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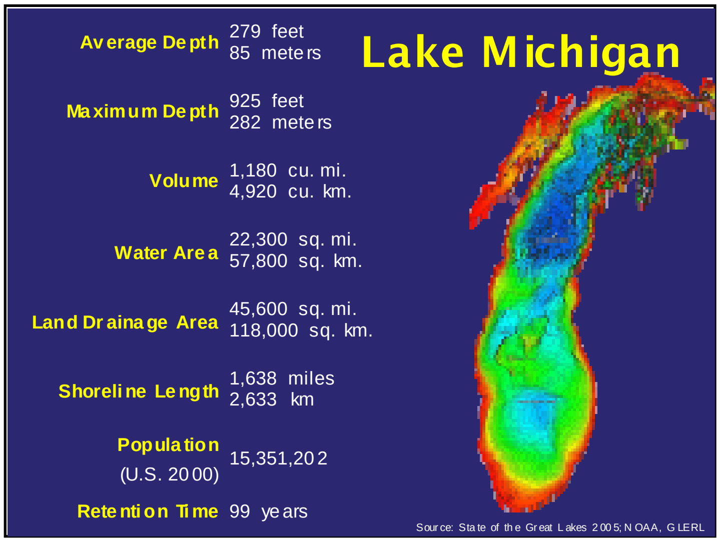
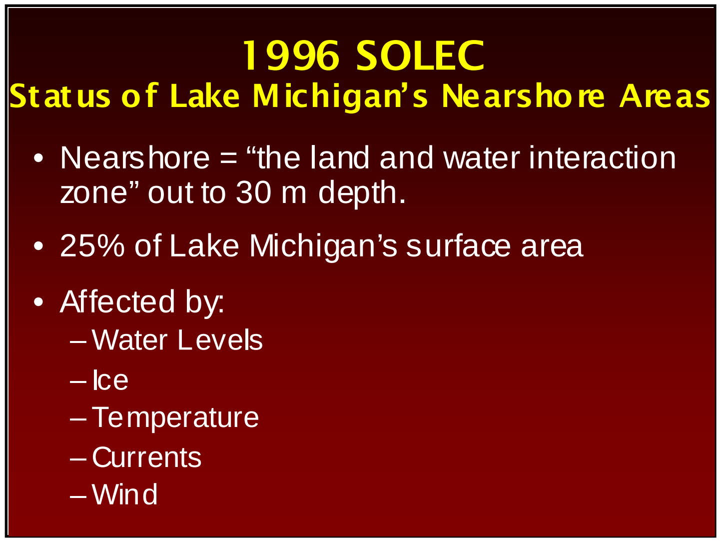
I am honored to have been asked to make this presentation on the Nearshore Water Areas of Lake Michigan. Although not a cheerful presentation, I hope that as I key in on impacts from Type E botulism outbreaks arising from this zone, that your interest and understanding of this major ecological warning sign will be enlightened. Botulism is having numerous impacts on the species of Lake Michigan and at our National Park Service, Sleeping Bear Dunes National Lakeshore including on the endangered Piping Plover which you see in this photo.



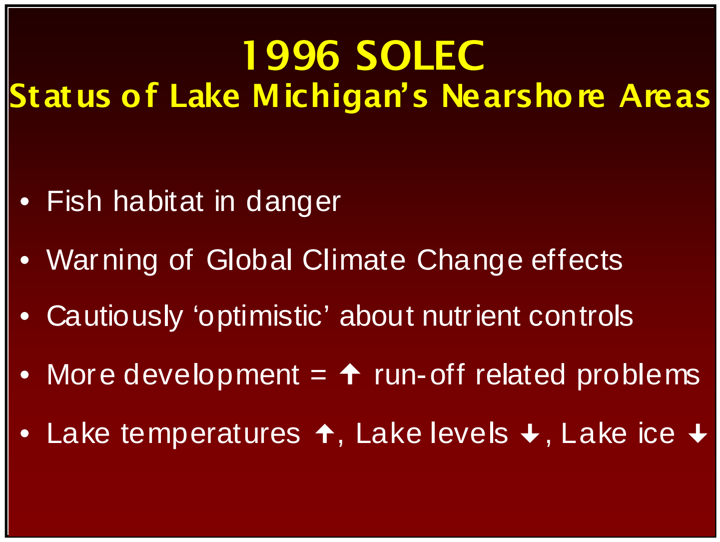
Lake Michigan is the second largest of the Great Lakes by volume. With depths down to 282 meters, it includes large expanses of both near shore and deep water environments. The shoreline length of 2,633 km, a growing population exceeding 15,000,000, and a water retention time of 99 years all produce unique management issues.

In 2008, there are several positive items. Lake Michigan continues to be a source of good drinking water for local residents, it exhibits a notable return of bird, mammal and aquatic species due to habitat restoration and dam removal, and shows a continued decline of contaminants in fish. BUT, we are currently observing dramatic symptoms of major ecosystem disruption.



A review of the Nearshore waters information presented for SOLEC in 1996 will show that the Nearshore zone was defined as "the land and water interaction zone" out to a 30 meter depth. From this definition, it can be estimated that 25% of Lake Michigan's surface area would be included in this "Zone".

1996 presenters also noted that Water Levels, Ice, Temperature, Currents, and Wind all play integral parts in the features and ecological processes of the Nearshore areas. I will propose that other components including light and even biological processes be added later in the presentation.



Other key points presented in 1996 included:

-Concern that fish habitat was in danger, although there was little mention of the food web

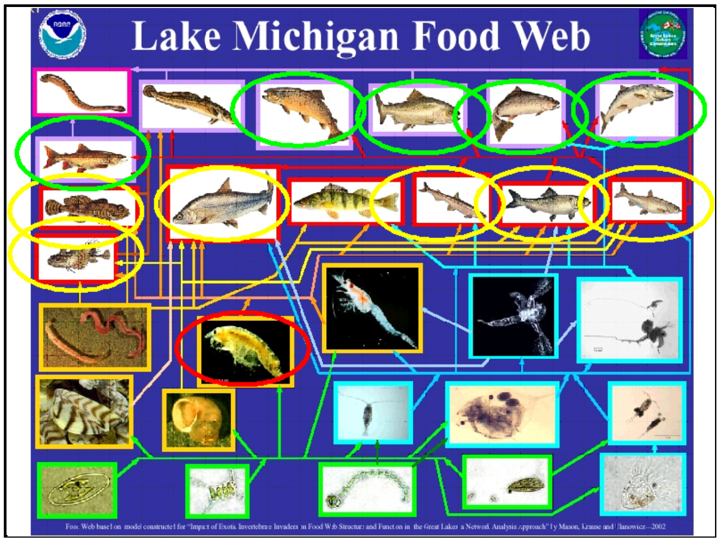
-Impacts and concerns with Global Climate Change were discussed

-That overall, everyone was cautiously optimistic about the effects of the nutrient controls put into place in the previous 2 decades

-That land use change impacts from a growing population continued to create more run-off related problems.

-That lake temperatures were on the rise, lake levels were dropping, and lake ice was occurring much less frequently during the winter months.

Nothing new to us today!



In 2008, I think that one of our areas of emphasis must be on the impacts that invasive species are having on the food pathways of the lake ecosystem.

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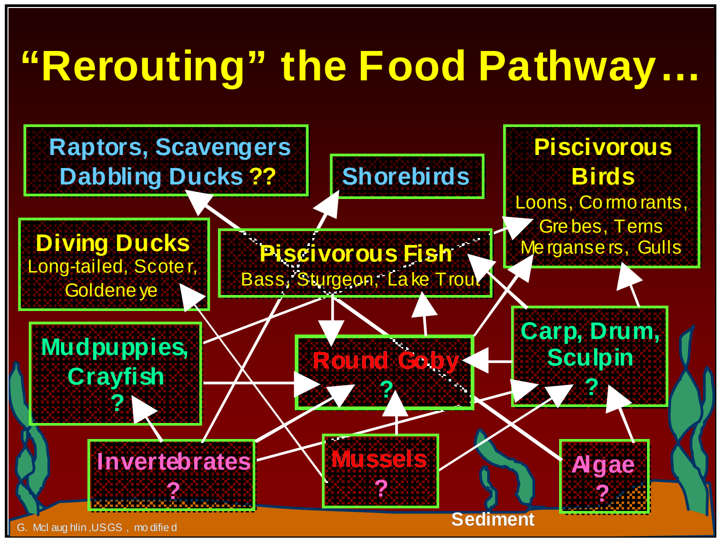
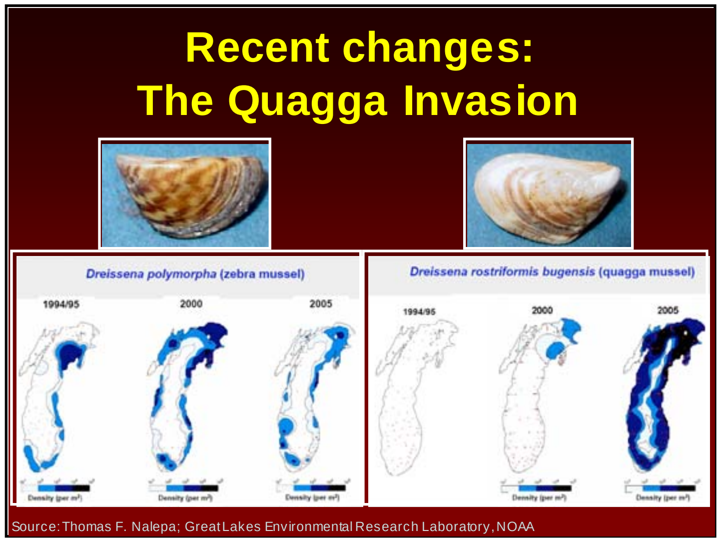
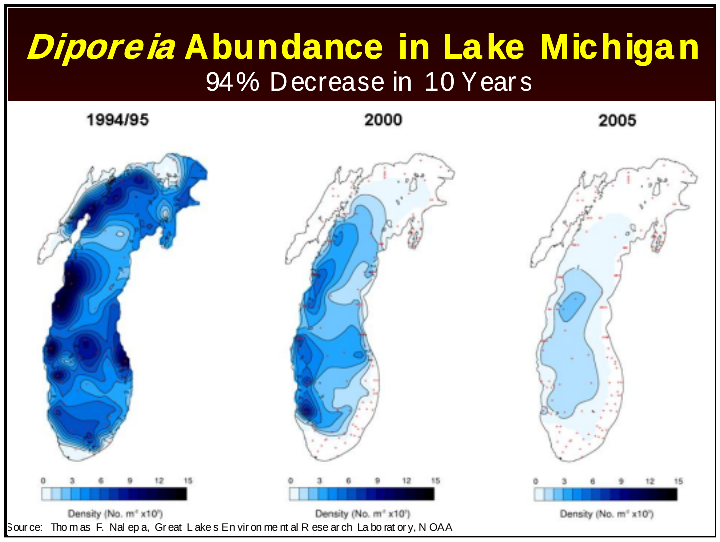


Dreissinids, gobies, spiny-hook water fleas, bloody red shrimp, carp, salmonids, alewives, and the list goes on and on, continue to impact the food chain and cause changes in the food web that I will go into more detail later.

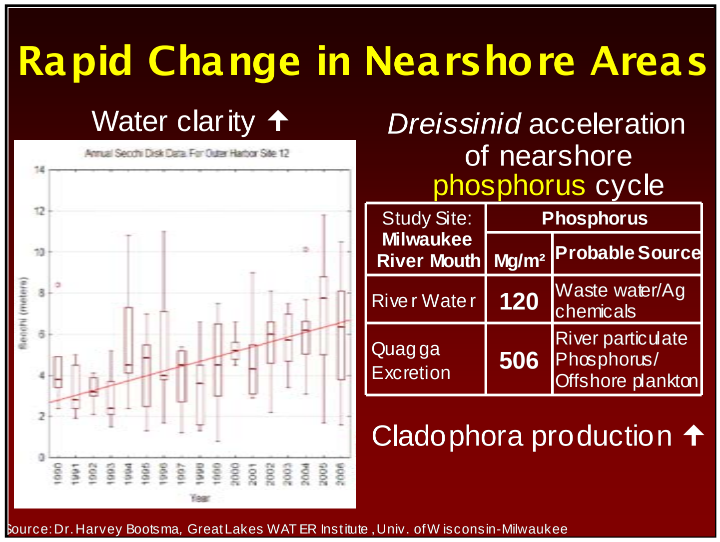
One key item to note is that the round goby is now at the center of the food web; both as a food item and as a predator.



A recent change that no one could have predicted even in 1996 was the invasion of Quagga mussels and their nearly complete displacement of the zebra mussel. The Quagga mussel can attach to sand, can function at much deeper depths, and filters even more than its more famous cousin. Very little of Lake Michigan will be “mussel free”.



And who would have forecast the near collapse of the Diporeia shrimp. The loss of this critical food item from the food chain **is** and **will have** huge impacts on the entire food web for years to come.

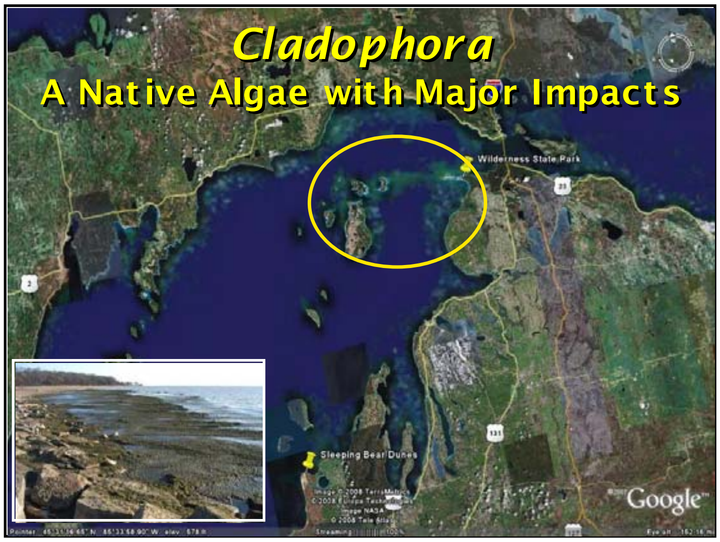


Recent research in Lake Michigan is also finding that the physical characteristics of the Nearshore areas are rapidly changing.

Water clarity has greatly increased as shown by this research from Dr. Harvey Bootsma at the University of Wisconsin's Great Lakes WATER Institute.

Additional research by Dr. Bootsma also indicates that the Dreissinid mussels are accelerating the phosphorous cycle in the Nearshore waters when compared with inputs from the Milwaukee River drainage. Their output was over 4 times higher in the bay compared to the input from the river.

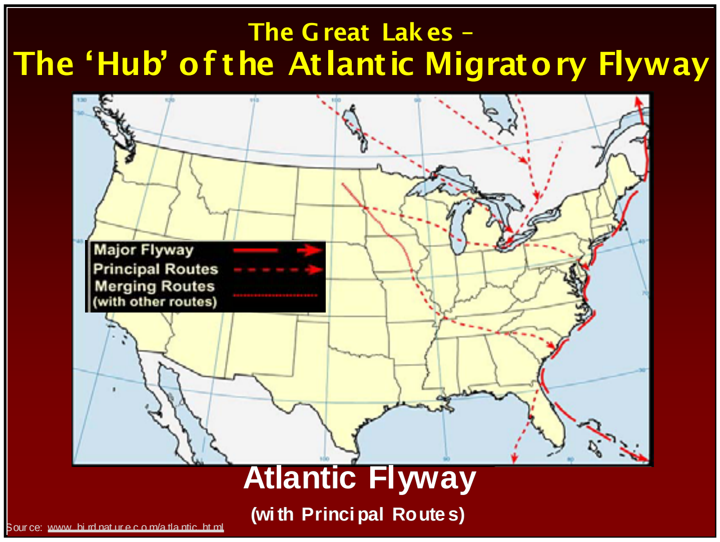
These two changes are then fueling a large increase in the production of Cladophora algae both in amounts produced and the area that is producing throughout the lake.



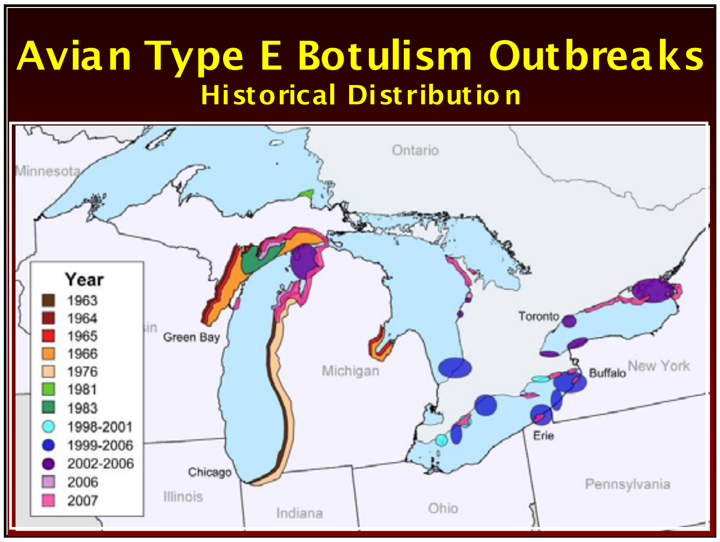
Cladophora algae covered beaches are becoming a common site around the entire shoreline of Lake Michigan. At one time associated with coastlines near heavily polluted streams and bays, it is now impacting all of the Nearshore waters. In fact, its growth can now be picked up by satellites and is readily visible from Google Earth.

Notice for example the shoals around Beaver Island in the northern portion of the Lake.

Round Gobies, another recent invader in the last 10 years, are spreading and increasing in numbers at a phenomenol rate. Capable of breeding 3 times a summer, they soon overwhelm the native sculpins and invertebrates, wreck havock with the egg and small fry of native fish spawning on the shoals, and enjoy unlimited food supplies of the expanding quagga mussels. A recent study along Western Lake Erie by Johnson et.al. estimated their numbers at 9.9 billion in 2002.

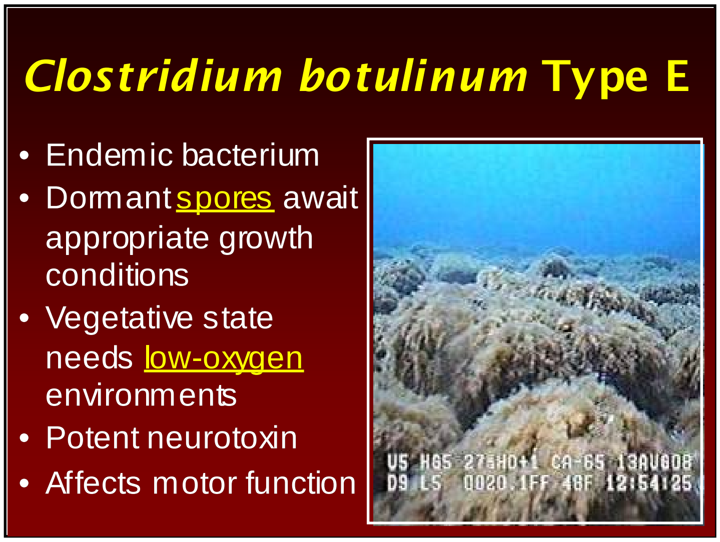


Before going into a more in-depth discussion of Type E botulism, it should be noted that the Great Lakes also serve as the hub of the Atlantic Flyway. In particular, they are the principle flyways and stopover points for the waterbirds, diving ducks, and shorebirds of the region.



Now for one of the “Symptoms” of the significant ecological changes occurring in Lake Michigan. In 1963, a major die-off event occurred, and, for the first time, Botulinum clostridum Type E was identified. In the following years, additional, but very sporadic die-off events occurred. However, in 1998 these events became annual occurrences on several of the other Great Lakes and since 2006, they are occurring every year on Lake Michigan.

As depicted, much more of the Lake Michigan shoreline has also been impacted and represents huge areas to inventory, to do research on, and to eventually treat.



A few interesting facts about Type E Botulism:

- Clostridium botulinum is a small rod-shaped bacteria that is endemic to the Great Lakes region and can be found in the soils and sediments.

- Microclimates as small as a few decaying Quagga mussels to entire nearshore areas rich in decaying algae and mussels could produce the toxin. The photo shows a cladophora bed about to slough off from the rocky substrate

- The bacteria survive as spores that can withstand a whole host of environmental extremes and do this for centuries.

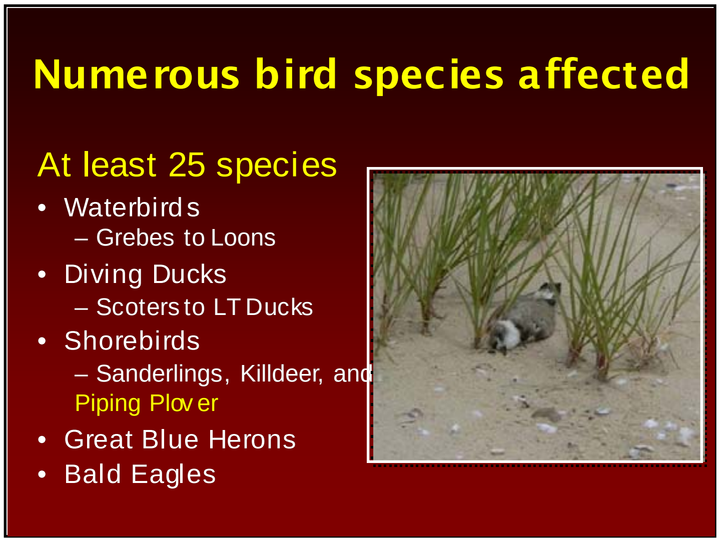
- They grow best in anoxic or low oxygen conditions

- The toxin produced by the bacteria is nature's most potent. A dose in the parts per trillion per kg of weight will kill most vertebrates. Invertebrates, such as quagga and zebra mussels, are not affected. Some scavenger wildlife species must have mechanisms to denature the toxin as they feed on carrion.

- The neurotoxin prevents impulse transmissions to the fish or animals muscles which leads to vulnerability to predation, respiratory failure or drowning as "limberneck" conditions develop.

A host of species are impacted by the toxin as it moves through the food chain. Soon the beaches are strewn with the carcasses of fish and birds. Some of the die-offs have resulted in the loss of 10,000 to 25,000 birds over a 1 to 2 month period.

One interesting note: Laboratory research at the University of Guelph has found that Round Gobies are very susceptible to Type E toxin. They found that the toxin spreads to the muscle tissue of gobies while staying primarily in the guts of most native fish. This could help explain a much quicker transfer of the toxin from prey to predator.



At least 25 species of birds have been collected, and, using the mouse bio-assay, wildlife disease laboratories have confirmed that individuals from each of the species have died from Type E botulism toxin poisoning. Small and large waterbirds from horned grebes to common loons have been found. Deep diving ducks like white-winged scoters and long-tailed ducks are also common victims. Shorebirds feeding along the lake also ingest the toxin and soon die.

In 2007 Sleeping Bear Dunes lost 2 adult and 2 juvenile piping plovers, an endangered bird in the United States and Canada, to botulinum toxin poisoning. In much smaller numbers, bald eagles and great blue herons have also been found.

Possible Food Chain Routes

Bird	Diet
Diving ducks	Mussels, crayfish, aquatic insects
Piscivorous waterbirds	Sick round gobies, native fish, mudpuppies
Ring-billed gulls	Sick fish, carrion, crayfish, mussel pieces
Shorebirds	Macroinvertebrates in algae, dead mussels, carrion, maggots/insects in carcasses
Bald Eagles	Fish or bird carrion

The food chain routes vary depending on the feeding characteristics of the various species.

Diving ducks may ingest the toxins through eating Dreissinid mussels, crayfish, and macroinvertebrates.

Most of the waterbirds will only feed on live fish, so ingesting sick fish is the sole pathway.

Gulls and eagles may ingest it from sick or decaying fish and bird carcasses.

And shorebirds can ingest it from a whole host of sources that wash up on the beach including macroinvertebrates, dead mussels, pieces of carrion, and from maggots/beetles in decaying carcasses. As you can see none of the pathways are very easy to disrupt.

Studying Type E Botulism toxins presents a whole host of problems which have greatly limited the research available. First it is considered a Biological Warfare agent/toxin and so research facilities must deal with major security and tracking requirements. Second the Great Lakes are BIG so pinpointing an outbreak is very difficult. Third, wildlife research funds continue to be diverted to more pressing "human food related issues" like Viral Hemorrhagic septicemia and Chronic Wasting Disease.

Recent research does indicate that:

A. Sick fish lose coordination, swim erratically and either bob at the surface or flounder near the bottom. This makes them a feeding magnet for waterbirds and predatory fish – especially when large numbers of fish are involved.

B. Large beds of decaying algae and mussels may create the anoxic conditions needed for toxin production. However, laboratory tests available for verifying the toxin in field samples are VERY limited.

C. The 1960's and 70's die-offs appeared to occur in heavily polluted waters and in conjunction with large alewife die-offs. Todays die-offs appear to need the combination of dense beds of Cladophora, quagga mussels, and plentiful round gobies. I still can only conjecture as to the why's.

D. Several stomach content studies completed on toxin killed birds implicate a whole host of possible food chain items as was discussed earlier.

Other research questions include:

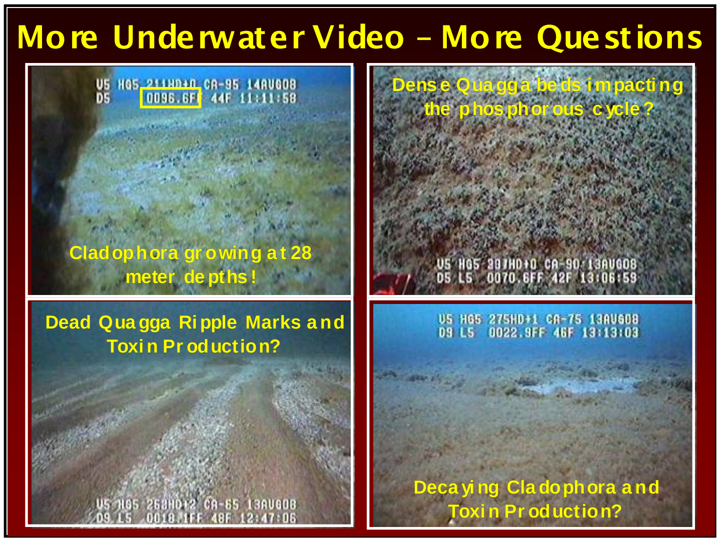
Can a Field test kit be developed for the toxin?

Are there ways to monitor for fish and bird die-offs as they begin (as opposed to 3 days later)?

Why do lake turnovers or storm events seem to initiate die-offs?

And a host of other questions remain unanswered.

Working with research staff from the NPS and specialists from the University of Michigan's Marine Hydrodynamics Laboratories, we used a small Remotely Operated Vehicle this summer to take underwater video so that we had a better idea of what was occurring in areas involved in recent die-off events. Just a few of the highlights include: First, fact that we DID NOT need to use lights on the ROV at depths of 48 meters (156") as seen in this photo and even at 62 meter depths last week. As you can also see the Quagga's are doing great on sandy and even mucky substrates.



We also found;

✓Cladophora was actively growing out to at least 28 meter depths (96') with much of it attached to Quagga mussels

✓Dense stands of Quaggas were just about everywhere. Our ROV technician found dense colonies of them on a shipwreck at 106 meter (350') depths a couple of weeks after our first set of transects.

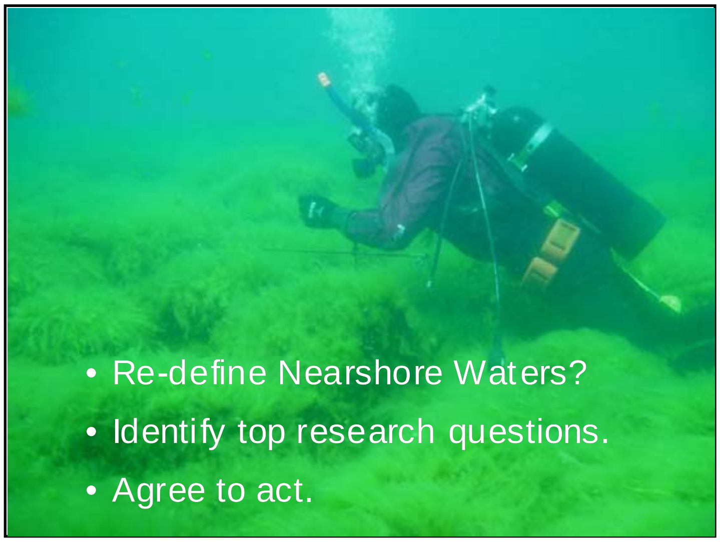
✓There were ripple marks of dead mussels and piles of decaying algae – both possible growth medium for C. botulinum toxin production.

✓There appears to be plentiful for Round Gobies and a nearly unlimited food supply of Quaggas.

I feel the evidence on our beaches points to huge if not catastrophic ecosystem changes under the Lake's surface. On a Lake Michigan scale, it is still very difficult to prioritize where the concerns should be. A few to consider: **<click>**

A. VHS may trump Type E botulism for impacts to sport and commercial fishing, but concerns with eating fish harvested from waters experiencing a Type E die-off far outweigh those in the minds of most residents. **<click>**
B. If we soon throw Highly Pathogenic Avian Influenza into North America wild bird populations, this is the gear I would be required to wear on the beach when picking up dead birds. **Would that impact your family's experience while playing at the Beach**? <**click>**
C. We live in the midst of worldwide markets that supply much of what we buy and use. With rapidly rising fuel costs, shipping huge quantities may become not only a choice but a necessity. Can we regulate all of the possible "INVADERS" just waiting to be released into the Great Lakes from ballast water, packing material, and Internet pet suppliers? Can we even begin to understand their impacts on the complex food webs found both below and above the Lake's surface

Is there hope – yes? But only with a partnering of efforts, more research in managing the invasives or breaking some of the food web routes, and much more public and political support on how we protect and care for these invaluable lake resources.



I thank you for your time! The issues presented here today help set the stage for this afternoon's breakout session. Several topics to be discussed include the need to:

- Possibly re-define what Nearshore Waters are;
- Identify top research questions; and,
- Agree on pro-active near-term actions, possibly based on the concept of the Precautionary Principle. For instance, adopt phosphorus bans as outlined in Lake Michigan's 2008 LakeWide Management Plan.

I hope that those who are interested will come and add to the discussion.

Acknowledgments

- NPS Sleeping Bear Dunes National Lakeshore Staff
- NPS Midwest Regional Specialists Brenda Moraska Lafrancois and Jay Glase
- U.S. EPA Great Lakes National Program Office – Judy Beck and Chiara Zuccarino-Crowe
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- U.S.G.S. National Wildlife Health Center Staff; Madison, Wisconsin
- Many other specialists and volunteers…

Thank you!