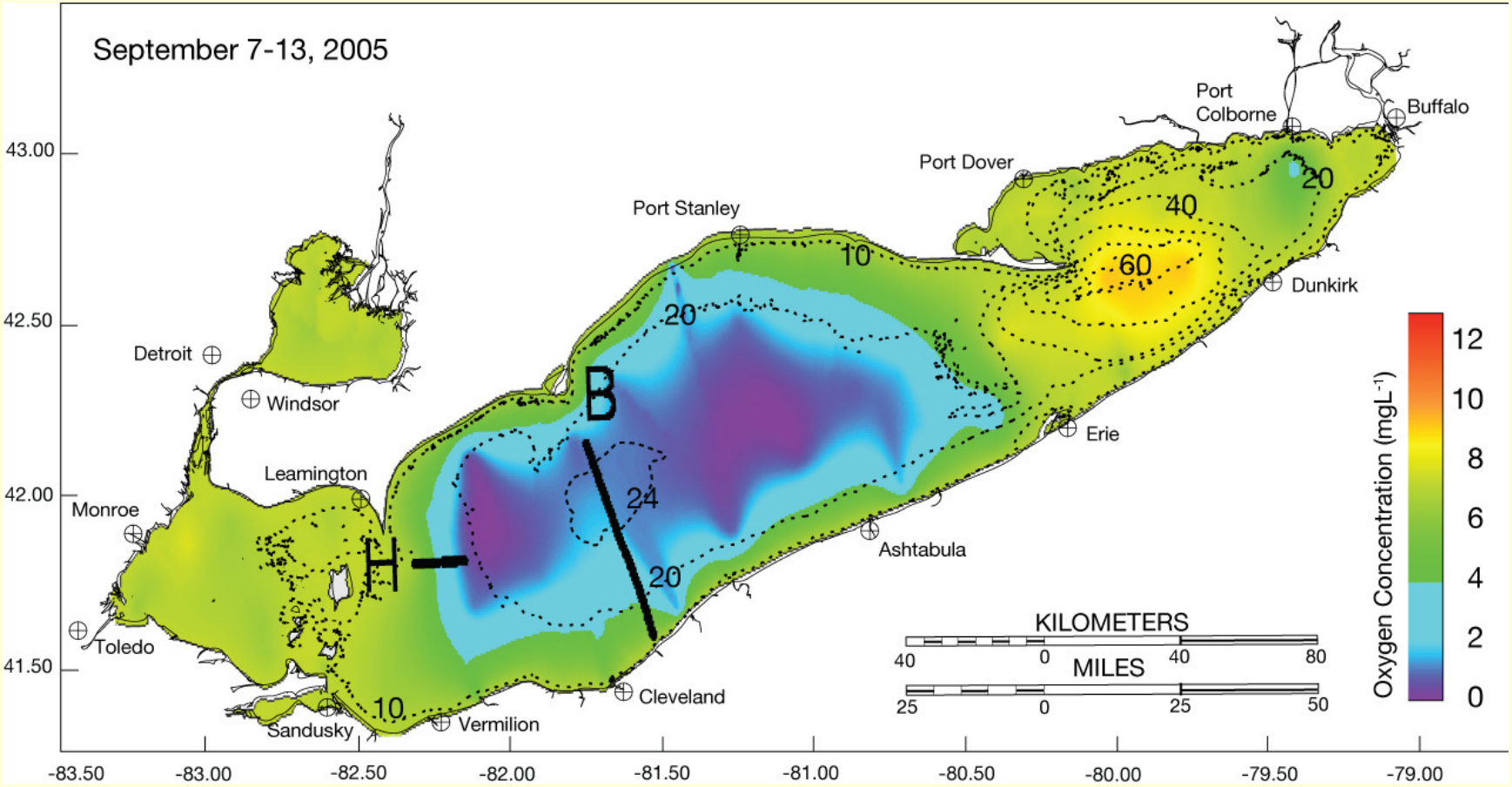
# What dreissenid mussels do: are they responsible for recent (unpleasant) changes in western Lake Erie?



**And what happens next?**

Hank Vanderploeg, GLERL NOAA
Henry.Vanderploeg@noaa.gov

# Hypoxia in the central basin—mussel caused?



# Are they responsible for Microcystis blooms and will they continue?

Microcystis plume in Maumee Bay, western Lake Erie

Lake Erie, Put-In-Bay,
Sept 2006,
Juli Dyble, NOAA-GLERL

Microcystis in a glass
Tom Bridgeman, U. of Toledo

Lake Erie, Put-In-Bay
August 2004
Juli Dyble, NOAA-GLERL

Lake Erie, South Bass Island
August 2004
Juli Dyble, NOAA-GLERL

# Are they responsible for muck on beaches?

The extent of the muck along shoreline at Bay City State Park

Diver in Cladophora bed off Sleeping Bear Dunes, 20ft

Photo by B. Lafrancois

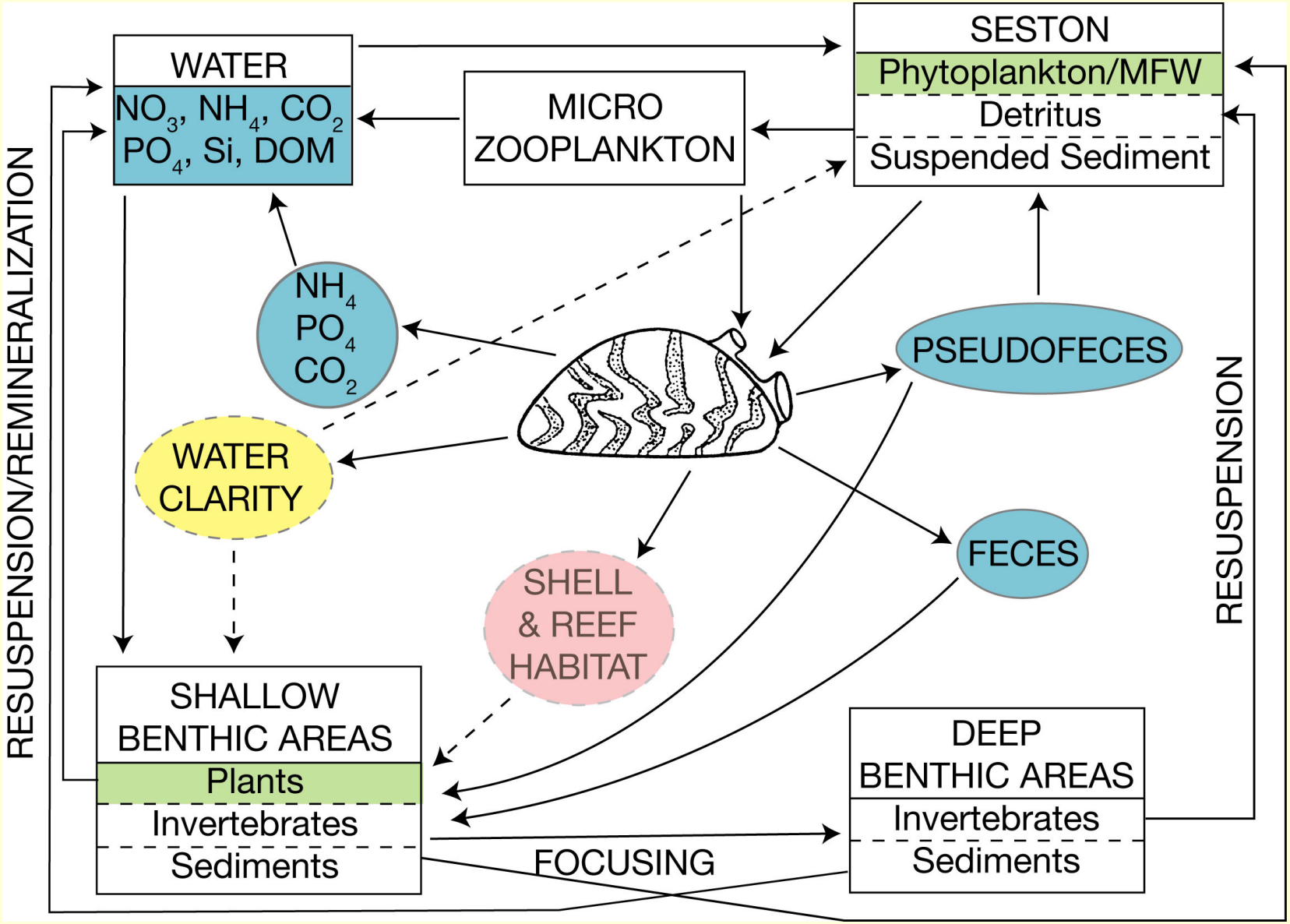
# Bird die-offs from botulism— is this mussel related?

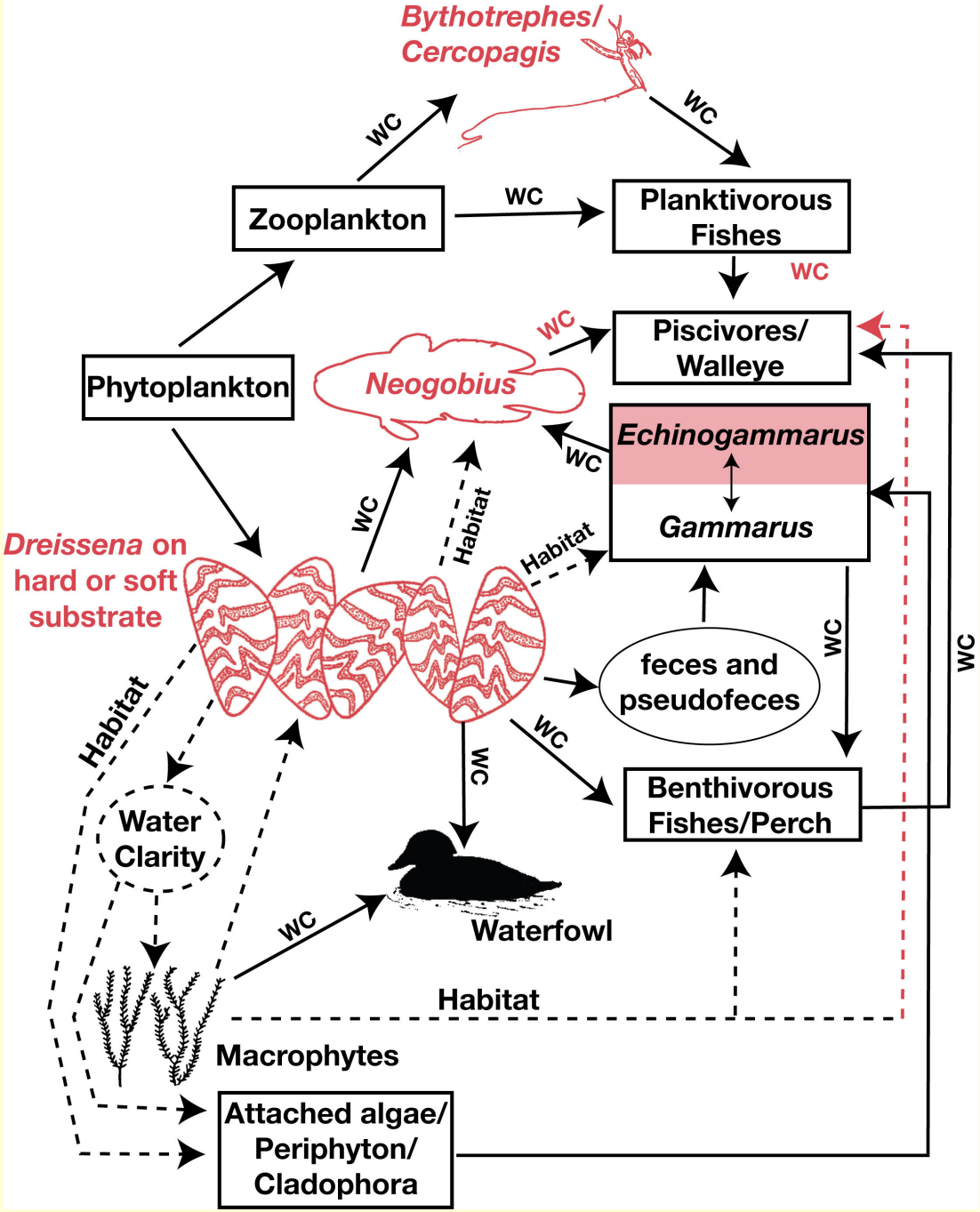
More than 1300 loons died during 2006–2007 from type-E botulism poisoning along the shores of northern Lake Michigan

# Big mats of filamentous toxic algae—mussel caused?


Tom Bridgeman of the University of Toledo holds up toxic algae found on the swimming beach at Maumee State Park.
( THE TOLEDO BLADE/DAVE ZAPOTOSKY )

# What zebra & quagga mussels do






**What Mussels Do:**

Some interactions of mussels with other members of the food web

**The Microcystis story started on Saginaw Bay in 1996:**

1) Vic Bierman said water quality models and P reduction are not consistent with blooms in 1994.

2) Hank blamed mussels.

Bay City Times

Tuesday, March 19, 1996

# Concerns about algae, mussels pack Bangor hall

■ Residents eager for information about water problems

By Kelly Adrian Frick
TIMES WRITER

Scientific researchers are in many ways still puzzled by the effects of zebra mussels and algae in the Saginaw Bay.

What became clear Monday night, however, was that their research has an interested audience.

About 140 people, mostly fishermen and shoreline pro owners, packed Bangor Tow Hall for what was hailed as State of the Bay" presenta The two-hour program, sponsored by the Bay County Waterfront Task Force, gave audience members highly technical lectures filled with scientific data and long, complex names for Bay inhabitants such as zebra mussels and algae.

But that didn't scare audience members who asked questions for more than 30 minutes after the presentations. Many of the

See BANGOR, 2A

From 1A

questions asked didn't directly deal with the research shown Monday night. Residents asked about the green algae — often referred to as muck — that washes ashore in the summer and about fish populations.

"People have a big concern about the bay. The Saginaw Bay is a tremendous resource that perhaps people have taken for granted," said Dan Manyen, owner of Steelie Dan's River Charters, a charter fishing business.

"I understand that science can't answer everything. But I know that the fishing isn't what it was in 1986 or 1987 and I'd like to know why."

Greg Little, a worker at the Bay Metropolitan Water Treatment Plant and sport fisherman, said he learned many new things about the Saginaw Bay waters but that many residents came hoping to hear solutions.

"We have to realize the zebra mussels aren't going away. The muck on the beaches probably isn't going away. We have to learn how to deal with that," Little said.

"I've got a lot of questions," said Mary Jo Braman, a Brissette Beach resident with six kids. "My kids swim in that water and I think we need to do even more research to find out exactly what is happening. There is so much that doesn't seem to have been researched."

The Saginaw Bay health report given Monday night addressed two specific research projects — the decrease of phosphorous in the Bay and the relationship between zebra mussels and different types of algae. The researchers were in town for today's Saginaw Bay Watershed conference at Saginaw Valley State University.

Victor Bierman, with LimnoTech Inc. in South Bend, Ind., said the high phosphorous content in the water during the 1970s caused a large amount of algae in the water, particularly blue-green algae — an unhealthy type of phytoplankton. But after $500 million of governmental funding was thrown at the problem, phosphorous has greatly declined in the water, he said.

That would be good news, except that blue-green algae that disappeared in the late 1970s reappeared in the water in 1994.

Hank Vanderploeg, an ecologist with the Great Lakes Environmental Research Laboratory in Ann Arbor, gave a detailed discussion on his research group's theory that zebra mussels are more than a nuisance to water intake plants and boaters. The creatures may also be partly to blame for the increase in blue-green algae. The algae, which is microscopic and not the same as the muck that washes to shore in the summer, may also be slightly toxic, Vanderploeg told the crowd Monday night.

Bierman said he was surprised at the intensity of the crowd and by the educated questions asked.

"I was actually frustrated," he said after the question-and-answer period. "I wish we were able to give more answers, but unfortunately science doesn't have all the answers."

Joseph Rivet, Bangor Township supervisor and a member of the Bay County Waterfront Task Force, said the questions may prompt future programs on other Saginaw Bay issues and discussions on what residents can do to help.

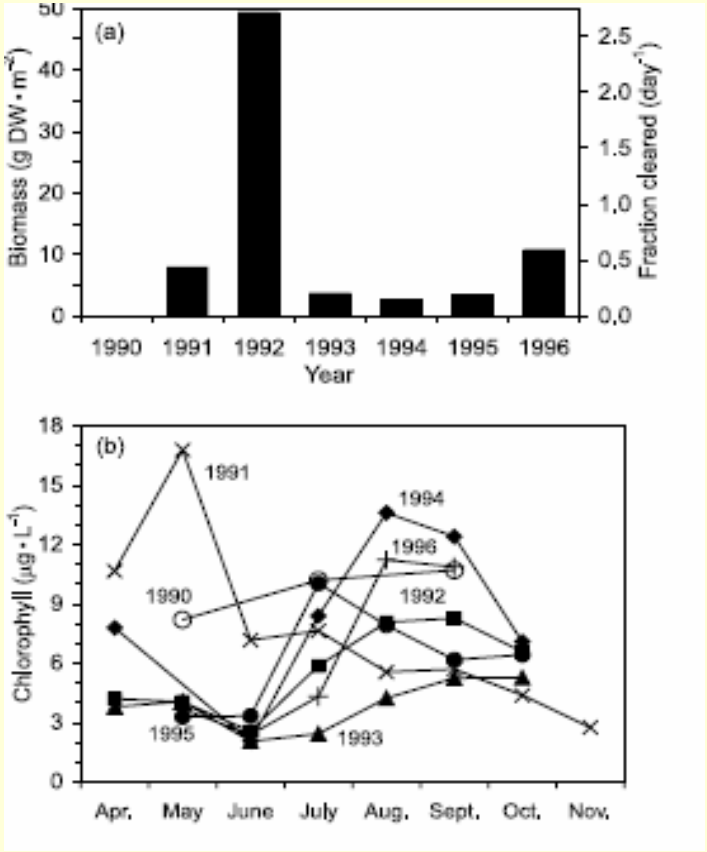
"This really shows that there is a need for increased research and more understanding about what is happening in the Bay," he said.

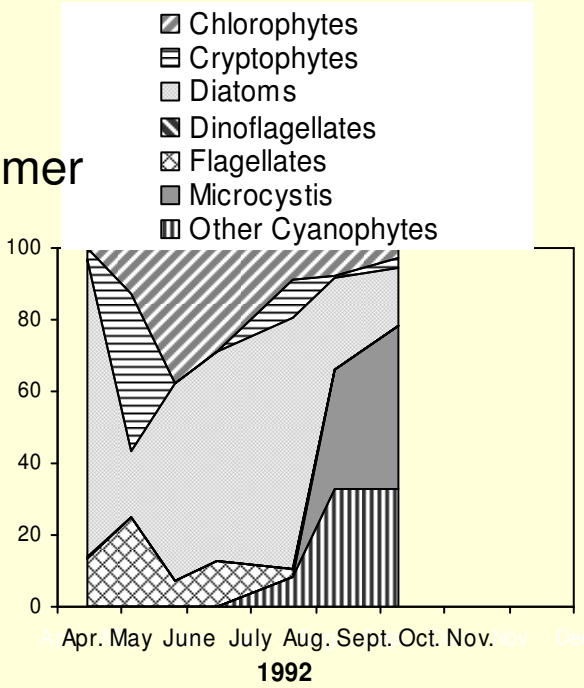
Charter captain Dan Manyen agreed.

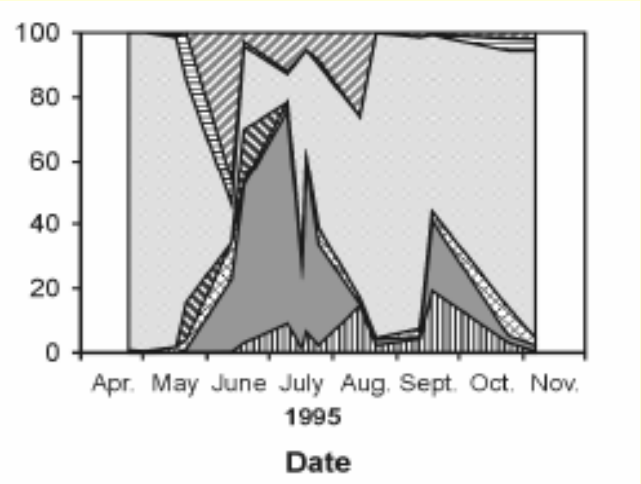
"We've got to start caring about this, and not just the property owners and fishermen," he said. "It affects the guy who sells pop and beer and gas to people coming out here too. The Bay affects us all."

# Saginaw Bay Story

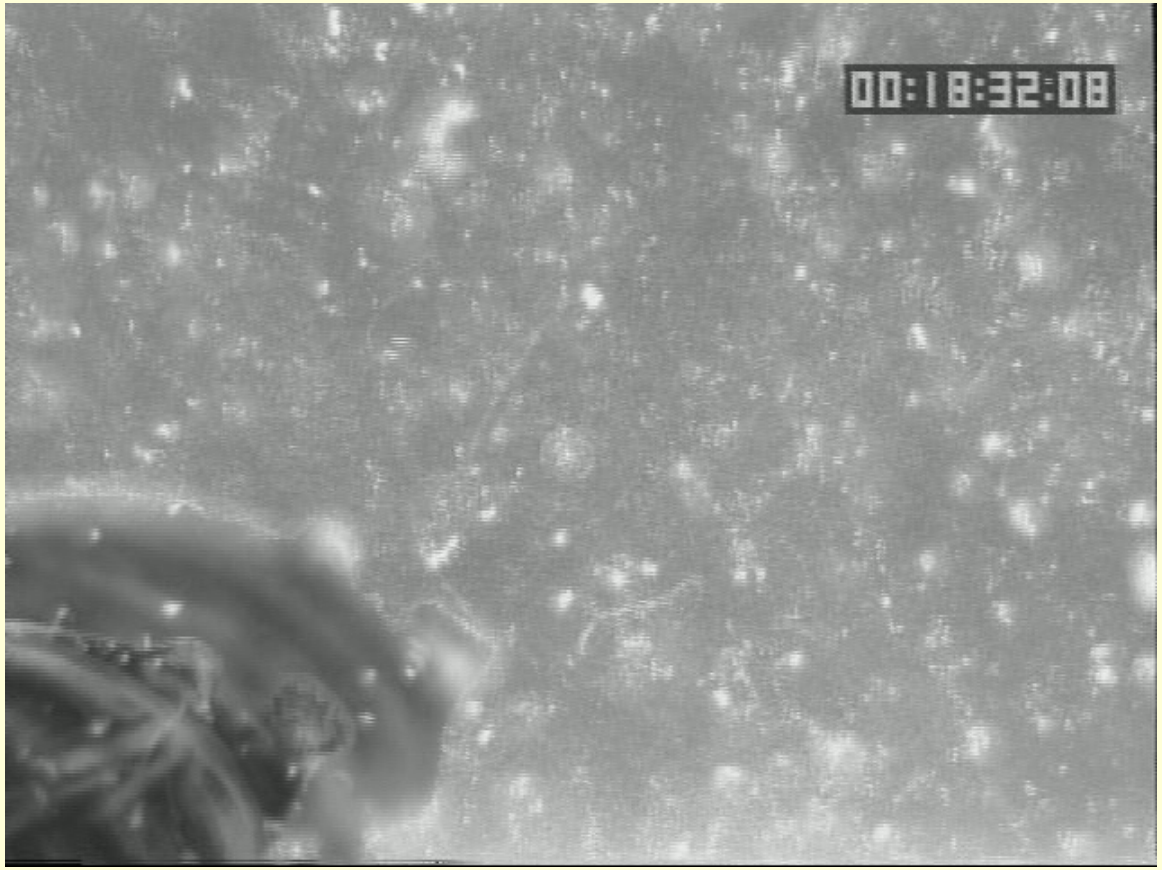
- Mussels knock down chlorophyll in Spring
- Chlorophyll & *Microcystis* increase during summer



# The Beginning of the story:
# **Mussels and Lake Erie *Microcystis* bloom of September 1995, Hatchery Bay**



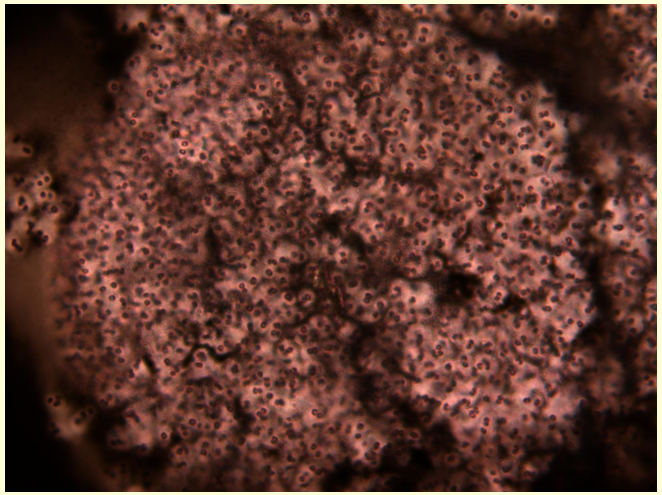

The selective rejection paradigm: large toxic colonies are rejected while small algae are ingested (Vanderploeg et al. 2001)

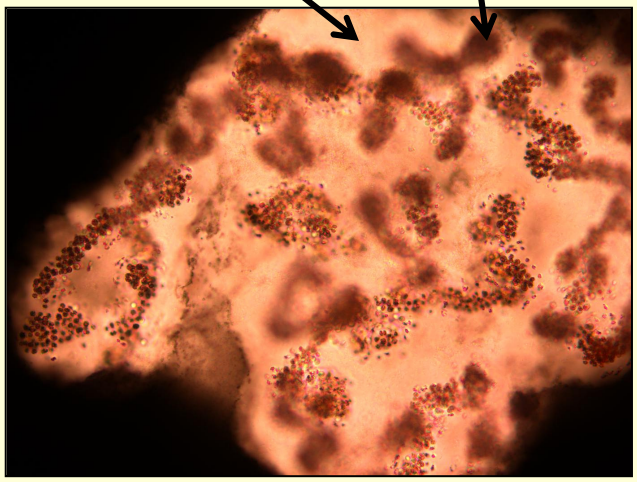
# Original paradigm details

- Abundant dreissenids clear a significant fraction of the water column per day
- Large toxic (or unpalatable) *Microcystis* are easily sorted from smaller phytoplankton and rejected as pseudofeces
- Pseudofeces are loosely aggregated with *Microcystis* returned to water column
- Nutrients from “processed” algae returned to water column to “feed” *Microcystis*

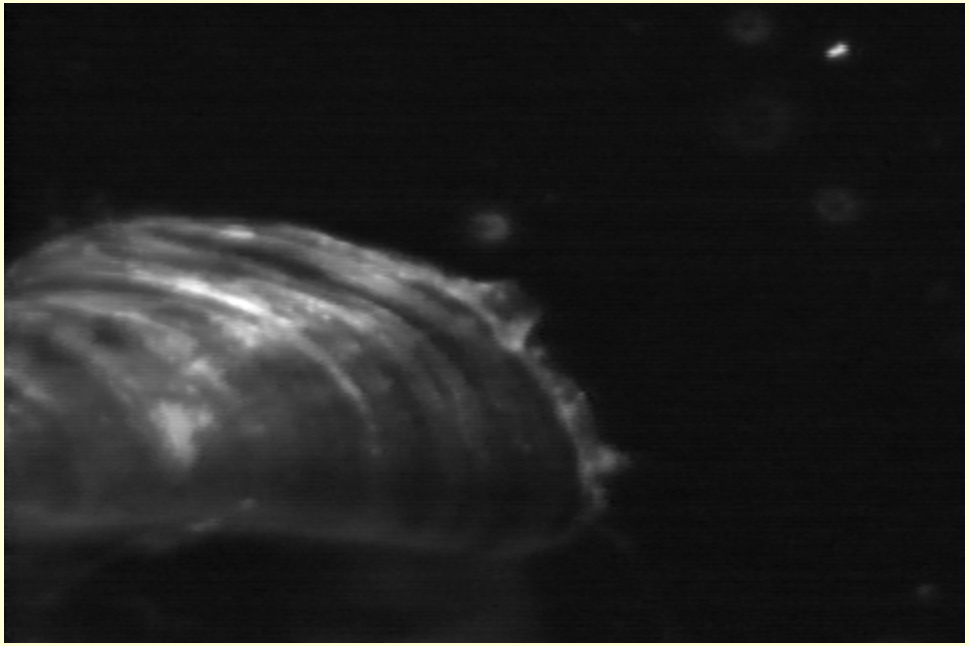
# Possible challenges of *Microcystis* to grazers & experimenters

- Colony size range ~20 µm - 2 mm (most > 53 µm)
- Microcystins and other toxins in cells
- Irritants/toxins in mucilage
- Viable gut passage?





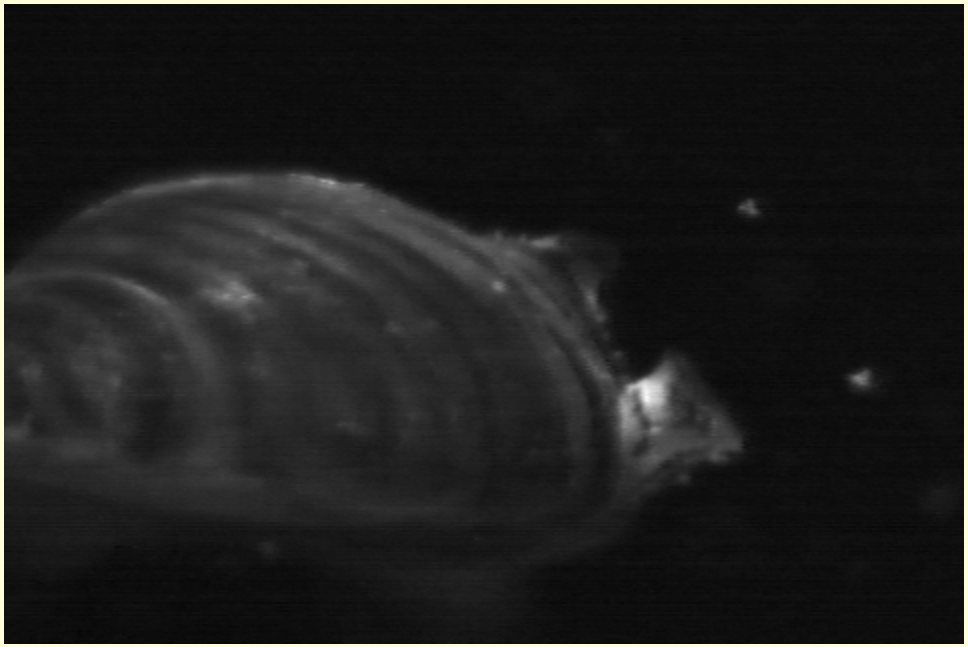
**Gilkey Lake (no mussels present) strain —** no feeding on any size category



Note symptoms of distress: siphon not fully open & weak expulsion response

| Fraction | Initial chl (µg/L) | Microcystin / chl | $F_A$ (mL/cm$^2$/h) |
|---|---|---|---|
| >53µm | 1.96 | 0.099 | -10.53 |
| <53µm | 0.84 | | -1.90 |
| Total | 2.79 | | -8.20 |

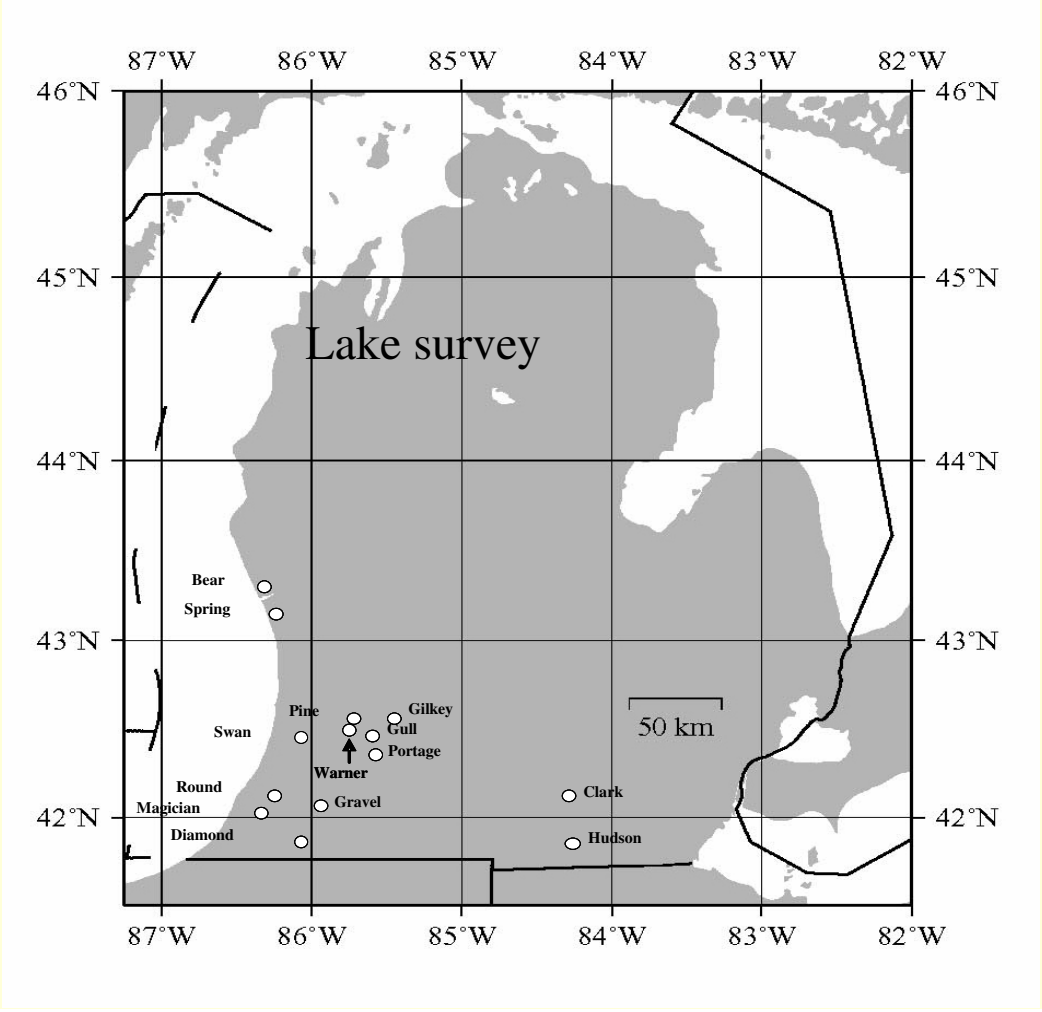
# Gilkey Lake strain plus *Cryptomonas*



Note rejection of individual colony as it enters siphon

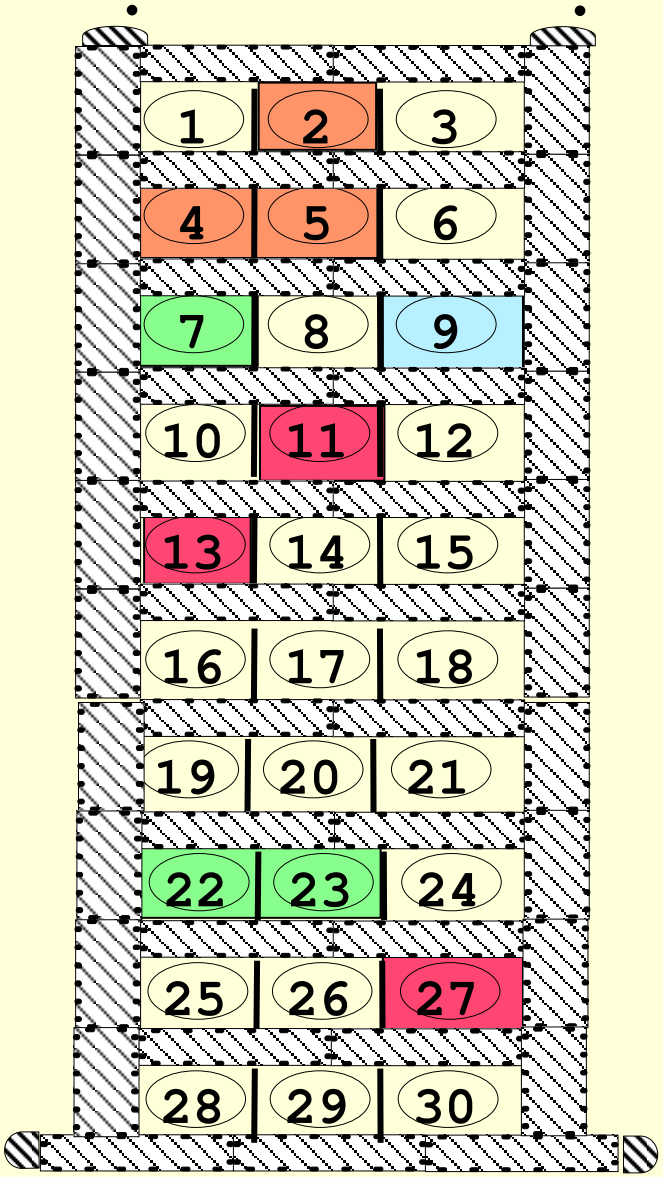
# More evidence and puzzling results

*Microcystis* increased in low TP lakes (<25 µg $L^{-1}$), but not in high TP lakes (>25 µg $L^{-1}$) invaded by zebra mussels (Raikow et al. 2004)



# Graduate student Geoff Horst with his 30 mesocosms at Gull Lake—each with different nutrient and mussel concentrations

# ZMEX2007 showing treatments examined by Team GLERL



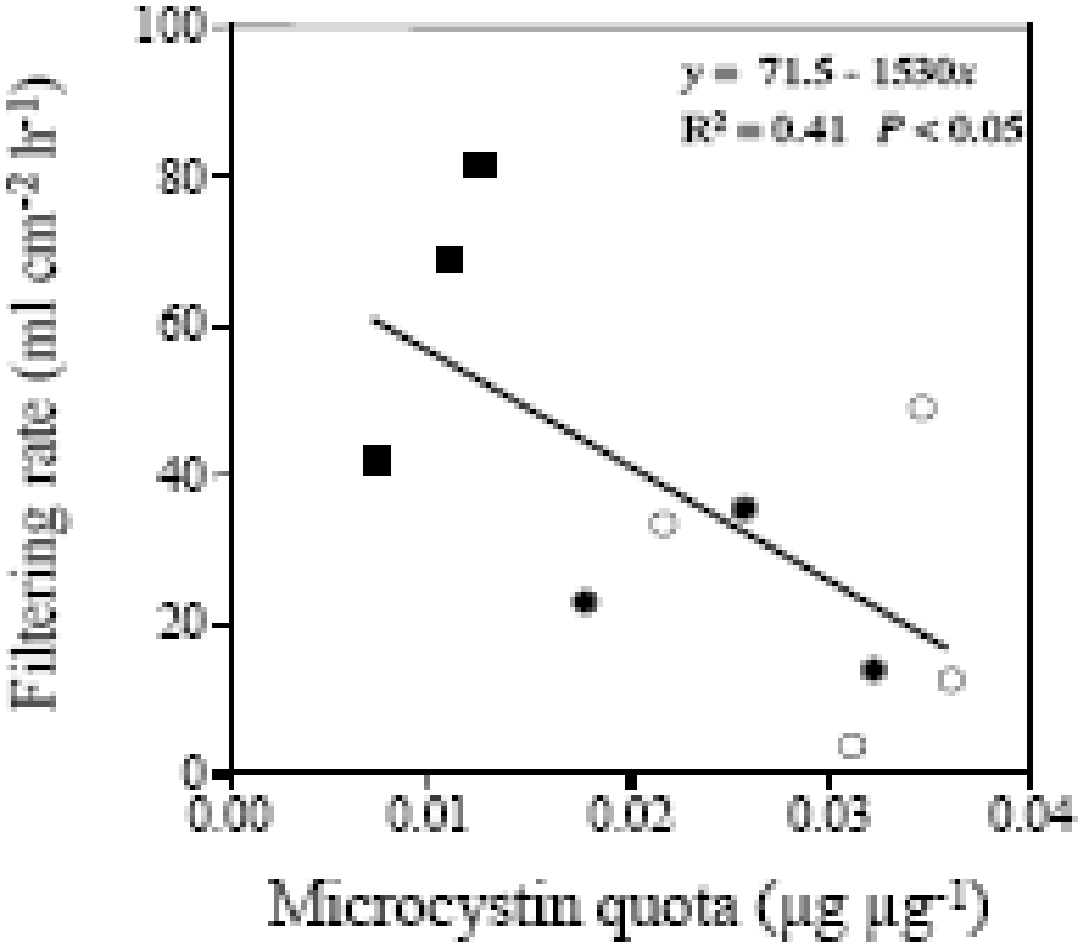

**Enclosure diameter = 2 m**

## TREATMENTS

**L = no P addition**
**M = medium P (15 ug/L)**
**H = high P (30 ug/L)**
**Mussel = mussel density (g/m2)**

| Enclosure | Mussel | Nutrients |
|---|---|---|
| 1 | 2.5 | High |
| 2 | 2.0 | Low |
| 3 | 1.5 | Medium |
| 4 | 2.0 | High |
| 5 | 2.0 | Medium |
| 6 | 3.5 | High |
| 7 | 1.0 | Low |
| 8 | 0 | Medium |
| 9 | 0 | Low |
| 10 | 0 | High |
| 11 | 4.0 | High |
| 12 | 3.0 | Low |
| 13 | 4.0 | Low |
| 14 | 0 | High |
| 15 | 3.0 | Medium |
| 16 | 0.5 | Low |
| 17 | 1.5 | High |
| 18 | 2.5 | Medium |
| 19 | 0 | Medium |
| 20 | 2.5 | Low |
| 21 | 0 | Low |
| 22 | 1.0 | Medium |
| 23 | 1.0 | High |
| 24 | 1.5 | Low |
| 25 | 0.5 | Medium |
| 26 | 3.0 | High |
| 27 | 4.0 | Medium |
| 28 | 3.5 | Low |
| 29 | 0.5 | High |
| 30 | 3.5 | Medium |

Clearance rate as a function of microcystin content in 10 enclosures on day 31 (3rd trip)

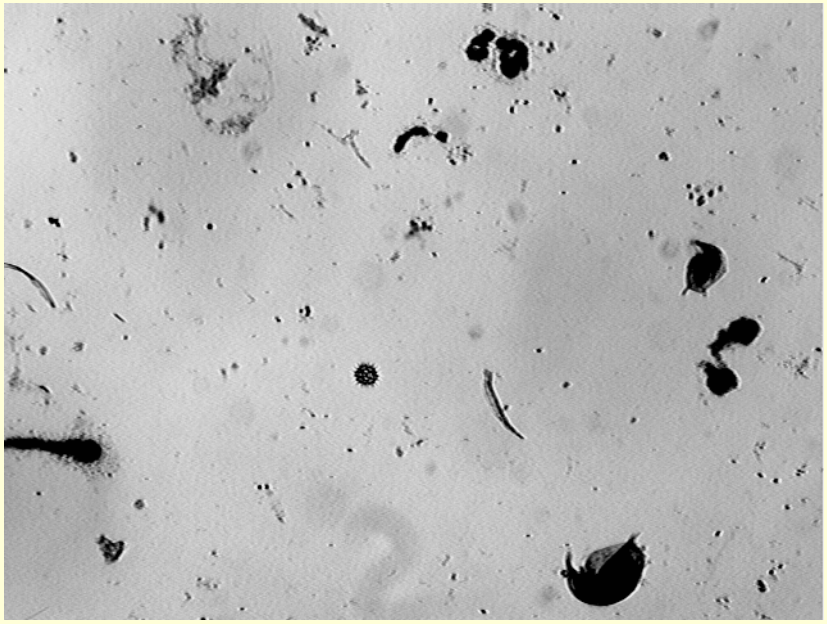


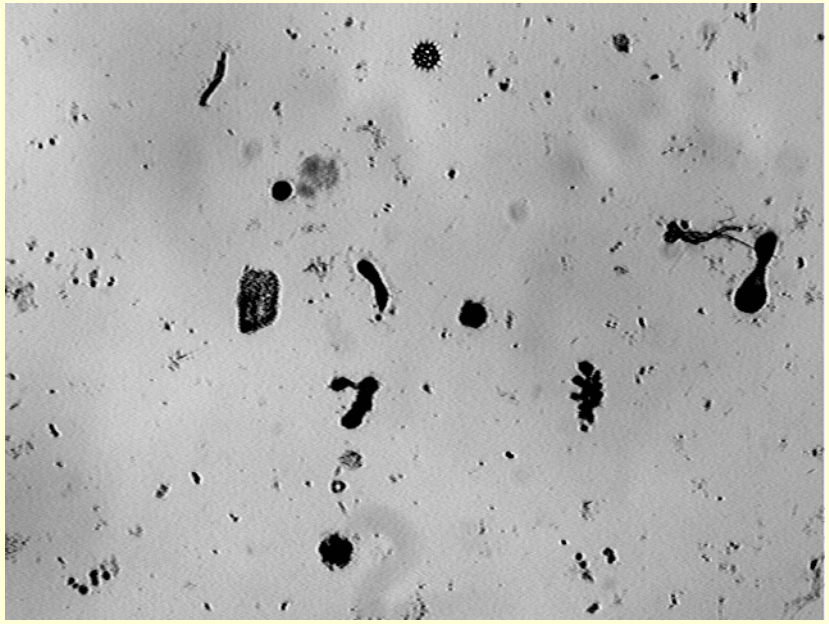
Clearance rates ($F_A$) and assimilation rates (A) of mussels on Lake Erie seston on 8/29-30/2006 for short and long feeding bouts—*Microcystis* dominating

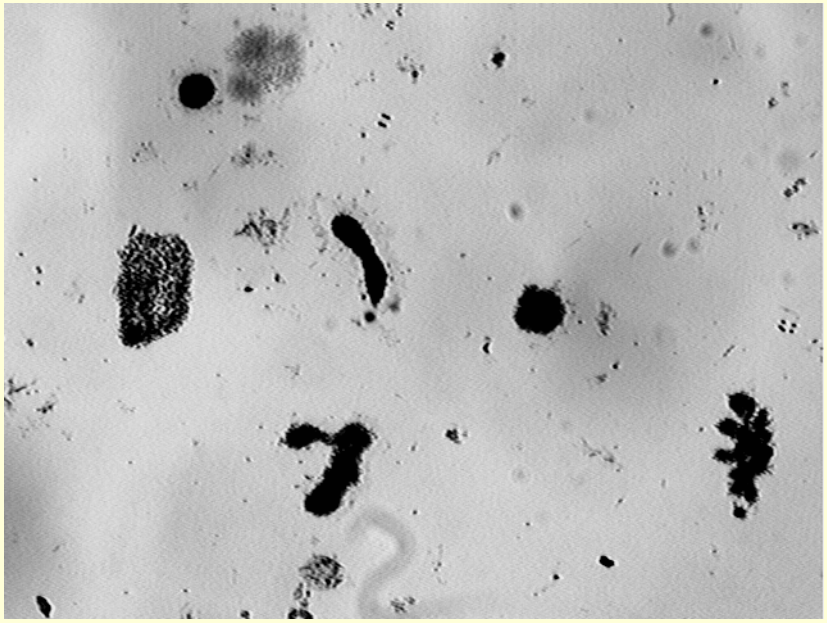
| Duration | Fraction | Chl conc. (µg/L) | $F_A$ (mL/h/cm$^2$) | A (% C/d) |
|---|---|---|---|---|
| 2 h | >53 µm | 17.5 | 6.0 ± 2.8 | 10.1 ± 4.8 |
| | <53 µm | 4.9 | -3.9 ± 3.4 | -1.9 ± 1.6 |
| | Total | 22.4 | 3.8 ± 2.0 | 8.2 ± 4.5 |
| 16h | >53 µm | 16.1 | 1.6 ± 0.5 | 3.2 ± 1.0 |
| | <53 µm | 5.0 | -0.5 ± 0.4 | -0.3 ± 0.3 |
| | Total | 21.1 | 1.1 ± 0.4 | 2.9± 1.2 |

Microcystin concentration (by ELISA) in seston measured at beginning and end of long term (16 h) feeding bout on Lake Erie seston 8/29-30/2006.

| | Microcystin conc. (µg/L) | | Microcystin:Chl (weight ratio) | |
|---|---|---|---|---|
| Sample | >53 µm | <53 µm | >53 µm | < 53 µm |
| Initial controls (3) | 3.09 ± 0.11 | 0.30 ± 0.01 | 0.192 ± 0.007 | 0.060 ± 0.001 |
| Initial quaggas (4) | 2.97 ± 0.24 | 0.29 ± 0.02 | 0.170 ± 0.014 | 0.058 ± 0.003 |
| Final controls (3) | 2.78 ± 0.18 | 0.34 ± 0.02 | 0.165 ± 0.011 | 0.052 ± 0.003 |
| Final quaggas (4) | 2.76 ± 0.14 | 0.39 ± 0.01 | 0.200 ± 0.010 | 0.070 ± 0.002 |





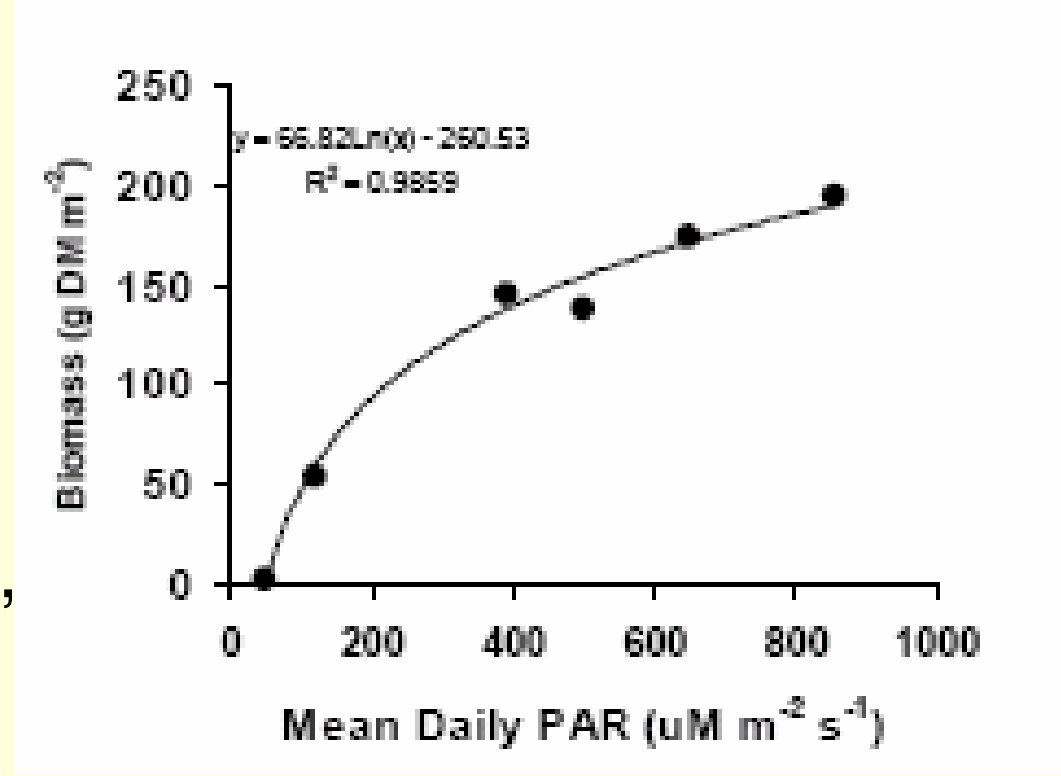


# *Cladophora*

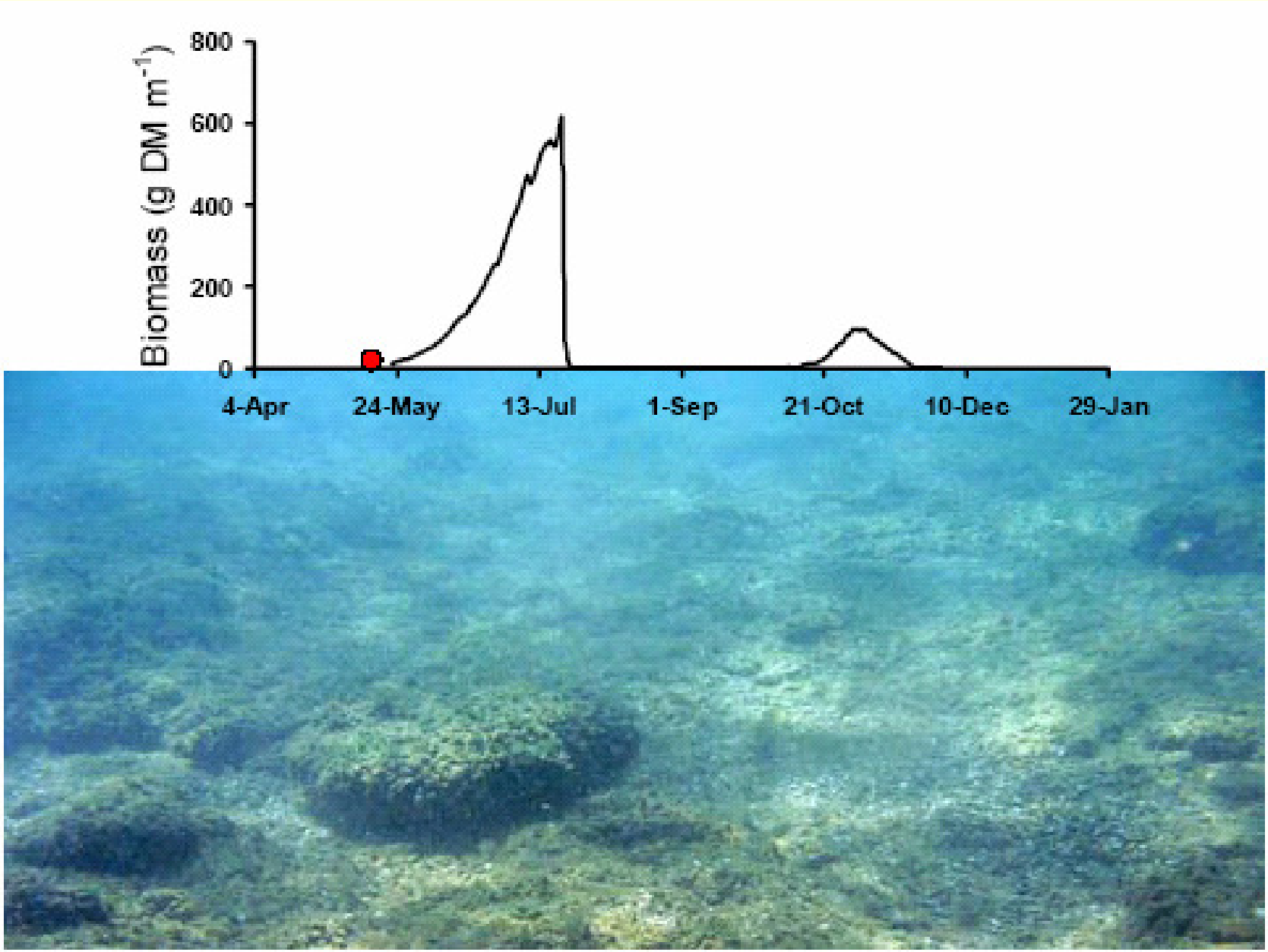
- Growth requirements
  - Benthic
  - Hard substrate for attachment
  - High light intensity (300-1200 uM/m2/s)
  - Moderate temperatures (18-24 C)
  - Blooms usually associated with $PO_4$

# Limits of *Cladophora* distribution

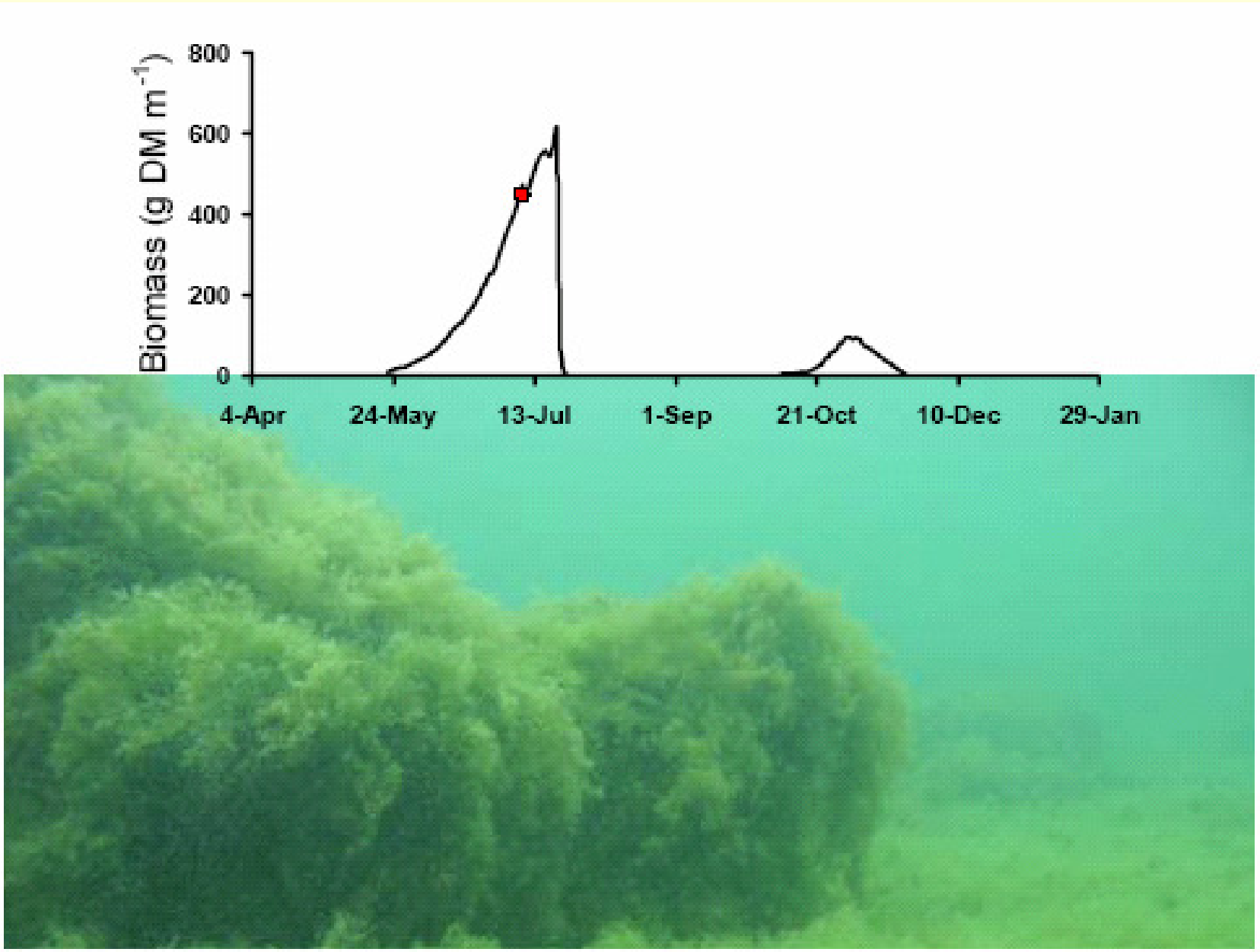
- Horizontal
  - Substrate limited
- Vertical
  - Light limited
- P stimulates growth
- Growth begins at 40°F, dies off at 75°C



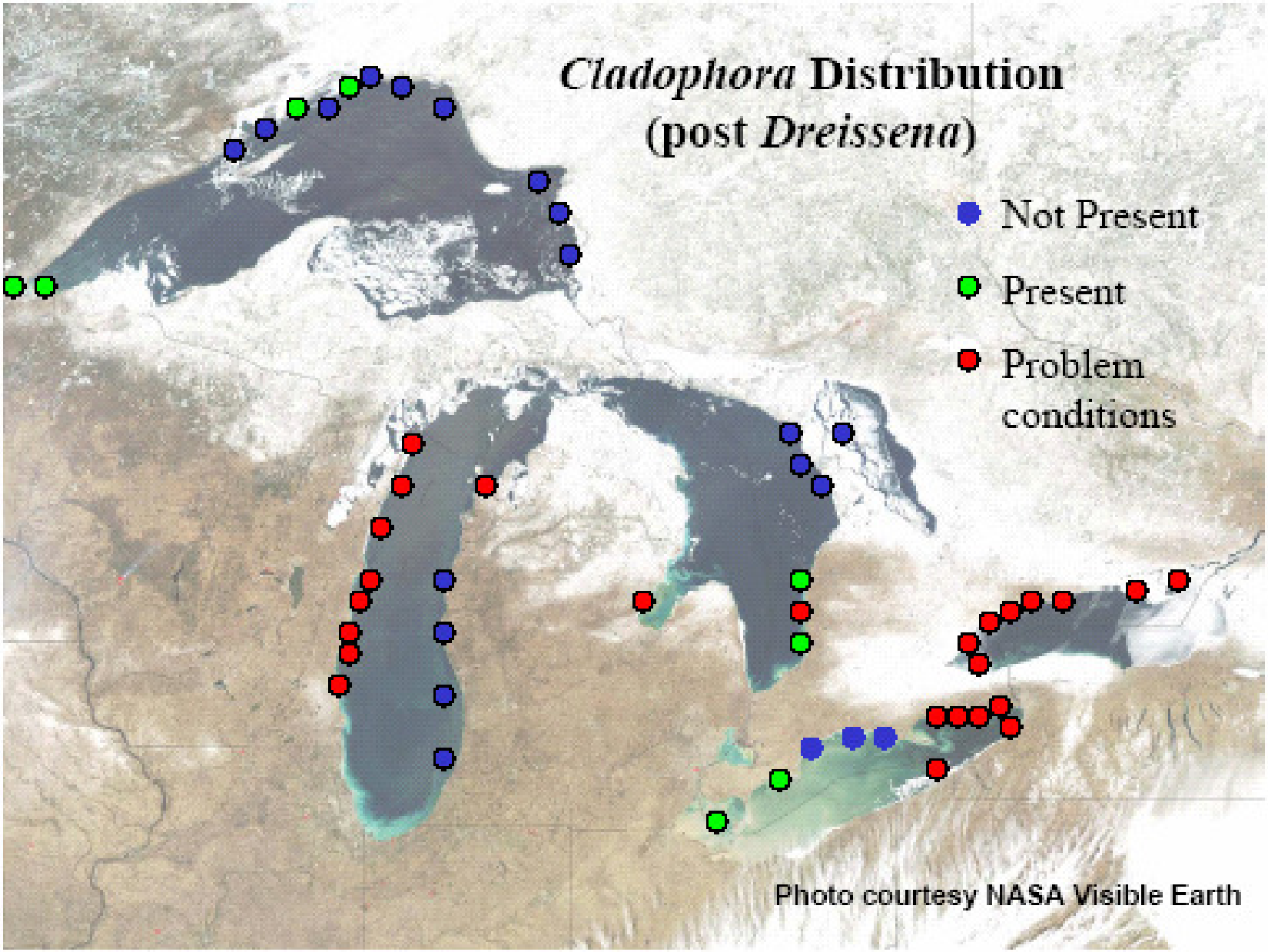

Scott Higgins, University of Waterloo




Scott Higgins, University of Waterloo



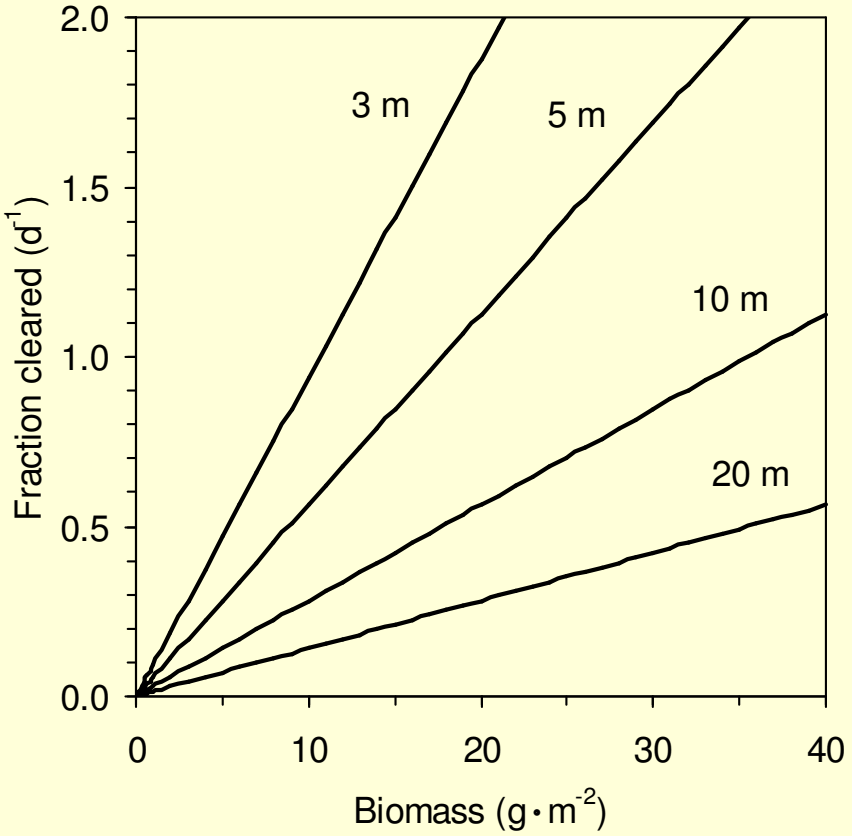

Scott Higgins, University of Waterloo




Scott Higgins, University of Waterloo

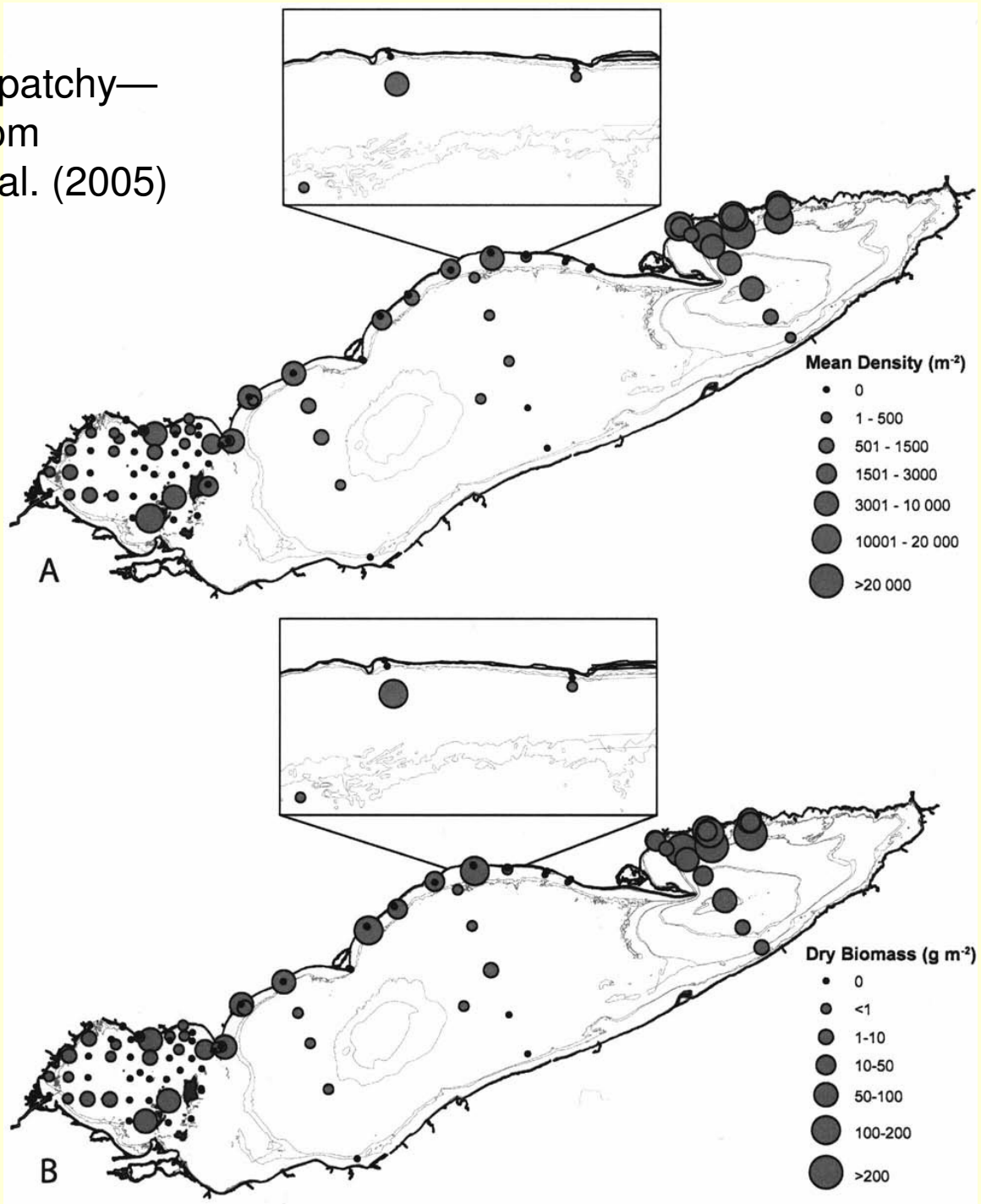
## Are there enough mussels to do the job?

Fraction of water column cleared (FC) depends on mussel biomass and water depth for a given filtering rate




If FC is large then they will remove algae at a fast enough rate to remove good algae and make the water clear

Mussels are patchy—
2002 data from
Patterson et al. (2005)



# Dreissenid Abundance and Impact

| Lake Erie basin | Year sampled | Mean depth (m) | Dreissenid dry biomass ($g\ m^{-2}$) | FC ($d^{-1}$) |
|---|---|---|---|---|
| Western | ’92-’93 | 7.4 | 26.2 | 0.99 |
| | 2002 | | 5.8 ±19.3 | 0.22 ±0.73 |
| Central | 2002 | 18.5 | 14.2 ±34.2 | 0.22 ±0.68 |
| Eastern | ’92-’93 | 25.0 | 15.4 | 0.173 |
| | 2002 | | 104.2 ±146.6 | 1.17 ±1.65 |

# Impacts could be greatest at middle to offshore depths—depending on substrate deph

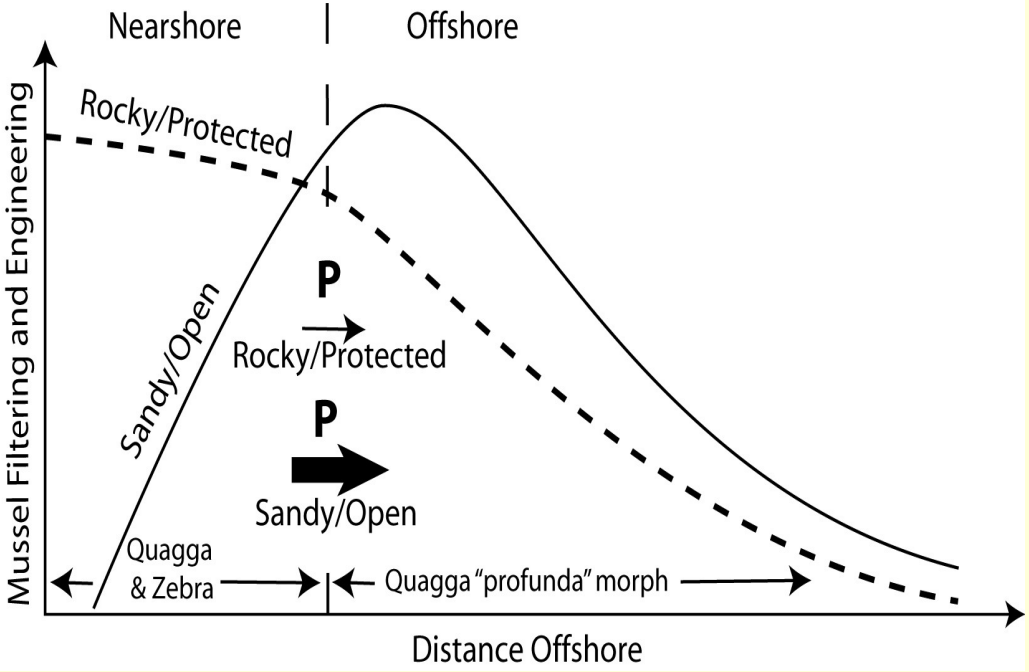
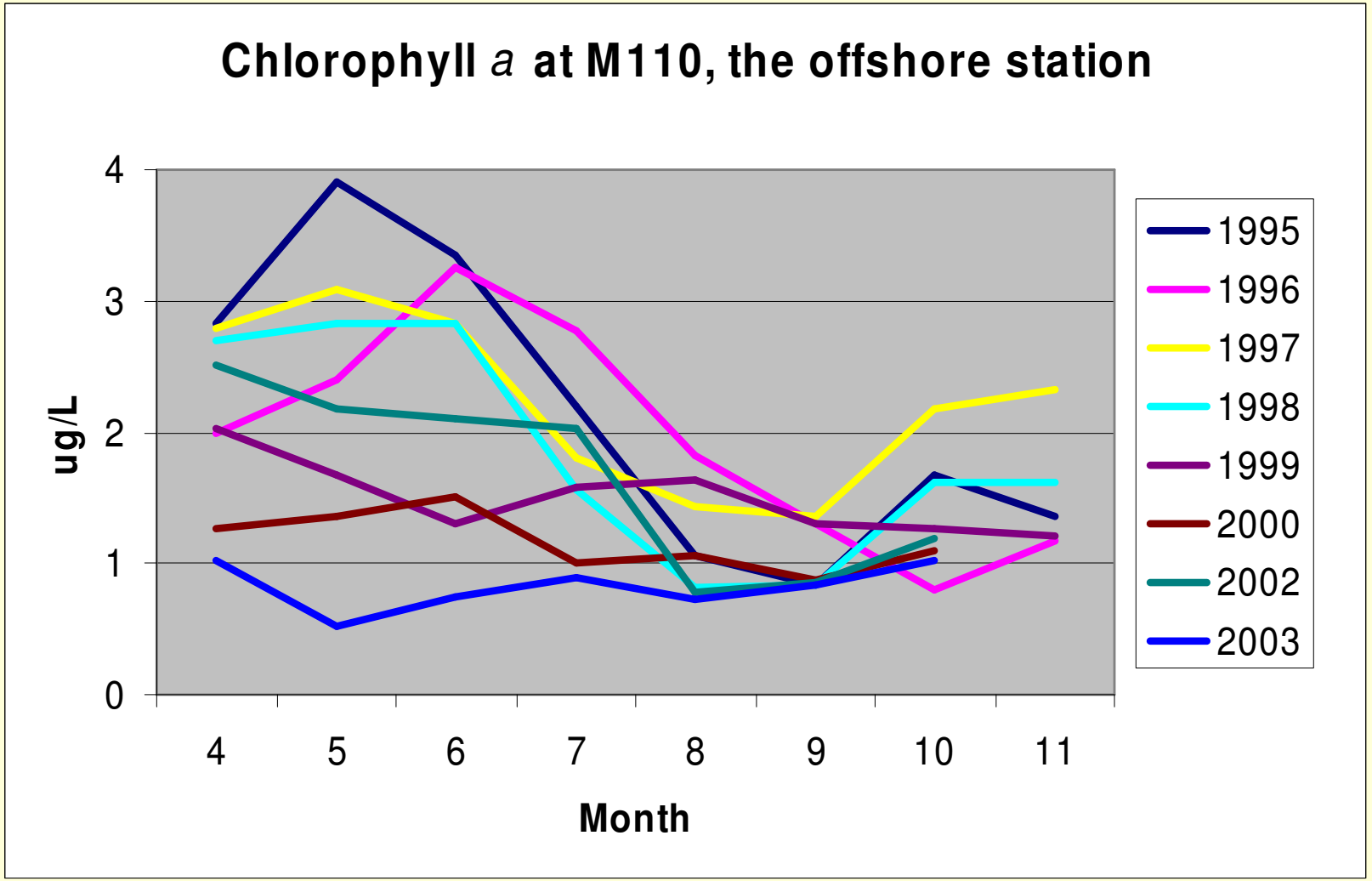


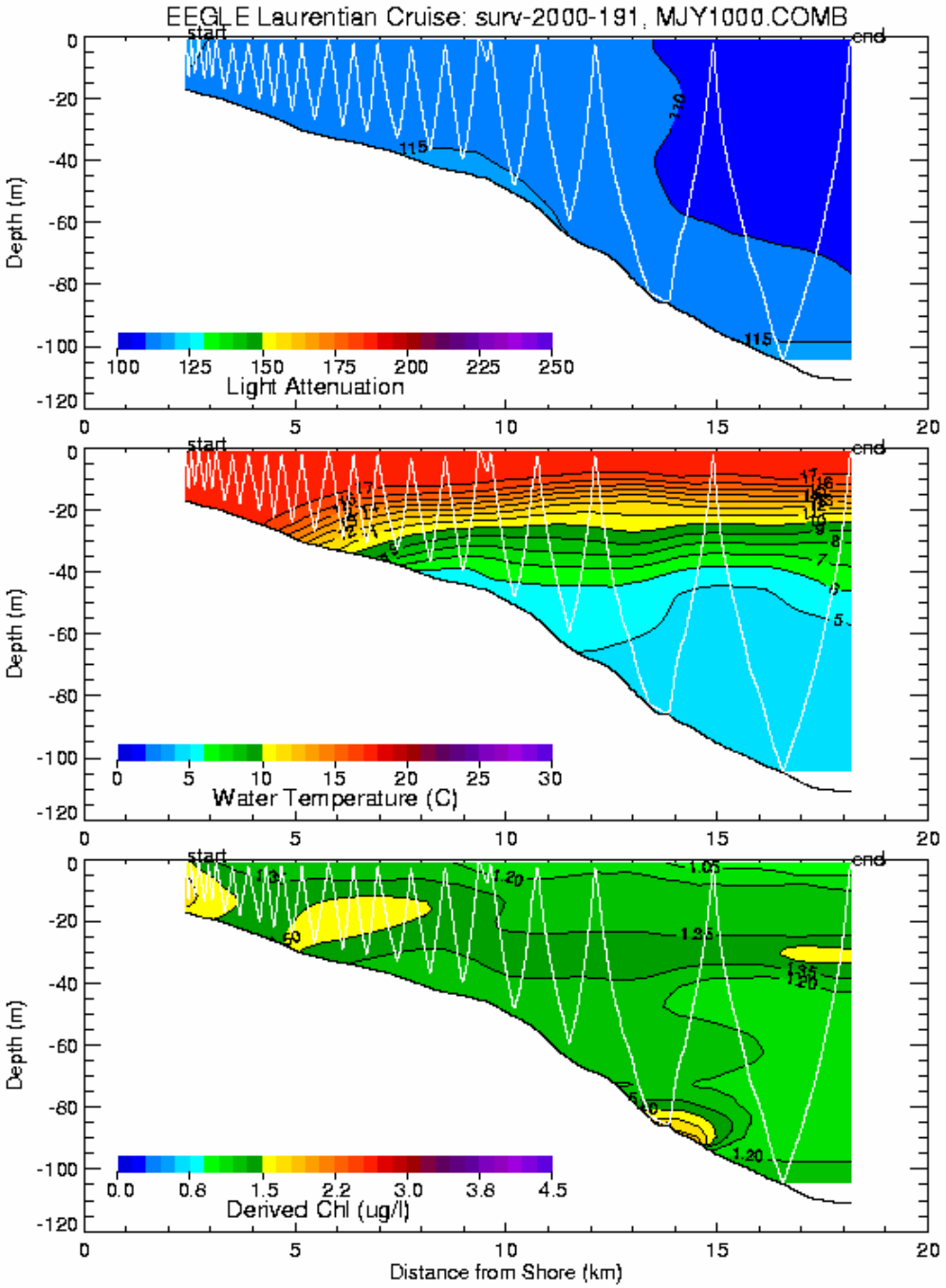

*Fig.2. Hypothetical distribution and impacts of zebra and two morphs of quagga mussels along a nearshore-offshore transect and how P transport is related to site and mussel abundance.*

The eastern basin could take the biggest hit

# Some patterns from Lake Michigan relevant to eastern basin of Lake Erie

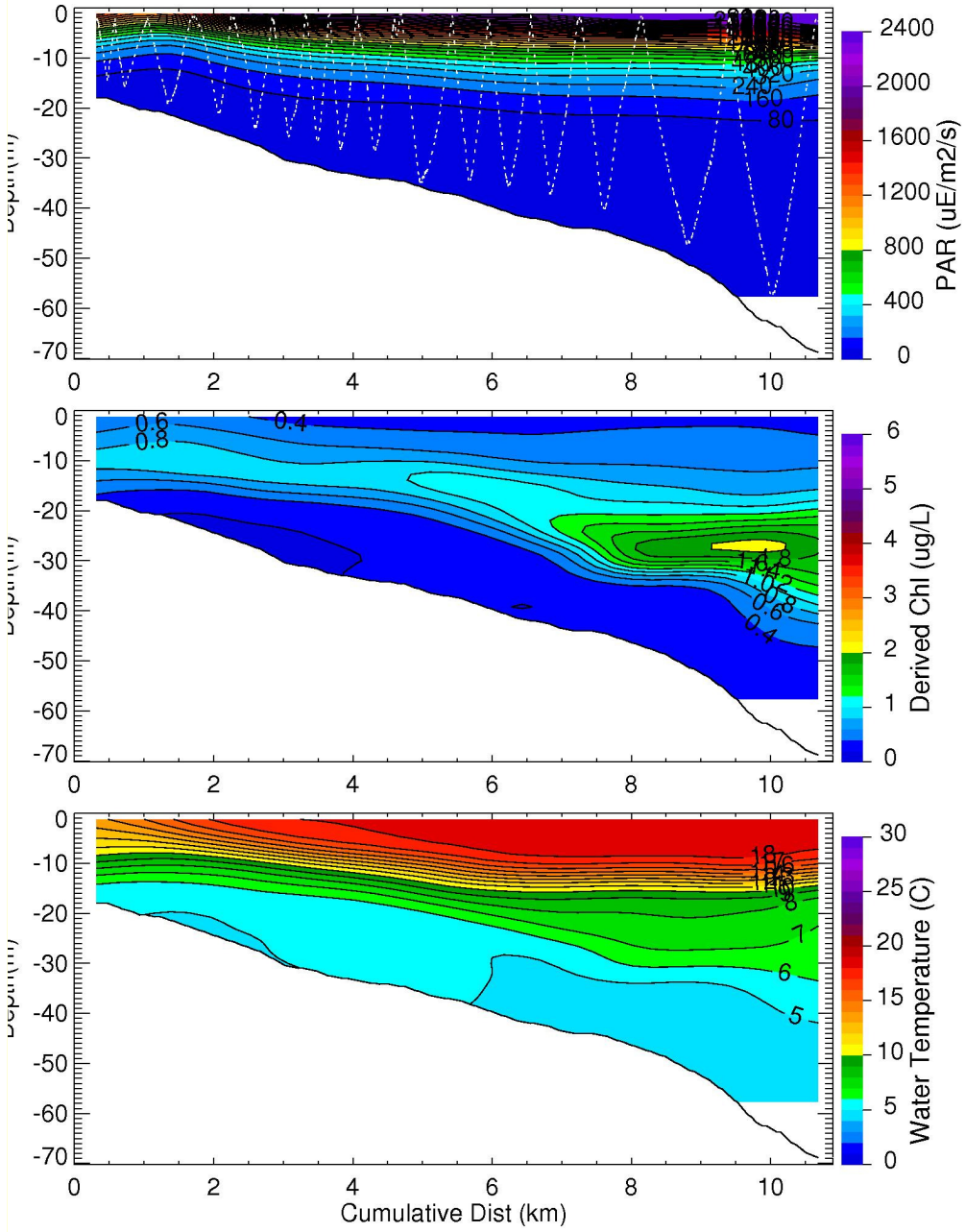


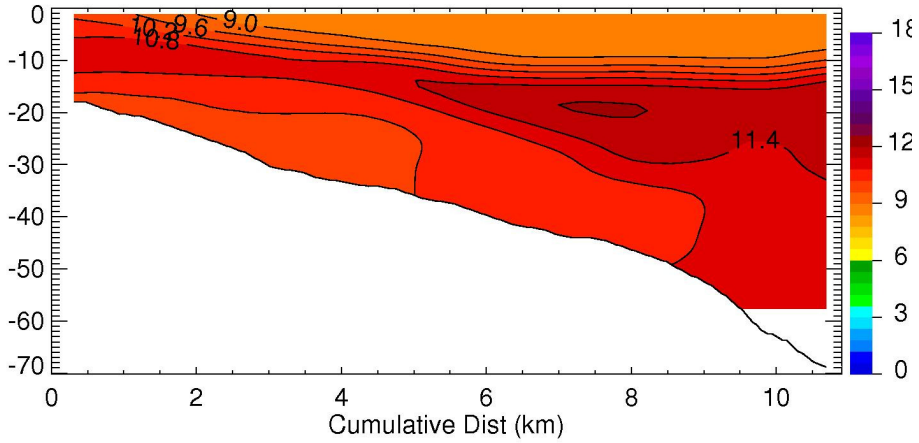

We knew this and that quagga mussels had been rapidly expanding into deep water in 2003, when we shut it down—would have been interesting to know dynamics in 2004-2006.



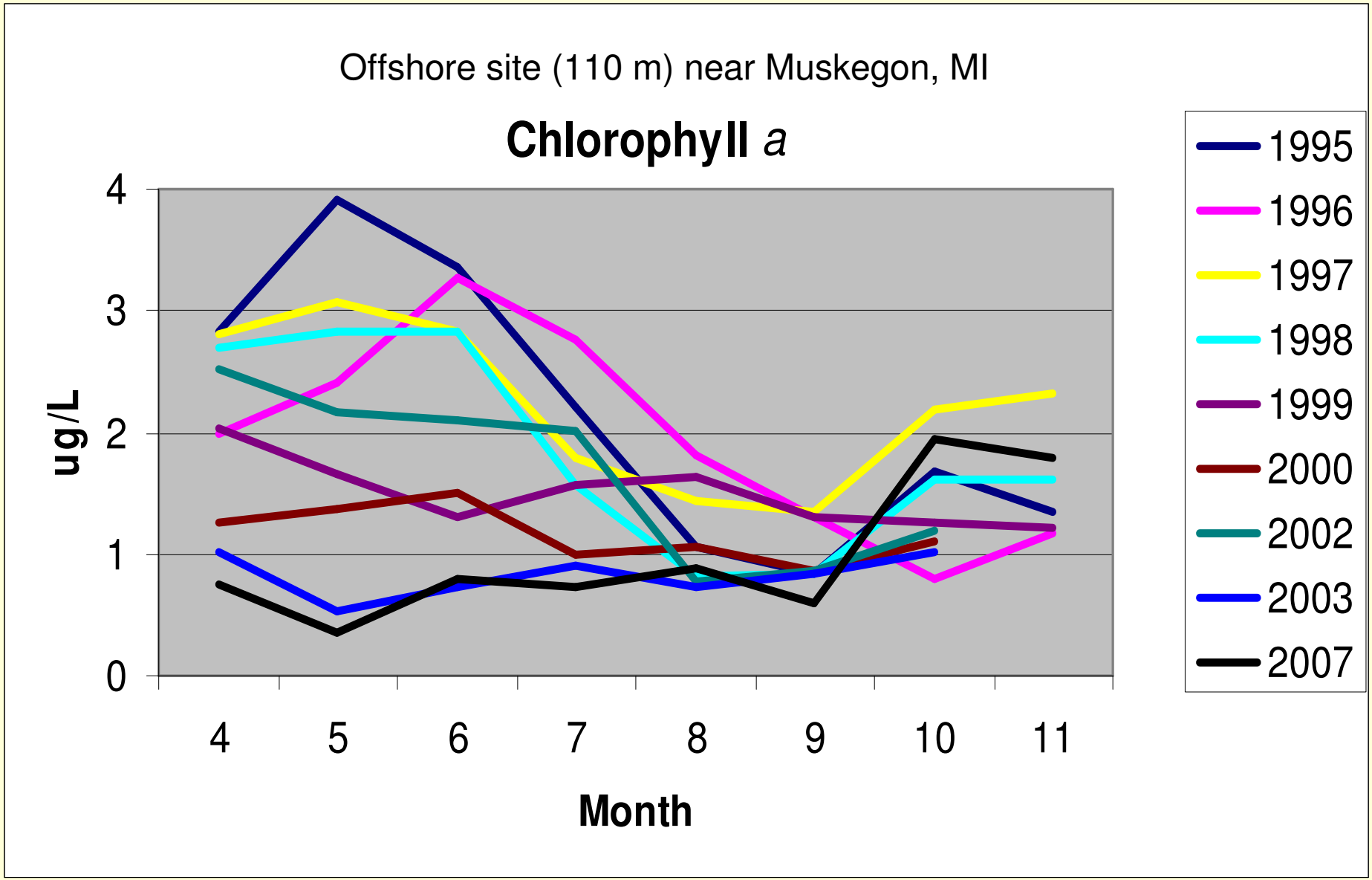

Thermal structure and chlorophyll in early August 2000 observed with PSS.

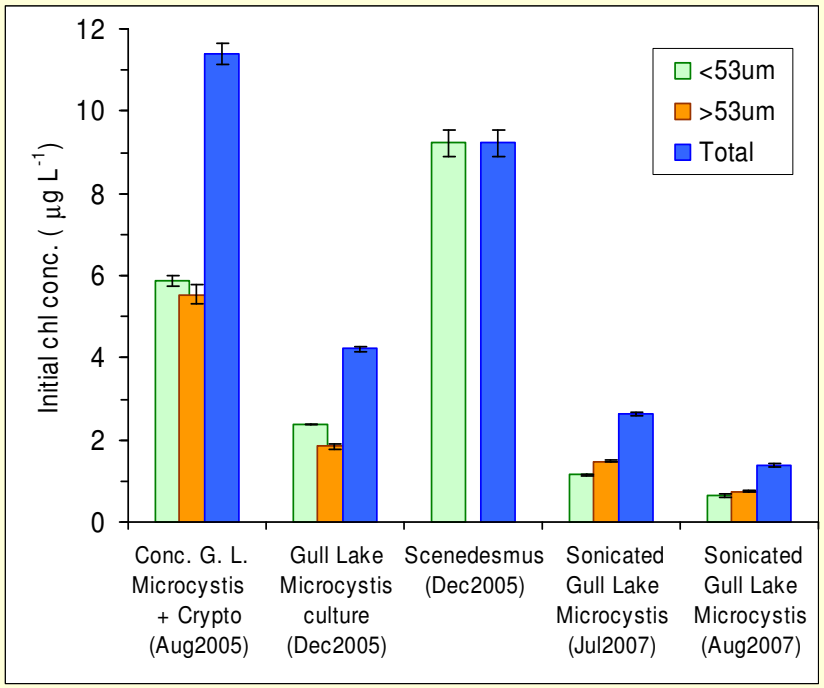
Laurentian? Test Cruise: Data_LOPC/2007.06.1/MT062907.dat
Timestamp = # Date: Friday, June 29, 2007, # Time: 08:44:08 Local time

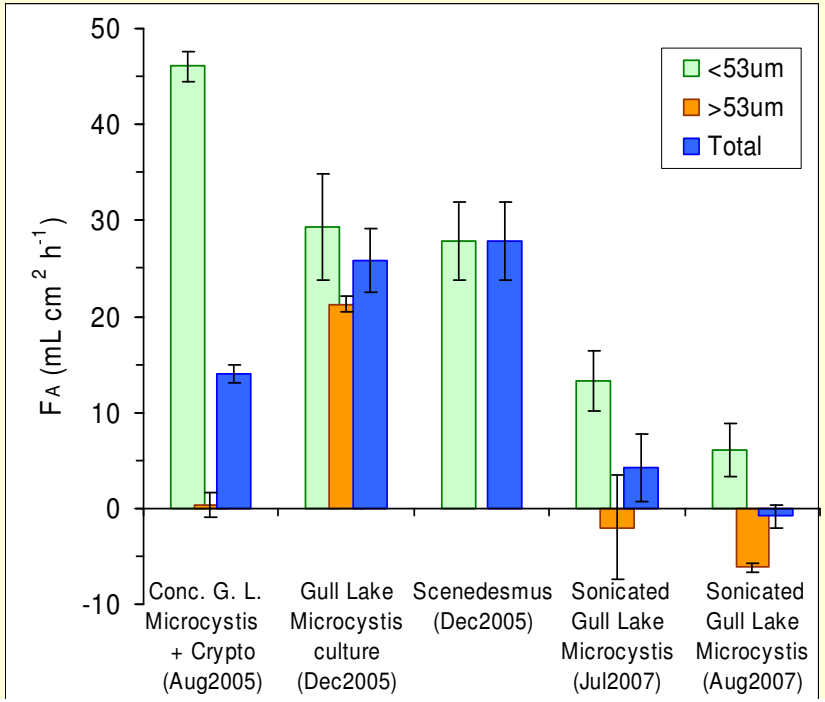


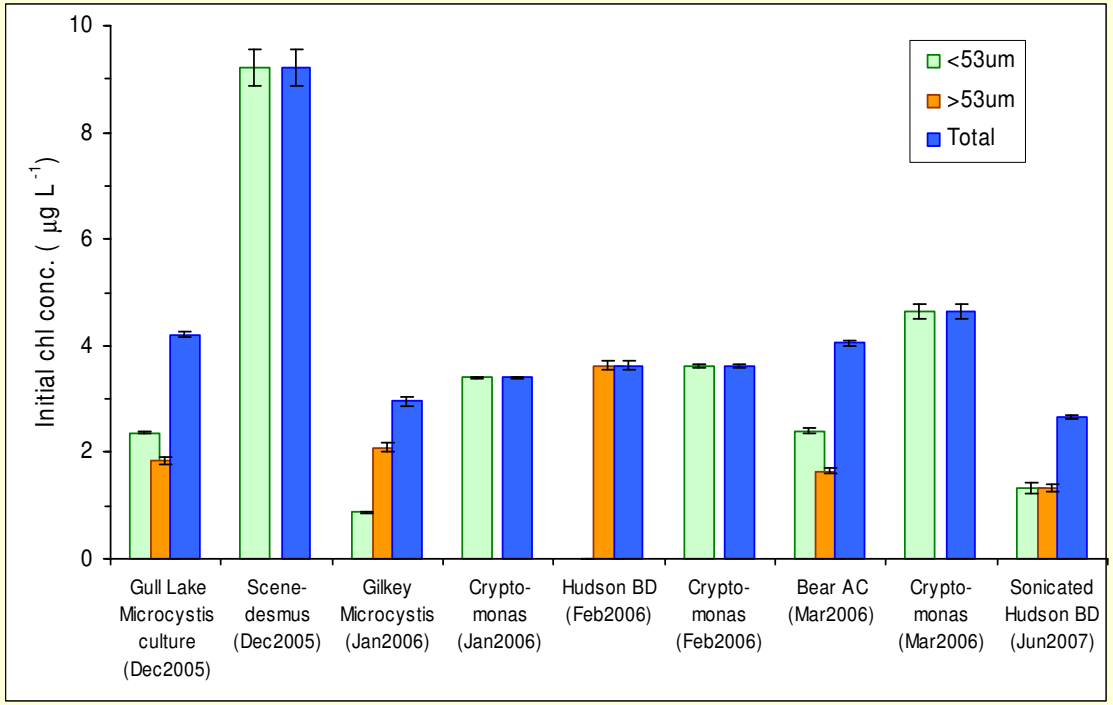

Late June 2007 LPSS test cruise along Muskegon transect—note chlorophyll distribution (ignore PAR, its garbage)

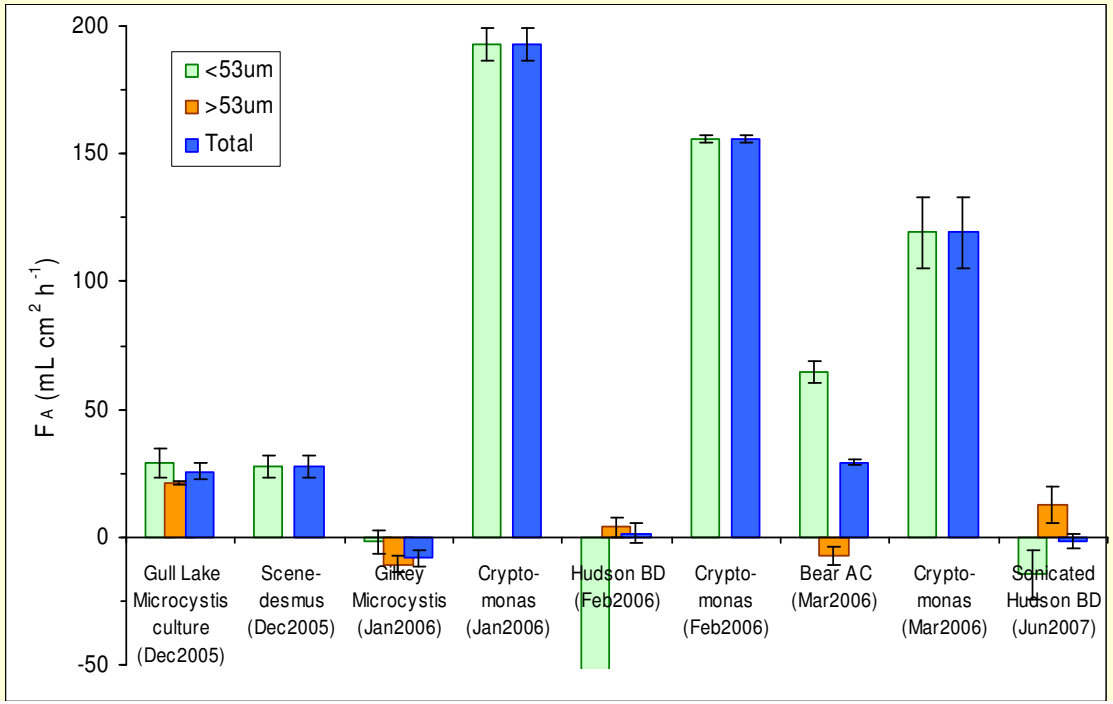

Offshore site (110 m) near Muskegon, MI
Chlorophyll a
ug/L
0
1
2
3
4
4
5
6
7
8
9
10
11
Month
1995
1996
1997
1998
1999
2000
2002
2003
2007




# Grazing experiments with cultures can lead us astray




Mussels respond differently to different *Microcystis* culture strains

# Innovative experiments at Gull Lake

- Standard 2-h feeding and nutrient excretion.
- Long-term feeding to see what *Microcystis* strains (genotypes) remain and their toxicity and toxic gene expression.
- Exam of pseudofeces to see what morphotypes and genotypes are rejected