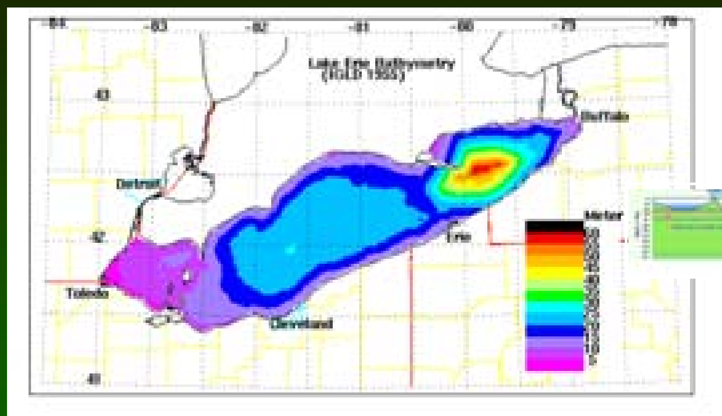
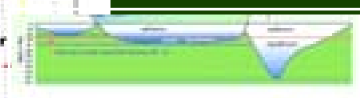
Good morning! It is a great pleasure to be here, and act as spokesperson on behalf of my coauthors, Susan Watson from Environment Canada and all the unlisted people in the audience who sent me information over the last few weeks. I especially want to thank Murray Charlton and members of the Annex 3 technical subgoup for providing access to their nearshore nutrients report.

I will be talking about Changes in the nearshore regions of Lake Erie, with an emphasis on the harmful algal blooms that have occurred there in the recent years. I would like to remind people that there will be a break out session on Nutrients and Harmful Algal Blooms this afternoon if you would like a second chance at this topic.

Nearshore Regions of Lake Erie





def. Nearshore: thermocline reaches bottom

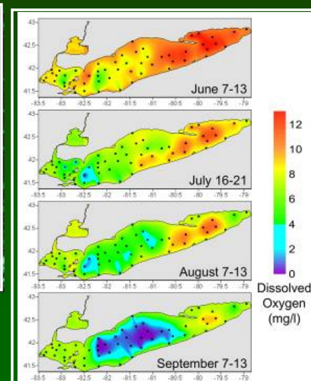
Affects: Nutrient cycling from sediments
Light transmission to the bottom
Mixing of the benthic layer

Nearshore regions are usually defined as those zones where the thermocline reaches the bottom. For Lake Erie, the thermocline is usually between 15 and 20 meters, so the nearshore zone would encompass all of the western basin. However the central basin only has an average depth of 23m, so that in some years, the thermocline may hit the bottom in this basin also. This can affect affect the movement of nutrients between the sediments and photic zone. Even in good years, this layer below the thermocline called the hypolimnion is extremely thin, making the central basin very sensitive to hypoxia or the formation of dead zones due to decomposition of algal biomass settling down from the upper waters. This is shown in the next slide

Nutrient Inputs into Lake Erie

- Target goals of Section 1 Annex 3
  - Reduce algal biomass below nuisance levels
  - Restore aerobic hypolimnetic conditions

Lake Erie Cladophora ca 1970's



NOAA 2000 data

One of the successes in Great Lakes management has been the control of eutrophication of Lake Erie through the reduction of phosphorus inputs. Two of the target goals in section 1 of Annex 3 specifically for Lake Erie were reduce the algal biomass levels in Lake Erie below nuisance levels. Many of you may remember the articles declaring Lake Erie was "dead" due to massive Cladophora blooms in the 1970s

The second goal was to reduce phosphorus so as to reduce the overall biomass in the upper waters. Decomposition of this biomass in the thin "lower" hypolimniom can consume all the oxygen in these lower waters and lead to the establishment of the Dead Zones. The right hand image shows this progress as you move from well oxygenated waters early in the season, but anoxic bottom waters late in the season as the system stratifies and the summer biomass is consumed.

Phosphorus Loads Have Decreased

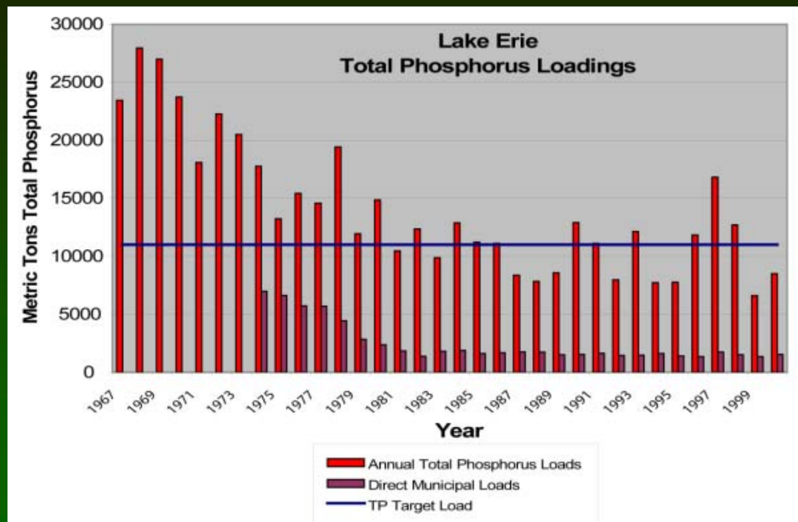
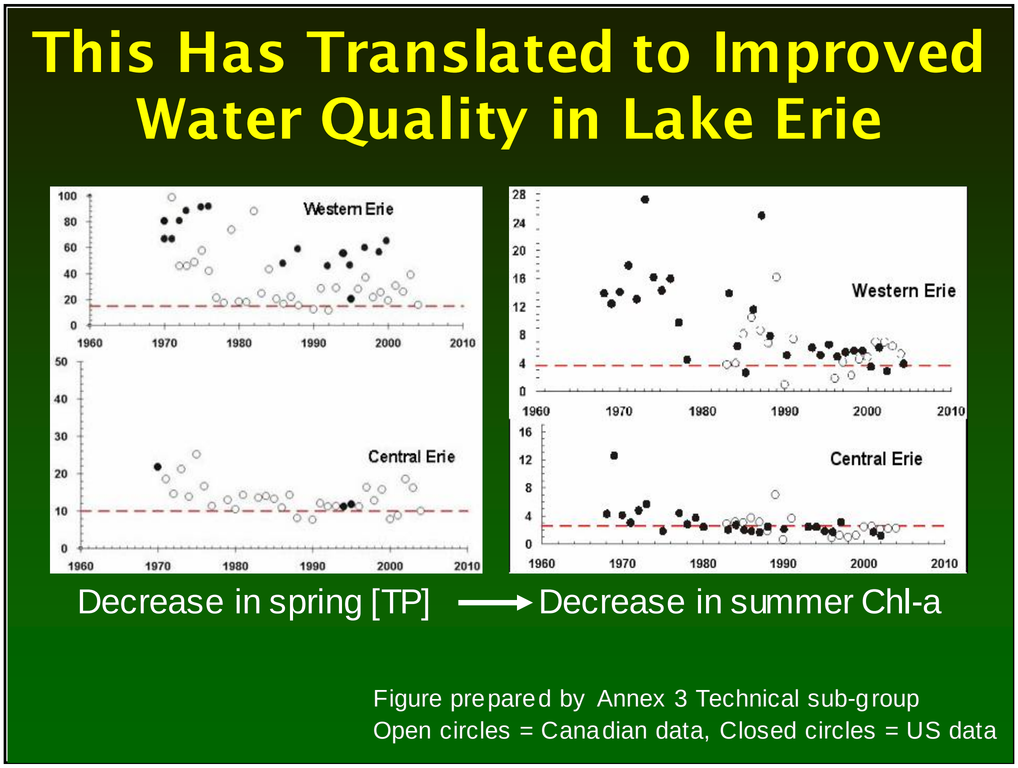


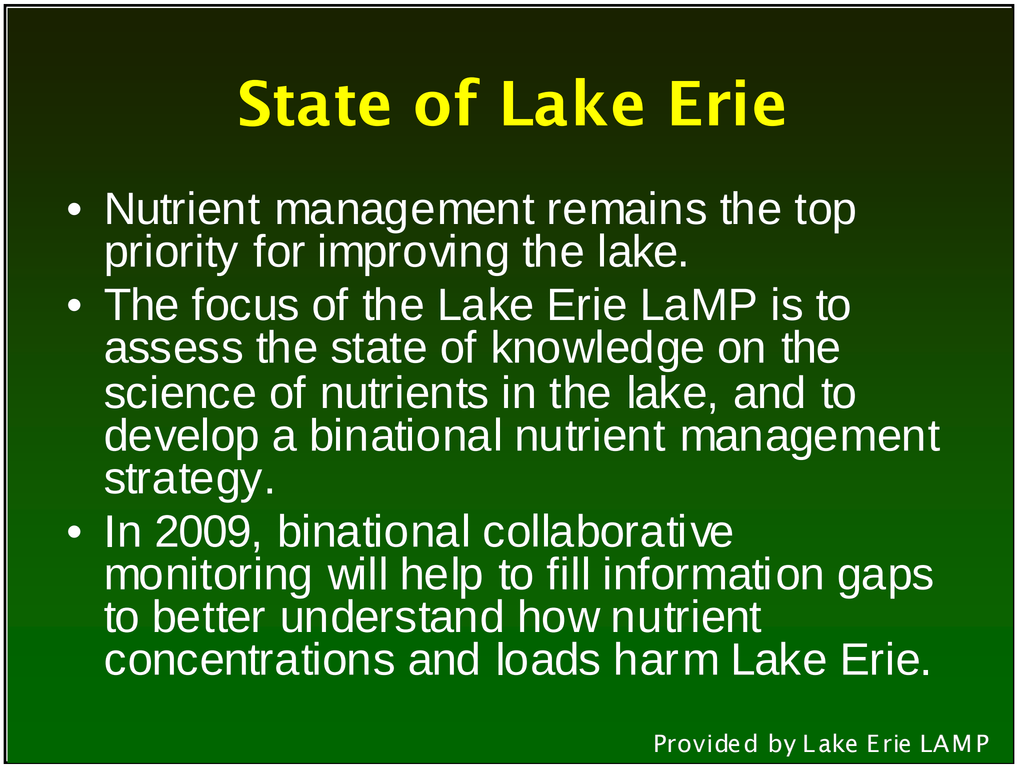
Figure 1. Total Phosphorus loads to Lake Erie from 1967 – 2001. Estimated direct municipal loads are also presented for the period of record (1974 – 2001).

Figure prepared by Annex 3 Technical sub-group

How are we doing in controlling the nutrients responsible for this biomass? P loading record from 1967 – 2002, show that phosphorus inputs into Lake Erie have decreased from the historical high of 27,000 metric tons to below 10,000, More recent data suggest this trend is pretty much holding its own, with the P –loadings hovering just below the target of 11,000 Metric Tonnes per Annum. It tends to exceed that target in high precipitation and runoff years, and be below that target in lower precipitation years.

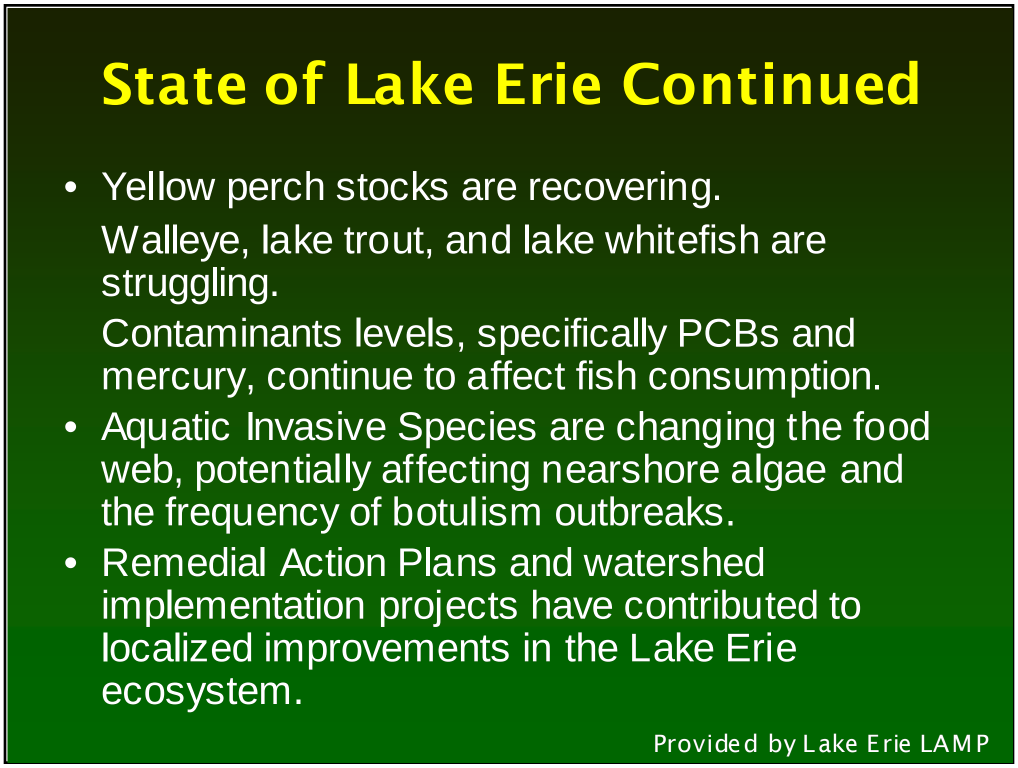


This decrease in total phosphorus loading has translated to a decrease in the spring total phosphorus concentrations. Here I am only showing the results for the western and Central basin of Lake Erie but most importantly, note that this decrease in total phosphorus has also translated to a decrease in the total chlorophyll concentrations for the Lake.



Let me summarize at this point on the State of Lake Erie with a series of slides provided by the Lake Erie LAMP

(1) Nutrient management (particularly phosphorus) remains the top priority for improving the lake. Accordingly, the focus of the Lake Erie LaMP over the next two years will be on assessing the current state of knowledge of nutrients in the lake (both open lake and nearshore), and using that information to develop a nutrient management strategy for the lake and a call to action for LaMP partners. The 2009, a Collaborative monitoring year for Lake Erie will be designed to fill information gaps to better understand how nutrient concentrations and loads harm the lake.



At the higher levels of the food chain:

Yellow perch stocks are recovering, however the top predator species populations of walleye, lake trout, and lake whitefish are struggling. Contaminant levels, specifically PCBs and mercury continue to affect fish consumption.

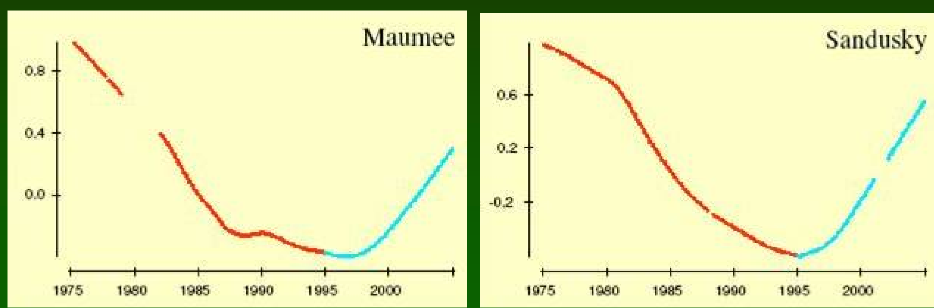
The Lake Erie Committee of the Great Lakes Fishery Commission continues to develop and implement strategies to improve, stabilize and monitor the status of the Lake Erie fish community.

Aquatic Invasive Species, such as zebra mussels, quagga mussels and predatory zooplankton, are changing the food web, potentially affecting nearshore algae and the frequency of botulism outbreaks.

All is not grim, and there have been some localized success stories due to watershed implementation projects.

State of Lake Erie Continued

- Disturbing trend that over the past few years, the in-lake soluble phosphorus concentrations and tributary loadings of dissolved phosphorus are increasing.

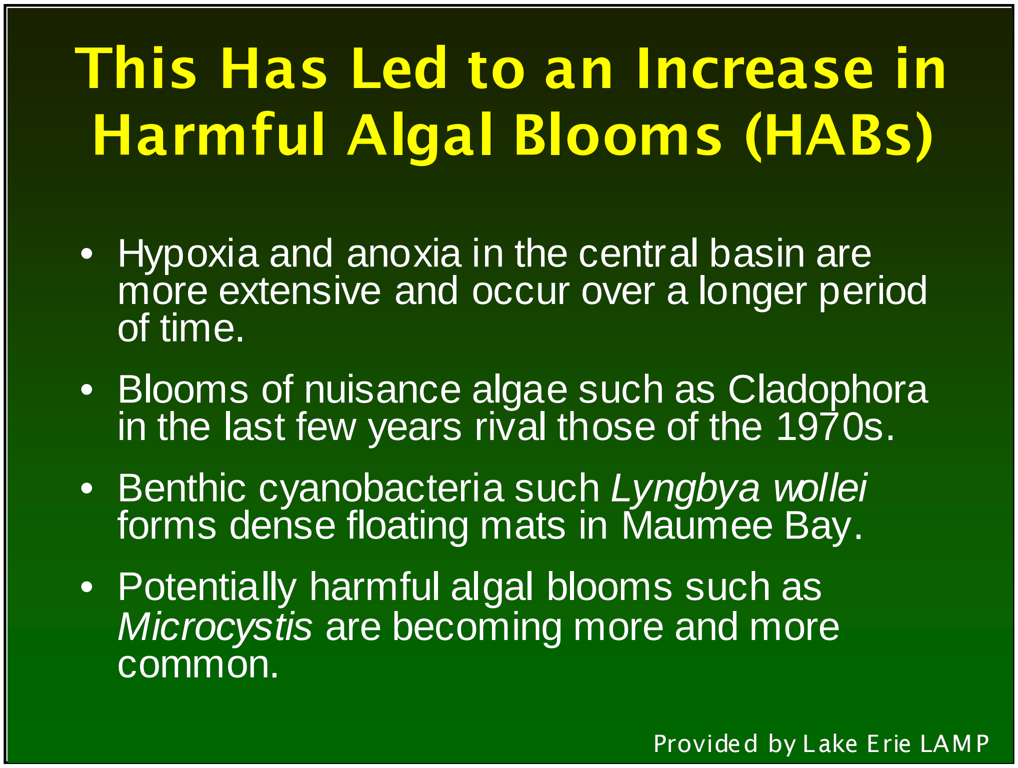


Dissolved reactive phosphorus levels entering Lake Erie

Provided by P. Richards Heidelberg College, courtesy of J. Reutter

However a disturbing trend over the past few years is that the In-lake phosphorus concentrations and tributary loadings of dissolved or soluble reactive phosphorus may be increasing increasing.

Shown here is an example for two of the primary river systems feeding Lake Erie. As you can see from the portion of the line in blue, the dissolved phosphorus concentrations which was steadily dropping over the last few decades, now appear to be on their way back up towards historically high levels.

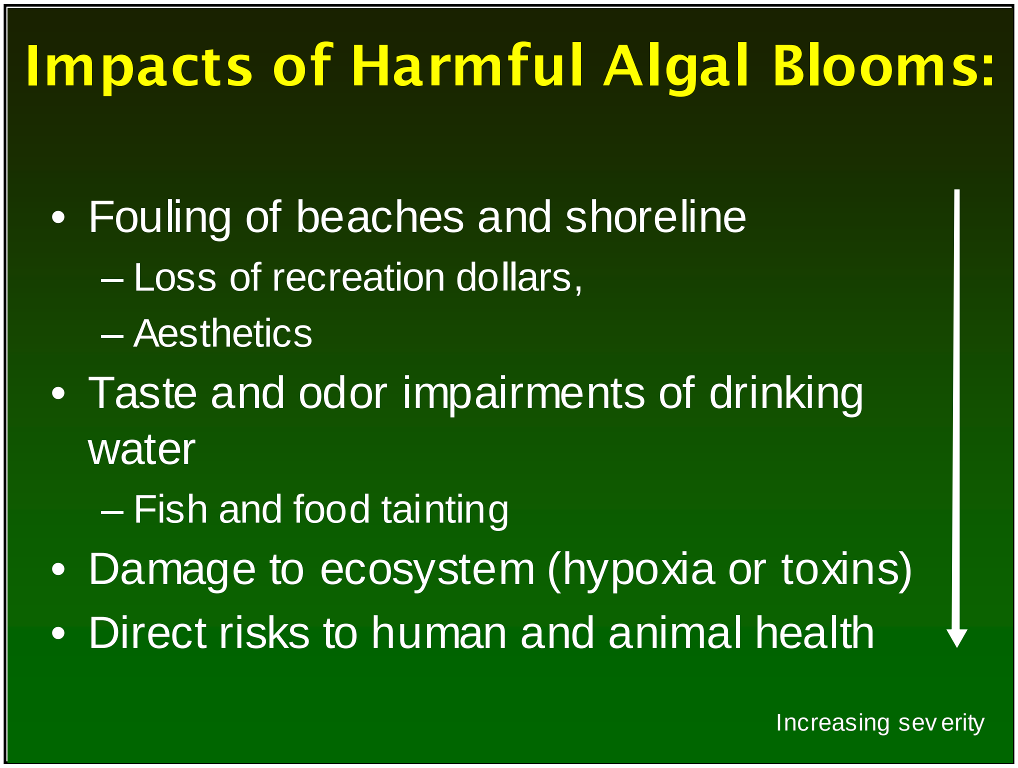


Soluble reactive phosphorus is a primary nutrient for algal biomass, and thus hypoxia and anoxia in the central basin are now more extensive and occur over a longer period of time, than in past decades

Blooms of nuisance algae such as Cladophora have been observed in the last few years that are starting rival those of the 1970s.

We are also seeing a resurgence of nuisance cyanobacteria blooms all-be-it different species. The benthic cyanobacterium Lyngbya wollei, which forms dense floating mats, has been growing profusely in Maumee Bay. These are altering food webs, causing algae outbreaks, reducing human uses of the beaches. Blooms of potential toxic Microcystis are also occurring over wide portions of the western and central basin.

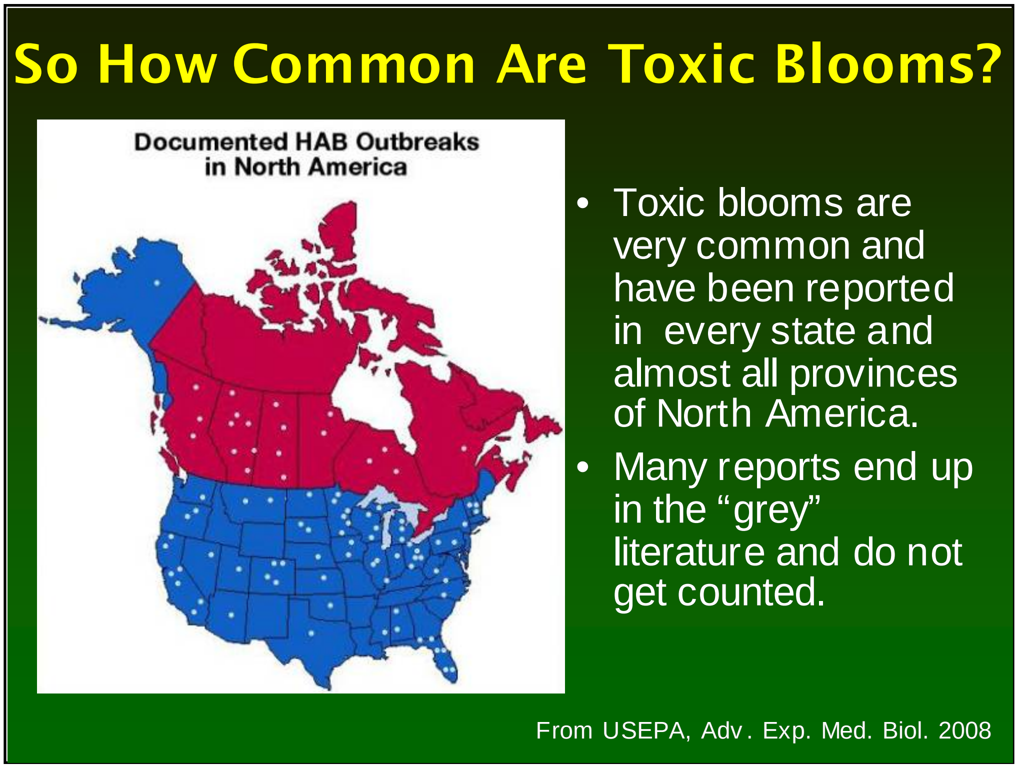
What does this look like in pictures? Here I am showing a satellite image of an October 2007 Microcystis bloom that occupied not only the western basin of Lake Erie but ranged throughout the central basin These blooms can reach very high densities, as shown by the glass in Tom Bridgman's hand. Microcystis species can produce potent toxins. Even if the blooms are not particularly toxic, as the Lyngbya bloom here with the rest of Tom, the sheer biomass material that accumulates on shore can cause issues.



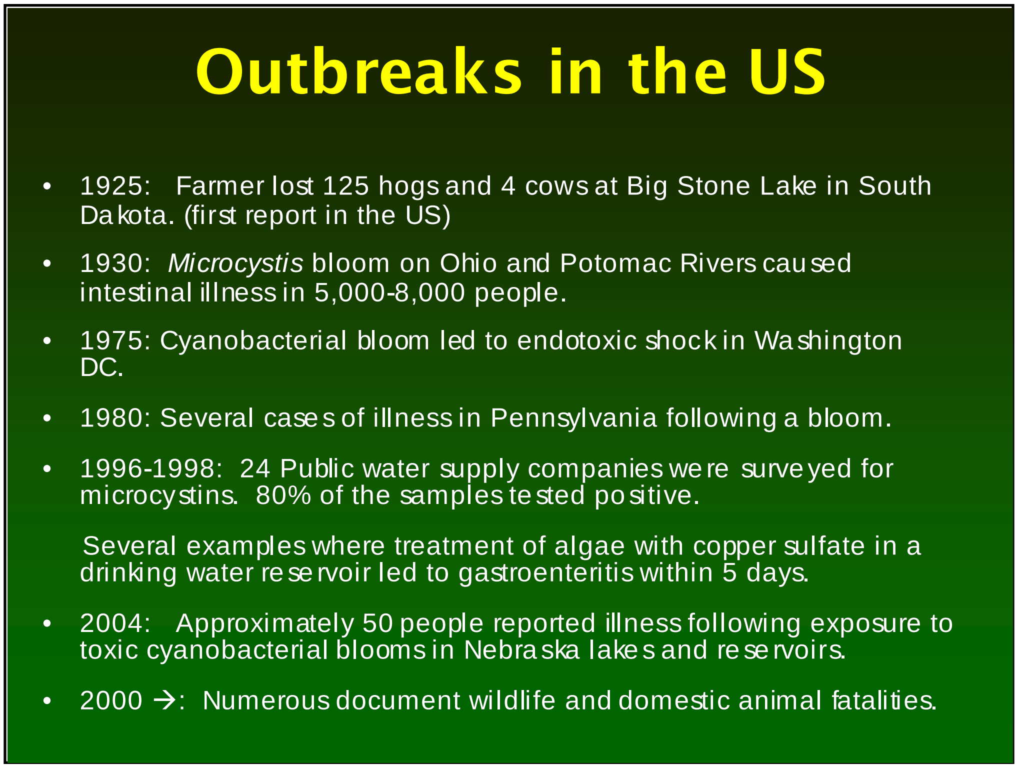
Theses blooms can lead to a number of harmful impacts. No one enjoys going to a beach covered with stinky rotting algae. This leads to an economic impact, both in a direct loss in recreational dollars and a more generalized effect though decreased property values and "attractiveness" of the shoreline.

Many of the blue-green algae or cyanobacteria species produce taste and odor compound that can affect drinking water quality, or can cause "off" flavors in fish.

Toxin production can also have a direct impact on the lower food webs, and (**animation**), importantly pose direct risks to Human and Animal Health. It is this latter issue where I would like to focus my remaining comments.



I want to emphasize that harmful or toxic algal blooms are not unique to the Great Lakes region. USEPA has recently completed a nation-wide assessment of Harmful Algal Blooms as call for in the Harmful Algal Bloom and Hypoxia Research and Control Act of 2007. Toxic blooms have been reported in all 50 states and in most if not all of the Canadian provinces. In the few cases where they have not, it is more likely due to the way these events are reported than an absence of toxic blooms.



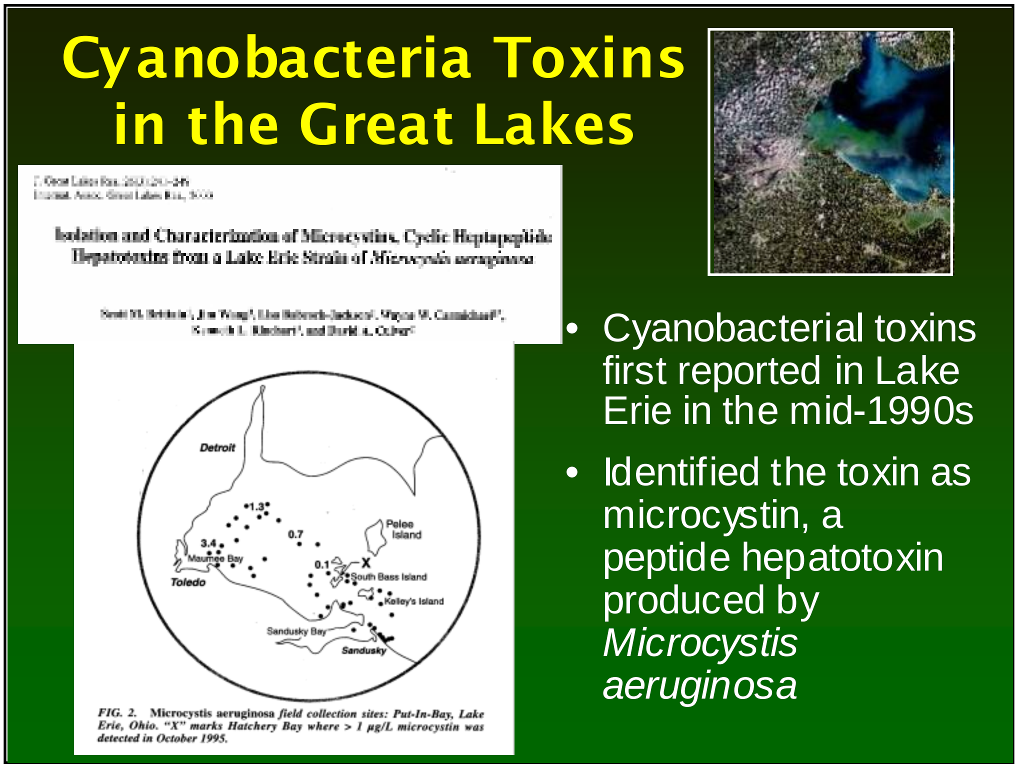
They are also not a new event: Shown here is a list of toxic outbreaks in the United Sates over the last century. However I would like to illustrate at few things:

<**Animation**>. First: these blooms can impact a large number of people. The 1930 : *Microcystis* bloom on Ohio and Potomac Rivers caused intestinal illness in 5,000-8,000 people.

<**Animation**>. Second, the most common problem is likely through drinking water. A study in late 1990's or 24 Public water supplies showed that 80% of their samples tested positive for cyanobacteria toxins. To protect consumers, the WHO has recommended an advisory guideline value of 1 ug microcystins/L; Canada has a slightly higher value of 1.5 ug/L

<**Animation**>. And third Finally, I would also like to point out that drinking water is not the only route of exposure. The 2004 event in Nebraska that resulted in 50 cases was due to recreation exposure to these toxins. There is now a second recommended guideline value of 10-20 ug/L for recreational exposure.

Both of these guideline values have been exceeded in Lake Erie in recent years.

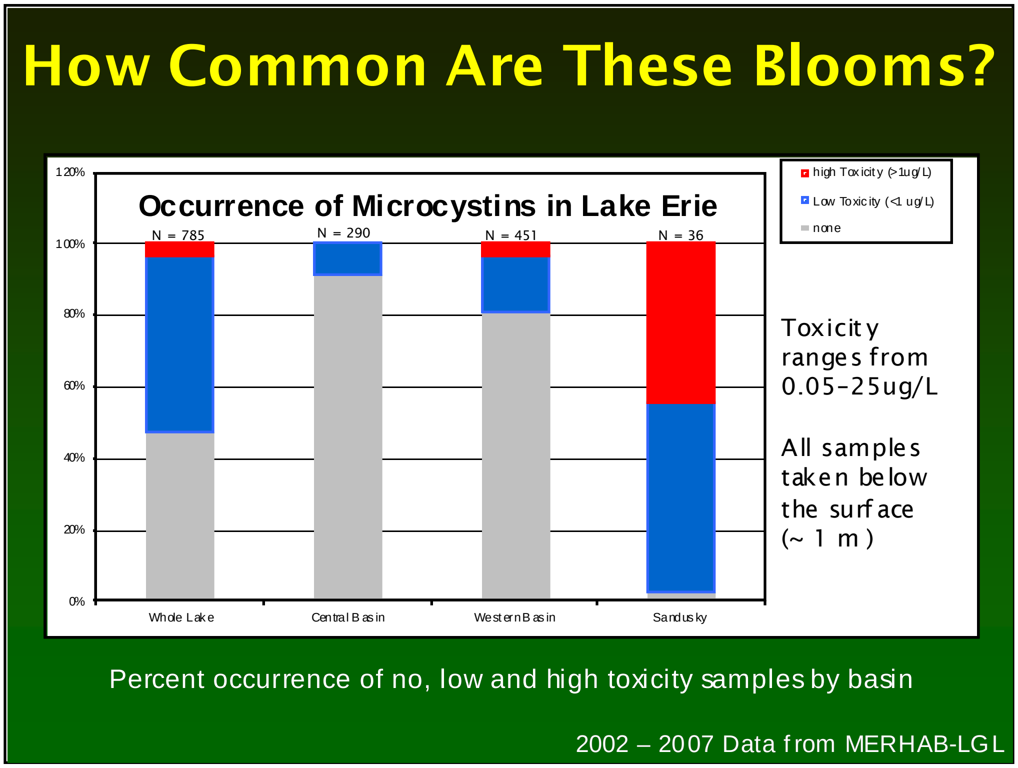


Returning to the Great lake and Lake Erie

Toxic *Microcystis* in L. Erie were first identified in mid 1990s in the western basin of Lake Erie. The satellite image in upper right shows the emergence of a large cyanobacterial bloom from the Maumee River region.

In response to this similar toxic events in L. Huron and L. Ontario, serveral monitoring programs were initiated to address the occurrence and toxicity of these outbreaks. This includes NOAA's regional program for Monitoring and Event Response of Harmful Algal blooms in the lower Great Lakes, The Great Lakes Environmental Research Laboratories Oceans and Human Health Initiative, and several program by Environment Canada and the Ontario Ministry of the Environment.

These efforts have shown that toxic cyanobacterial toxins is a complex problem with > 20 different species and 200 different toxins identified in freshwater systems. In the Great Lakes, the issue has now expanded beyond simple blooms of *Microcystis* in the W. basin of Lake Erie to include all five lakes and the St Lawrence River.

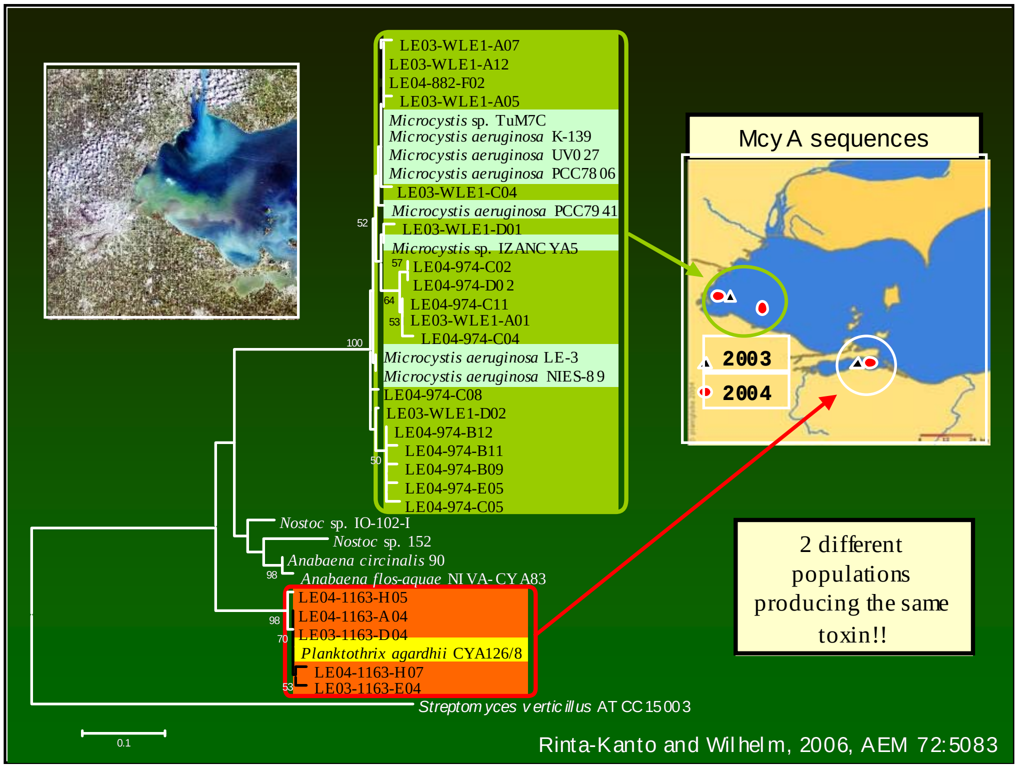


How common are these blooms?

This graph shows the monitoring data from NOAA's MERHAB-LGL program between 2002 and 2007. On a whole lake basis, toxicity was observed in about half of the samples collected. This 50% number agree very well with other large ecosystem surveys of toxicity, namely Ponds and Lakes in New York State, Reservoirs in Nebraska, and water supplies in Europe.

However this number can be a bit misleading due to sampling bias. The central basin had detectable levels of toxin in about 10% of the samples whereas the western basin contained some level of toxicity in about 20% of the samples collected. More importantly, the western basin has a number of samples shown in red that would exceed the drinking water guidelines and even values that exceed the recreational guidelines.

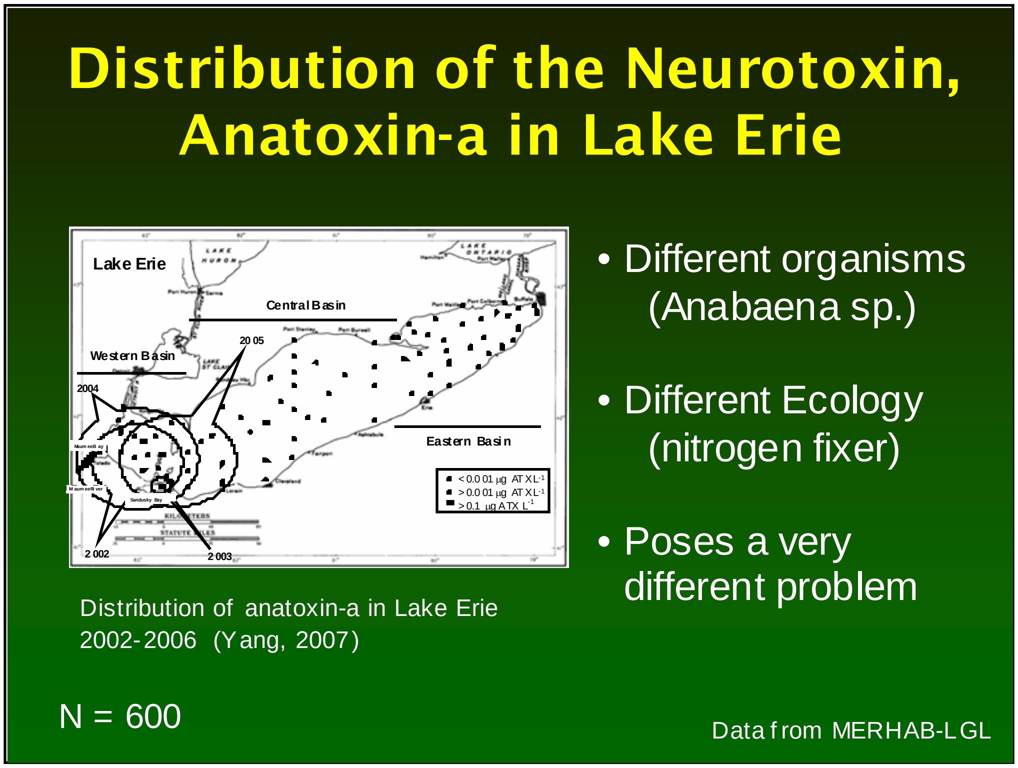
Compare this to samples collected from the Sandusky Bay showed a >97% chance that they would have at least detectable levels of microcystin toxicity and over half the samples exceeded 1 ug/L. Interestingly, the maximum values in Sandusky are actually lower than those observed in the western basin.



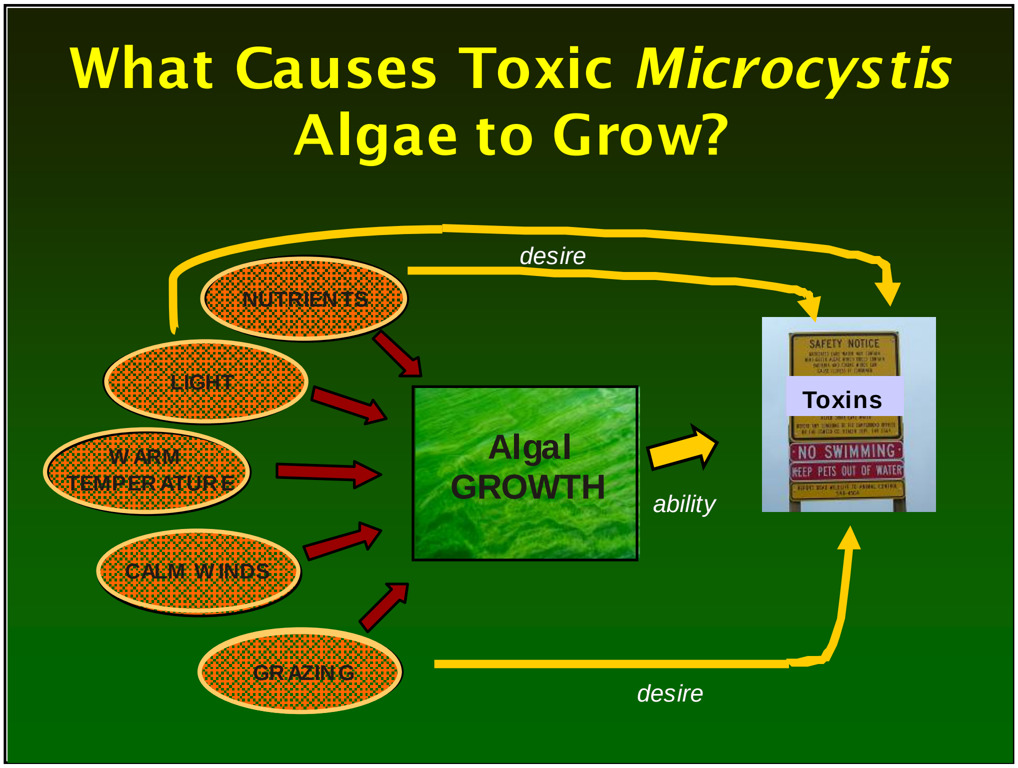
This is a very complex slide and I hesitated about putting it in but it helps to explain that past observation. One of the good things about working with microcystins is that there exits a very strong toolbox of molecular techniques. We know the genes responsible for toxin formation and can that information in our efforts to identify risks.

<**Animation** >As you can see from the list here in green, these samples collected from the Maumee region of western Lake Erie all aligned near known Microcystis strains, supporting our initial observations that Microcystis is the likely toxin producer in this location

<**Animation** >However – look what happened with the samples collected from the Sandusky Bay region. Here the sequences aligned with Planktothrix species. Thus in this particular case, Plankthonthrix (not Microcystis) was the predominate toxin-producing genome in the water column. We potentially could have two different organisms, with very different ecologies and nutrient requirements, making the same toxin in different regions of the same lake. This becomes nightmare from a management standpoint as future management plans must account for this diversity.



We also have other toxins to worry about in addition to just microcystins. Here we are showing the distribution of the neurotoxin, anatoxin-a in Lake Erie. This toxin is produced by a very different species called Anabaena. It is much more associated with embayments surrounding the lake than either the nearshore or offshore waters. In these systems, levels of this toxin have also been reported at concentrations that have been associated with animal fatalities in other systems.



Finally, I would like to spend a little bit of time discussing the major factors causing these toxic blooms to occur. For this, I am going to focus my comments on Microcystis species, recognizing that not all factors may be the same for all species.

<**Animation** > First and foremost are Nutrients. **Nutrients** are generally higher in the western basin. Microcystis can vertically migrate, thus may be able to get down to the nutrient rich bottom waters and back up to photic zone at the surface. Dressenid mussels may also be important and recycling the phosphorus and nitrogen nutrients, making them more "bioavailable" for these algae.

<**Animation** > **Light is a key feature and** many of the blooms are associated with River inpouts. The Maumee River is the largest Great lakes Tributary, draining about 5600 square miles of agricultural land, The algae need to balance the beneficial nutrients from the river, versus the effect of turbidity from suspended sediments coming out of the river. This may create zones where blooms can initiate.

<**Animation** > **Temperature has an** effect also. Shallow waters warm up faster and work on other systems suggest that Microcystis has a low temperature threshold and the water must get above a certain temperature before the blooms initiate. Climate change could potentially have a major impact on length of the temperature window available for these blooms.

<**Animation** > There are other factors such as wind and weather that can be important.

<**Animation** > and **Grazing effects:** These is very little evidence that the toxins themselves serve as antigrazing compounds, but Microcystis forms large colonies that are generally not effectively grazed by consumers such as zebra mussels. Many of you have seen the nice underwater video images by Hank Van der Plug showing the zebra mussels spitting out Microcystis colonies. This selective feeding can both remove competitors and enrich a system in Microcystis However you must be careful. Zebra mussel in the Hudson River have effectively removed toxic Microcystis from that system.

<**Animation** > <**Animation** > However Algal Growth does not necessarily mean toxins are produced. For that to happen, you need to have the genetic ability to make toxins.

<**Animation** > The cell also has to have the desire or will to make them. We really don't know what factors that induce toxin formation in Microcystis, or cause a change in the population from non-toxic to toxic variants.

Desire (Why Algae Make Toxins?)

- In general, toxic strains have a large N, P requirement than non-toxic (Zurawell et al 2005) Healthy cells make more toxin.
- Effect of trace metals has been inconsistent. No direct effect, but low Fe can impact nitrogen utilization.
- High Light intensity seems to promote toxin production. (cell health effect?). UV light effects also appear inconsistent.

However we do know that

In general, toxic strains have a large N, P requirement than non-toxic (Zurawell et al 2005). Healthy cells make more toxin.

The effect of trace nutrients has been inconsistent and, in most cases, can be related back to their effects on N utilization.

High Light intensity seems to promote toxin production. Though this may be another indirect effect on cell health.

Summary

- Cyanobacteria produce a number of toxins but not all species are toxic.
- Hepatotoxic microcystins are probably the toxin of most concern for human health.
- These toxins can be produced by a number of different species making visual monitoring difficult. Both toxic and non-toxic populations exist.
- Healthy cells tend to make more toxin, thus higher nutrient conditions in the nearshore region tend to promote higher biomass events and additional toxic blooms.

Some let me summarize what we do know

Cyanobacteria produce a number of toxins but not all species are toxic.

Hepatotoxic microcystins are probably the toxin of most concern for human health.

These toxins can be produced by a number of different species making visual monitoring difficult. Both toxic and non-toxic populations exist at the same location.

Healthy cells tend to make more toxin, thus higher nutrient conditions in the near shore region tend to promote higher biomass events and additional toxic blooms.

And with that, I would like to remind you about the nutrient and HAB session this afternoon if you would to discuss this in more detail.

Acknowledgments

- Susan Watson, Environment Canada
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