these worthy goals. Because the regulations imposed costly (but not necessarily the most economical or efficient) solutions on industries, people in the highly industrial Great Lakes region now regularly assume environmental protection and economic

well-being are in opposition to one another, i.e., that as one benefits, the other must be harmed.

This assumption is currently being disproved by leading companies in a number of Great Lakes region industries that are experiencing significant environmental accomplishments while reducing costs. However, moves to protect global climate from the harmful effects of greenhouse gases have been seen by some members who were present at the discussion as a means to transfer wealth from the Great Lakes industries to other factions within the US and to other, less-developed countries. Even with this negative background, industrial leaders are concerned about the ecological footprint of their industries and there is a strong commitment to minimize the environmental impact of industrial activities. While regulation is seen as necessary, it was suggested that faster and more effective solutions to environmental threats (especially ones as severe and far-reaching as climate change) can be found through collaboration with the industrial sector.

To understand this, one must be acutely aware that industry is in business to make money, not to pollute. If economical, money-saving, effective, competitive methods to avoid pollution are available, then those mechanisms will be instituted as soon as it is profitable to do so. In the current anti-collaborative climate, many environmentally-friendly innovations have occurred and are continuing to occur, but these innovations are frequently hidden because of fear that the innovation will become the next regulatory standard and because hiding proprietary technologies can increase profit margin. For example, one major company in the Great Lakes region has experienced an annual 22% reduction in greenhouse gas emissions over the past five years but refuses to discuss it in public for fear these accomplishments will become the baseline for even deeper cuts when new standards are set by the government.

Environmental regulations that ignore the economic realities of doing business in the modern, global marketplace create a setting that discourages substantive progress toward critical environmental goals.

- ***Economic realities that exist for businesses.***

The foremost economic reality of industry is that unless a profit on capital investment is made the capital is lost and the business will cease to exist. To make a profit, investments must be allowed to mature. A corollary reality is that making a product is not sufficient to ensure a profit; consumers willing to buy the product must exist and it has to be sold for more than it costs to produce.

- ***Impacts of social factors.*** The public's willingness to buy can change rapidly and most consumers are not willing to be the first to try new, unproven, innovative commodities. In addition, new technologies must start out small and gain a market share. High-risk investment capital for moderate and small business ventures is extremely rare in the Great Lakes region. To move from a great idea to mass production and mass marketing requires sufficient time to ensure maximal safety of invested capital and also requires a relatively stable policy environment. Infrastructure to support the new product must be developed before consumers are willing to buy. For example, photovoltaic shingles to collect clean, renewable energy for houses have tremendous potential to help greenhouse emissions but the reality of moving this technology from the "great idea" stage to the "mass production and common usage" stage will require vast amounts of investment capital, a work force trained to produce, install, and maintain the technology, and a public willing to buy it.

In addition to a public willing to buy, a key social factor is the availability of a trained work force with the ability to transition as needed in response to the threat of climate change. Coordinated effort and incentives on the part of all

segments of the region will be necessary to implement change.

## 2. How may climate change impact our lives?

The majority of industry/commerce (excluding tourism, agriculture, construction, fisheries, and the pulp/paper industry) in the Great Lakes region is not directly threatened by the predicted effects of climate change. Nevertheless, nearly all industries in the region are highly vulnerable to the secondary impacts of global climate change. That is, industry/commerce can be severely damaged by rapid, unpredictable changes in economic/environmental policy or in consumer opinions and desires. For example, the WEFA report projects disproportionate loss of jobs and industrial activity in the Great Lakes region if the U.S. response to the Kyoto Protocol is the institution of a carbon tax or permit fee of \$200 per metric ton. Additional secondary impacts may occur as a result of impacts on other regions because of the global interdependence of industry, commerce, and markets. For example, if compliance costs are lower for European nations or Japan than for Great Lakes industries, this disparity will be reflected in the cost of goods and resultant market share in the international marketplace.

## 3. What additional information do we need?

Extensive economic modeling with a wide variety of possible policy responses is needed in order for industry to best adapt to potential changes. Education of the general public in both the primary and secondary impacts of climate change is needed. A part of that education should include an understanding of the constraints under which industry/commerce operate. In addition, business people from all industries (including the smallest) need education on the potential impacts of climate change, both primary and secondary.

Multiple government-scientist-industry partnerships are needed to facilitate communication and information exchange. The media should have reliable information sources that are not slanted toward scare tactics. Climate change (and the potential economic disaster resulting from an improper response) is far too dangerous both environmentally and economically to use an adversarial “court of public opinion” to decide the issue. Consensus building, with industry as full partners in the discussion, is critical to an effective response.

## 4. How do we cope with climate change?

The key tools that can facilitate the adaptation of industry/commerce to climate change are the implementation of policies that set an economic environment, and the removal of barriers that impede change, and the promotion of consumer markets. All responses to climate change should be tested for dual benefit. That is, their ability to impact the threat of climate change as well as their ability to stimulate desirable economic growth and economic opportunity, energy (and other) efficiency, and innovation, should be evaluated. Following is a series of suggestions for the implementation of climate change strategies and policies.

### *Strategies*

- ***Emissions trading.*** Establish emissions trading. For example, as in the case of sulfur emissions, if companies could reduce their emissions below their allotment, then they could sell their unused emissions. This helped to harness market competition to improve air quality.
- ***Desirable markets.*** Use market incentives to stimulate the type economic activity that is desired.
- ***Investment capital.*** Stimulate investment capital for both medium and small business in the region that is responsive to climate change.

- **Technology Development.** Help the orderly development of innovative technology to a level where it is ready for production and marketing.
- **Market opportunities.** The Annex I emissions problem (i.e. the lack of emissions standards in the Kyoto Protocol for nations that are currently underdeveloped) might be mitigated by economic incentives and trading policies that develop markets, for example in China or elsewhere for clean, renewable energy sources (leapfrog technology). Helping China to develop solar and wind energy rather than to continue developing their coal burning facilities would open a market for these new technologies, decrease global greenhouse gas emissions, improve air quality and human health in China, and promote economic development in this populous country.

### **Implementation**

Implementation of changes is critical to a successful transition. Rather than uniform, regulatory responses that have the strong potential to harm the economy, an orderly transition that takes advantage of all beneficial (i.e. dual benefits as outlined above) opportunities should be implemented. A series of suggestions follows:

- **Short-term, quick-response.** Industries should take advantage of situations where the technology exists and it is proven. For example, the cement industry is a sizeable industry in the Great Lakes area, which is a significant contributor to CO<sub>2</sub> emissions (one ton CO<sub>2</sub> is released for each ton of Portland cement manufactured). A low CO<sub>2</sub> cement exists and it is stronger than Portland cement. This new cement can use current infrastructure and is made with waste from another industry, but cannot be marketed because of building codes. With the removal of governmental barriers, huge carbon emissions and economic benefits could result.

- Use systematic methods to educate industry in the existence of already-proven alternatives to the status quo technology. Such alternatives should cost the same (or less) than current technology but should also help the carbon emissions problem.
- Stimulate energy efficiency in all new construction of industrial plants, homes, and renovations.
- Facilitate growth of markets for these quick-response items through incentives and trade policies.
- **Medium-term responses.** Longer time to implementation would be needed for technology that is promising but not ready to market yet.
- Stimulate speed of development, discourage or remove market barriers, and facilitate dissemination.
- Set-up a government-sponsored development fund.
- Facilitate growth of markets through incentives and trade policies.
- **Long-term responses.** This is a sweepstakes race for big money in the future. For example, the car company that develops the next generation of vehicles will be highly successful.
- This process cannot be rushed because implementation requires vast changes in infrastructure and markets.
- The costs of errors in this arena are huge. Consumers are not forgiving if they have bought a technology that does not work well for them. Thus, care must be taken to fully test innovations before whole factories are modified for production. Such transitions will require huge amounts of investment capital that will be available as this generation of capital matures with a profit.

- These responses must be done in an orderly manner and with sufficient time to ensure the safety of investments

## **CONCLUSION**

In conclusion, the consensus from the breakout group is that the response to the threat of climate change must recognize, value, and partner with the realities of industry/commerce. Industry cannot be viewed as a source of money to solve the world's problems. It should be viewed as a partner whose activities can help develop new wealth, sustainability, and a stable climate for earth.



# HUMAN HEALTH SECTOR REPORT

*Session Chairs: Joel Scheraga and Brett Hulseay  
Rapporteur: Janet Burke*

## INTRODUCTION

The Human Health breakout group included participants from academia (researchers from public health, meteorology and geography); government environmental agencies (i.e., the U.S. Environmental Protection Agency and Environment Canada); and the Sierra Club).

The discussion group was expected to interpret the four questions broadly in an effort to reduce the chance that significant issues would be overlooked. Because this was an initial effort, failing to include potentially critical issues was considered a greater mistake than including issues that, upon further study, turn out to be relatively unimportant. The participants were not asked to make quantitative assessments of the impacts that they discussed.

The level(s) of confidence that the group had in these decisions were used to identify areas where more information or research is needed. Lastly, the group suggested strategies for coping with climate change and variability, which included both mitigation and adaptation strategies.

## THE 4 QUESTIONS ADDRESSED

### 1. What are the current concerns?

Participants grouped current stresses on human health into the three main categories of public health: healthcare, environment, and lifestyle. The stresses for each of these categories were first suggested and then considered implicitly regarding their importance with respect to the Upper Great Lakes region. Participants then

discussed and decided whether climate change/variability would exacerbate or ameliorate each of the current stresses.

### *Health care system*

The most important stresses that were identified for the health care system were:

- **Limited access to health care.** A large segment of the population, including the unemployed and those in jobs without many health benefits have no or insufficient health insurance. This limitation results in a segment of the population requiring costly treatments instead of more cost-effective preventative care.
- **Rationed health care.** Besides there existing a segment of the population that is uninsured and underinsured, doctors, hospitals and other health care facilities make decisions on how to treat people based on skyrocketing costs of procedures, surgeries, medications, and reduced resources.
- **Aging population.** This segment of the population has been growing because of many factors including better health habits and better health care. This segment therefore has required increased health care, particularly for treatment of “geriatric” diseases. Because this segment usually consists of retired people who are on fixed incomes, their insurance coverage is limited.

### *Environment*

Environmental factors that were identified as current stresses to human health included:

- **Severe weather events.** Severe thunderstorms, tornado outbreaks, and lake effect snowstorms can cause instantaneous injury and death. Also, extended heat waves, particularly in urban areas (e.g., Chicago during the summer of 1995), can contribute to deaths of elderly people who are unable to get relief from the heat.

- **Reduced air quality.** High ozone and particulate matter levels in the ambient air from industrial emissions, motor vehicles, and residences cause breathing discomfort. Several segments of the population that are at risk include people who exercise outdoors, bicyclists (commuters), the elderly, and people who suffer from asthma and other respiratory ailments.

- **Reduced water quality.** Pollution from industrial sources, people with a disregard for the environment, and increased outdoor recreational activity have all contributed to reduced water quality. Infectious agents, such as cryptosporidium, have also contributed to reduced water quality. A large segment of the population, especially that which relies on the Great Lakes for recreation of one form or another, is at risk.

- **Exotic species.** International trade practices result in reduced environmental diversity (e.g., the impact of zebra mussels in the Great Lakes) and provide opportunities for disease transmission across national borders.

### *Lifestyle*

A number of lifestyle issues were identified as current stresses on human health, including:

- **Poor diet.** Lack of nutrition is known to contribute to certain diseases.

- **Lack of exercise.** Lack of exercise is known to contribute to reduced heart and lung function and to increase the risk of disease and potentially death (e.g., cardiac disease).

- **Smoking.** There is a well established link between smoking and deaths from both lung cancer and cardiac disease. Of particular concern is the increase in teenage smoking (more than 60% in the last 10 years) which will translate into future health problems.

- **Substance abuse.** Alcohol and drug abuse continue to be an issue of concern with regard to human health.

- **Stress.** The demands of family life and careers can contribute to stress-related illnesses.

## 2. How may climate change impact our lives?

Climate change was determined to have both direct and indirect impacts on the stresses that already exist for human health. Impacts were classified as direct if it was thought that human health would be directly affected by the climate change, and as indirect when human health effects would be a secondary result of climate change. Many of the impacts that were identified could exacerbate the current stresses on human health in the region.

### *Direct impacts*

- **Severe weather.** Possible increases in the frequency of and/or a change in the timing or the location of severe weather events (e.g., tornadoes, lightning, and flash floods) could lead to increased injury and mortality. The tornado outbreak that occurred across southern lower Michigan during the summer of 1997 was suggested as a scenario that might occur more frequently.

- **Heat waves.** Over 500 people died from the heat wave in Chicago during the summer of 1995. This event was suggested as a scenario that might occur more frequently in the region due to climate change. Urban areas in the midwest do not necessarily have the infrastructure to deal with extended heat waves.

- **Lake-effect snow.** Possible changes in lake-effect snowstorms due to climate change were discussed, but it was not clear to the participants how climate change would impact lake-effect storms. If fewer lake-effect snowstorms occurred due to higher temperatures, then the

impact on human health would be reduced. However, only slightly warmer conditions may lead to increased lake-effect ice-storms, which could pose a serious health hazard from the standpoint of more traffic fatalities and extended power outages.

- **Fog.** Although the impact of climate change on meteorological phenomena such as fog formation are unknown, small increases in the mean temperature or changes in flow patterns could have significant impacts on the specific humidity and hence on fog formation. Increased fog formation could pose a serious health hazard from the standpoint of more traffic fatalities.
- **Cloudiness.** Possible increases in cloudiness downwind of the Great Lakes (e.g., over Michigan), especially during late fall and winter, could lead to increased incidence of seasonal-affective disorder (SAD).
- **Atmospheric pressure.** Possible increases in atmospheric pressure (gradients) may aggravate certain maladies such as migraines and arthritis.

### *Indirect impacts*

- **Air quality.** Possible increases in the duration of heat/cold waves may result in higher levels of air pollutants (e.g., ozone, particulate matter) particularly if air stagnation episodes occur with these weather conditions. Increased energy production during these extended heat/cold waves could also contribute to elevated levels of air pollutants. Increased air pollutant concentrations could lead to increased morbidity and mortality.
- **Water quality.** Possible changes in the frequency and the intensity of heavy rains and flooding could lead to reduced water quality (e.g., cryptosporidium) and increased morbidity and mortality.

- **Health care.** Possible changes in the frequency and the intensity of severe weather events (as well as other aspects of the weather as mentioned above) could place an increased demand on the health care system. For example, increases in heat stress could exacerbate an existing stress on health care access, leading to further rationing of health care.
- **Vector-borne diseases.** A possible increase in the mean winter temperature and precipitation could lead to an increased survival of vector-borne pathogens and to increased Lyme disease, for example.
- **Pest infestations.** Possible increases in insect and pest infestations as a result of regional climate change could result in greater use of pesticides, which could lead to higher levels of toxins in food and water, and increased morbidity and mortality.
- **Exotic species.** Possible changes in regional climate could lead to increased survival of exotic species that enter the region from international trade practices and to greater transmission of diseases from other areas of the world.
- **Accidents.** Possible decreased participation in winter sports due to climate change may ameliorate some recreation-related accidents. However, increases in warmer weather (outdoor) activities may exacerbate other recreation-related accidents.
- **Allergies.** Possible reductions in seasonality (the differences in weather conditions between seasons) could lead to increased levels of allergens (e.g., pollen, spores) and longer allergy seasons.

### **3. What additional information do we need?**

The level(s) of confidence that the group had in these decisions were used to identify areas where more information or research is needed.

- **High resolution models.** Better regional or nested general circulation models are needed to evaluate the regional-scale implications of climate change/variability (e.g., for the Upper Great Lakes region). For example, it is necessary to know how climate change and variability will (do) impact heat wave frequency and intensity, storm (e.g., rain/snow) frequency and intensity, and water levels and water quality.
- **Risk assessment.** High risk areas, sensitive populations, and important socioeconomic factors need to be identified so that public health methods can be developed and implemented to prevent or reduce the health impacts of climate change.
- **Warnings.** Location-specific extreme weather warnings need to be developed to prevent or reduce the health impacts of severe weather events (e.g., a heat-index based on health indicators).
- **Impacts assessments.** Information on the potential impacts of climate change/variability on the health care system is needed. To this end, an evaluation of the impacts of the Chicago heat wave and tornado outbreaks on the health care infrastructure could be performed.
- **Water quality modeling.** The effect of precipitation variability and severe storms (flooding) on water quality needs to be investigated. The group was uncertain as to whether potential deterioration of water quality would occur and whether it would significantly impact human health in the region.
- **Socioeconomic projections.** The potential for population and demographic changes to become additional factors that exacerbate health impacts needs to be studied.

#### 4. How do we cope with climate change?

Strategies for coping with or mitigating climate change impacts were divided among mecha-

nisms for the health care system, public health objectives, and government responses.

#### *Public health strategies*

- **Integrate warnings.** Indices that quantify health related weather hazards could alert people more clearly and more convincingly about risks on any given day. Such indices could complement existing indices like the UV and the Heat Indices.
- **Preventative measures.** Vaccinations, pest control, and behavioral/lifestyle changes could all reduce the number of people that require more costly acute and chronic treatments.
- **Risk communication.** The education of the general public, health care professionals, and government officials about potential impacts of climate change on human health should help reduce impacts.
- **Data collection.** Improved surveillance and monitoring systems to identify indirect health impacts should help reduce impacts and should help increase lead times for preparedness.

#### *Strategies for the health care system*

- **Preparation.** Response procedures should be developed to prepare for extreme weather events.
- **Education.** Health care providers should be educated to be able to identify health impacts of climate change/variability.

#### *Government/regulatory responses*

- **Relocation.** People should be removed from high-risk areas such as flood plains. Possible strategies that were mentioned included imposing tax disincentives in flood prone areas.
- **Reduce emissions.** Emissions of criteria air pollutants should be lowered to counter the growing number of respiratory illnesses that are being reported.

## GOVERNANCE & EDUCATION SECTOR REPORT

*Session Chairs: Perry Samson and Michael Donahue  
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### INTRODUCTION

The Governance & Education breakout group consisted of participants from environmental organizations, academia, Native American tribes, concerned citizens groups, and Canadian government organizations. The Governance & Education breakout group differed significantly from the other workshop groups. Instead of considering climate change in relation to a single subject, governance issues were debated on the first day of the workshop, while on the second day educational issues were discussed. The two facilitators for this sector, one for governance and the other for education, each developed their own set of questions to pose to the group because the questions asked in the other breakout groups did not directly apply to governance and education.

The discussion group was expected to interpret the workshop questions broadly in an effort to reduce the chance that significant issues would be overlooked. Because this was an initial effort, failing to include potentially critical issues was considered a greater mistake than including issues that, upon further study, turn out to be relatively unimportant. The participants were not asked to make quantitative assessments of the impacts that they discussed.

### GOVERNANCE – SIGNIFICANT FINDINGS

Reactions to the role of government in addressing climate change and its impacts varied. One group member suggested that governments should simply get out of the way, stating that the bureaucratic structure is simply too slow and

inefficient to facilitate the radical and innovative changes that may be needed to deal with climate change. Other members of the group disagreed with this radical approach and felt that governments should provide strong international, domestic, and local leadership. Governments should continue to fund research programs in environmental science and renewable energy resource development and communicate the results of this research to the public in a politically unbiased manner. Group members also agreed that governments should participate in voluntary partnerships with business and industry so that the two groups can work together, instead of against each other, to modify industrial practices which have a negative impact on the environment.

Several strengths and weaknesses of current government efforts were discussed. Among the strengths, group members noted the rising importance and visibility of climate change issues on the local, state, national, and international levels. Science research also continues to produce useful information about our changing environment. This progress is due to the sizable amount of money that has been allocated to climate change research and the large number of talented scientists at government agencies and research universities. The fact that climate change is becoming a political issue is both a strength and a weakness. The conflicting interpretations of research results were a large concern to all members of the group. Other weaknesses included the lack of coordination and integration among different government programs, the existence of antiquated energy and land-use laws, which promote methods that have a negative impact on the environment, and the fact that governments listen too strongly to economic, and not social and environmental arguments.

Climate change issues have affected government in the delivery of public services in several ways.

The possibility of climate change has induced more anticipatory work and the development of adaptation strategies. Governments have been spending more money on agencies and services that deal with climate change issues. Governments have also begun to consider tax incentives as a way to encourage business and industry to modify practices that harm the environment.

Group members had several suggestions for actions that governments must take to address climate change impacts. The federal government should create a rational and flexible energy policy that can be adjusted to meet regional climate change concerns. Climate change initiatives should be tied to other regulatory programs instead of creating specific carbon emission regulations. The federal government should promote voluntary partnership programs with business and industry and establish positive and negative economic incentives both for business and industry and the general public. Governments should also review antiquated laws that hinder the use and development of renewable energy resources as well as revise construction codes to prevent people from building or rebuilding on land that is particularly susceptible to frequent natural disasters. It was suggested that the federal government join with insurance companies to develop strategies for dealing with the possibility of the increasing frequency and intensity of natural disasters. Determining whether a public or private weather service will best fit the nation's needs for predicting and monitoring extreme weather events was another suggestion. Group members emphasized that the public should be informed about climate change impacts. Research and the dissemination of research should be funded by federal and state governments. Federal and state governments should also educate citizens and make special efforts to educate the media. State and local governments should encourage use of climate change issues in public school curricula.

## THE 4 QUESTIONS ADDRESSED

Four questions were posed to the group by the facilitator. The following format was used for the discussion of each question. First, group members silently generated ideas. Second, the facilitator went around the table and gave each member an opportunity to speak. Members could either share an idea with the group or pass. Group input was allowed as new ideas were expressed. Ideas were recorded on a chart by the facilitator. We continued the round-robin discussion until every member had passed or time was up. Finally, the group was given an opportunity to reconsider what had been recorded. Members with strong objections to specific ideas expressed their concerns. If the group reached a consensus, then the idea was modified.

### **1. What is the appropriate role of government (at any level) in addressing issues associated with climate change?**

Governments should simply get out of the way. The bureaucratic structure is too slow and inefficient to facilitate the radical and innovative changes that may be needed to deal with climate change.

Government at all levels (federal, state/tribal, and local) should provide strong leadership and be environmentally responsible ("walk the talk"). All levels of government should inform and involve the public and encourage them to act politically and personally.

All levels of government, especially federal and state governments, should provide research funding, particularly in environmental science and renewable energy resource development.

All levels of government should interact with business and industry via a balance of regulatory and voluntary programs. While there is a strong need for regulation, governments should

also participate in partnerships with business and industry to help the private economic sector to reach emissions and energy consumption goals. Governments should also encourage the development of energy-efficient technology and support innovative environmentally-responsible industries.

The federal government must participate and play a leadership role in international negotiations on greenhouse gas emission regulations and targets. Instead of simply thinking globally and acting locally, the federal government should promote international action.

The federal government should steer the direction of country and state policy making, support technology transfer (conversion of new research results into usable technology) and the creation of adaptation strategies, and promote and enforce conservation of water and energy.

The federal government should facilitate the communication of research results. It is important that the scientific community and the general public receive factual and unbiased information. All sides of the issues should be presented and misrepresentation of information for political purposes must be avoided. A federally-funded yet politically independent body of scientists should exist to review and disseminate research.

State and tribal governments should interpret federal policy in terms of what needs to be done at a state or regional level.

State and tribal governments should not only get the information about climate change to the people, but also apply the research.

State and local governments should actively participate together in land-use planning.

Local governments should involve all members of the community in strategic planning

activities related to climate change adaptation strategies.

## **2. What are the strengths and weaknesses associated with current government efforts?**

### *Strengths*

Climate change issues have been of rising importance and visibility on local, state, national, and international levels.

The United States is participating in international discussions on climate change. The United States has a large amount of international influence that it could use to promote further debate.

Vice President Al Gore has provided strong leadership in environmental issues.

Some educational outreach programs have been successful.

Scientific research continues to produce useful information about our changing environment and as a result our knowledge about the Earth and its climate is increasing at a rapid rate.

A sizable amount of money has been allocated to a large number of diverse organizations for climate change research, although this amount still pales in comparison to the funds the military receives from the federal government.

The partnership between the federal government and research universities has been strong. The United States has a large number of talented scientists.

### *Weaknesses*

There are conflicting interpretations of research results. This is a result of the promotion of a political agenda or due to the “de-contenting” or “research brokering” that inevitably must happen in order to communicate research

results to politicians, the general public, and even scientists.

The influence of large companies and their lobbyists on the government was considered a weakness.

The lack of coordination and integration among different government programs, particularly between federal and state governments has hindered progress.

Some broad national policies miss regional concerns completely.

The existence of antiquated energy and land-use laws promote methods that have a negative impact on the environment and discourage the development of new practices which have smaller environmental footprints.

Government agencies such as the Environmental Protection Agency (EPA) have limited authority, especially in terms of the ways in which they can spend money on public outreach and education.

Weakness: Governments listen too strongly to the economic arguments. The social and environmental concerns are often ignored.

Weakness: The public is largely uninformed and an uninformed public will not support the legislation that is needed to slow climate change.

### ***Strengths & Weaknesses***

The climate change issue is becoming politicized.

A large number of oversight committees in the House and Senate are involved with climate change issues. Although this is evidence that the level of concern is high, the sheer number of the committees means that it is very difficult to pass climate change legislation.

### **3. How are climate change issues affecting government (at any level) in the delivery of public services?**

The possibility of climate change has induced more anticipatory work and the development of adaptation strategies. Governments have begun to look forward to the future.

Governments have been spending more money on agencies and services which to with climate change issues, e.g. this workshop.

Weather and long-term climate prediction have become priorities for the Federal Emergency Management Agency (FEMA).

There has been an increase in expenditures for natural disaster relief.

The federal government has begun to consider tax incentives as a way to encourage business and industry to modify practices that harm the environment. There has been an emphasis on alternative, creative responses as opposed to just regulation.

### **4. What specific actions must government (at any level) initiate to fulfill its role in addressing climate change impacts?**

All levels of government should take advantage of the current positive political environment.

The federal government should recognize its leadership role in the international community and promote the development of climate change policy by ratifying the Kyoto treaty or offering a reasonable alternative.

The federal government should initiate discussions with Canada about climate change adaptation strategies in the Great Lakes region.

Strategies to limit emission of greenhouse gases and to adapt to potential climate change should

be developed at all levels of government, especially at the local level.

The federal government should create a rational and flexible energy policy that can be adjusted to meet regional climate change concerns and develop national energy conservation goals.

The federal government should attempt to reduce carbon emissions not with explicit regulations but by tying climate change initiatives to other regulatory programs.

The federal government should promote voluntary partnership programs with business and industry and establish positive and negative economic incentives in the form of tax breaks or tax increases to encourage the use of renewable energy resources.

Federal and state governments should review antiquated laws that hinder the use and development of renewable energy resources.

Governments should revise construction codes to prevent people from building or rebuilding on land that is particularly susceptible to frequent natural disasters.

The federal government should team with insurance companies and develop strategies for dealing with the possibility of the increasing frequency and intensity of natural disasters.

The federal government should impose penalties for purchasing cars that have low gas mileage ratings and offer incentives for the purchase of energy-efficient automobiles.

The federal government should continue to fund the investigation of the use of nuclear-generated power and the safe storage of nuclear wastes.

The federal government should determine whether a public or private weather service will best fit the nation's needs for predicting and moni-

toring extreme weather events, the most likely manifestation of climate change.

Governments should discourage the further expansion of urban areas by promoting public transportation.

All levels of government should continue to fund research and the dissemination of research.

The federal government should create and support a politically independent consortium of scientists that would advise the government and provide some sort of unbiased information source.

Federal and state governments should educate citizens about climate change impacts by conducting outreach activities, creating public service announcements, and supporting the development of resource materials for K-12 teachers. Special efforts should be made to educate people in the media such as newspaper editors and television news directors in order to increase the amount of media coverage of climate change issues.

State and local governments should encourage the use of climate change issues in public school curricula.

## **EDUCATION – SIGNIFICANT FINDINGS**

Since global warming and other possible manifestations of climate change are slow and intangible processes, group members decided that it is essential to be opportunists and distribute information about the impacts of climate change during severe weather events, major international conferences, and at other times when the public's attention is focused on climate. This information would include a general description of the atmosphere and the greenhouse effect. It would emphasize that although not all things are known about climate change, the consequences of all possible climate change

scenarios must be considered. The public should also understand that scientific data can be interpreted in different ways in order to promote a specific point of view. Finally, it is important that people realize that the causes of climate change are directly linked to human behavior. The negative effects of climate change can only be reduced by lifestyle modification.

Because the issues associated with climate change involve science, math, and social studies, climate change education provides a unique opportunity to build integrated, multi-disciplinary educational experiences. These experiences can be used to promote team-teaching methods and to generate student-centered activities that use real-world examples to teach problem solving skills. This interdisciplinary approach would avoid the extremely difficult task of changing curriculum standards to include climate change education objectives. Materials developed for climate change education should target specific educational proficiencies found on standardized tests, take advantage of real-time weather information that can be provided by the internet, and utilize other distance learning activities. Producers of such educational materials should design the curricula so that all school districts can participate. Teachers must be trained not to advocate particular agendas since the improper discussion of politically sensitive issues can jeopardize climate change education.

Informal methods of educating the public about climate change impacts include museums, posters, and temporary information booths placed in highly traveled areas. These sources of information should emphasize the personal actions that can be taken to help slow climate change. Partnerships between government organizations and business and industry can also be used to educate the general public. The refurbishing of public and private buildings with energy-efficient and money-saving technology are golden opportunities to educate people about the causes of climate change. Religious organi-

zations may provide a forum to address the issues of overpopulation and overconsumption which contribute to climate change. Activities are needed to make people think about the consequences of certain behaviors in terms of how they may contribute to climate change. Televised public service announcements and national debates may also be an effective way to inform the public. Finally, the issues of climate change should be linked to the sustainability movement.

#### THE 4 QUESTIONS ADDRESSED

The discussions were similar to brainstorming sessions. The facilitator initiated each discussion by presenting four questions concerning the methods, audience, concepts, and activities associated with climate change education, but the topics gradually changed over the course of time. Eventually the questions concerning methods and audience were combined and a new topic was created: problems encountered in climate change education.

##### **1. What are the methods for fostering an informed debate on climate change and what are the ramifications and audiences these methods would target?**

All methods should be used. Additionally, it is possible that there are no new methods left to try: all methods may have already been used to educate the public about climate change.

Museums, posters, and temporary information booths should be placed in highly traveled areas to educate the public.

Government should partner with business and industry to educate the general public.

Information should be distributed and the public should be informed during the times when climate issues are in the public eye (during severe weather events or major international conferences).

Materials should be distributed at national teacher conferences.

Materials should be prepared about climate change science which target specific educational proficiencies found on standardized tests and that help the teachers learn how to use them.

Teachers should be trained to address the wide variety of political, economical, and ethical issues that are associated with climate change in a sensitive manner.

Curricula for school districts that exploit the interdisciplinary nature of climate change education should be prepared. In order to allow all school districts to participate, curricula should be designed so that only inexpensive materials, which can be obtained locally are required. Climate change should be used as a case study to integrate science, math, English, and social studies. A team-teaching approach to climate change education should be promoted. Teacher-directed yet student-centered hands-on learning experiences should be promoted that can be used to teach students at all levels problem solving skills and the general process of science.

Create courses on climate change impacts and science should be created at the community college level.

Materials should be produced that can be used by religious, environmental, and civic groups to inform the public about climate change issues.

Distance learning and/or the internet should be used more.

A national debate should be televised on the potential causes and manifestations of climate change involving representatives from business and industry, government, and academia to inform the general public. Public service announcements produced by government

agencies and environmental groups should also be televised.

Public and private buildings should be refurbished with energy-efficient and money-saving technology as opportunities to educate students and the general public about the causes of climate change.

Issues of climate change should be linked to the sustainability movement.

Geographic information systems (GIS) software should be used to produce if-then scenarios dealing with future changes in land-use due to climate change.

## **2. What are the problems encountered when educating people about climate change?**

Environmental education is often seen as advocating a liberal agenda, which makes it an easy target for politically conservative groups.

Changing curriculum standards to include climate change education would be extremely difficult.

A large gap is developing between science and the media.

Getting climate change education into the classrooms of teachers who are not highly motivated to change their curriculum.

Global warming and other possible scenarios are slow, intangible, and uncertain processes which makes it hard to motivate people to make the changes that may be necessary to slow climate change.

Atmospheric science, the centerpiece of climate change, is often caught between other academic subjects, and therefore very few students learn about the atmosphere.

Improper discussion of politically sensitive issues such as overpopulation and overconsumption can jeopardize climate change education.

**3. Which identify concepts should be presented as a necessary part of a climate change curriculum?**

There are inherent uncertainties in science. There are things that are known about climate change and things that are not known. The consequences of all possible manifestations of climate change should be taught.

Scientific data can be interpreted in different ways in order to promote a specific point of view.

A general understanding of the atmosphere and the greenhouse effect is crucial.

The causes of climate change are directly linked to human issues such as overpopulation and overconsumption. The negative effects of climate change can only be reduced by modifying our lifestyles.

**4. Which activities might best stimulate an informed debate on climate change issues?**

Several activities that were discussed include:

Activities which present unusual facts about the Earth's climate.

Interdisciplinary laboratory activities relating to climate change, which require the integration of several academic subjects in order to solve problems.

Real time weather information over the internet and the exchange of weather-related personal experiences.

Activities that calculate the amount of carbon dioxide and other greenhouse gases that are added to the atmosphere by common everyday

practices such as taking a shower, driving to work, washing the dishes, etc.

A "life skills" game that requires the players to think about the consequences of certain lifestyles in terms of how they may contribute to climate change.

Posters that emphasize the personal actions that the public can take, such as insulating the home, carpooling, etc., to help slow climate change.