Naturally Occurring Chemicals:

Nutrients

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A key objective of GLWQA is to

"restore and maintain the chemical integrity"

of Great Lakes basin waters.

Chemical integrity:

1. Stability. Are concentrations stable over time?

2. Soundness: Is ecosystem functioning altered / impaired?

-What is chemical integrity?

-For some chemicals, we know that changes in concentration affect numerous other parameters. For others, there have been significant changes, but we don't really know what the impacts are.

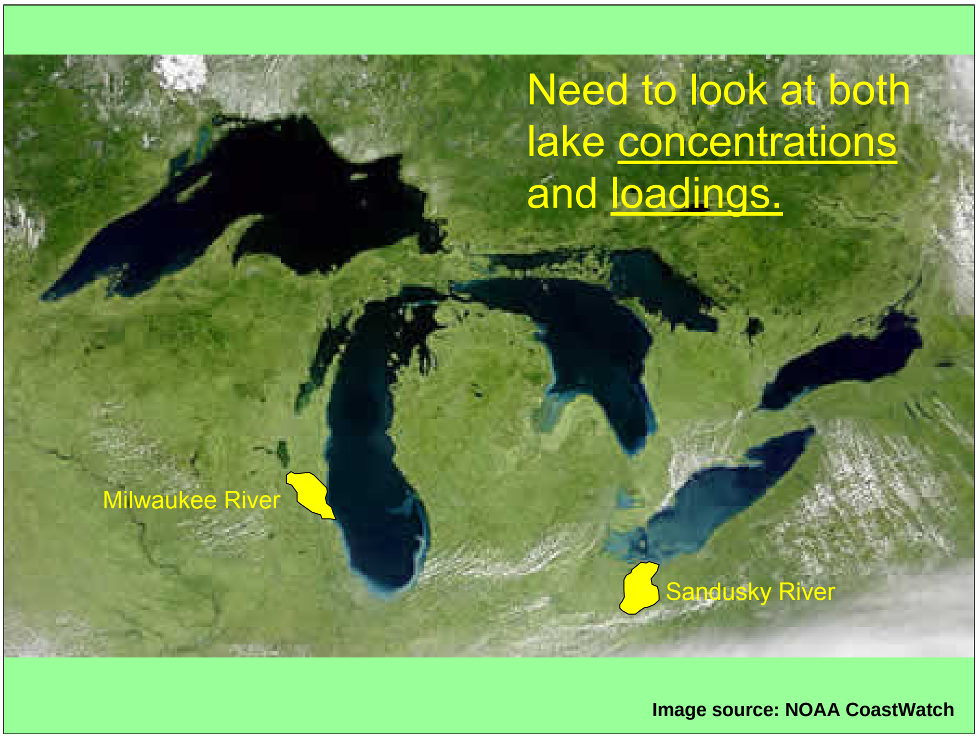
-The objective of this presentation is to review historic changes of "natural" chemicals in the Great Lakes, discuss causes of these changes, and to look forward to expected future conditions and their implications for ecosystem integrity.

Natural Chemicals:

- Chloride
- Calcium
- Nitrogen
- Phosphorus

-The “natural” chemicals that this presentation focuses on are those that influence plankton dynamics (phosphorus) and those that reflect human impacts on the watersheds and atmosphere (N, Cl^-) and those that reflect biological changes (Ca^{2+}).

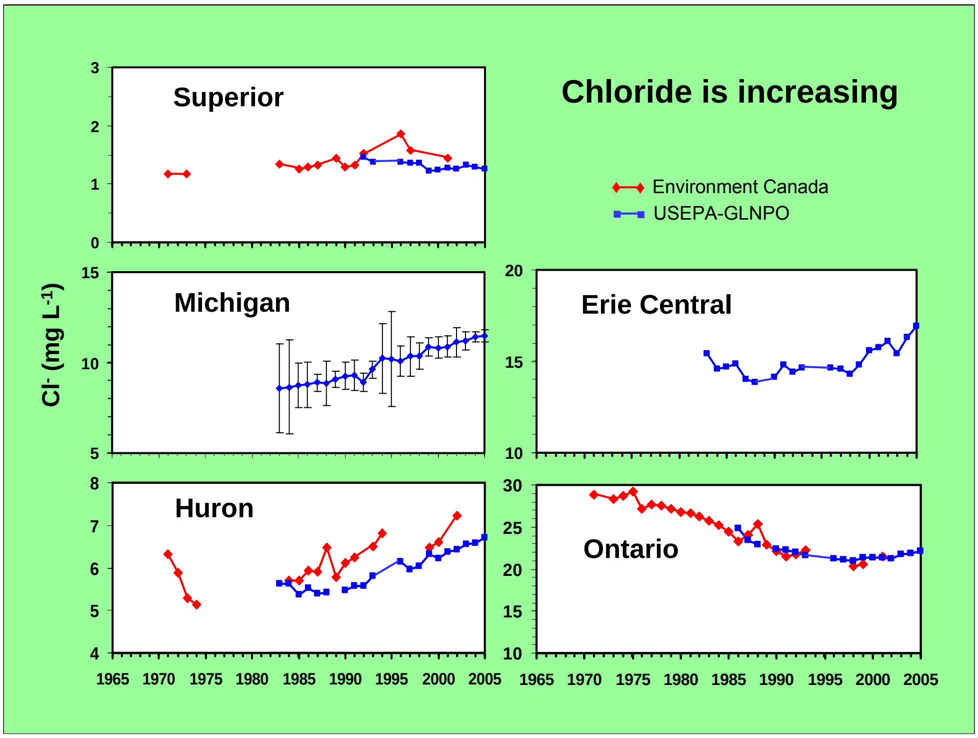
-Susan Watson will cover natural chemicals that have more direct effects on human health – natural toxins.



-The Great Lakes are large, and they have long residence times. Therefore, they respond slowly to changes in inputs. We need to monitor the lakes, but if we really want to keep our finger on their pulse, we need to monitor loadings.

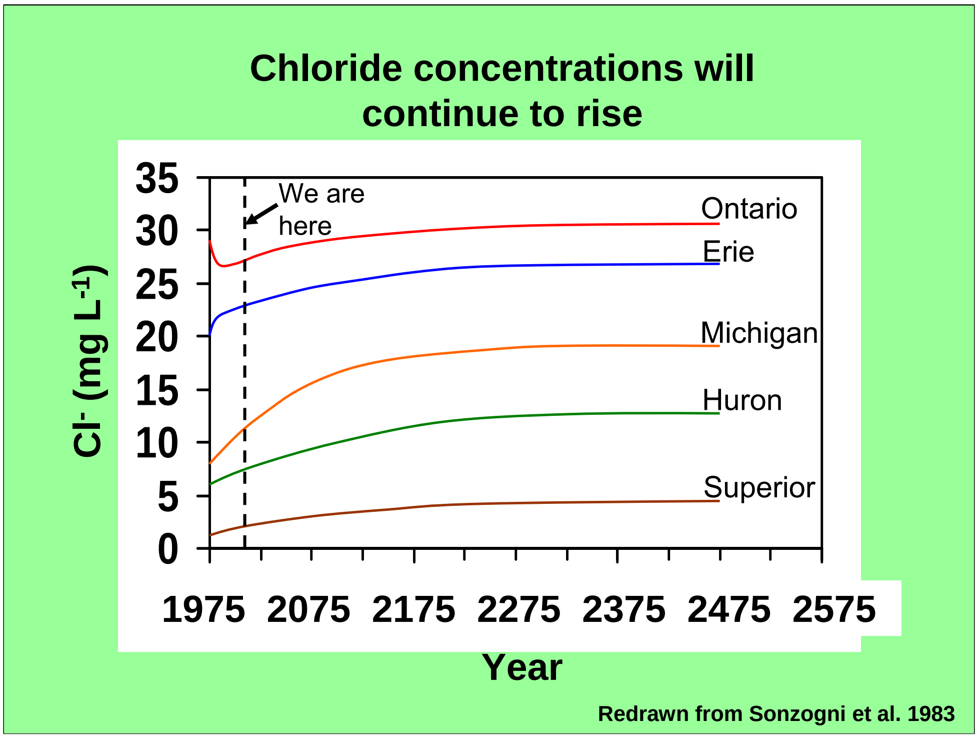
-Although we do not have recent total load estimates for most lakes, an examination of some river data can provide insight into recent trends.

-We will look at two case studies: The Milwaukee River (Lake Michigan) and the Sandusky River (Lake Erie).



-In all lakes except Ontario, chloride concentrations have been increasing. Decline in Ontario reflects delayed response to decreased industrial inputs several decades ago. Note different vertical scales.

-Delayed response of Lake Ontario highlights the slow response of lakes to external inputs, which is illustrated more clearly in the next slide …



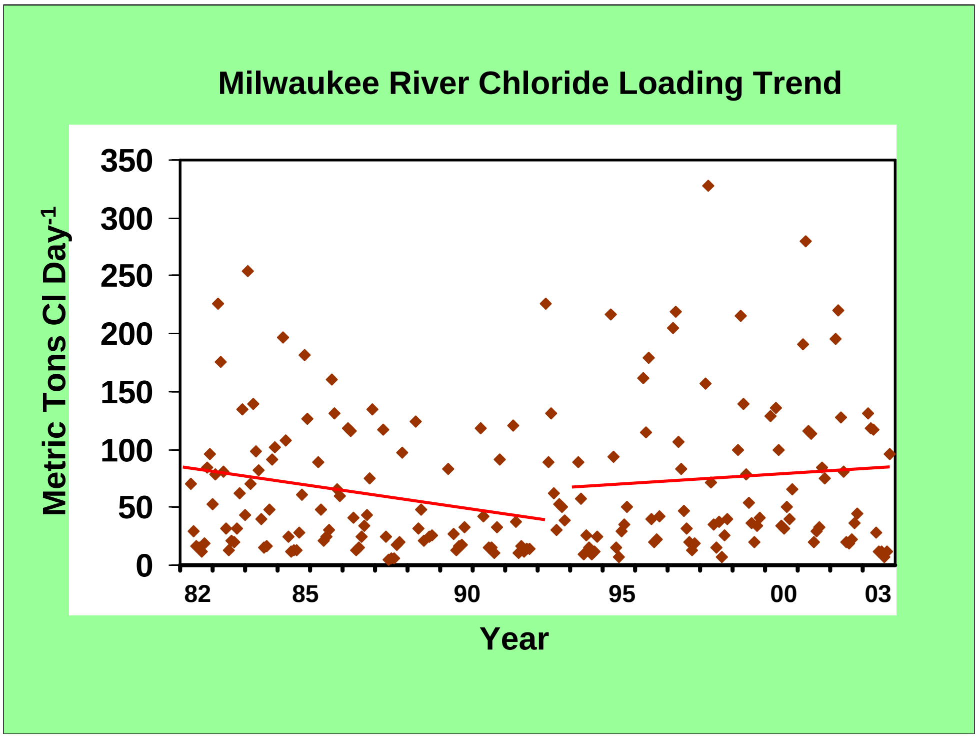
-Model results, which calibrate well against existing data. Cl- can be modeled as a function of loading and lake hydrology.

-All lakes are increasing. Inputs are from industry, domestic, municipal water treatment, and road salt.

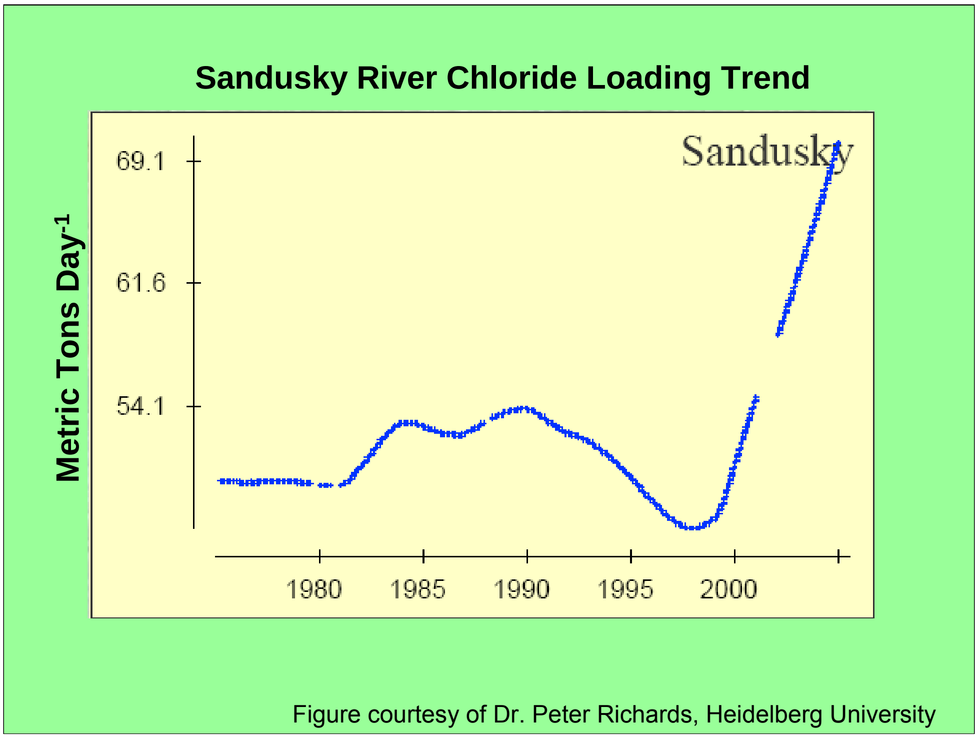
-Due to long residence times of individual lakes and entire system, it will be many years before steady state is reached if current inputs remain unchanged.

-The same will be true for any conservative chemical.

-Highlights the need for monitoring of tributaries.



Chloride inputs from Milwaukee River have stabilized. At steady inputs, Lake Michigan chloride will continue to rise.



-Loading is actually increasing from some tributaries. In this case, future chloride concentrations will be higher than those predicted by model.

Chloride Sources:

- Industry
- Municipal
- Domestic
- Road Salt

Ecosystem Effects:

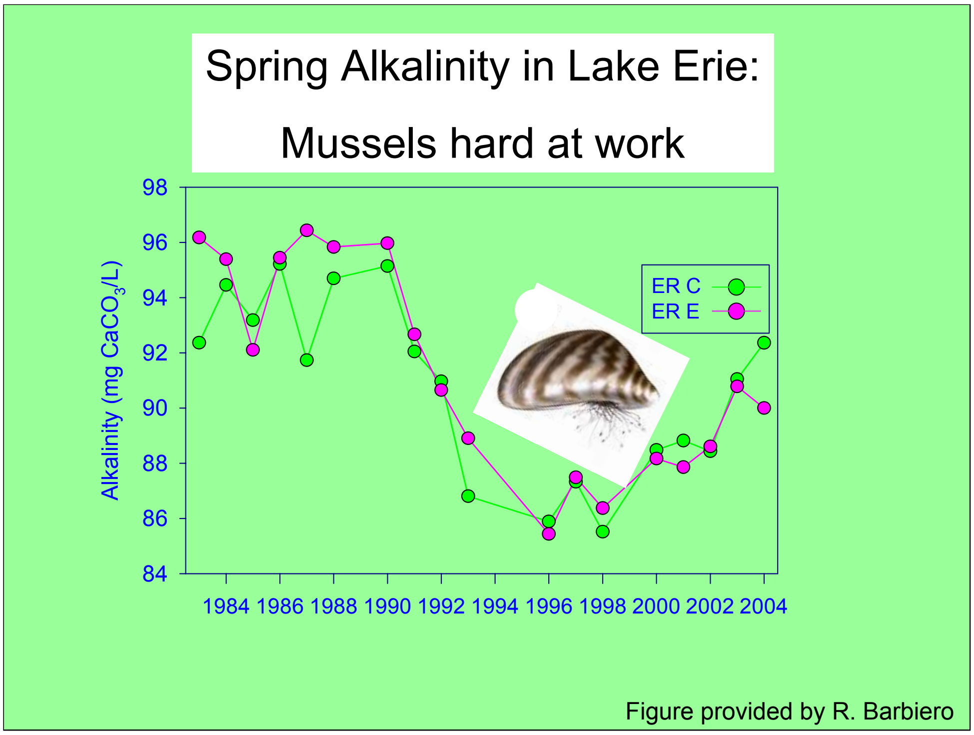
- Phytoplankton species ?
- Phosphorus uptake dynamics ?
- Chloride may serve as a proxy for other chemicals

Why monitor chloride?

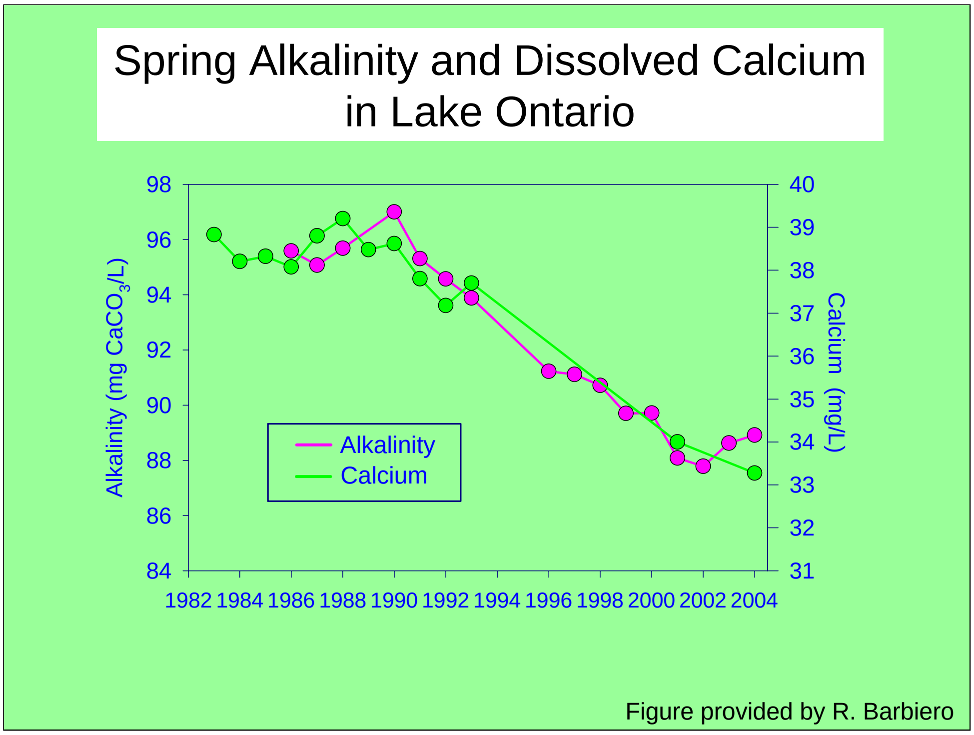
-Can influence plankton composition, even thought it is not a controlling nutrient.

-It is a conservative ion, and therefore not altered within the lake by biological processes.

-It can be a useful indicator of the extent to which lake chemistry is being altered by changes in the watershed and atmosphere. May serve as an index for the loading of other chemicals.



-Dramatic change of alkalinity observed in Lake Erie. Rick Barbiero has shown that most of this change can be attributed to sequestering of Ca by mussels. More recently, alkalinity has rebounded, possibly due to dissolution of old shells and a return to steady state.



-Lake Ontario “takes in what Lake Erie can send her”. Barbiero has shown that mussel shell formation can only account for a fraction of the change in Lake Ontario; the rest is due to sequestering in Lake Erie.

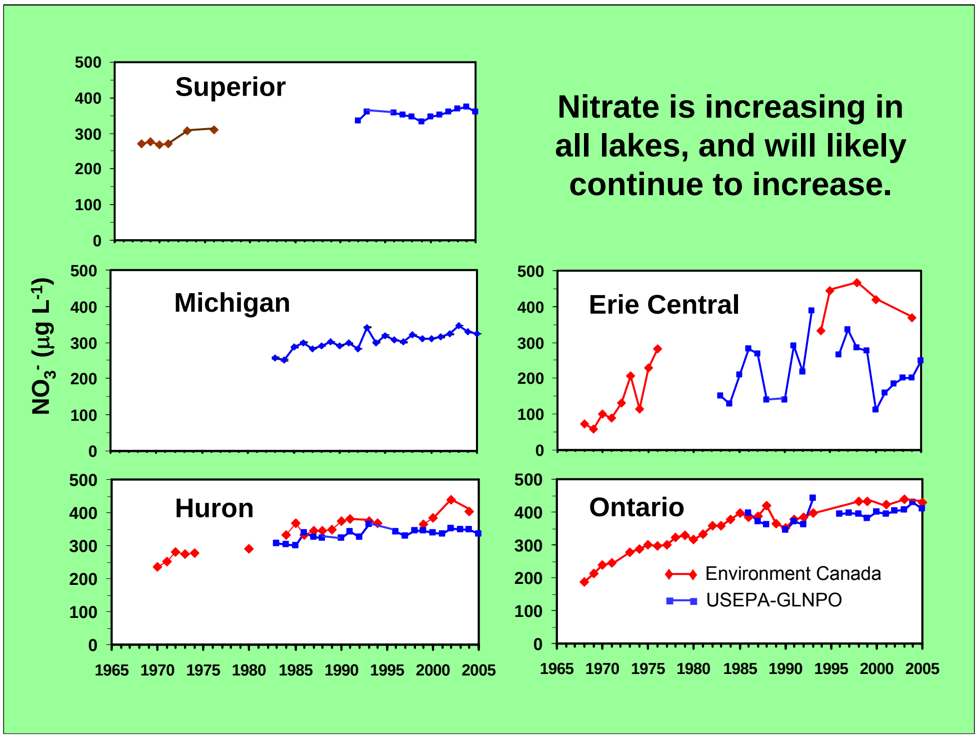
Ecosystem effects of calcium loss:

- Phytoplankton species ?
- Phosphorus dynamics ?
- Water clarity → photosynthesis
- Underscores the potential impact of biological changes

-Potential effects: Increased water clarity, fewer whiting events. Therefore, possible increased photosynthesis, due to greater light penetration.

-Potential changes in phytoplankton species composition, and phosphorus cycling.

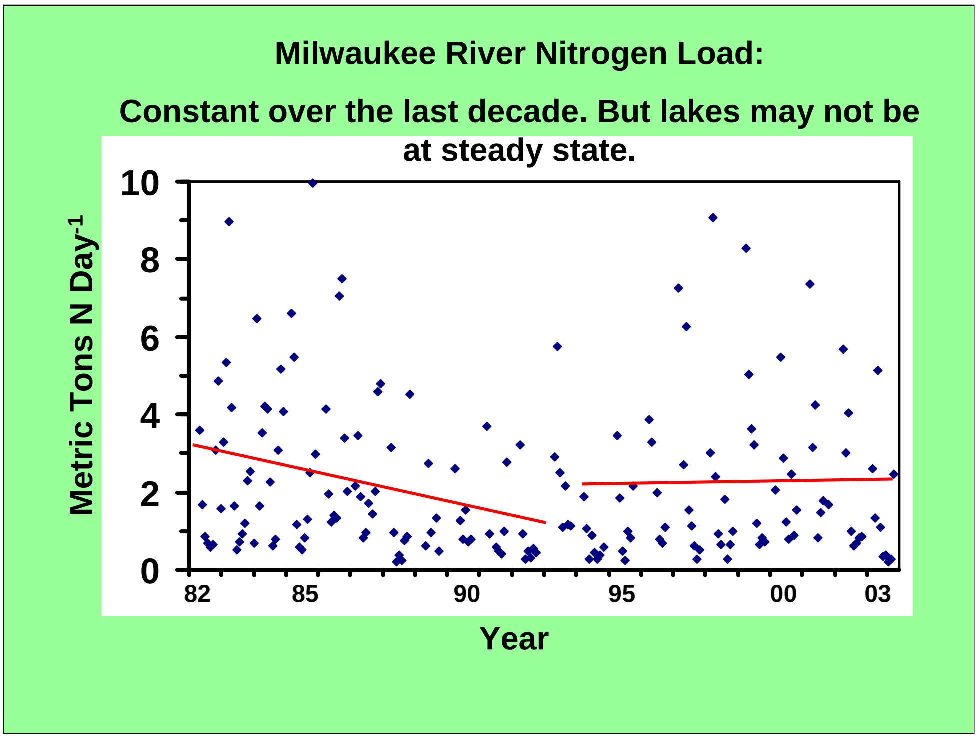
-The calcium story shows how large an effect new species can have.



-Nitrate levels have increased in all five lakes. The results of fertilizer / manure applications and atmospheric deposition.

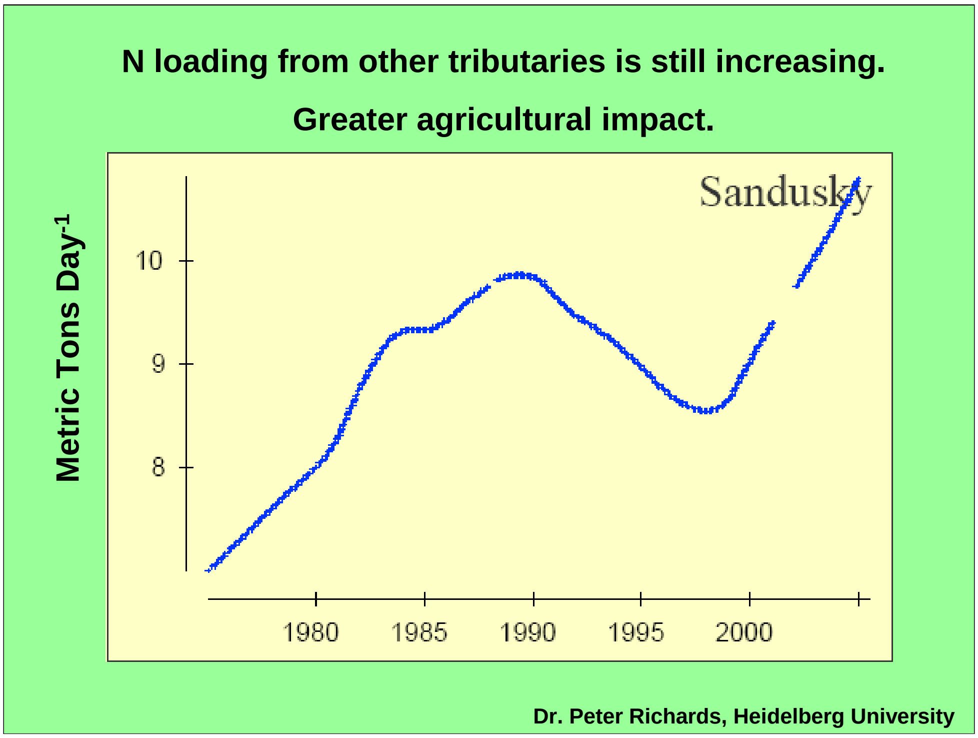
-Note that, unlike chloride, nitrate concentration is quite similar among all lakes. Underscores the importance of atmospheric deposition.

-Nitrate is not as conservative as chloride, and it has not been modeled, but it will also likely continue to increase at least for the next few decades if current loading rates remain constant.



-Nitrogen load from Milwaukee River has stabilized.

-The lakes have not yet reached steady state, and N concentrations will likely continue to rise for several decades if current N loading rate is constant.



-N load is still increasing from the Sandusky River and some other Lake Erie tributaries.

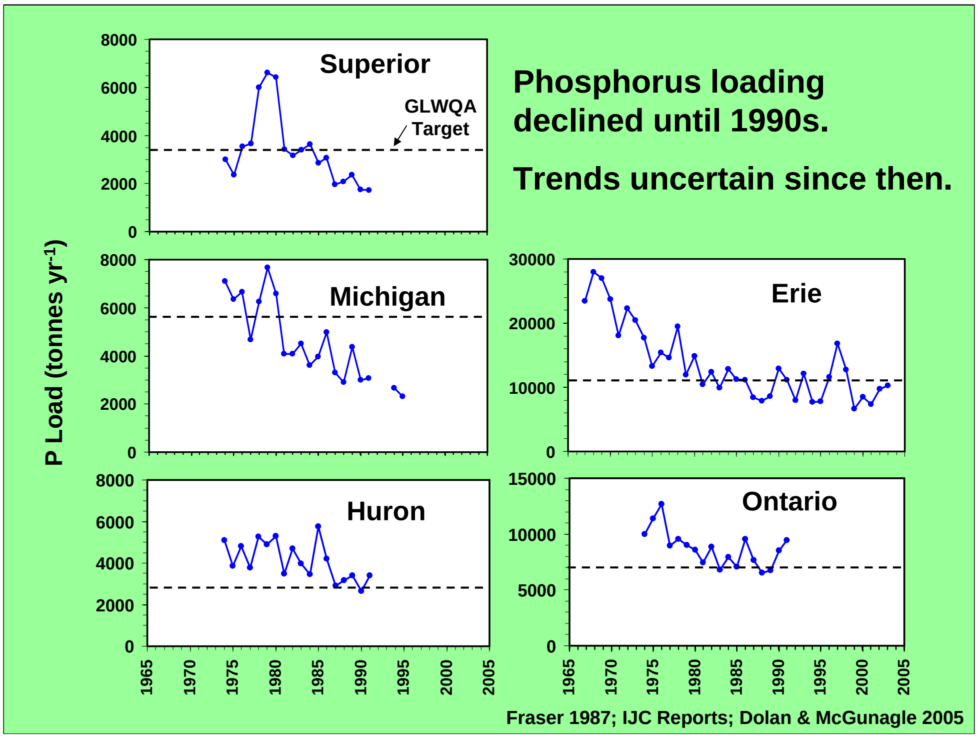
-Loading rates are significantly greater than for the Milwaukee River, probably due to greater agricultural impact.

Ecosystem Effects of N Loading:

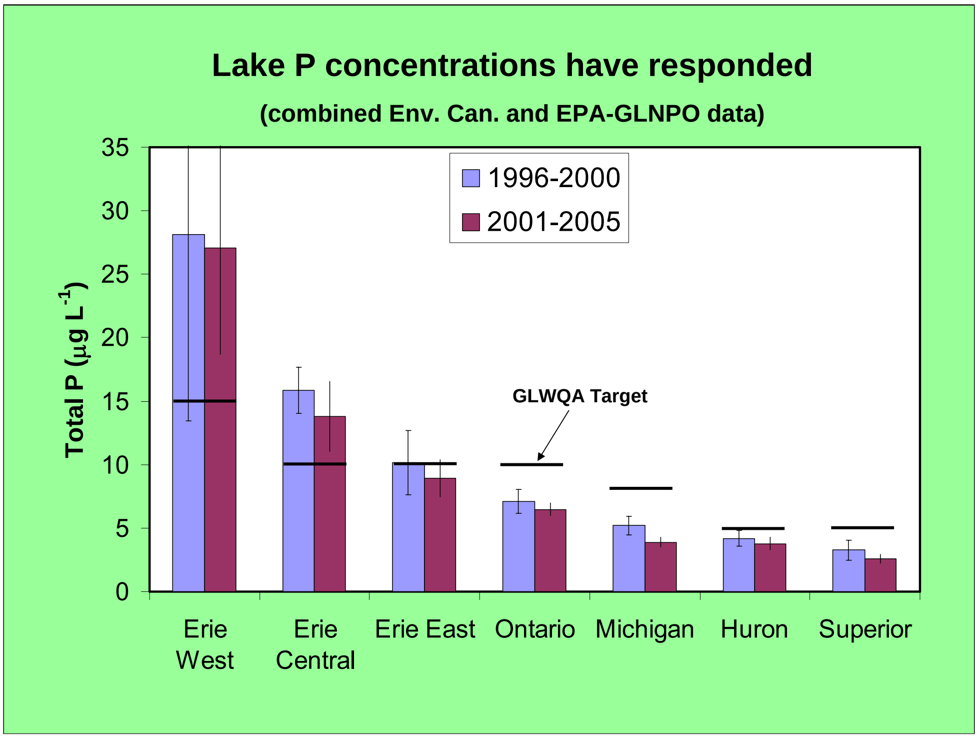
- Phytoplankton species composition ?
- Downstream eutrophication

-No documented obvious effects. Nitrogen may possibly affect phytoplankton species composition.

-Oxygen demand has increased in the St. Lawrence estuary. There is evidence that this may be due in part to eutrophication.

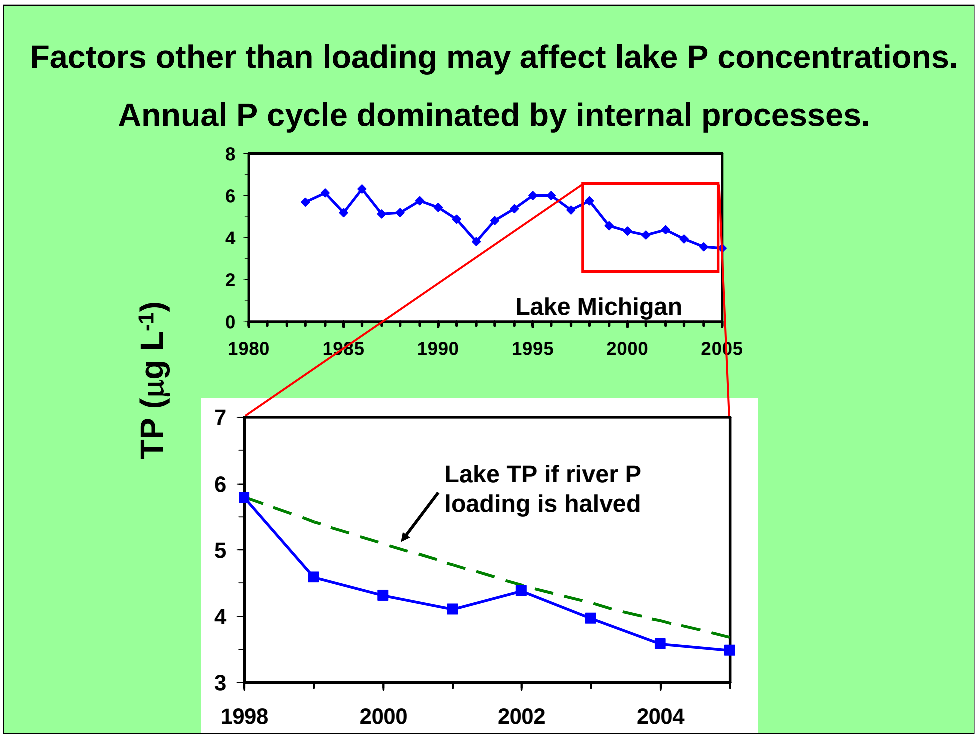


-When last calculated, all lakes except Ontario had P loadings below targets. More recent estimates for Erie indicate its load exceeded target levels in 1997 and 1998 – very wet years. For the other four lakes, we don't know what the recent loading trends are.



-A summary of trends over the past decade. Again, there has been a TP decline in all lakes, but changes in Erie have been marginal and have not met target levels in western and central basins.

-Are target levels the ideal levels, or do we want to get TP as low as possible?

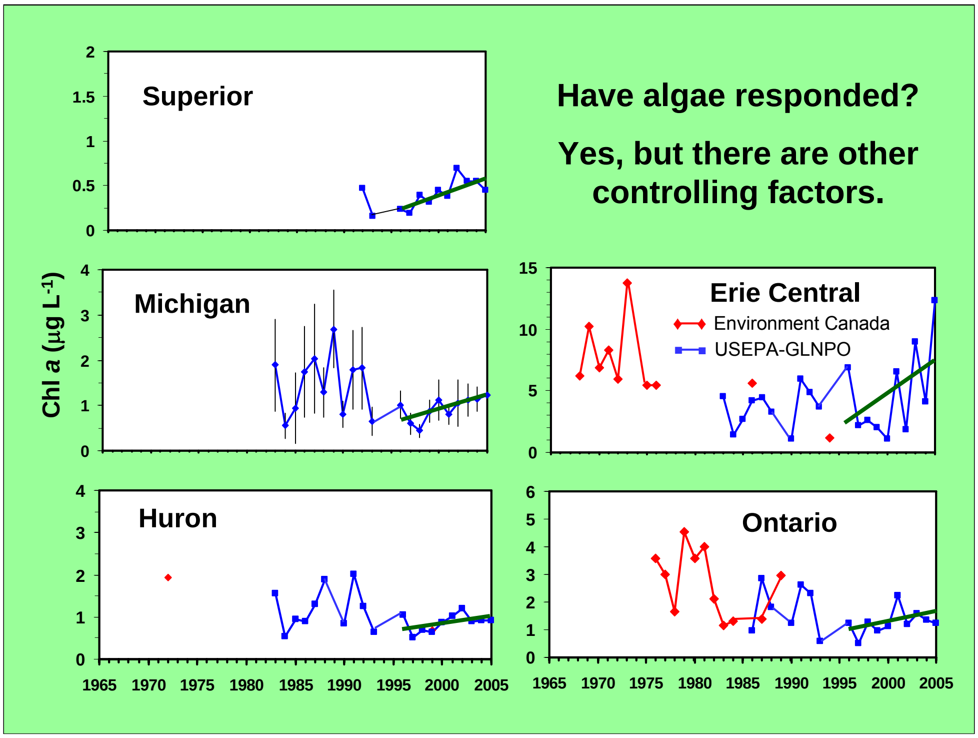


-Ups and downs of TP concentration do not necessarily correspond with changes in loading.

-This is due in part to long residence times, and therefore long equilibration times, but also due to changes in internal cycling dynamics.

-The decrease in TP between 1998 and 2005 would require that phosphorus loading be halved. As we will see in a minute, this was not the case. There must be internal processes that are causing large inter-annual fluctuations in TP concentration.

-The lesson is: be cautious in how we use lake concentrations to assess the success of nutrient abatement programs, especially when there are large changes in biota composition that may have top-down effects.



-The primary objective of reducing P concentration is to control algal abundance and species composition.

-Despite decreases in TP concentration, it appears spring chlorophyll concentrations have generally increased over the past decade. Not sure why; possible decrease in zooplankton grazing. Water quality management is more than a simple bottom-up process. We need to consider biological interactions as well.

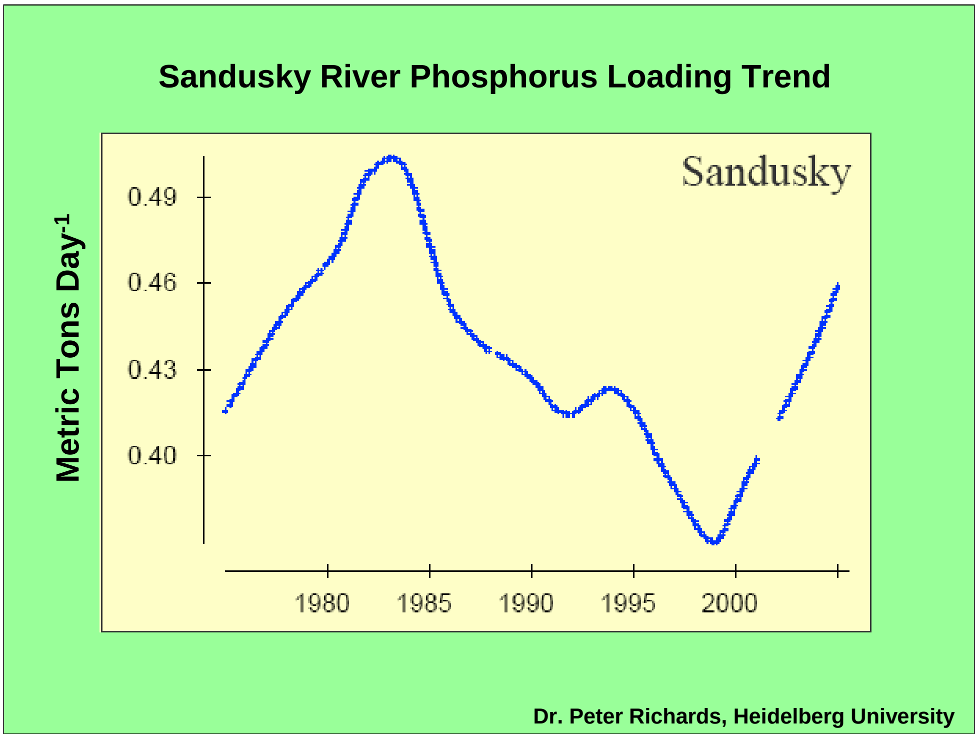
-Data not shown, but summer chlorophyll concentrations have generally declined.

PHOSPHORUS CONTROL:

MISSION ACCOMPLISHED ?

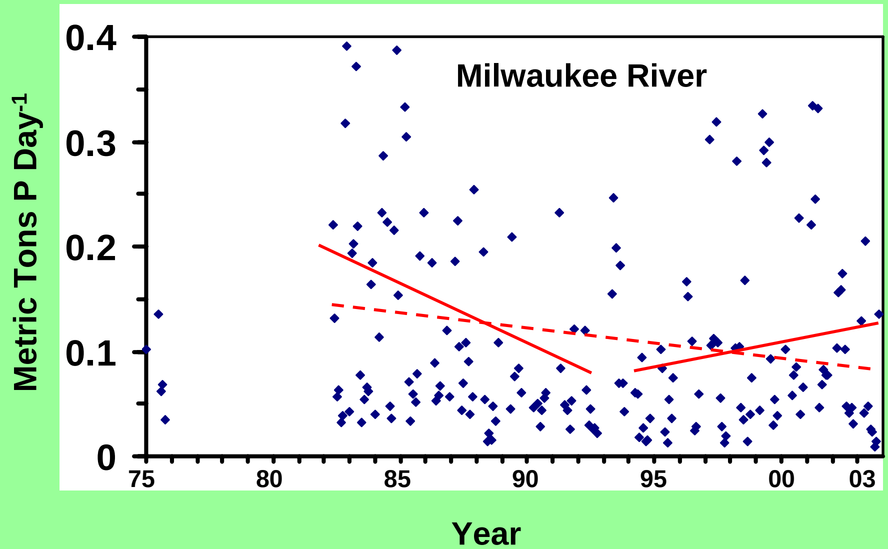
-Phosphorus concentrations are below target levels in most lakes, and when last estimated, loading rates appeared to be at or below target levels.

-So have we achieved our goal?



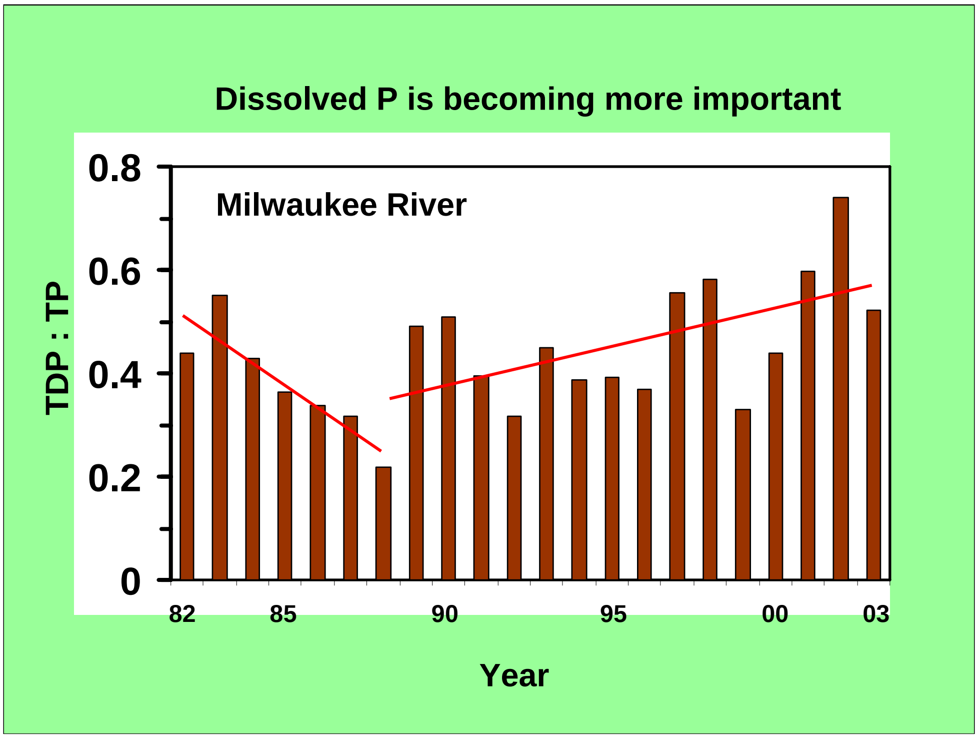
Evidence of recent increase in P loading for some Erie tributaries.

Continued tributary monitoring is necessary



-Over the past 20 years, there has been a slight downward trend in Milwaukee River P loading. This is due to decreases in the 1980s and early 1990s. In the past decade, P loading has not declined.

-Question: does it need to be any lower? If it does, what source(s) do we target?



-Not only has P load been increasing, but P speciation is changing.

-More of the P load is now in the dissolved form, which may be more readily available to algae.

-Reason?: Uncertain, but may be the result of increasing soil P loads, and increasing drainage of farm land.

Sandusky and Maumee River Watersheds
Lake Erie

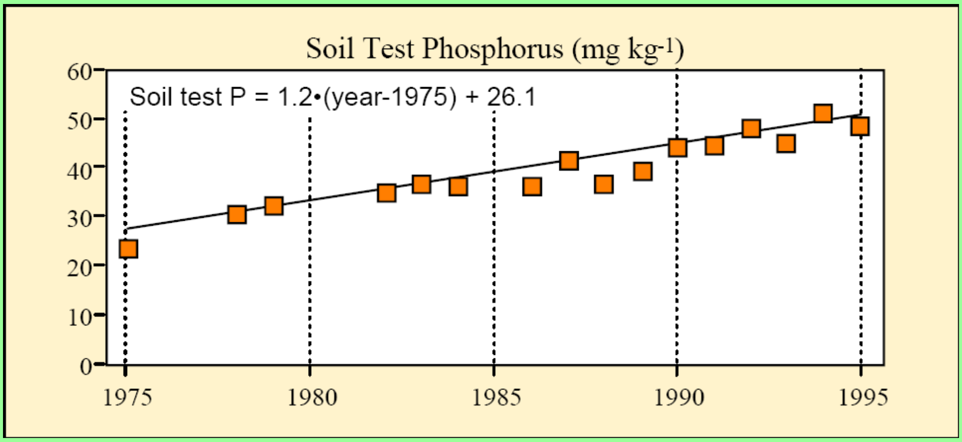
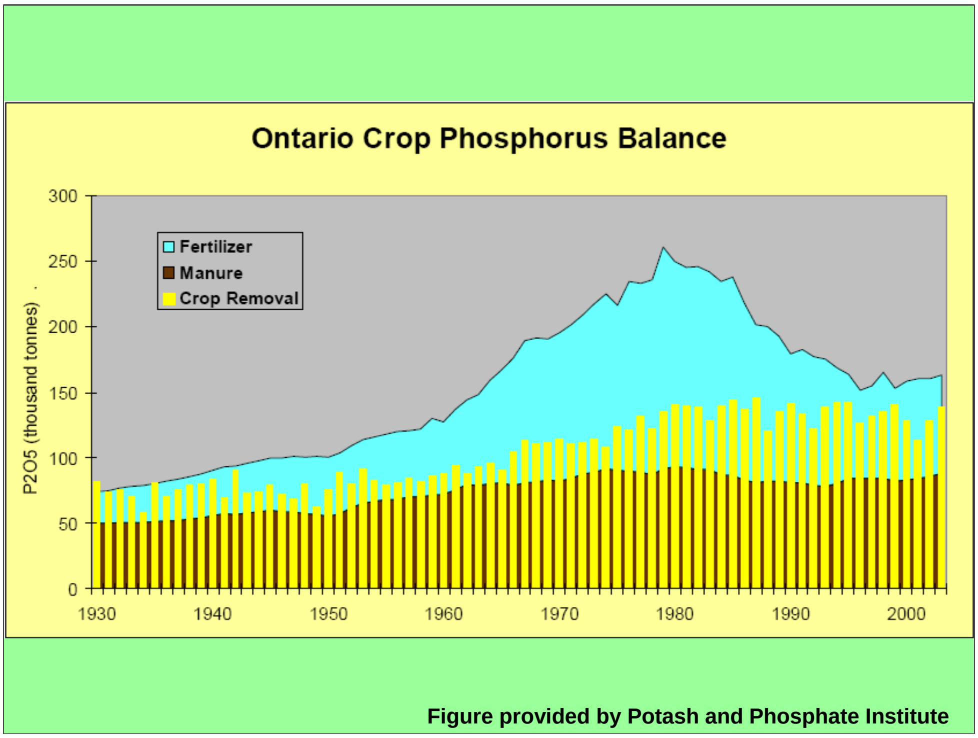


Figure courtesy of Dr. Peter Richards, Heidelberg University

-If we need to further reduce P inputs, where do we look?

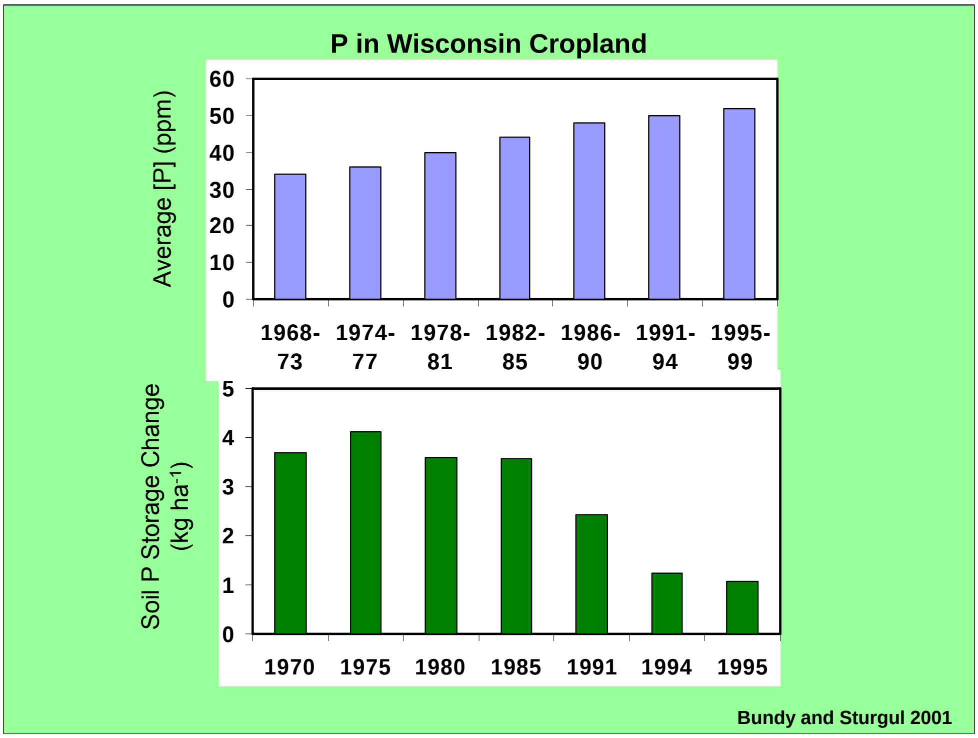
-Agricultural P is an important source, and may continue to increase.

-Agricultural soils have been accumulating phosphorus. In most cases, they have more than is needed by crops.



-In Ontario farmland, P inputs were previously much higher than removals.

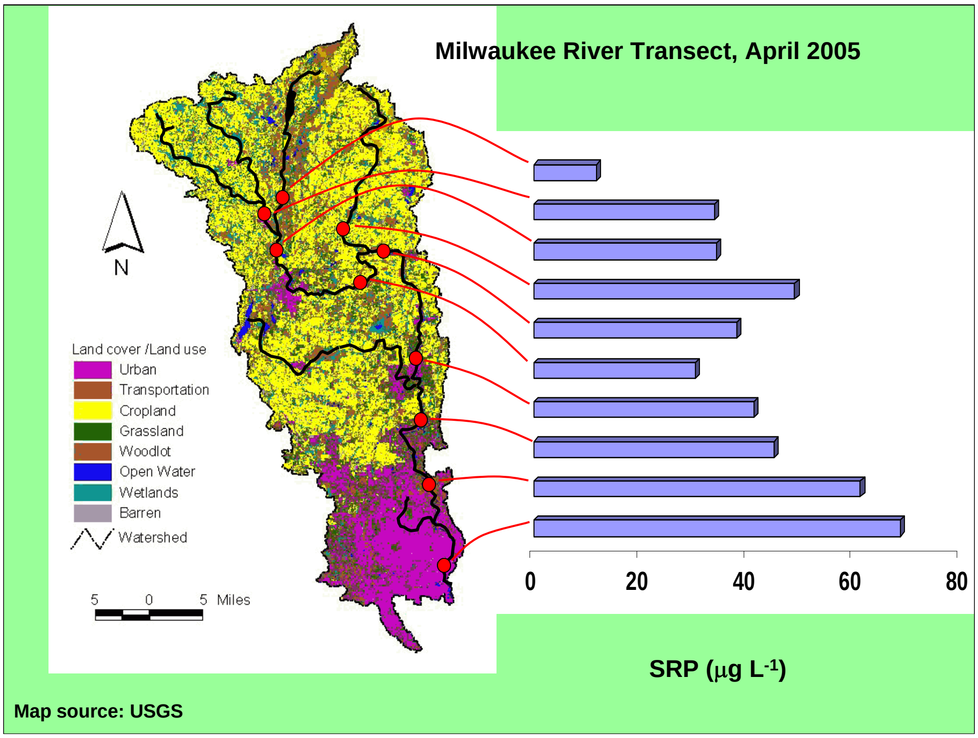
-More recently, a balance between inputs and removal is being approached.



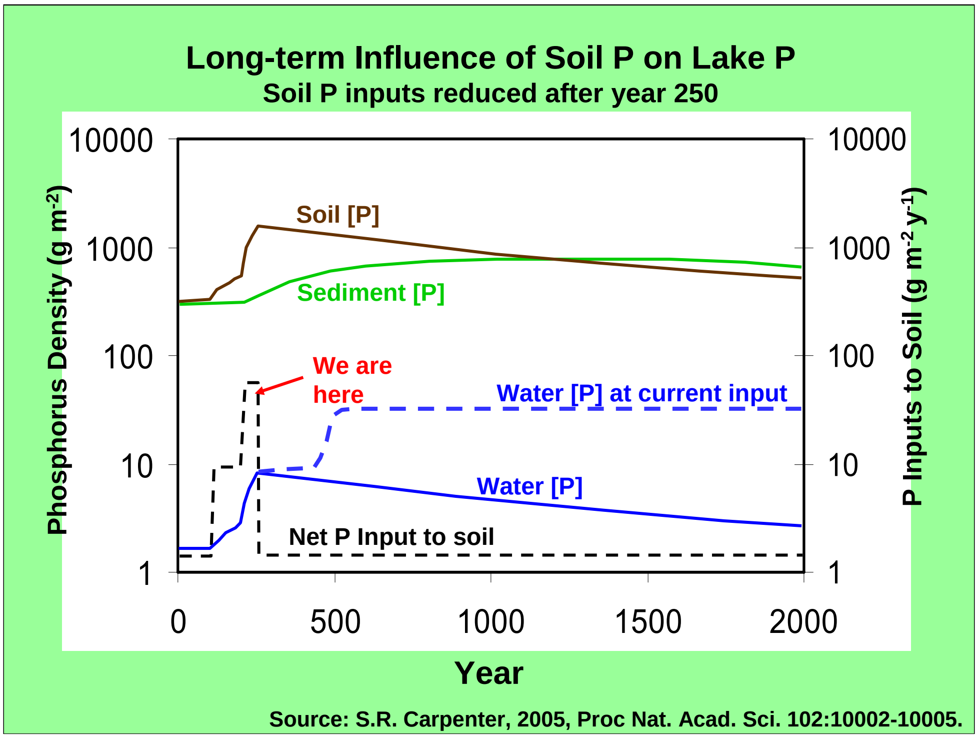
-But soil P is still increasing.

-Currently, more P is going into the soil than coming out, although we are approaching a balance.

-Management must target hot spots, not entire watershed. Must also target high loading periods – usually spring.



-Where is P coming from. Agricultural, but perhaps also urban. May explain lack of recent TP increase upstream.



-Carpenter's soil – lake P model.

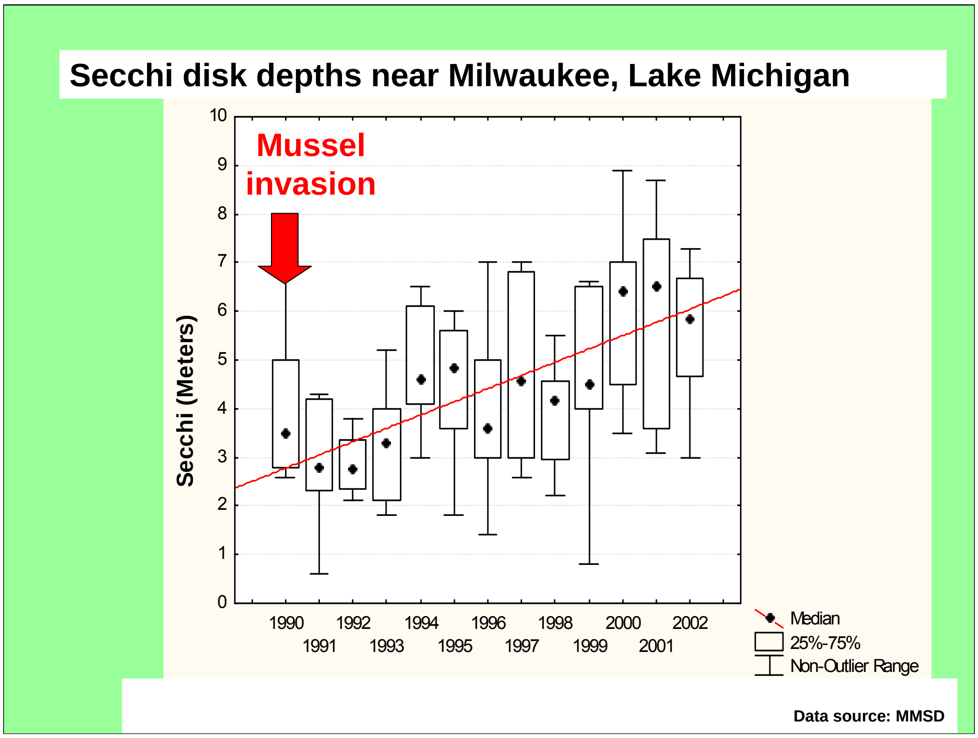
-Soils have a huge store of P, with a very slow turnover time.

-Even if P inputs to soil are decreased, soil and lakes will respond very slowly.

-Cladophora at a depth of 9 m in Lake Michigan. A symbol of nearshore eutrophication.

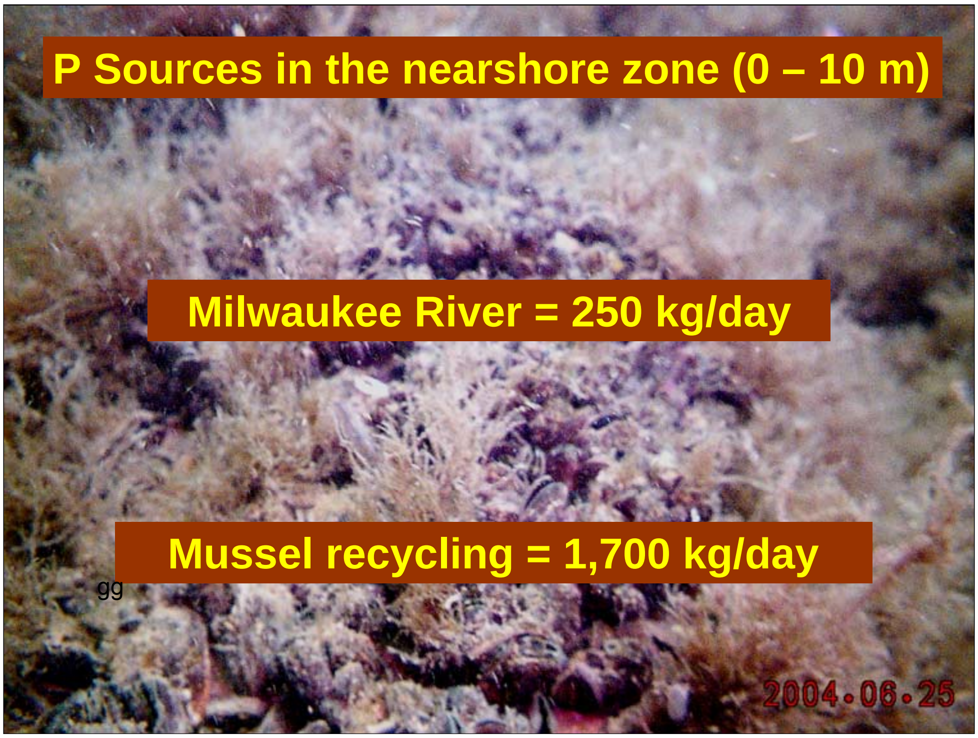
-Cladophora. It’s not quite so attractive when it’s on the beach.

-Smells; unsightly; plugs up water intakes; may harbor bacteria.



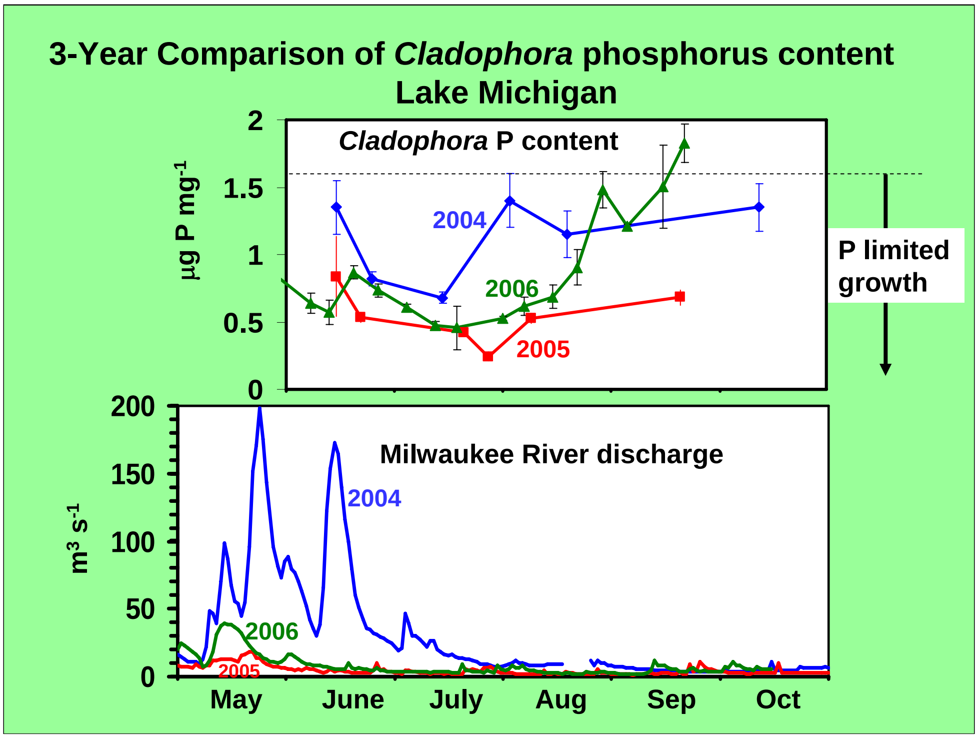
-Water clarity in most of the Great Lakes has increased markedly, thanks to dreissenids.

-Increased water clarity has upped the ante with regard to phosphorus control requirements.



-Dreissenid mussels have altered the nearshore phosphorus cycle.

-Mussels, along with light, have changed the relationship between phosphorus inputs and algal response.



-Cladophora phosphorus content provides and index of water column phosphorus availability. It also is a driver of Cladophora growth.

-Inter-annual differences in Cladophora P content match difference in river discharge. This suggests that river P inputs, especially in spring and early summer, have a significant influence on Cladophora growth.

-So – even though P loading is below target level, is there a need to reduce it further?

Conclusions:

- Concentrations of some "natural" chemicals – N, Cl, Ca – are changing, but the effects on ecosystem function are uncertain.

- For most lakes, P concentrations are at or below target levels. TP has stabilized over the last 5 to 10 years, with the exception of Erie.

- P loads are probably at or below target levels, but recent measurements are available only for Lake Erie

- There are some signs of recent increases in P loads. Possible causes:
  - Weather
  - Urban impacts
  - Increased soil P content

Conclusions:

- Long residence time of the lakes makes river monitoring imperative.
- In the nearshore zone, changes in water clarity and nutrient cycling have altered the relationship between P loading and algal abundance.
- More P abatement would benefit the nearshore zone, but would it benefit pelagic zone?
- Slow turnover rate of soil P may pose a long-term hurdle to further P loading reductions.