Conference Report on Milwaukee Workshop

Workshop Title:

Climate Change and the Great Lakes Water Ecology:

What Are the Potential Impacts, and What Can We Do?

June 15, 2001

Morning Presentations

How will climate change affect weather patterns and lake levels in the Great Lakes region?

Peter Sousounis, University of Michigan, and Brent Lofgren, Great Lakes Environmental Research Lab, NOAA

Evaluating changes in synoptic patterns is tantamount to understanding regional climate change. To date, the synoptic evaluations that have been done regarding climate change output from General Circulation Models have been restricted mainly to examining changes in storm tracks across large areas (e.g., the Atlantic Ocean). In this presentation, we looked at output from the Canadian Coupled Climate Model (CGCM1) and the Hadley Coupled Climate Model (HadCM2), which were used as part of the U.S. National Assessment of Climate Change. We examined potential changes, relative to present conditions, in synoptic patterns, as well as changes in temperature, precipitation, and lake levels over the Great Lakes region toward the end of the 21st century.

Both models show a decrease in the number of extremely cold days, an increase in the number of extremely hot days, and an increase in precipitation for the –future—particularly for heavy precipitation (e.g., > 12.5 mm) events. Both models show a decrease in surface windspeed and an increase in the number of days with an easterly wind component. Both models exhibit decreases in cyclone numbers for the future. The Canadian Model shows a general decrease in the number of moderately strong cyclones and decreases in each month. The Hadley Model shows a slight increase in the number of strong cyclones but a greater decrease in the number of weak –cyclones—especially during the spring. The Canadian Model exhibits significant decreases in the number of anticyclones in summer and significant increases in fall, but the model does not exhibit any systematic changes in terms of intensity. The Hadley Model shows a slight increase in the number of weak anticyclones but a greater decrease in the number of strong anticyclones. Most of the decreases occur during the –summer—so that the seasonal distribution is more uniform.

In addition, the net effects on lake levels of the Great Lakes because of future changes in temperature and precipitation as simulated by the Canadian Model and the Hadley Model are quite different. The CGCM1 yields a drop in the level of Lakes Michigan and Huron of 0.72 m (2.4 feet) by 2030 and 1.38 m (4.5 feet) by 2090. On the other hand, using the results of the HadCM2, the same lakes rise by 0.05 m (0.2 feet) by 2030 and 0.35 m (1.1 feet) by 2090.

All of the changes are consistent with changes in the general large-scale flow patterns. An understanding of all these synoptic changes provides richness and a more conceptual understanding of how climate change may affect the Great Lakes region.

How might future climate affect lake temperature, mixing, algae, and small invertebrates?
John Lehman, University of Michigan

Forecasting future conditions of the Great Lakes in response to climate change puts scientists in an uncomfortable role. The most confident prediction is that ecological surprises will emerge. The living communities of our lakes have intimate and complex two-way linkages to the physical and chemical world, and many of the linkages still await discovery.

The challenges of projecting future ecological conditions arise mainly from our incomplete understanding of the present state and the ways that biota can respond. Different visions of future climate generated by alternative climate models lead us to anticipate fundamental changes in the physical environment of the lakes. Water temperatures will be higher, the lakes will not mix deeply for as long as they do now, and more ultraviolet light will strike the water surfaces. We understand that deep mixing resets important elements of the biological and chemical clockwork of the lakes, and that temperature changes the speed of these clocks. To date, the direct responses of organisms to climate variables have received most or all of scientists' attention. We need to remain alert to the far-reaching consequences of ecological complexity. We do not yet know enough, for example, to project how temperature, mixing, UV light, and biological processes will interact to affect toxic metals like mercury that become concentrated up a food chain. We do not yet know exactly which new species will establish themselves in the lakes and which existing species will be eliminated, or what new or invigorated parasites will emerge. Our ecological knowledge does warn us about the types of surprises that will occur. But current theory is no substitute for a strong program of observation and interpretation of Great Lakes ecology as an insurance policy and early warning system for future environmental problems.

The lakes are changing: Do fishes care about climate change?
John Magnuson, University of Wisconsin-Madison

All aspects of a fish's life such as survival, growth, and habitat choice are dependent on water and water temperature, both of which are directly affected by climate warming. Warming alters the amount of thermal habitat suitable for coldwater fishes (trout), coolwater species (perch and walleye), and warmwater fishes (bass and bluegill). In streams, ponds, and shallow lakes in the Great Lakes region, warming scenarios reduce habitat for coldwater and coolwater fishes but increase habitat for warmwater species. In deeper lakes that thermally stratify in summer, such as Lake Mendota and Lake Michigan, warming increases the amount of thermal habitat for all three thermal groups of fishes. However, coldwater habitat suitable for coldwater fishes is degraded by loss of oxygen in deeper water; this loss is severe in the shallower or more productive lakes such as Mendota and could be severe in the larger lakes such as Lake Michigan if thermal stratification became more permanent. Warming also is expected to increase the invasion of warmwater fishes into the Great Lakes and the streams and inland lakes of the region. Invasions of warmer water fishes would move progressively northward, and extirpations of coldwater and coolwater fishes in the streams and inland lakes would become progressively more common initially in the southern part of the region. The invasions would result in species interactions that can accelerate the rate of extirpations. For example, in Ontario's inland lakes, the arrival of warmwater basses (usually by stocking) results in the loss of minnow species. Fishes are an excellent indicator of the expected changes from global warming because they are sensitive to water temperature and interactions with the northward migration of fishes; they also are highly valued by people.

Implications of climate change in the Laurentian Lakes: What can the African Great Lakes tell us?

Harvey Bootsma, University of Wisconsin, Milwaukee

The African Great Lakes are similar in size to the Laurentian Great Lakes, but they experience a much warmer climate. Thus, they can provide clues as to what changes might be expected in the Laurentian Great Lakes if the regional climate warms. Two notable aspects in which tropical large lakes differ from temperate large lakes are hydrology and lake circulations, which in turn affect nutrient cycles, algal production, and fish production.

Although the African Great Lakes experience annual rainfall similar to that of the Laurentian Great Lakes, greater evaporation rates under warm conditions result in reduced outflow. This reduction in outflow has implications for lake levels, contaminant retention, and hydroelectricity generation. Deep tropical lakes also tend to be permanently stratified. Observations in the African Great Lakes suggest that permanent stratification of the Laurentian Great Lakes would result in lower deep-water dissolved oxygen concentrations, large changes in the cycling of nitrogen and phosphorus, and greater inter-annual variability of plankton and fish production.

Question and Answer Panel Discussion: Morning Session

***Question 1:* John Higgins, The Nature Conservancy**

When building climate change models based on mean values, you often see very similar degrees of fluctuation, as in the models just shown. But people working with climate change models and hydrologic changes are often very interested in the variance, since the predicted change in variance could be greatly increased with climate change. For example, though the lake level highs and lows have not changed dramatically in Lake Huron and Lake Michigan over the last 70 years, the variance of changes is larger than the difference of highs and lows. So, I'm wondering if you've developed any variance in your models to allow for more extremes to result from the models.

Response: Brent Lofgren, Great Lakes Environmental Research Laboratory, NOAA

Hopefully in the next year, daily data will be used more as inputs into hydrologic models to incorporate a little bit more of the change in variability that is projectedby the GCMs. But how reliable the projected change in variability will be is a question worth asking. Another question to ask is: "What kind of analyses will we want to do with this variance data?" Specifically, what time scales will we look at? Are we interested in looking at storm activity on a weekly scale? Are we interested in looking at lake level rise over a five-year period? All of these kinds of analyses will require a lot of data handling, so these questions will need to be considered

***Question 2:* George Stone, Milwaukee Area Technical College**

What is the "shelf life" of the Canadian and Hadley models? How often are they revised?

Also, it seems as though we've had an unusually cool, wet spring in the Great Lakes region. Is there any evidence thus far that that has had any effect on lake levels?

Response: Brent Lofgren, Great Lakes Environmental Research Laboratory, NOAA

Actually, the Hadley Center has recently come out with a new version of its model, the HADCM3, for which the results have begun to be published. Interestingly, the results of this new model agree more closely with the Canadian Climate Center model that we have been using. One of the major changes of this new Hadley model is in its handling of atmospheric aerosols that reflect sunlight, and [the model now] ends up projecting warmer temperatures into the future [than before]. Whatever the newest model is, that is the one that is essentially considered to be the best.

As for the recent low temperatures and high precipitation rates, such trends need to build up over a couple of years to create a significant change.

***Question 3:* Thomas Johnson, Large Lakes Observatory, University of Minnesota Duluth**

The modeling results look promising for fishing on Lake Superior, since availability of prey increases with rising temperatures. I am interested in knowing to what extent fish production in the Great Lakes is linked to phosphorus input to the lakes. Has anyone done a very simplistic comparison of overall fish productivity in the Great Lakes and the overall phosphorus levels?

Response: John Magnuson, University of Wisconsin-Madison

If you add phosphorus to a point and have increased algal and subplankton productivity, you get the classic bottom-up effect. If you compare lakes, about half of the variability is often associated with

this kind of bottom-up effect, so you would expect phosphorus availability to play a role. Years ago, Dick Ryder developed an index of fish yields from lakes that consisted of a simple ratio of total dissolved solids (which would include nutrients), divided by mean depth. That simple ratio explained a lot behind the yields of fish in lakes around the world. So, it is well established that those bottom-up effects are real. If it goes up and up, you begin to get a change in status—for example, if the deep waters get anoxic (oxygen depleted), then the whole framework will change. But I haven't seen anything presented today that suggests that the waters are going to go anoxic in a hurry.

***Question 4:** Thomas Johnson, Large Lakes Observatory, University of Minnesota Duluth*

One of the reasons that I am asking about phosphorous in Lake Superior is that its bedrock is different from that of the other Great Lakes. Because Superior doesn't have limestone and therefore doesn't have the high total dissolved solids, I'm wondering what kind of impacts warming might have on it.

Response: John Magnuson, University of Wisconsin-Madison

These models that I presented are very simple. If you began to include the whole food web and productivity and some of the feedbacks, you would get a lot greater variety of scenarios. Both because of its shape and runoff of nutrients into the area, Superior will remain a low-productivity lake, even with a lot of activities going on. I would imagine that of all the Great Lakes, Superior is the one that is most susceptible to a food web shortage.

Response: John Lehman, University of Michigan

Just because a lake is low in total dissolved solids, that doesn't mean that it can't become ibritrophic, and that was the reason for choosing these lakes for nutrient experiment work. Inputs of nutrients from the watershed will be largely controlled by anthropogenic processes, and we don't know what the future holds for population migrations and how inputs will change. Another dimension to look at is the lake geometry index—a geometrical factor that has a fair bit of predictability. Lake geometry affects whether or not lakes will form strong thermal stratification and become depleted of oxygen in the deep layers. And, of the Great Lakes, Superior and Ontario are the most susceptible to forming strong thermal stratification and deoxygenation according to that ratio. So, it will be interesting to see if the predictions of these mixing models hold up and if the duration of thermal stratification in Lake Superior increases faster than that of the other lakes.

***Question 5:** Lon A. Couillard, City of Milwaukee, Milwaukee Waterworks*

What is the potential effect of climate change on algal blooms? How might it affect the water quality for domestic water producers?

Response: Art Brooks, University of Wisconsin-Milwaukee

There has already been an increased abundance of some algal species growing on rocks along the shores of Lake Michigan, which are likely explained (at least in part) by warmer water temperatures. Generally, in warmer water, there tend to be greater numbers of cyanobacteria—bluegreen algae that do somewhat better under lower nitrogen levels, since they can fix their own [nitrogen] from the atmosphere. So, we might see some changes in this respect.

Response: John Lehman, University of Michigan

Increased duration of thermal stratification will lead to a relative loss in the number and success of the diatom species, which are opportunistic, fast-growing clean water algae. However, diatoms

cannot tolerate high rates of loss, so an increased duration of thermal stratification may lead to their replacement by either colonial greens—which may not present much of a problem other than filter clogging—or by colonial or filament-forming bluegreens—which can present more of a problem, in terms of taste, odor, and general nuisance.

Response: Harvey Bootsma, University of Wisconsin-Milwaukee

One must consider the multiple effects that climate change will have. Warming will affect algae production and composition. But as changes in thermal structure and stratification occur, some modeling suggests that production will actually decrease, because the longer stratified period does not allow nutrients to get to the surface water. What we might expect to see is different effects in near versus offshore areas. Offshore areas are more dependent upon annual mixing to bring up nutrients, whereas near-shore areas may be more responsive to inputs from catchments (where surface runoff is gathered). Therefore, even with constant nutrient inputs, near-shore areas will be more responsive as temperature increases.

Response: Art Brooks, University of Wisconsin-Milwaukee

We have talked about some of the hydrologic effects and the fact that water levels may drop, which means that most intakes would be drawing in more surface water than deeper water, which in turn may mean that more productive water will come in, due to the physical factors.

Response: John Magnuson, University of Wisconsin-Madison

A paper was written on year-to-year variation of water clarity in Lake Mendota and what the statistical explanatory variables did over the last 30 years or so. It was found that water clarity was equally influenced by three things—all three of which will be influenced by climate change:
(1) Runoff—which will probably increase due to increased precipitation;
(2) Stability of the water column—where the warmer the water—the warmer the summer—the less erosion of the deeper nutrient waters there will be during the summer, ultimately resulting in less upwelling or internal reloading of phosphorus; and
(3) Population size of daphnia—a herbivore that feeds on phytoplankton. Daphnia varied based on the abundance of fish that [feeds on] them. In the eastern part of Great Lakes, we have a number of very effective warmwater zooplanktivores—the probability that they would become dominant in our systems would increase under a warmer climate.

Question 6: ***Patty Glick, National Wildlife Federation***

Has anyone looked into how reduced lake levels may affect species that rely on lake shores for breeding and other purposes?

Response: Art Brooks, University of Wisconsin-Milwaukee

Based on aerial photographs of the Mink River, we have seen great variations on the extent of wetland areas along the coast. The photos revealed that the wetlands increased and decreased by several orders of magnitude over a 10-year period, ranging from a trickling stream to a wide flooded wetland area. Since climate change will only exaggerate the natural variations that already occur, the implications of climate change on wetland production and nursery areas are very significant. This will affect productivity.

Response: John Magnuson, University of Wisconsin-Madison

John Brazner at the EPA lab in Duluth would be a good resource person to speak to regarding the effects on lake shore species.

Other effects to consider may be the within-year variations. For example, if water levels were to drop rapidly, fish species that spawn in the sand and the gravel might be stranded—but that would have to be fairly fast-moving water level drops. During the winter, fishes like the whitefish spawn on rocks just below the high water mark, and if there were a large loss of water in the winter, one might expect exposure of the ice settling on them. But I think those [effects] are unlikely, though it will depend on how big the variation is.

Response: John Lehman, University of Michigan

Another potential impact would be from a change in ice scouring that can occur during the winter—during the modification of shallow water habitat.

Question 7: Patty Glick, National Wildlife Federation

Do researchers know how natural variations of lake shore levels affect different populations of species over decades? For example, do we know how water level fluctuations affect different populations of species, such as impacts on hatching rates?

Response: Art Brooks, University of Wisconsin-Milwaukee

I suspect that some work has been done on that, though I am not familiar with any such research. Certainly, inter-annual variations such as the extent of ice cover, the duration of spring mixing, and other things of that nature would affect phytoplankton production.

Response: John Lehman, University of Michigan

We haven't analyzed numbers specifically in that way. There is anecdotal evidence in terms of some invertebrate species development; for example, we know that fast-growing species that do well in warm water are successful members of the fauna during unusually warm years—but no systematic review has been done.

Response: John Magnuson, University of Wisconsin-Madison

In the fish literature, there are correlates of year-class reproductive success in some species that are related to climatic factors that may be linked to water levels, but they may not actually be directly caused by the water levels. For example, walleye usually do better in situations where there is more runoff in the spring, and perch have higher reproduction in springs that are warm and dry instead of springs that are cold. Sorting out the exact causes for high or low productivity would be difficult.

Question 8: Dave Michaud, Wisconsin Electric Power Co.

Given the demonstrated effects of zebra mussels in the near-shore area on phytoplankton and maybe even on benthos, would it be difficult to discern the effects of climate change in the next 30 years from the effects of zebra mussels and other exotic zooplankton that are already causing damages? How hard is it going to be to discern global climate impacts from exotic impacts?

Response: John Magnuson, University of Wisconsin-Madison

Discerning the causes and impacts of climate change from all other variables is difficult, but scientists enjoy trying!

Question 9:* *Dave Michaud, Wisconsin Electric Power Co.

Based on recent observation from being a large water user along the western coast, I can tell you that we have had to spend almost $10 million dealing with the zebra mussel, both in terms of direct and indirect impacts. Given the tremendous impacts that have occurred in the near-shore area from one species alone, I have serious doubts as to whether we can even begin discerning subtle changes in trophic-level dynamics, when there are monster invaders causing so many changes.

Response: John Lehman, University of Michigan

But climate change and invasive species are not necessarily independent issues. Changes in the physical environment, such as temperature and mixing, in many ways facilitate the introduction of exotics and will increasingly continue to do so. Lots of introductions are occurring all of the time, but we only notice the catastrophic ones that affect us. But, as mixing patterns change and the vertical extent of warm water changes, deep water intakes that are currently unaffected by the zebra mussels, thanks to cold temperatures, may be affected in the future when the water warms. So there may be an interaction between climate change and exotic species in the future.

Response: Art Brooks, University of Wisconsin-Milwaukee

Another unknown that should be considered in the Great Lakes is the fact that these are managed systems, yet managers of the lakes have not paid any attention to climate change projections and are continuing to practice the same behaviors. If they decide to put more salmon or trout in the lake, that could change the whole mix as well. So we are not just looking at a random input of exotics, but maybe a purposeful input of exotics that scientists have minimal control over.

Response: John Magnuson, University of Wisconsin-Madison

Though zebra mussels are no doubt a pressing issue for the hydroelectric industry, and climate change may not influence the industry in the same way, climate change may influence how you place inputs, or the efficiency of your cooler system.

The navy has already started thinking about how they would deal with military issues in an ice-free Arctic! This demonstrates the long-term investment time for which some people are, and must, think about to protect certain interests. So, the only thing that I can encourage people to do is not to get too caught up in dealing only with the most pressing issues of the day, but also to think about some longer term problems that will affect them in the future.

Response: Harvey Bootsma, University of Wisconsin-Milwaukee

Certainly, introduction of exotics does make it very difficult to predict what will happen in the future. But, as mentioned earlier, though phosphorus inputs can explain about 50 percent of the variability in primary production and other top-down mechanisms also influence this variability, that does not mean that it is not useful to look at the relationship between phosphorus and chlorophyll. In the same respect, despite variability and the complexity of factors that affect lakes, it is still worth considering the potential impacts of climate change on lakes. There are fundamental physical

factors that we need to know about lakes as a result of climate change. Even though there will be other changes superimposed on these climate change-related impacts, our ability to predict the results of exotics is improved by fundamental background data that will allow us to better know how systems will change over time.

Question 10: ***Alberto Vargas, Wisconsin Coastal Management Program***

What are the next steps that should be taken to further the climate change debate? What is the role of science? Do we need to refine predictions? Provide economic assessments for different scenarios? Based on what newspapers are saying, the discussion is not so much centered on whether or not climate change is happening, but on the economic implications.

Response: Peter Sousounis, University of Michigan

What we have learned from the first assessment is that we need to expand on three major areas: (1) we need a better understanding of the inter-annual/decadal variability of systems from year-to-year, not by mean; (2) we need to conduct more interdisciplinary studies; and (3) we need economic answers. For the latter need, since stakeholders have the best idea of how weather may affect their industry, scientists need to foster better relationships with stakeholders and provide them with the necessary information for them to determine the economic answers.

Response: John Magnuson, University of Wisconsin-Madison

We need to know what the impacts may be and what potential adaptive strategies can be adopted. Most people do not propose adaptive strategies but simply believe that we'll just have to cope with whatever changes result. Also, the climate system needs more work. For example, the U.S. needs to know more about its carbon budget—where are the sinks? Are there adaptive mitigation measures to be taken in agricultural, forestry and/or lake management to increase carbon storage? We also need to keep providing policymakers with information to allow them to develop an action strategy on climate change at the international level. So, there is clearly a large role for communication and education—lots of priorities!

Response: John Lehman, University of Michigan

Studies have revealed that there is much uncertainty and a great need to fill in the gaps in our scientific knowledge. For example, maybe we need to know more about seasonality of maximum rates of primary production. Therefore, in addition to exploring the socio-economic side of the problem, we also need to know how good a job we are doing at putting the right numbers into our equations. An example of uncertainty worth further interdisciplinary research is the variation in cloud cover during the day and night. Cloud cover variability can have a huge impact on climate and lakes. These impacts, which could have huge effects on projections, cannot be deciphered from the GCMs but will need to come out of mesoscale models. But right now we don't much data on cloud cover, so these impacts are still largely unknown.

Question 11: ***Jo Sandin, The Milwaukee Journal Sentinel***

How will we be able to find out variability in cloud cover between day and night, now that the National Oceanic and Atmospheric Administration (NOAA) has replaced humans with machines that are not capable of monitoring cloud cover? Nobody is looking out the window anymore, because we are not paying anyone to do it. Do we know if it will be cloudier in Milwaukee?

Response: Peter Sousounis, University of Michigan

It is hard to pay observers 24 hours a day. Remote sensing does actually have some advantages. It allows more spatial cover over remote areas of the lakes and the algorithms used to interpret satellite data are getting better and providing more accurate numbers for cloud cover. On the whole, satellite-derived cloud cover is probably doing a better job than human observers could. The algorithms are compared to mesoscale output, which will help refine both. Using this newly refined information, we hope to obtain better estimates of how cloud cover will change the picture.

Response: Brent Lofgren, Great Lakes Environmental Research Laboratory, NOAA

The problem with remote sensing is that it eliminates the temporally homogenous record at any one point of cloud cover that one would get by using a consistent method of measurement. In most cases, one would want an overlap of several years, but some things, such as cloud base height, are not necessarily measured by satellites. A similar problem has arisen with the elimination of river flow measurement sites maintained by the U.S. Geological Survey, which has occurred at some sites in the Great Lakes basin over the last few years.

Question 12: ***Patty Glick, National Wildlife Federation***

Despite the many uncertainties that exist in the current science on global warming, there is very little uncertainty that human activities are causing the Earth to warm. Yet, by constantly talking about uncertainty, policymakers hone in on the different layers of scientific uncertainty and then do not act. As scientists, do you feel comfortable conveying so much uncertainty, knowing that the declaration of uncertainty causes policymakers to delay action?

Response: John Magnuson, University of Wisconsin-Madison

As scientists, we must say what we feel confident about and what we feel uncertain about, or we are lying and cheating. Policymakers need to decide if, in the face of uncertainty, we should act conservatively or take the risk-prone approach. What people have discovered in the past is that we would have been well off to have taken the risk averse strategy—known as the precautionary principle. So, most scientists would tell policymakers that if you're looking at an uncertain future, you should take the cautious approach. Science only plays a certain role in deciding policy. As scientists, our role is to reveal the uncertainty to force political debate on important environmental issues. Scientists can only reduce uncertainty; they cannot eliminate it.

Comment: ***George Stone, Milwaukee Area Technical College***

An important part of risk assessment is to ask the question, "What are the consequences?" There is uncertainty about contracting or not contracting a disease, but that does not cause people to forgo inoculation. Likewise, we do not know when or where earthquakes are going to occur, but that does not prevent us from passing building codes and construction requirements to prevent casualties and costs if an earthquake does occur. I think this kind of approach, where you take not only probability into account, but also the severity of the consequences, is important for policymakers to consider.

Afternoon Presentations

What are the potential impacts of Lake Michigan water levels on drinking water production, quality, and demand?

Roger Johnson and Bill Soucie, West Shore Water Producers Association

More than 40 drinking water plants in four states draw on Lake Michigan as a water source. All of the plants have water intakes that extend from about 900 feet (40 m) to upwards of 15,000 feet (4.5 km) into the lake. The intake structures typically rest in 10 -50 feet (5-15 m) of water.

High- and low-water levels affect water plants differently. However, most water plants are designed to withstand 100-year historic high and low lake levels. Some water plants built in the late 1800s have actually persevered through these extremes and continue to pump water today. High water levels pose the greatest challenge to shoreline water plants. The combination of elevated lake level and wave action makes these facilities particularly vulnerable to flooding. In contrast, lower lake levels would provide increased protection for these utilities. Lake levels below 100-year historic lows may decrease the ability of some water producers to draw enough water from the lake to meet customer demand. Deeply submerged intakes facilitate water conveyance through intakes to pumping stations. Shallow water limits water withdrawal. If customer demand then exceeds the ability to withdraw water, some intakes may require extension.

Water quality changes during high and low lake level extremes are difficult to identify. The major water quality factors that treatment plants work with today are water temperature, turbidity (suspended solids), and microbiological quality factors. These factors also change more often than other water quality factors. New water temperature extremes may pose a few challenges. Colder winter water may lead to increased ice formation on intakes and a decreased ability to supply water. Warmer summer water may lead to increased algal blooms and the resulting taste and odor events. Taste and odor problems would increase treatment costs. Turbidity and microbiological changes already fluctuate greatly during the year, especially for near-shore shallow intakes. Although water plants are designed specifically to handle these extremes, slightly increased usage of coagulants and disinfectants may be anticipated.

Changes in climate also may affect public water demand. Water production typically increases by more than a factor of two during the hot summer months. Extended dry and hot weather results in maximum water demand since irrigation increases. If treatment plants are unable to produce sufficient quantities of water, demand will have to be reduced or water supply increased. Increasing the supply would most likely involve increases in water rates.

Overall, water providers are cautiously confident that the climactic changes anticipated for the 21st century will not dramatically affect our ability to supply drinking water to the communities we serve. However, we will continue to monitor lake levels and water quality closely to assure production of high-quality water in sufficient quantities.

What are the challenges and opportunities facing commercial fishermen?
Ted Eggebraaten, Wisconsin Commercial Fishing Association, Door County Chapter

Chubs, whitefish, lake trout, yellow perch, and rainbow smelt are important commercial fishes harvested in the Great Lakes. Species are harvested at various depths and times of the year, using a variety of gear types and techniques. Gill nets, trap nets, and pound nets are the most common gear used in the region, though trawls and trap nets are still used by some. Historically, natural cycles cause variability in fish populations, but invasive species have caused the most significant changes to local fish populations. Whether climate change will affect Great Lake fisheries for better or worse is unknown.

Climate change will bring warmer water, which will affect species composition and lead to a greater introduction of exotic species. Depending on the market value of the fishes that thrive under warmer conditions, climate change will either hurt or help the fishing industry. Changes in water clarity also will affect fishing practices and catch levels, if nets become more visible at shallower levels. Improved water quality from zebra mussels has allowed whitefish to detect gill nets and swim deeper in order to avoid them. Because gill nets can go no deeper than 150 to 180 feet, problems could result if climate change produces a significant further increase in water clarity. In addition, greater water clarity allows predatory birds, such as cormorants, to hunt more fish and create added competition for fishermen. Other possible changes include lower lake levels that could lead to dredging in order to maintain the use of existing docks, and shifts in prevailing winds, which could affect fishing dramatically (with more easterly winds resulting in decreased fish catches and more westerly winds resulting in increased catches). On a positive note, reduced ice cover would facilitate fishing during the winter months. How the fishing industry will change and adapt under climate change remains to be seen.

Water quality and public access: Who’s watching the waterfront?
Eric Skindzelewski, President, Lake Shore Fishermen Sports Club

The Lake Shore Fisherman’s Sports Club has worked to achieve greater public access to lake shores and clean water for about 20 years. After confronting countless barriers and eventually paying high costs for legal representation without achieving results, the club decided to embark on a major outreach campaign to win public support. The club conducted workshops and educational seminars about public access, and conducted a successful campaign to inform government at various local, state, and national levels about the need for greater public access.

After 15-20 years of this outreach, the club prevailed. A state park was established and a boardwalk constructed; public access to piers and many lakefronts was awarded; children now are allowed to ice fish in county parks; and laws were passed to ensure that there are enough fish for the public to enjoy. Other notable accomplishments of the club include improvement of boat ramps and the provision of fishing pole holders and other amenities for the public, all paid for by the local government and donations from the public. Today, the club supplies videos on water safety to children and holds educational workshops in parks twice each year, fostering the enjoyment and care of water resources and the natural environment. Approximately 80,000 children and 40,000 elderly have attended the seminars.

What are the potential impacts of climate change on fresh water recreational fishing opportunities in the United States?
Susan Herrod Julius, USEPA

As greenhouse gases accumulate in the atmosphere and alter the climate, rising temperatures, changes in precipitation, and changes in other weather patterns are likely to affect ecological processes and ecosystem services. Among the systems and organisms affected may be a variety of fish species. The potential negative impacts on fish species and the popularity of recreational fishing led to an EPA-sponsored research project that examined the potential impacts of climate change on fish species survival and the consequent impacts on future recreational fishing opportunities. The study modeled the effect of temperature changes on habitat conditions in various geographic areas and the subsequent effect on the ranges of fish species. An economic model in the second step of the analysis projected changes in recreational fishing behavior based on measures of habitat changes and fishes estimated by the thermal model. Results were expressed as changes in total days spent fishing for each class of fish (cold, warm/cool, rough). The annual damages represented by lost fishing opportunities were calculated using values per day spent fishing for each class of fish developed from a series of recreational fishing valuation studies.

The modeling results showed that 21 of 48 states would lose at least one of the 31 fish species studied in the analysis. More than 75 percent of the scenarios that were modeled resulted in economic costs associated with climate change being significantly larger than benefits (on the order of about $239 million in losses per year), indicating that the costs will likely outweigh any benefits for recreational fishing. Using very conservative assumptions, cold water fishing losses were estimated at $1.3 to 3 billion per year (1993 dollars). This modeling exercise is a first attempt to characterize and assess the economic impacts of climate change in the Great Lakes region and provides a sense of the magnitude of the problem.

Question and Answer Panel Discussion: Afternoon Session

***Question 1:* Jonathan Higgins, The Nature Conservancy**

In the analysis of water and air temperatures that fed into Susan's work on the potential economic impacts of climate change on fresh water recreational fishing opportunities in the U.S., were warm-versus cold-dominated systems split out, or was a mean value used?

Response: Susan Julius, U.S. EPA

A mean value was used in the analysis.

***Question 2:* Jonathan Higgins, The Nature Conservancy**

I'm wondering if groundwater-dominated systems may buffer against climate change impacts to some extent, given their colder, more stable water. Are our predictions about the decimation of cold-water species in groundwater-dominated streams really as extreme as the projections discussed today?

Response: Art Brooks, University of Wisconsin-Milwaukee

Groundwater follows mean annual temperatures, so it would still be affected, though there may be a greater lag time in its response to ambient temperatures.

Response: John Magnuson, University of Wisconsin-Madison

Modeling of groundwater-fed streams under the scenario of a doubling of carbon dioxide has been done, and, though they have not indicated 100 percent loss like the work presented today, they did end up with considerable shortening of stream miles that are cold water. I also wonder if any of the streams monitored by the USGS are actually trout streams.

Response: Susan Julius, U.S. EPA

These were just a sample of streams, they were not discerned—so some may be trout streams.

Response: John Lehman, University of Michigan

There is also a confounding influence of stream hydrograph performance as a function of whether or not fish species are groundwater fed or surface water fed. That is something dealt with in an assessment by David Allen, at the University of Michigan, where some attention was paid to the issue of cold water fish in groundwater-dominated systems. That may be a source worth consulting.

***Question 3:* Jonathan Higgins, The Nature Conservancy**

I have seen that assessment and it really does not address the question of to what extent the hydrologic performance will affect species. I am interested in the conservation angle, in terms of what potential degree of impacts will result for different types of systems, and what spatial configurations we will have to take into account when spending conservation dollars. Are there certain streams systems that might naturally be buffered from climate change, based on water sources?

Response: John Lehman, University of Michigan

The final steady state solution is still going to be towards warmer groundwater temperatures, though it may take a longer time to get there. If it is a variance issue, you might be able to see the buffering work, which is an excellent topic for further analysis.

Question 4**: **Art Brooks, University of Wisconsin-Milwaukee

In Susan's economic analysis on recreational fishing, five of the species considered were exotic species. How did that fit into your economic calculations, when it came to stocking those fish?

Response: Susan Julius, U.S. EPA

The numbers were not costs of stocking. Essentially, they are estimates of what a person is willing to pay to spend a day fishing for that type of fish. We did not look at any issues concerning the maintenance of fish populations. The economic analysis looks at what people value the most, without differentiating between native and exotic or what will survive best.

Question 5**: **Art Brooks, University of Wisconsin-Milwaukee

Looking into the future, what might the costs be of maintaining suitable fisheries, of re-stocking systems, or stocking something else?

Response: Susan Julius, U.S. EPA

We did not look at how costs might change in terms of stocking, or any issues related to maintaining fish populations. As for the costs of maintaining fisheries, this analysis did not assess that. That would be an excellent to look at further. As it is now, they introduce new stocks of species into systems during the summer months, for the sole purpose of fishing, and then the fish die by the end of the season. One would presume that they will probably adapt their stocking practices; I do not know.

Question 6**: **Peter Sousounis, University of Michigan

Is it possible to take some aspects of algorithms used for the economic assessment on fishing and apply them to other industries? Are there some general thought processes developed that can be applied to future analyses for other industries?

Response: Susan Julius, U.S. EPA

Our economic models were specifically developed for fisheries, but the general thought processes used could apply.

Response: John Furlow, U.S. EPA

General methodologies for conducting economic assessments are being developed by a group at Colorado State University. Focused on gateway communities bordering the Rocky Mountain National Park, they are looking at what it is that brings tourists into the area, at what the economic benefits are to the community, and then assessing how the local economy will be affected if any changes occur to the natural resources base. For example, what will the economic impacts be if there are no more buffalo or elk? The study looks at willingness to pay, travel costs, etc., and this type of economic analysis—though not necessarily widely respected—is fairly well developed.

Response: Susan Julius, U.S. EPA

Another thing to consider is that even if you argue with the numbers of the economic analysis, it offers at least one attempt to estimate what the impacts will be, to get a sense of the magnitude of the problem. Before conducting the analysis, we first looked at all the activities that can be measured in terms of market or non-market data, and then checked if we had enough economic data to connect changes in activities with economic impacts. Recreational fishing is one of the few categories for which we had enough data linking climate to changes in species of interest, and then to the economic value of those changes.

Comment: ***Michelle DePhilip, The Nature Conservancy***

To add to that, an economic analysis was conducted by the University of Illinois in Chicago on the economic value of the natural resources in southern Lake Michigan. The analysis estimated the individual value of different fish species and then calculated what people would pay for the natural resources of the area.

Question 7: ***Mike Rau, Wisconsin Gas Water Services***

Has there been a study done on warming, taking into account possible population trends that may change in the Great Lakes region, given that people like to live in places that are warm and by water? For example, Florida is a prime destination for people. Has any study looked at the economic impacts of these types of future population trends in the area?

Response: Susan Julius, U.S. EPA

That is a really good question. I do not believe that that's been done yet, but there are ways for that to be studied, using economic modeling approaches that look at all the variables that determine where people live and why—and it is very much weather-related

Response: Peter Sousounis, University of Michigan

It is indeed a very interesting question. At the start of our assessment, we were provided with socioeconomic and population data projections for 2030 and 2050. However, those population projections do not account for the interaction between variations in population trends and a warming climate. They were straight, independent population projections.

Question 8: ***Art Brooks, University of Wisconsin-Milwaukee***

The Chicago workshop in March was concerned more with water levels, and the shipping industry had figures showing that for every inch that the lake drops, they must offload "X" hundred tons of iron ore from ships. In other words, they directly equated lake levels with economic impacts. Have water producers looked at increased pumping costs and the use of more effective chemical reactions to clean water under certain processes? Do you keep track of the pumps as they are running to monitor the amount of horsepower used to draw in water?

Response: Roger Johnson, West Shore Water Producers Association

For some of the lakes, the horsepower must be increased to get the volume that they want. Often, what happens is that the level over the intakes is less, decreasing the amount of water that can be taken in. Therefore, it costs a lot more to increase the horsepower, plus it also reduces the volume of water that they can take into the plant.

***Question 9:* Art Brooks, University of Wisconsin-Milwaukee**

Do you keep track of the pumps as they are running to monitor the horsepower used to draw water in? If so, do you see a difference in kilowatts consumed in 1986, when water levels were at an all-time record high, compared to now, when they are at an all-time record low?

Response: Roger Johnson, West Shore Water Producers Association

I do keep track of pumping, because it is one of our highest costs. The last three years, we have had a very wet spring. At my plant, which is different than those in the Chicago area, the pumps are at the bottom of the lake. We monitor the kilowatt-hours per million gallons of production, and that hasn't changed over the years.

***Questions 10:* Jeanne Bisanz, University of Michigan**

Do you estimate demand? In the short and/or long-term?

Response: Roger Johnson, West Shore Water Producers Association

Yes, we do estimate demand—usually broken down by month and by temperature. As the temperature increases, people's use of water increases. April, May, and June are the highest water-use months, when everyone waters their lawn. By July and August, people are less excited about watering lawns, so water use decreases. We are really dependent on forecasts, and where we are going to be in terms of our production of water use. We estimate over a five-year time frame, though it is hard to predict. For example, we more or less base our production on population projections, based on average use of water per day, per person, as well as industrial usage. But this can be difficult to predict with any degree of accuracy, if a big water user comes into the area or moves out.

***Questions 11*: Jeanne Bisanz, University of Michigan**

Do the West Shore Water Producers supply any farms with water?

Response: Roger Johnson, West Shore Water Producers Association

No, we don't supply farms. We only supply residential and industry uses.

***Questions 12:* Lon Couillard, Milwaukee Water Works**

If global warming warms summer climate in the Great Lakes region, we will likely be reluctant to switch our plants to desert plants. Could that increase our irrigation demands and affect our water consumption?

Response: John Magnuson, University of Wisconsin-Madison

Even the people in Phoenix who have desert gardens, water them at the same rate that they would grass!

***Question 13:* John Lehman, University of Michigan**

I***t seems to me that there were concerns about days with high turbidity and high contamination related to a weather event, as well as about taste and odor events related to algal production of particular kinds of species. If there were a way to get a handle on the frequency and probability of*** *those kinds of events in the future, would that be useful to you? Or is that outside of the management and planning sphere that you engage in?*

***Response:** Roger Johnson, West Shore Water Producers Association*

That would certainly be useful. As algal blooms increase, so too do taste and odor problems, which require expensive changes to systems. Different methods used to rid water of bad tastes and odors, such as granular-activated carbon and powder-activated carbon, cost about $0.60 to $0.80 per pound. The more chemicals we must use, the higher are our costs, and the more it ends up costing the consumer.

Question 14: *John Ferland, U.S.EPA*

Is there any correlation between changes in temperature to changes in algal blooms and use of carbon or ozone treatments to rid water of bad tastes and odor?

Response: Roger Johnson, West Shore Water Producers Association

We can run tests that measure odor-free water against raw water, and based on how high the threshold odor number is, we can determine how many pounds of carbon will be needed to clean it. We can also run tests to determine the concentration of bluegreen algae, which help us predict changes in the taste and odor of water and in what it will cost us per million gallons produced.

Question 15: *John Ferland, U.S.EPA*

Have your costs to rid water of bad tastes and odors over the last years increased at all?

Response: Roger Johnson, West Shore Water Producers Association

Our carbon costs have increased over the last three years.

Question 16: *John Ferland, U.S.EPA*

Is the cost increase because of a change in use of carbon or because of a change in the cost of carbon?

Response: Roger Johnson, West Shore Water Producers Association

The cost increase for carbon is due to the increased odor in water that costs more to clean.

Comment: *Art Brooks, University of Wisconsin-Milwaukee*

A comment for people who work on the water all of the time: some of the best records that we have of long-term changes in the lakes are from water producers. For the last 75 years, they have collected this data, counting phytoplankton every day, until the zebra mussels appeared and [then the water producers] unfortunately stopped. I urge you all not to stop looking at shifts in algal populations! It may prove to be very useful to you at some time in the future.

Question 17: *Brent Lofgren, Great Lakes Environmental Research Laboratory, NOAA*

I have a question for Art Brooks regarding spring phytoplankton blooms being triggered by light availability. In a worldwide conference I participated in a short while ago, they seemed to indicate that phytoplankton blooms are triggered by temperature thresholds, not light.

Response: Art Brooks, University of Wisconsin-Milwaukee

In Lake Michigan, algal blooms begin when temperatures are still 4 degrees or less, so my opinion is that they are triggered by light. Maybe in other lakes they may be triggered by nutrients or temperatures; I don't know.

Response: John Lehman, University of Michigan

Certainly, the growth trigger will vary by type of algae. Diatoms, which are very successful in the Great Lakes—particularly in Lake Michigan, are extremely capable of growing in cold temperatures at low average light intensities. About 50 years ago, it was demonstrated that even without cold temperatures, light can cause full blooms in some types of algae.

Question 18: ***John Lehman, University of Michigan***

The presentation on commercial fishing illustrated a really nice interface between some knowledge of natural history and environmental issues. Is there not some aspects of the cormorants' biology and feeding biology or production that we really need to know more about in terms of their future impact on future fishing?

Response: Ted Eggebraaten, Wisconsin Commercial Fishing Association, Door County Chapter

Certainly, there is a lot more that we need to know about. But as a gill netter, I rely on my net being invisible. With algal blooms, our production goes way down, because by the end of February or early March, algae rolls along the bottom the lake and gets stuck on our nets, making the nets visible to fish, so they swim around them. I don't know if a change in algal species will affect us, since there is much variability among species, with some getting caught in nets more than others, and some being more visible than others. If one species of algae finds something it really likes (like the zebra mussels), and then really blooms, then the impacts on the commercial fishing industry may be big.

Question 19: ***John Higgins, The Nature Conservancy***

Are commercial fishermen looking for potential alternative methods for fishing? For example, are you looking at other large lake fisheries that might have some of the same conditions that our lakes may have in the future? Do you have any idea of what those techniques might be and how they would affect you?

Response: Ted Eggebraaten, Wisconsin Commercial Fishing Association, Door County Chapter

Commercial fishing is constantly evolving and progressing. We will always use new materials and try new methods. I experiment with at least a half dozen new techniques over the course of the year. Fishing and fishermen are very adaptable, we constantly try new things, which is what has kept us alive in many ways. It could be that our production times may be compressed; for example, maybe we will fish only during spawning season or at other opportune times of the year.

Question 20: ***Jeanne Bisanz, University of Michigan***

How many commercial fishermen would you say are at Lake Michigan?

Response: Ted Eggebraaten, Wisconsin Commercial Fishing Association, Door County Chapter

There are probably about 90 license holders in Wisconsin, most of whom are concentrated in groups. So, in Wisconsin, there are maybe about 40 to 60 operations of commercial fishing. Michigan probably has about the same number, and there are a couple in Illinois also.

***Question 21:* Patty Glick, National Wildlife Federation**

This question is for Harvey Bootsma: Do you have any ideas of what the future impacts from climate change will be for the African Great Lakes? Are there any projections for them?

Response: Harvey Bootsma, University of Wisconsin-Milwaukee

There is some evidence of climate change in the African Great Lakes, though not to the same extent or magnitude as that seen in temperate areas. In looking at Lake Tanganika and Lake Malawi, we know that a small change in temperature will result in large changes in thermodynamics and stratification. Lake Tanganika is only about 1 degree warmer than Lake Malawi, but its thermocline is about 100 meters, whereas the thermocline is about 200 meters in Lake Malawi.

Response: John Magnuson, University of Wisconsin-Madison

With increased stability of the thermocline, one researcher recently found that there was less mixing. There was some evidence that the deep waters were warming up from geothermal heat.

***Question 22:* Patty Glick, National Wildlife Federation**

Are the African Great Lakes also relied upon as fishing resources as the Great Lakes are here?

Response: Harvey Bootsma, University of Wisconsin-Milwaukee

Yes. While angling is not very popular in Africa, fishing for food is. Lake Malawi has thousands, possibly tens of thousands, of fishing operations on it. The emphasis is a little different than here, with less emphasis on commercial fishing and much more so on subsistence. Seventy-five percent of the protein from local peoples' diets is from fish. The economic factor is greater in Lake Victoria, though, as it is the source of one-quarter of the freshwater fish from all of Africa, much of which is imported to Europe and elsewhere.

***Question 23:* Patty Glick, National Wildlife Federation**

Will commercial fishing operations in Africa be able to adapt to climate change the way the commercial industry here will? Or will they be more adversely affected?

Response: Harvey Bootsma, University of Wisconsin-Milwaukee

It depends on the change. If it was a fairly simple change, like a change in gear type, then that may be okay. But tradition is just as important as practicality over there, so tradition may slow the process of change in fishing practices.

***Question 24:* Art Brooks, University of Wisconsin-Milwaukee**

We have representatives of two energy suppliers here, and I'm wondering if they have any ideas about what the economic impacts of warmer lake temperatures will be in terms of less gas or electricity sold for heating water versus the additional costs of pumping.

Response: David Michaud, Wisconsin Electric Power Co.

In terms of water temperature, clearly there is an impact because most utilities with operations on the lake use a very high volume cooling. The efficiency cycle in power plants is linked directly to water temperatures. Systems have been designed based on expected variabilities in water temperatures, keeping historical high and low temperatures in mind. But if temperatures change significantly, or even by a few degrees Fahrenheit, it can drastically affect the efficiency of the steam cycle. As the water warms at nuclear plants on a per unit basis, you can lose anywhere between 15 and 30 megawatts of output on a given day, just because of a few degrees Fahrenheit increase in temperatures. And engineers know this. Yet, if this were to occur on a permanent basis, cumulatively around the lake, the net loss would be hundreds of megawatts for plants using this kind of cooling. You would basically have to replace that generation with something else—independent of low flow and population increases. So, it is an issue.

Low water levels may also cause problems. If water levels fall below a certain point, all of a sudden large circulating water pumps will be in-taking air or cavitating—which would have a monstrous effect on efficiency. Those types of things were not thought about in 1986, when people were concerned about preventing inundation. Now, we're worried about the opposite.

In the water levels game, there are winners and losers. On the positive side, you get less erosion and less flooding. On the negative side, dredging and other factors can be big money items, not to mention the environmental effects.

In terms of planning for demand, you plan by population projections. But if temperature increase is added to the mix, in addition to increased demand from consumption—from air-conditioning, etc.—things get difficult. In the case of plants that use cooling towers, efficiency cycles will take a hit from higher ambient temperatures, and those lost megawatts will have to be produced in some other way. This would affect the planning cycle for providing essential energy. As you can see, it is not just the energy industry affecting climate, but climate change will produce positive feedbacks that exacerbate the problem.

Response: Mike Rau, Wisconsin Gas Water Services

On a smaller scale, warmer lake temperatures will decrease energy use for water heaters.

Question 25: John Furlow, U.S. EPA

Do the electric utilities use the lakes to vent hot water after you cycle it through? Do you worry about there being regulations on thermal pollution to prevent you from using the lakes to vent hot water?

Response: David Michaud, Wisconsin Electric Power Co.

In the 1970s, people were concerned about the cumulative effect of venting hot water, so the utilities did a large number of studies around the lake to see if it would heat the near-shore area in any significant way. First of all, nuclear plants generally warm water more than coal plants. But, after looking at the plumes or spheres of influence in an area of 3 square miles, the envelope of this warmwater area was about 1 degree Celsius above ambient temperatures—and fluctuated throughout the day. On a surface area basis, the thermal enrichment was not significant, considering that Lake Michigan is about 22,000 square miles, so people decided that there are more important issues on which to focus their concern. Quite frankly, any regulations on this might force people to go to closed-cycle cooling, where water is taken into cooling towers, evaporated, and then water leaves the basin, all of which would cause even more problems.

Question 26: ***John Magnuson, University of Wisconsin-Madison***

But this mixing zone issue could be a bigger problem in some of the older plants on small rivers?

Response: David Michaud, Wisconsin Electric Power Co.

Absolutely. For utilities on the Great Lakes, thermal enrichment is probably inconsequential, but that is not the case on small rivers, where [the] area of impaction can occupy the entire cross-section of a river. Thermal blockage of migratory patterns of fish can occur in these cases. Fortunately, there are not many power plants built on limited resources like that, and are not likely to be in the future, either, for these reasons.

Comment: Harvey Bootsma, University of Wisconsin-Milwaukee

The City of Toronto has actually looked at pumping hypolimnetic water (water that lies below the thermocline, is noncirculating and remains perpetually cold) for cooling of the city, and there was some concern that that would heat Lake Ontario. So, physical modeling was done to determine if this would be the case, and it was found that it would not have a measurable effect on the thermal structure of the lake.

Question 27: ***John Higgins, The Nature Conservancy***

I have a question about water withdrawn from lakes. Cities like Chicago, for example, take a lot of water out of the lake, process it, and it eventually goes down into the river drainage. While I do not think that this volume of water is actually that large, is this going to be an issue for the public? Will there be public concern about water being withdrawn from the lake and then being put back in, if we are expecting lower water levels?

Response: John Lehman, University of Michigan

I actually heard the flip side of that in the late 1960s, when the City of Chicago proposed to volunteer pumping of its secondary effluent sewage into Lake Michigan, in order to compensate for lower lake levels. The response was of course no, since the volume is not significant enough to increase water levels and, of course, the added nutrients in near-shore areas would be adverse.

Question 28: ***John Higgins, The Nature Conservancy***

But I am wondering about what the public's perception is of this issue. Do you they think about it? Are they concerned more about water volume than they are about water quality?

Response: Ted Eggebraaten, Wisconsin Commercial Fishing Association, Door County Chapter

I had someone ask me something about that a few weeks ago. They said that the lake is low because the Chicago River is draining Lake Michigan. I do not know for sure, but I'm guessing that substantially more water is lost to evaporation than to the Chicago River. But, I think it may be a perception of the public.

Response: Val Klump, UW-Milwaukee Great Lakes

There are in fact many diversions into and out of the Great Lakes, with greater diversions actually going into them (with large diversions from Canada into Lake Superior). But every time low or high

lake levels occur, the public thinks that there is a plug somewhere in the system that can be pulled or stopped, but the fact is: there is not.

***Comment:** Rochelle Sturtevant, GLERL*

I would agree that there is definitely a public misperception about a "plug." You do hear Chicago mentioned, as well as hydropower on Niagara as being a drain on lake levels.

Response: John Lehman, University of Michigan

But that is a point to which science can speak. It is only a question of whether or not the public is listening.

Comment: John Higgins, The Nature Conservancy

But that is an important issue—the translation of science to the public is often more important than the scientific realities themselves, since the public determines how money is spent and what policies are formed. Public opinion is what drives how environmental problems are dealt with, and I get concerned when people get crazy ideas about lake levels, what you can do with water, and who is using what water. They think that users of waters (power plants, etc.) have huge impacts on lake levels without thinking about what it would mean to re-engineer some of these systems.

Comment: John Magnuson, University of Wisconsin-Madison

One global change impact that is occurring, due to increased flooding, is better water management. This has and will force the public to key onto the issue and improve behavior.

Question 29: Art Brooks, University of Wisconsin-Milwaukee

John Jansen, as an academic and employee of the Department of Natural Resources, do you have any take on what our lake will do?

Response: John Jansen, Department of Natural Resources

I cannot even imagine what the commercial fisheries will be fishing for. Right now, it is mostly coldwater species, which could be lost even if the lake does not go anoxic in the bottom, just because of changes in trophic dynamics that were discussed earlier. If the lake stratifies for too long and primary production does not settle to deep parts of the lake, then we will not have the coldwater fish that the commercial fishermen are harvesting. If yellow perchstone come back, which is a whole other issue, I have no idea what the commercial fishing industry will fish for—probably some exotic species that we do not have in the lake yet.