DEALING WITH CHANGE In his book *Collapse: How Societies Choose to Fail or Succeed*, Jared Diamond describes four common ways that societies and even entire civilizations have collapsed in the past:

- They fail to anticipate a problem before it arises.
- When the problem arises, they fail to perceive it.
- After they perceive the problem, they fail to try to solve it.
- When they try to solve it, they do not succeed.

Each of these has parallels to the ways that many governments and individuals around the world have been responding to the problems posed by climate change.

SEEING CLIMATE CHANGE IN WATER

Based on a presentation by John Magnuson, Emeritus Professor of Zoology and Limnology, University of Wisconsin-Madison, Member of the Intergovernmental Panel on Climate Change

Lake Mendota: Jeff Miller, UW-Madison University Communications

A MINER'S CANARY Every fall, the Center for Limnology (lake science) at UW-Madison posts a graph of the date each winter when Lake Mendota has frozen over in the past, and everyone at the center gets a chance to guess when it will occur in the coming winter. Few even came close last winter (2006-07), when the lake did not freeze over until January 20—the second latest date in the center's 150 years of records.

The center's ice-on, ice-off records go back to the 1850s, when they were started by early settlers and Madison residents because the lake's ice was important to them—it was harvested for local use in early "icebox" refrigerators, and after the railroads arrived in the late 1800s, lake ice became a commodity that was shipped as far away as New Orleans.

This lake ice record shows that in the 1850s Lake Mendota was frozen over for about four months each winter. By the early 2000s, however, the ice cover lasted an average of just three months a year. In other words, the amount of time the lake is ice-covered is nearly 25 percent less than it was 150 years ago. If this trend continues, the time will come when Lake Mendota will be ice-free all winter long.

Canaries were once carried into coalmines as an early warning of the presence of poisonous gases: because of their small size, they would succumb to any gas in the mine long before a human was affected. In this sense, the shrinking duration of Lake Mendota's ice cover is like a woozy miner's canary, because if the massive glaciers covering Greenland and Antarctica experience a similar 25 percent reduction in ice, the resulting rise in ocean water levels will flood many coastal areas of the United States, creating millions of climate change refugees from New York City, San Francisco, southern Florida and the Gulf Coast.

People have a tendency to remember most the recent past, which makes it hard for us to recognize and deal with something as gradual as climate change. Without a long-term written record or some mental reference, we lack the context to notice what's changed and end up living in what Magnuson called "the invisible present."

A related concept is "the invisible place," where we tend to think of what is happening to Lake Mendota, for example, as something that is happening only in Madison, so we may fail to see it as something that's occurring throughout our state and perhaps around the world.

MELTING ICE RECORDS A few years ago, Magnuson began looking at the long-term ice cover records for five other Wisconsin lakes and found the same trend of later ice-on and earlier ice-off dates. He and his colleagues then looked at ice records from around the world and found almost identi-

cal trends throughout the Northern Hemisphere—in Canada's Northwest Territory, Finland, central Russia and Japan.

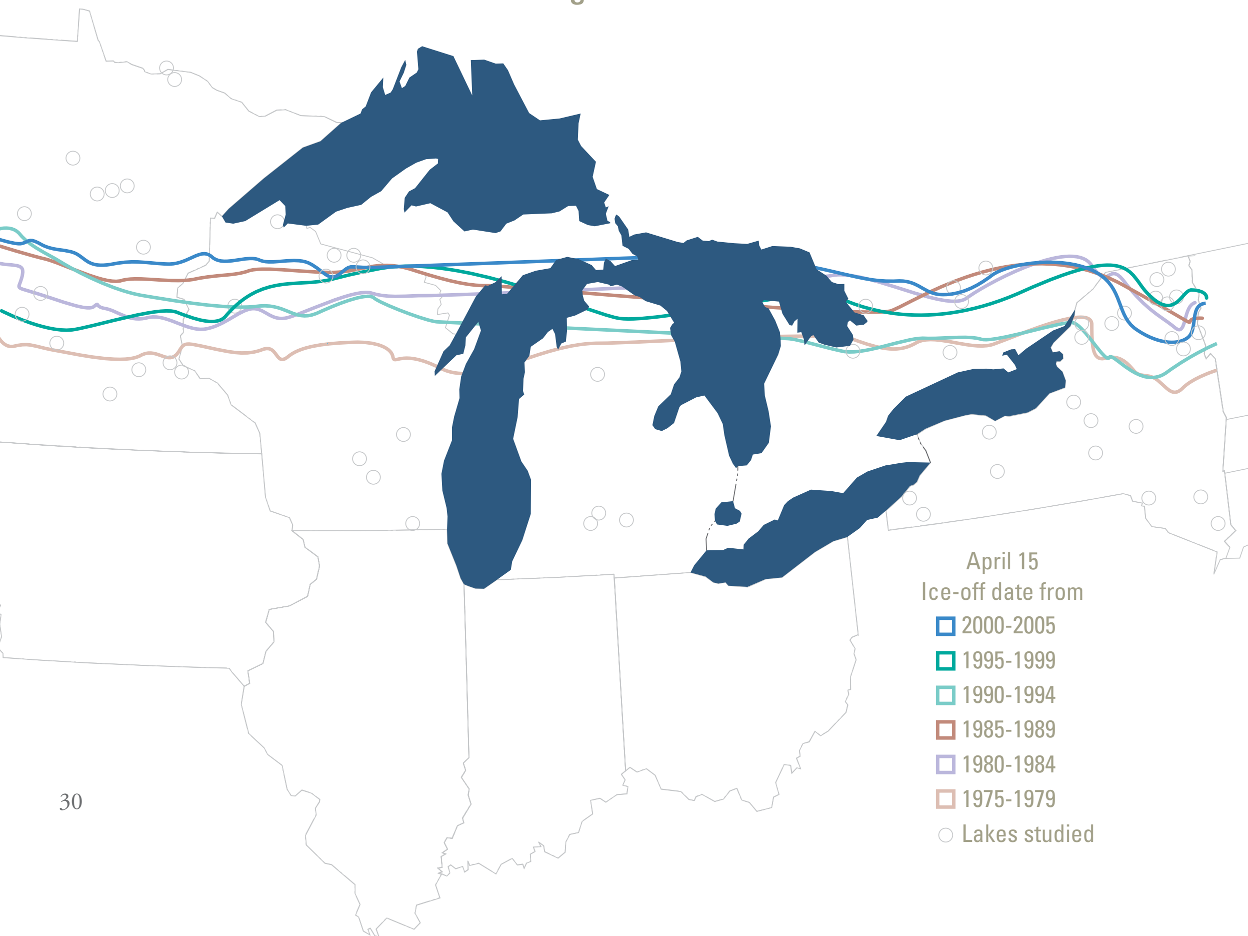
Priests at a Shinto shrine in Suwa Ko, Japan, maintain a record of ice on Lake Suwa that goes back nearly 600 years. From 1443 to 1825, these records show that the length of time the lake was ice-covered was getting about one day shorter per century; from 1800 through 1993, however, the duration of ice cover was shrinking at a rate of 19 days per century—identical to the rate measured at Lake Mendota.

When the change in average winter air temperature in the Northern Hemisphere over the last 150 years is compared with the average duration of ice cover on 17 lakes around the world during that time, the correlation between the rising air temperature and shorter periods of ice cover is clear. It also shows the rise in temperature and rate of decline in ice cover has accelerated since 1975.

In Wisconsin, the air temperature record also shows an accelerating rate of increase. From 1895 until about 1975, the temperature was increasing at a rate of 0.04 degrees Fahrenheit per decade; from 1975 through 2005 it was increasing at an average rate of 0.7 degrees per decade. During the same 30-year period, the average ice-off dates for Wisconsin lakes were arriving 3.3 days earlier each decade. Ice-on dates are arriving the same number of days later, so Wisconsin lakes are presently losing about a week of ice cover every 10 years.

Lakes in northern Wisconsin near Ashland and in Vilas County are losing an average of five to six days of ice cover per decade, while lakes in

Northwward migration of warmer climate



southern Wisconsin—like Lake Geneva, Lake Mendota and Big Green Lake—are losing an average of nine days of ice cover each decade. That's an extremely rapid rate of change.

GIVING MEANING TO NUMBERS Numbers and statistical statements like "average summer temperatures eight to 18 degrees warmer" and "extreme rainfall events 50-100 percent more common" generally don't mean a lot to most people. In *Confronting Climate Change in the Great Lakes Region*, a report published in 2003 by the Ecological Society of America and the Union of Concerned Scientists, the coauthors (including Magnuson) decided to use temperature and precipitation gradient maps of the present climate of the United States as a way of conveying more vividly what future climate projections mean for Wisconsin and other Great Lakes states.

This exercise showed that by 2030 summers in Wisconsin would be more like those in Illinois today, and by 2095 our summers would closely resemble those of present-day Arkansas and our winters would be like Iowa's. For Illinoians, summers in the future are likely to be like living in eastern Texas today.

Minnesota offers a particularly dramatic example of climate change. By the 2090s, summer temperatures and precipitation in Minnesota are expected to resemble the hot, relatively dry summers of present-day Kansas. This poses a serious threat to many species of Minnesota's native plants, wildlife, trees and fish, which aren't found in Kansas because the climate simply isn't suitable for them to exist there.

Empirical evidence clearly shows this northward migration of warmer climate is already occurring. A line drawn on a map connecting Midwestern lakes with April 15 ice-off dates in 1975 would run from Minneapolis through Wausau to Grand Traverse Bay on Michigan's Lower Peninsula. By 2004, that same line was running from Mille Lacs, Minn., through Hurley-Ironwood and across Michigan's Upper Peninsula.

COLD FISH, NO FISH / WARM FISH, MORE FISH Fishes are often classified according to whether they prefer warm water, cool water or cold water. The white sucker is an example of a cool-water species of fish. Its thermal cousins include walleye, northern pike and yellow perch, three of Wisconsin's most popular game fish. A study of where white suckers exist today and where they might persist 50 years from now in a much warmer United States showed a large reduction in the number of areas where this fish and, by inference, its cool-water cousins could survive—especially at lower elevations in states south of Wisconsin, but also in many waters here.

The story is a little different for lake trout and salmon in Lake Michigan, Lake Superior and Lake Huron, where some climate models indicate the depth and area of water within the optimum temperature range for these cold-water salmonids actually may increase. The Great Lakes will probably continue to serve as a southern refuge for trout, salmon and other cold-water fishes well into the next century.

However, the projected increase in temperatures accompanying the expected doubling of carbon dioxide levels during this century will move the thermal habitat boundaries for fish about 300 miles north of where they are today. This could exterminate cold- and cool-water fish populations south of the new thermal habitat boundaries, and invasions by new warmer-water species of fish may wipe out other resident species. Because they are more vulnerable to warming, streams and shallow ponds will experience greater changes and losses in fish populations than deep lakes.

EFFECTS ON THE WATER CYCLE Rising temperatures will accelerate the global water cycle. This means more droughts, more storms and more floods. Over the last 100 years, Wisconsin's average daily precipitation did not change much. Over the last 30 years, however, we've been getting an average of three more inches of rain annually than we did during the previous 30 years.

Over next 100 years, our winter precipitation is expected to increase by 30 percent while summer precipitation will decrease slightly under a scenario of continued high greenhouse gas emissions that triple the atmospheric concentration of carbon dioxide and cause a double-digit rise in average temperatures. Under a reduced emissions scenario (atmospheric carbon dioxide levels double before they start to decline), winter precipitation eventually returns to its long-term average and summer precipitation tends to increase slightly.

However, one thing that shows a marked increase under either scenario is a dramatic increase in both 24-hour and seven-day heavy rainfall events. It isn't until the last couple of decades of the century that the frequency of both events starts to drop under the low-emissions scenario. This leads to more stormwater runoff, more erosion and floods, which can have dramatic effects on the chemistry, physics and biology of our lakes, rivers and streams.

Tomato leaf stoma: Dartmouth College

EFFECTS ON GREAT LAKES WATER LEVELS The present water levels of the three upper Great Lakes—Superior, Huron and Michigan—are running near their all-time record low levels. Lake Michigan has more than 100 years of measured water levels, yet this record shows no definite trend either up or down, so it's difficult to attribute the lake's present low water levels to climate change.

Lake Michigan's water level has oscillated by as much as six feet over the last 100 years. One climate model says the lake's mean water level will rise 18 inches above its historic average; another says it will be five feet lower. Whichever is the case, future water level oscillations will occur around that.

Just two natural variables really control Great Lakes water levels: the amount of precipitation and the rate of evaporation. The effect of human water consumption and diversions can be measured in inches. Warmer average temperatures are causing less ice to form on the Great Lakes in winter, which greatly increases evaporation. Less ice cover also causes a net increase in water temperature, which delays the formation of ice cover the following winter. As a result of this "positive feedback loop," Lake Superior is warming up at a faster rate than is the air above it.

Increasingly warmer air temperatures and warmer water temperatures mean much higher evaporation rates. The projected regional increase in winter precipitation notwithstanding, the weight of evidence is that Great Lakes water levels generally will get lower.

LEAVE IT TO LEAVES Another major change in the water cycle may come from the underside of leaves. Leaves take in carbon dioxide through pores on their bottom side called stomata. The hypothesis goes like this: with more carbon dioxide in the air, plants don't need to have their stomata open as much to get all the carbon dioxide that they need for photosynthesis. If their stomata aren't open as much, they don't lose as much water through evapotranspiration. Therefore, plants become more water-use efficient, and this should leave more water in the ground. Some scientists believe that this is responsible for the increase in water flow being seen in many rivers on continents throughout the world.

We are also seeing increased water flow in Wisconsin. For example, the average base flow of the Grant River near Burton—which comes from groundwater, not runoff—has shown a step increase of nearly 50 percent since 1970. Many other streams and rivers in Wisconsin show the same thing. Around the state we've seen a step increase in water levels at many groundwater wells and several seepage lakes as well. However, we're also seeing a lot of variation in base flows and lake water levels. As some lakes flood their shores, others are drying up.

Across Wisconsin, lake levels in seepage lakes, average base flow in streams, total annual flow in streams and the groundwater level in wells have all gone up since early 1970s. This could be the result of the rise in the amount and intensity of precipitation we've been getting—and perhaps partly because our trees and other plants are consuming less water due to higher concentrations of carbon dioxide in the air.

MANIFESTATIONS OF CHANGE Short-term variations in climate are simply the vagaries of weather. Long-term trends are signs of climate change. What we're seeing here in Wisconsin—rising temperatures, shrinking periods of ice cover on our lakes, and increasing amounts of rainfall—are not just variations in our weather; these are long-term trends— the local manifestation of a changing global climate.

It is important that we recognize them as such and try to anticipate the myriad problems they pose, and then act to address the causes as well as the effects of climate change.