“Surprising synergies between invasive species and climate impacts”

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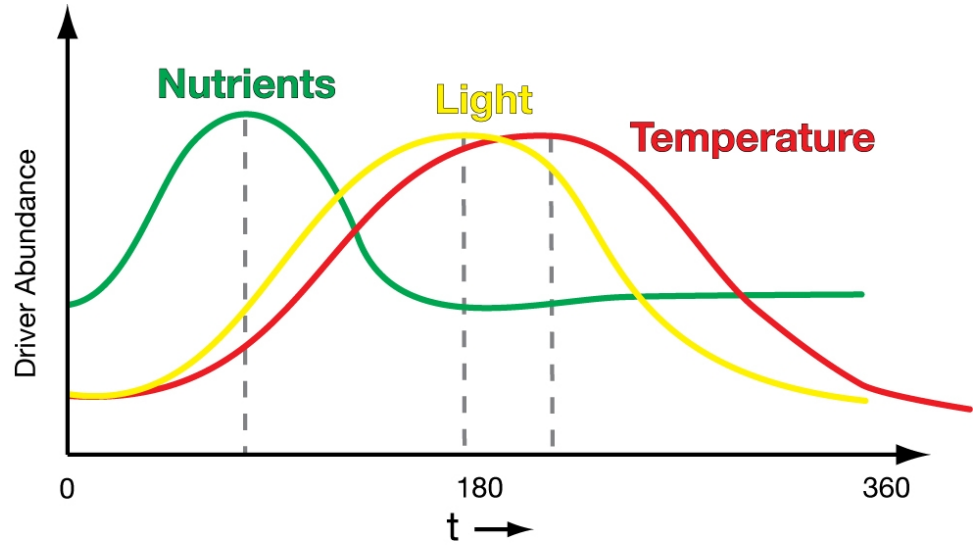
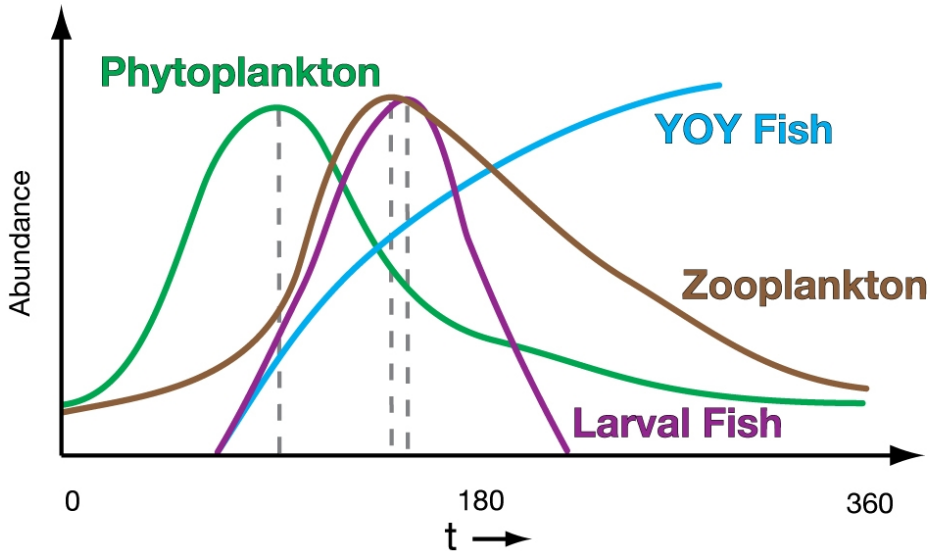
Temperature affects Ecophysiolgy of organisms

- A lot of processes like respiration have a $Q_{10} \approx 2$
- P/B increases with temperature within a certain range and drops off thereafter depending on species
- Temperature tolerance varies among species.

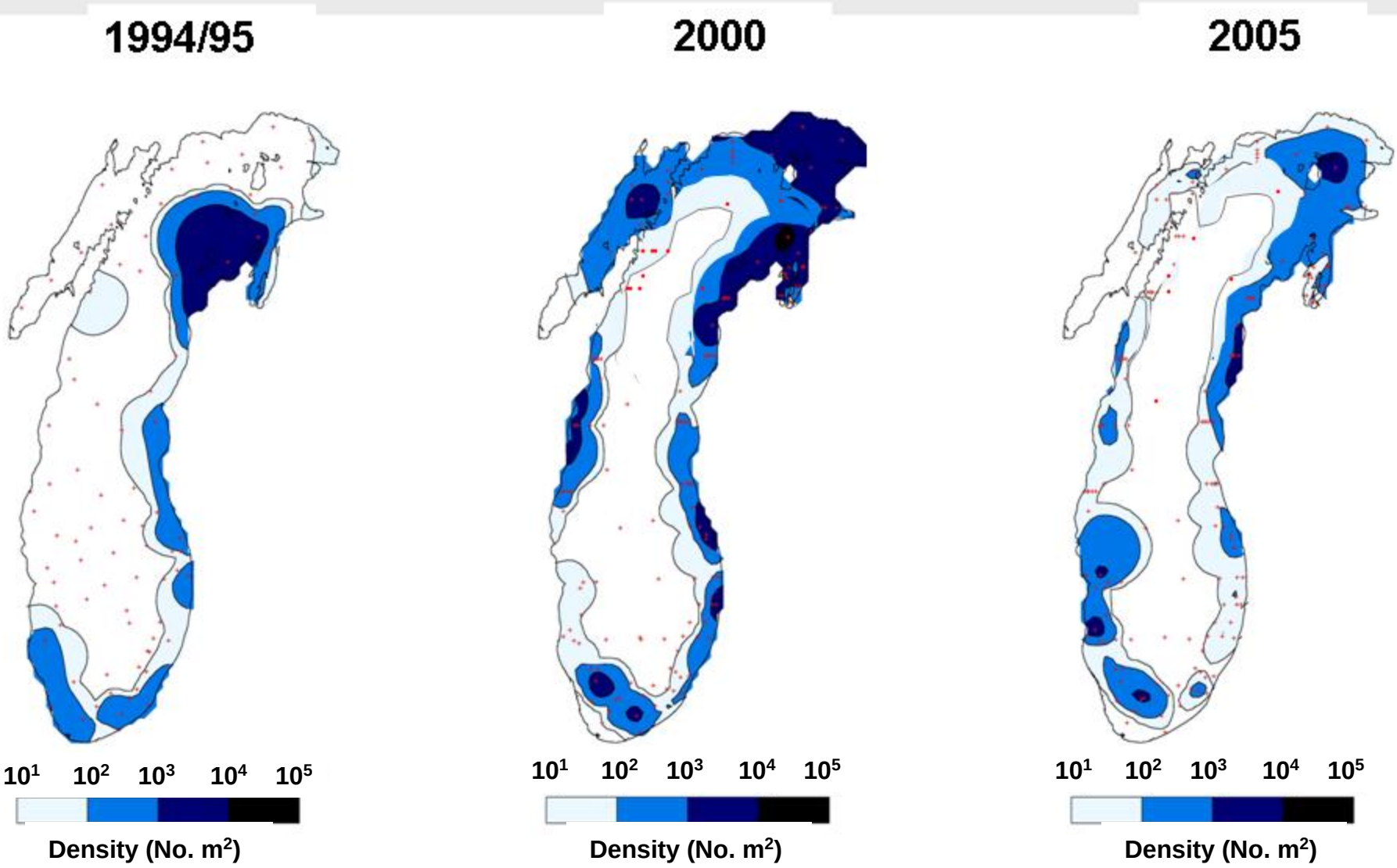
Resources and Predator-Prey Mismatch Hypothesis (MMH) in a Hypothetical Large Lake (aka “the phenology story”)



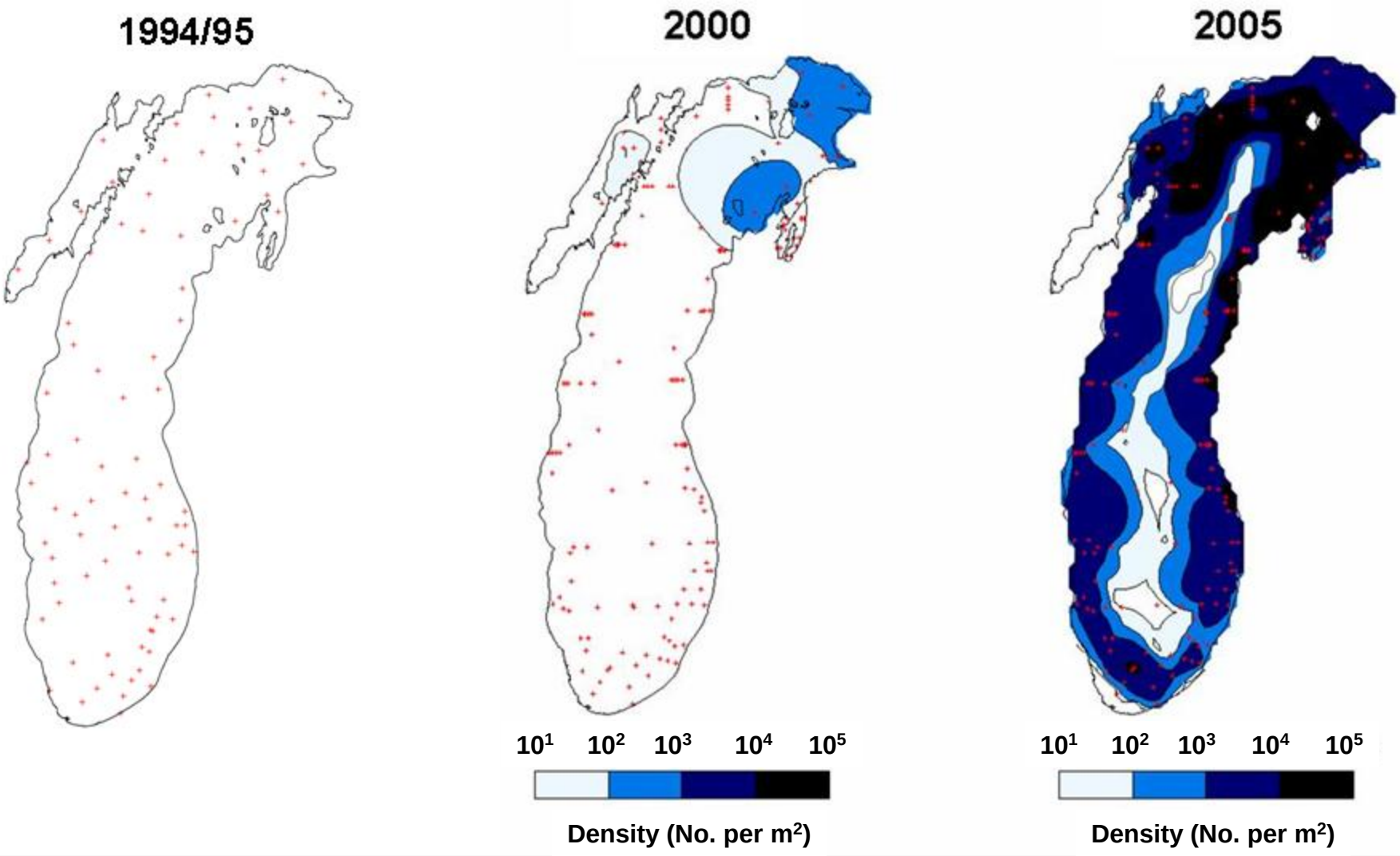


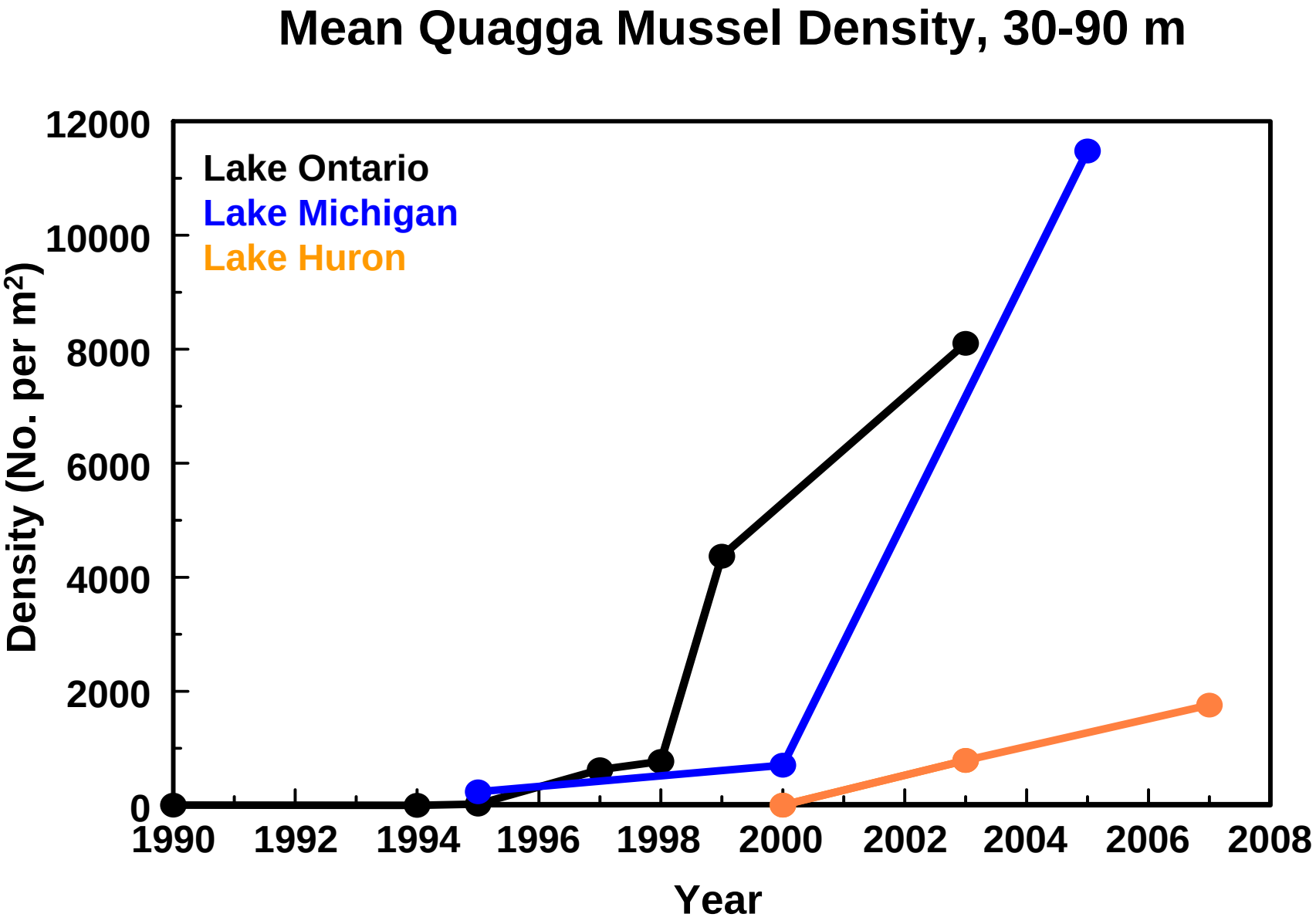
The Great Lakes is now a *Dreissena* dominated system

Dreissena polymorpha (zebra mussel)

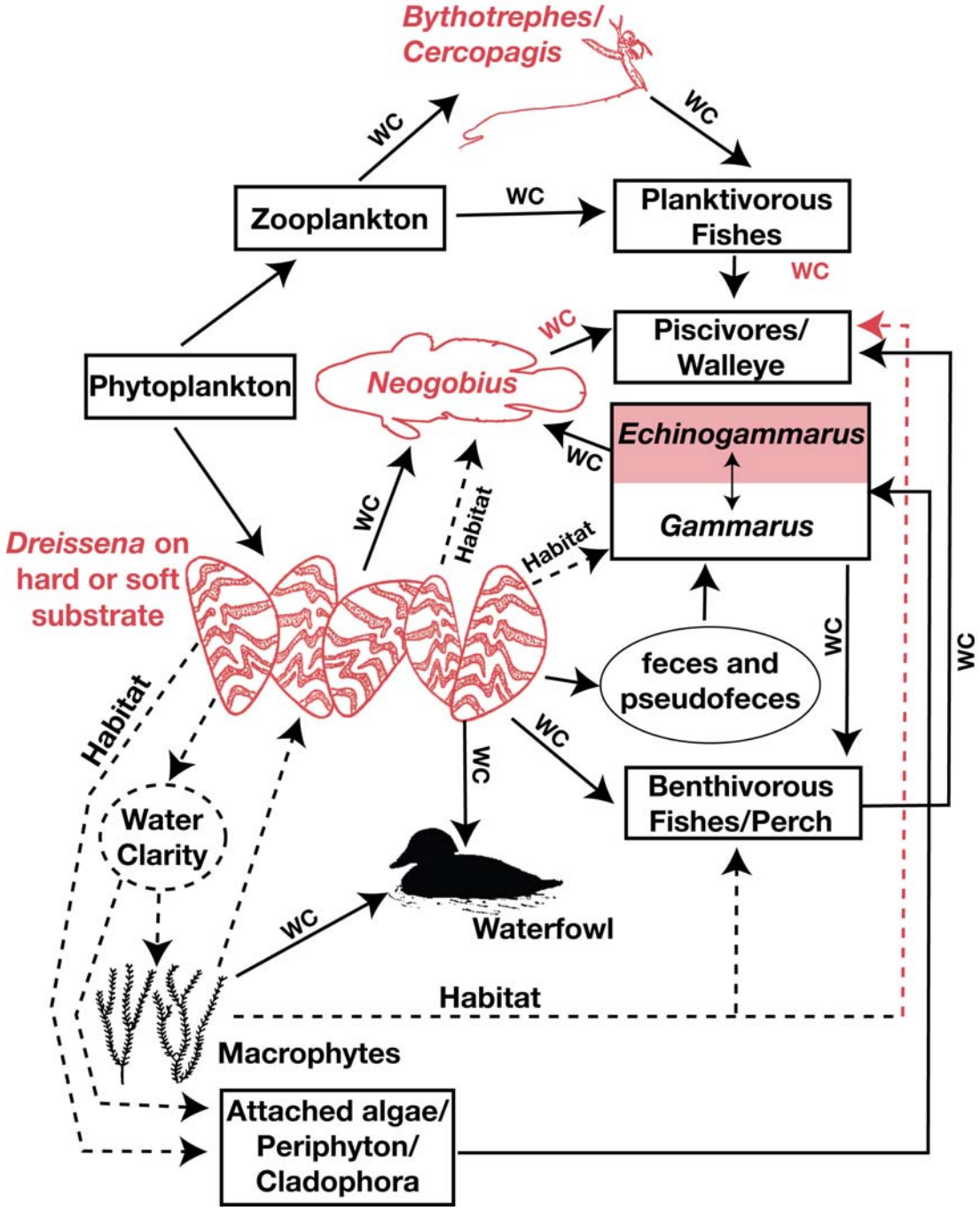


Dreissena bugensis (quagga mussel)




Mean Quagga Mussel Density, 30-90 m
Lake Ontario
Lake Michigan
Lake Huron
Density (No. per m²)
12000
10000
8000
6000
4000
2000
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Year

What mussels do in nearshore areas

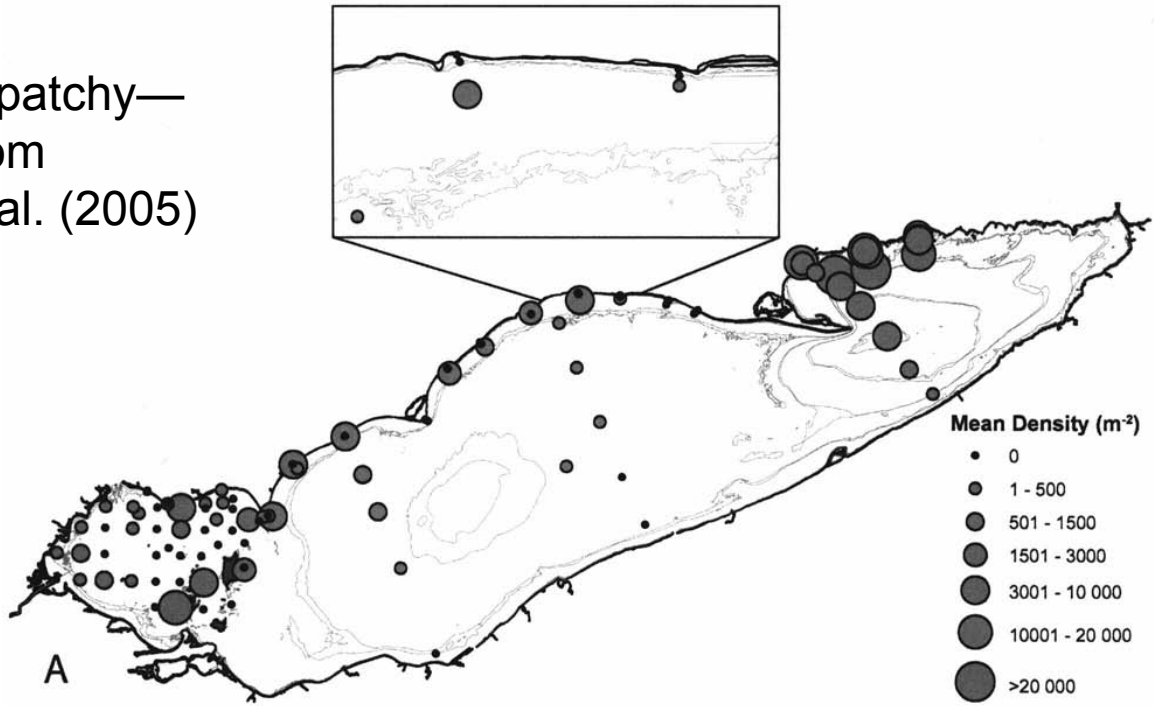


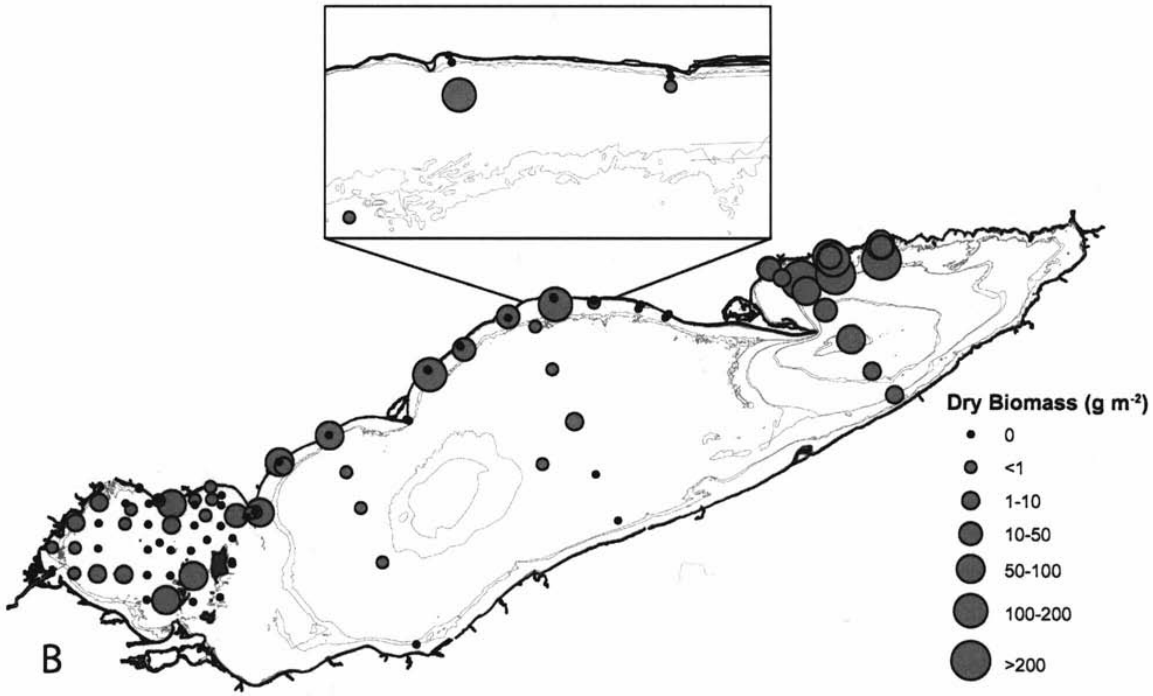
What Mussels Do:

•Some interactions of mussels with other members of the food web.

•Nearshore shunt hypothesis (Hecky et al. 2004) argues the community that develops nearshore retains P there.

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





Dreissenid abundance and impact as fraction of water column cleared (FC)

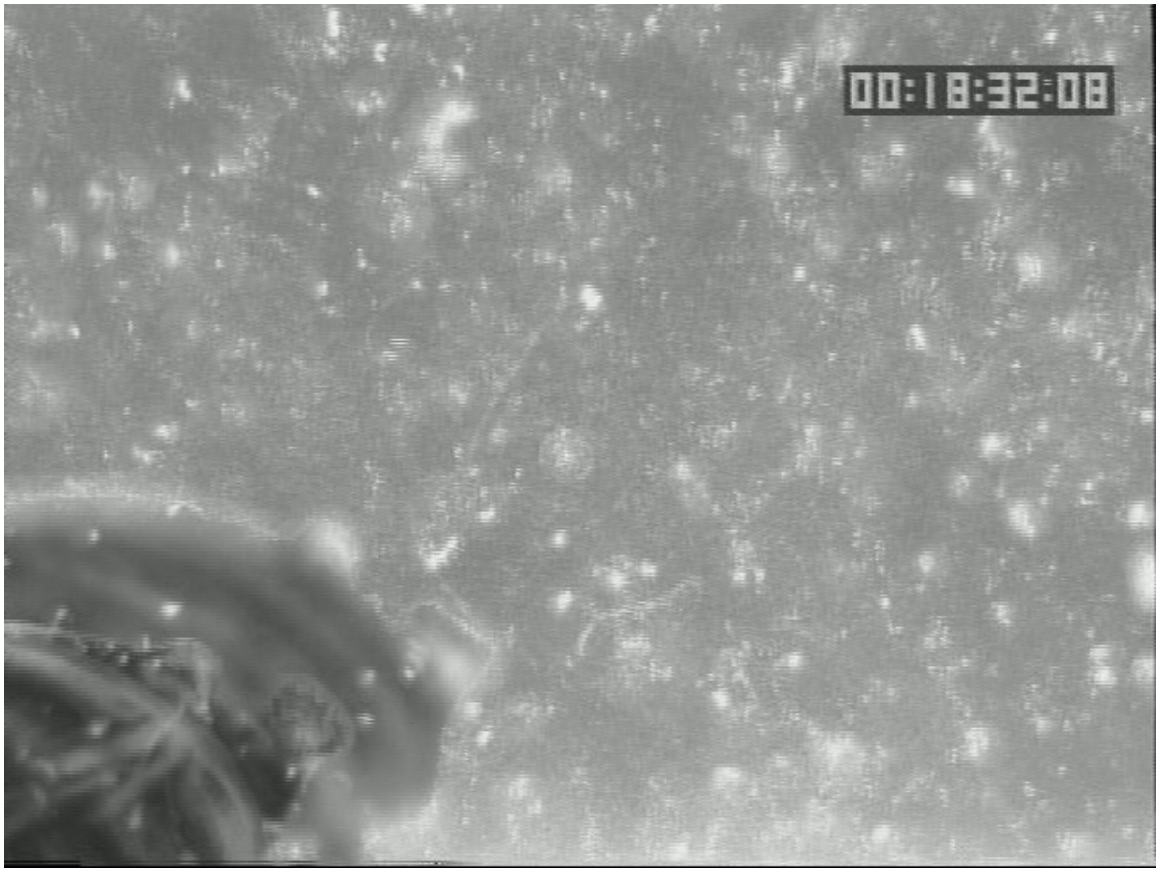
Lake Erie basin	Year sampled	Mean depth (m)	Dreissenid dry biomass (g m^{-2})	FC (d^{-1})
Western	’92-’93	7.4	26.2	0.99
	2002		5.8 ±19.3	0.22 ±0.73
Central	2002	18.5	14.2 ±34.2	0.22 ±0.68
Eastern	’92-’93	25.0	15.4	0.173
	2002		104.2 ±146.6	1.17 ±1.65

Nearshore shunt hypothesis example: increased light causes proliferation of *Cladophora* and retention of P in the nearshore region

Diver in Cladophora bed off Sleeping Bear Dunes, 20ft

Photo by B. Lafrancois

Mussels promote Harmful Algal Blooms: **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)

Some say “Blooms Like It Hot”* (But maybe not… in Great Lakes)

“A link exists between global warming and the worldwide proliferation of harmful cyanobacterial blooms.”

*Title, figure, and quote from H.W. Paerl & J. Huisman (*Science*, 4 April 2008)

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

Nearshore shunt hypothesis example: increased light causes proliferation of *Cladophora* and retention of P in the nearshore region

- If temperature increases mussels will not do as well during hot summers
- Water will not be cleared
- Respiration of *Cladophora* will increase and it will not be as much of nuisance in summer, but could be a problem earlier in year.

Diver in Cladophora bed off Sleeping Bear Dunes, 20ft

Photo by B. Lafrancois

Offshore vs. Inshore Engineering Hypothesis: Impacts could be greatest at middle to offshore depths depending on substrate

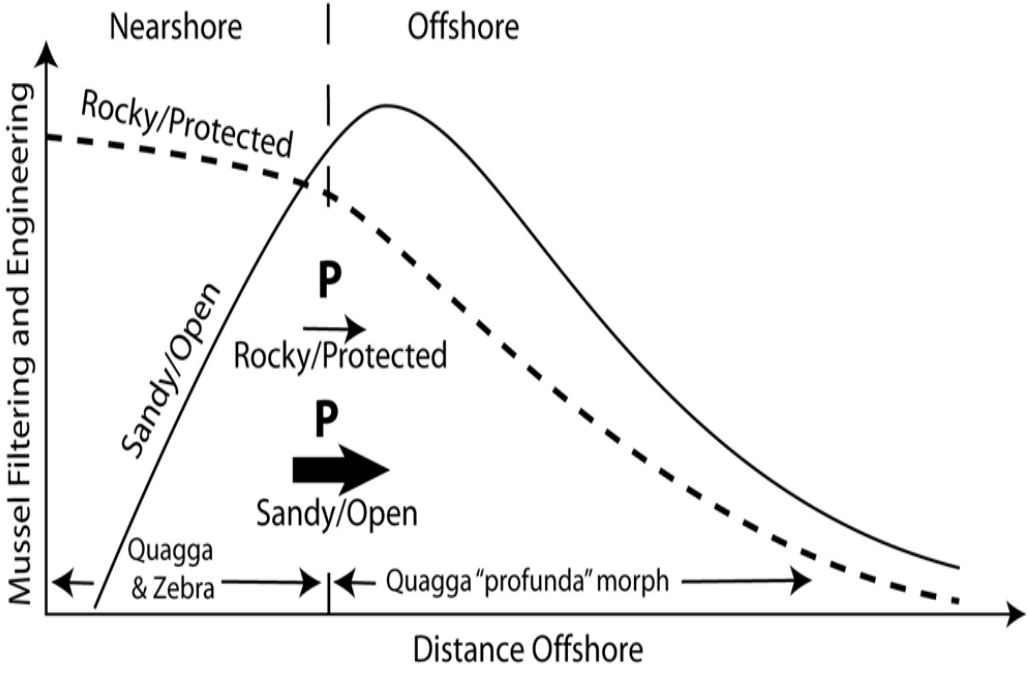
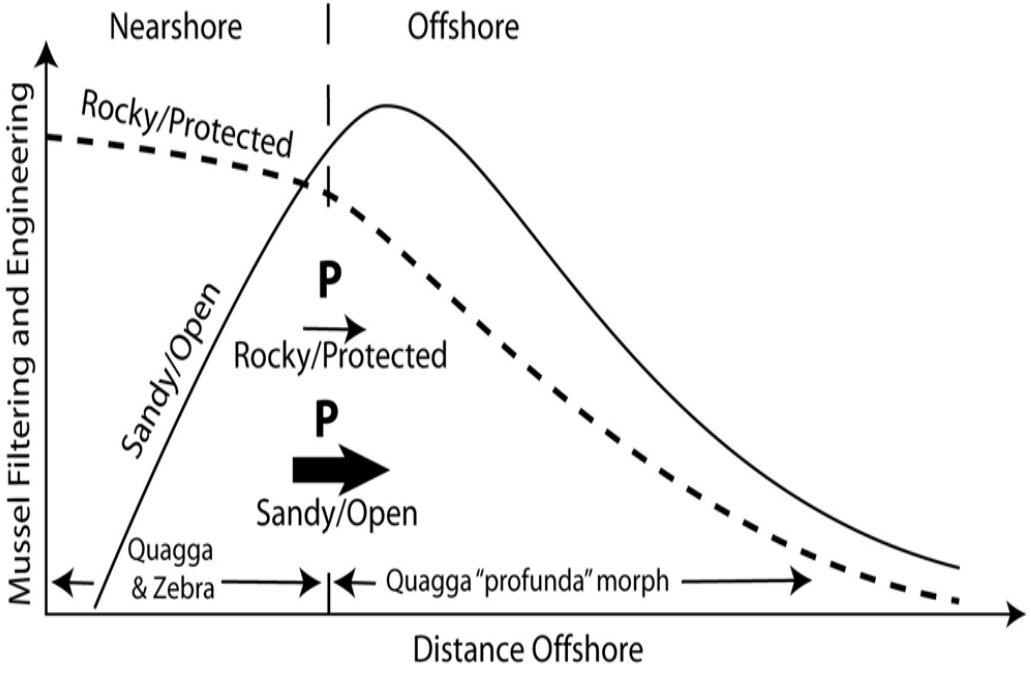


Fig.2. Hypothetical distribution and impacts of zebra and two morphs of quagga mussels along a nearshore-offshore transect and how P transport is related to site and mussel abundance. Muskegon corresponds to a sandy/open site

Offshore vs. Inshore Engineering—Is mussel biomass high enough to do job in offshore waters?



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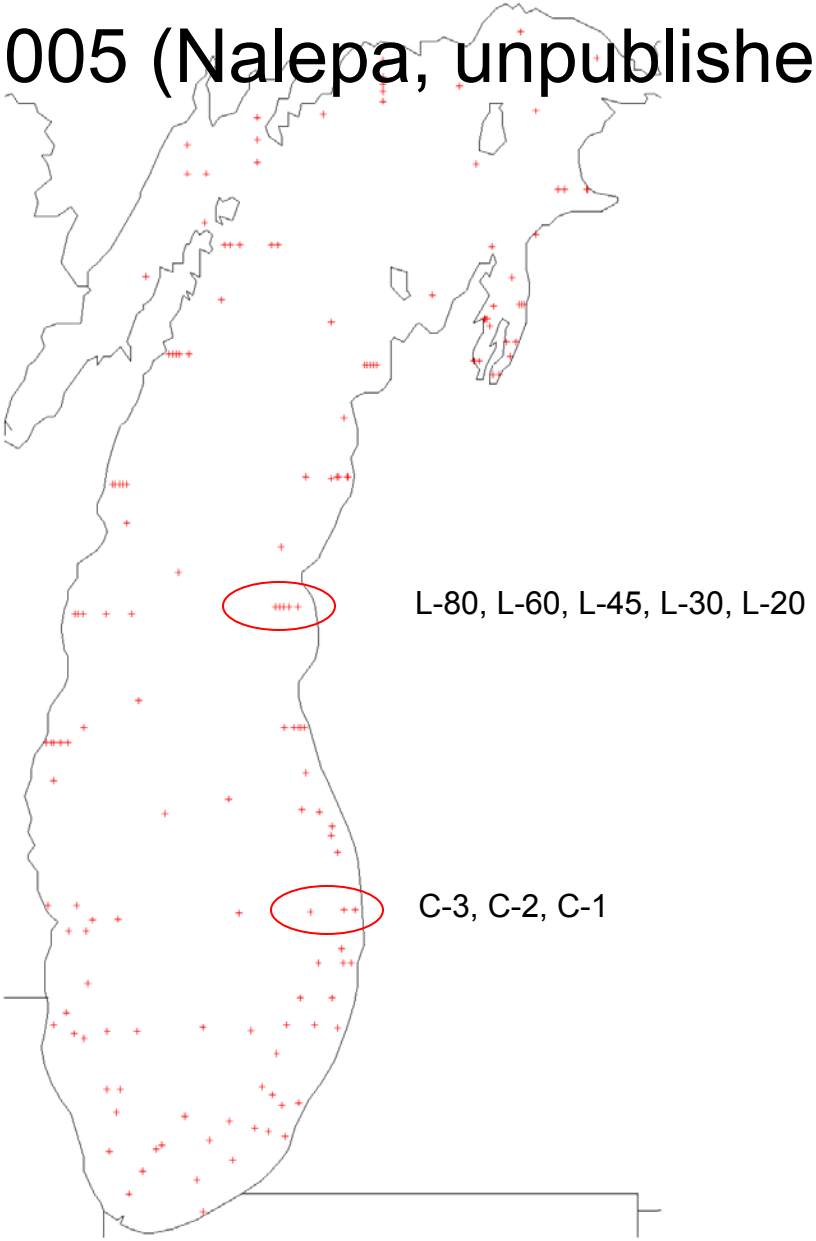
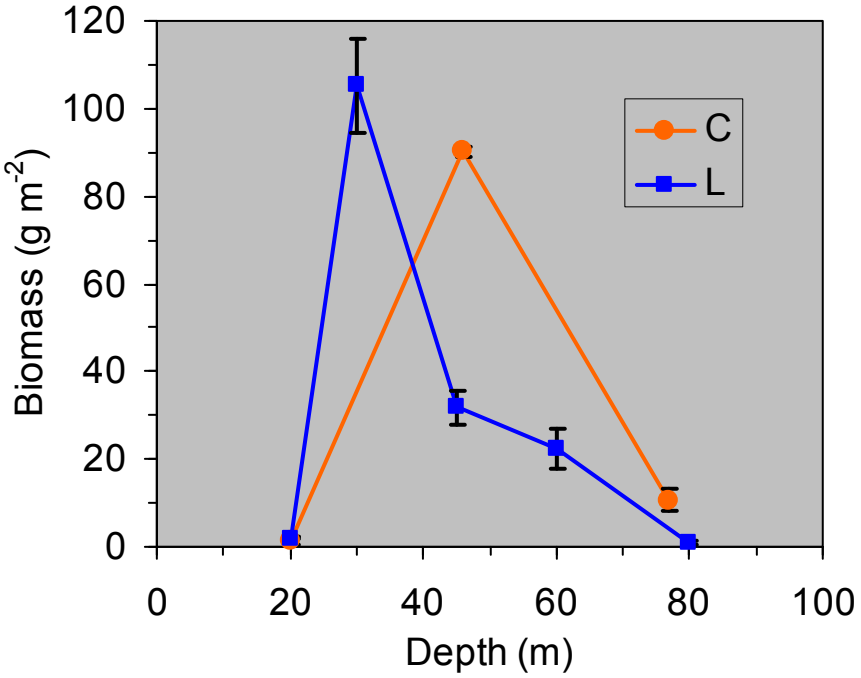
Impacts are expected to be highest in winter or winter-spring transition

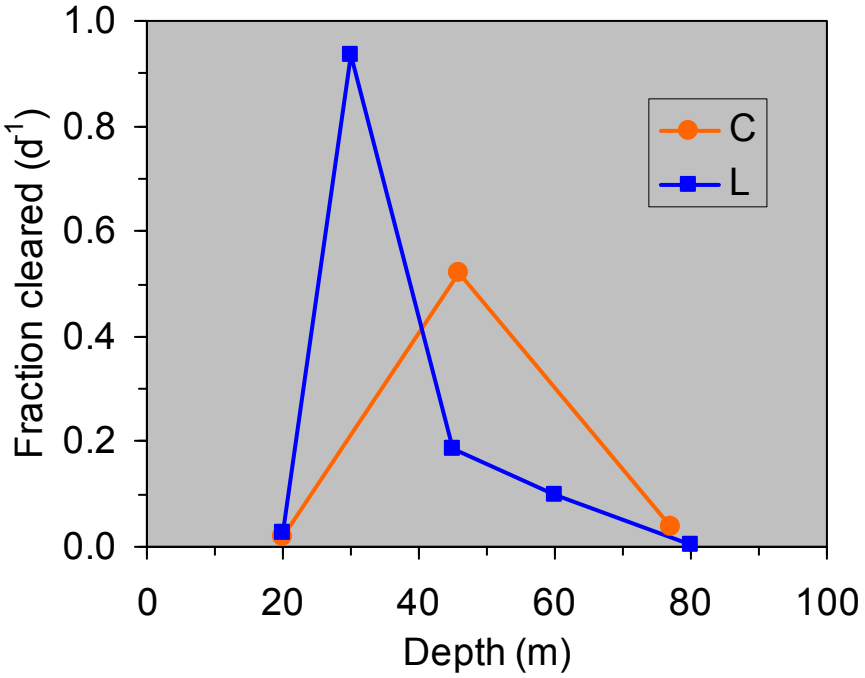
- Mussels are connected up with the water column because it is isothermal and well mixed.
- Phytoplankton are limited by light at this time and are growing very slowly.

And these station locations for biomass and impact calculations for 2005 (Nalepa, unpublished)



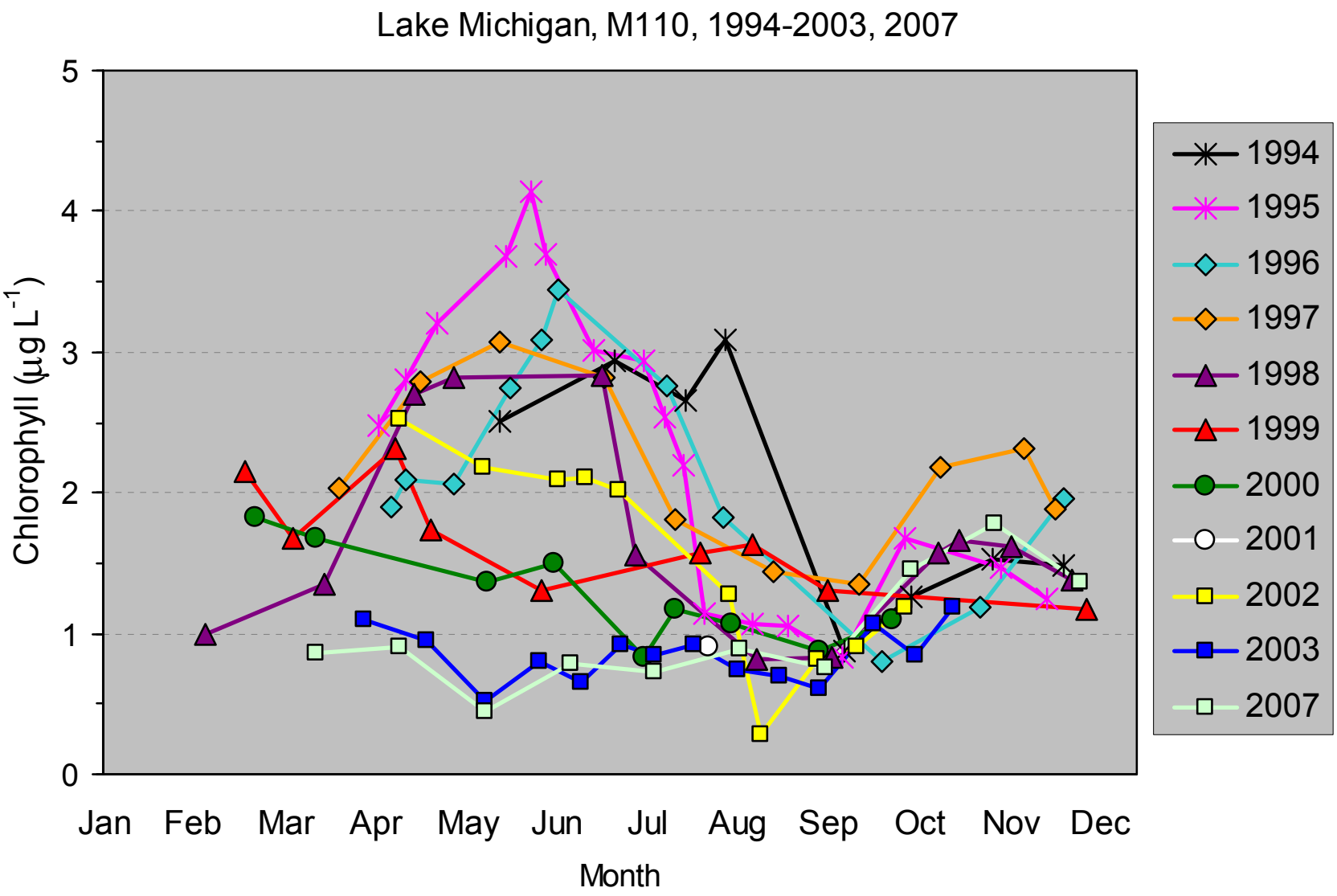
Biomass in 2005 and impact as FC (Vanderploeg, unpublished) of profunda morph quagga mussels in winter (3ºC) in eastern Lake Michigan



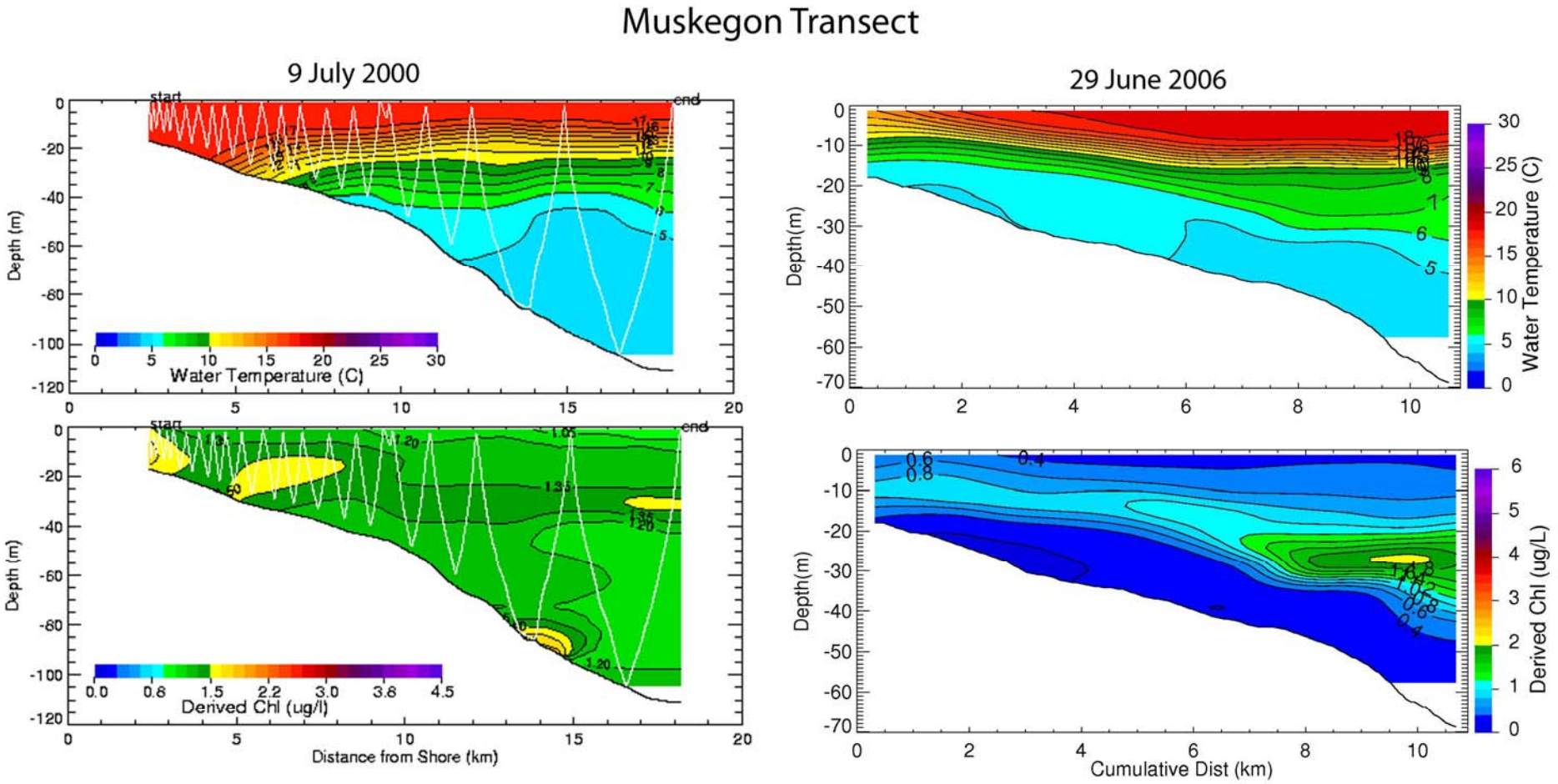


Results from 2007 & 2008 (Fahnenstiel & Pothoven, unpublished data) show Secchi disc readings at 45-m station up to 19 m and very large drop in net diatoms

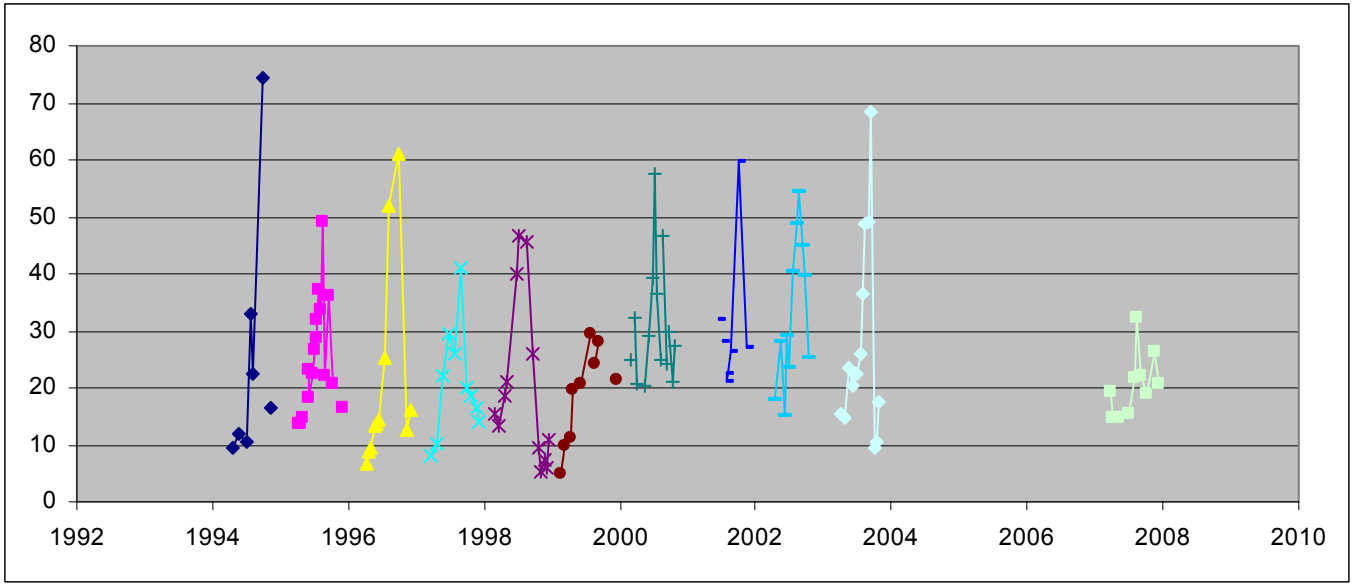
Massive drop in chlorophyll—a consequence of the mussels?



Spatial structure of summer chlorophyll concentration has changed in Lake Michigan

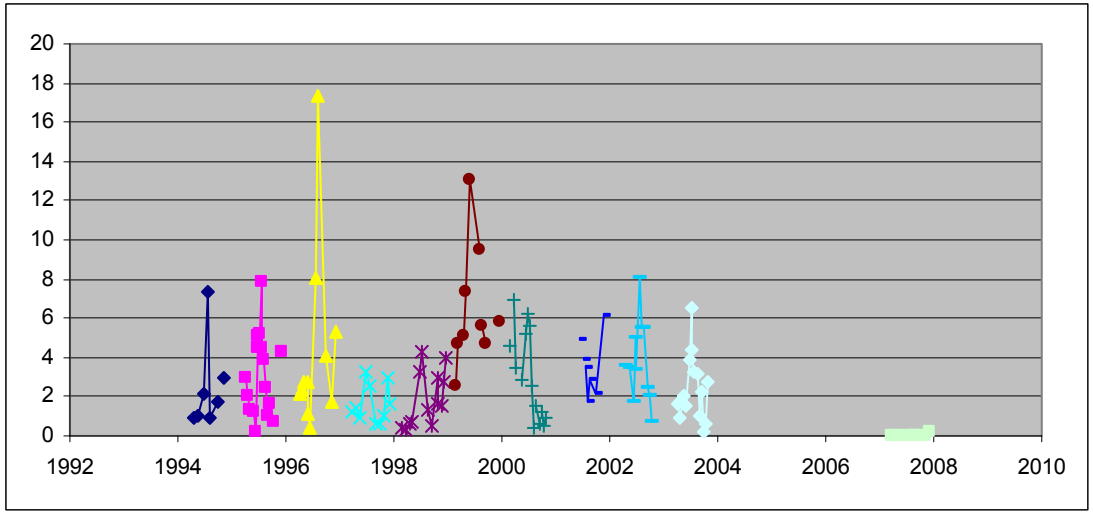


Zooplankton has dropped to new low level at time when fish are at an all time low



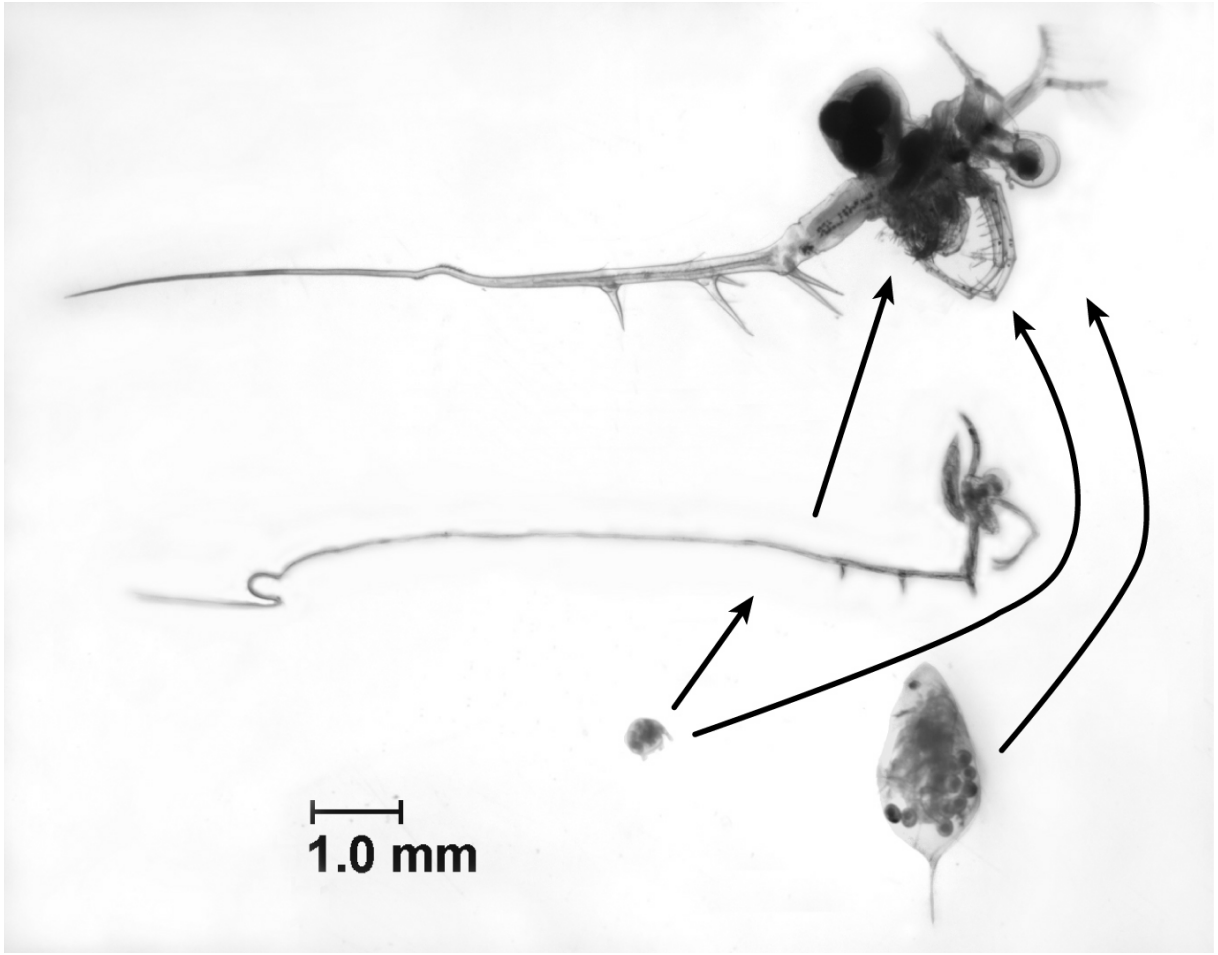
Total zooplankton biomass (g m^{-3}) at M110

Cyclopoids, which feed on microzooplankton took the biggest hit

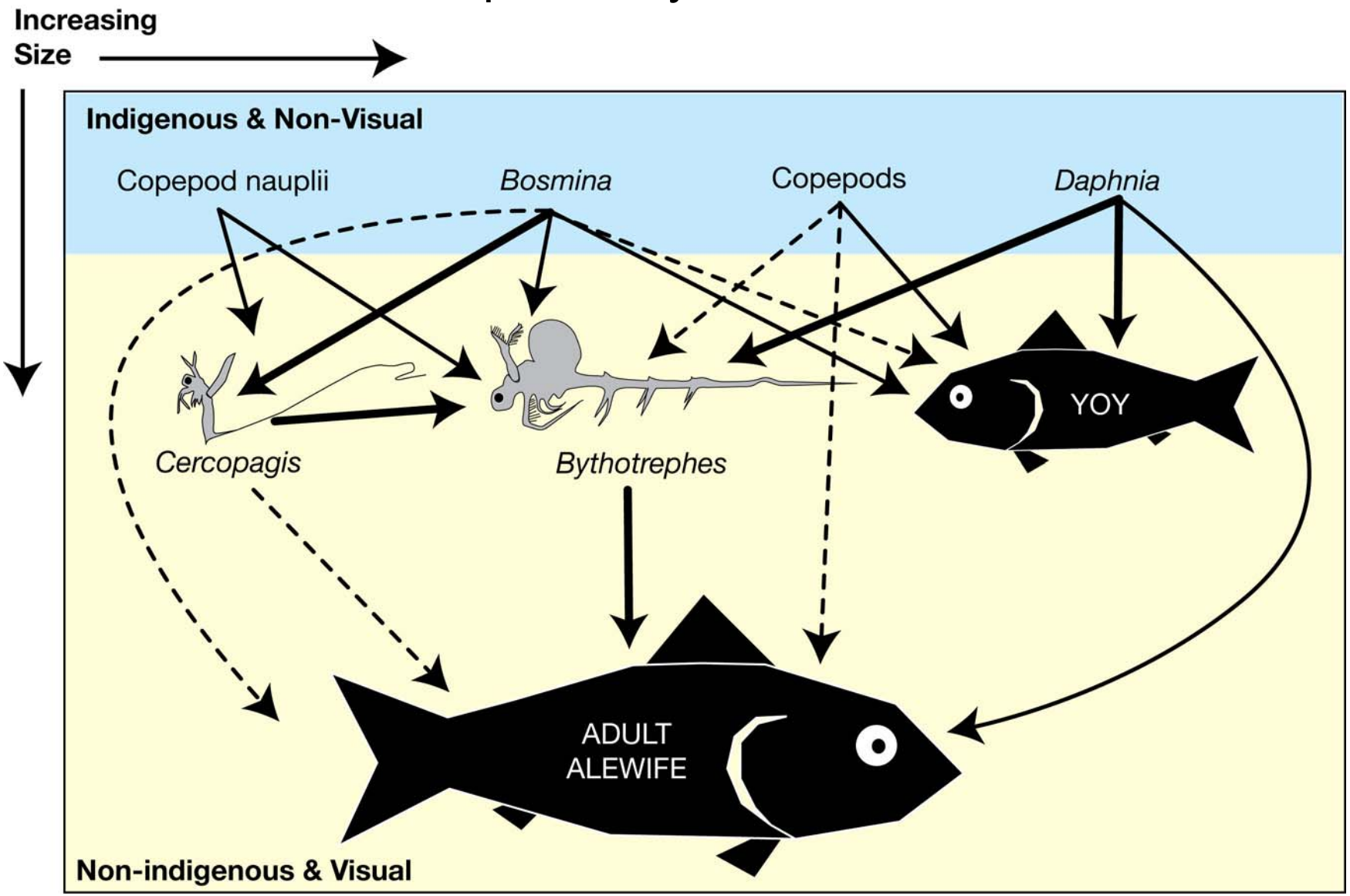


Cyclopoids (g m^{-3}) at M110

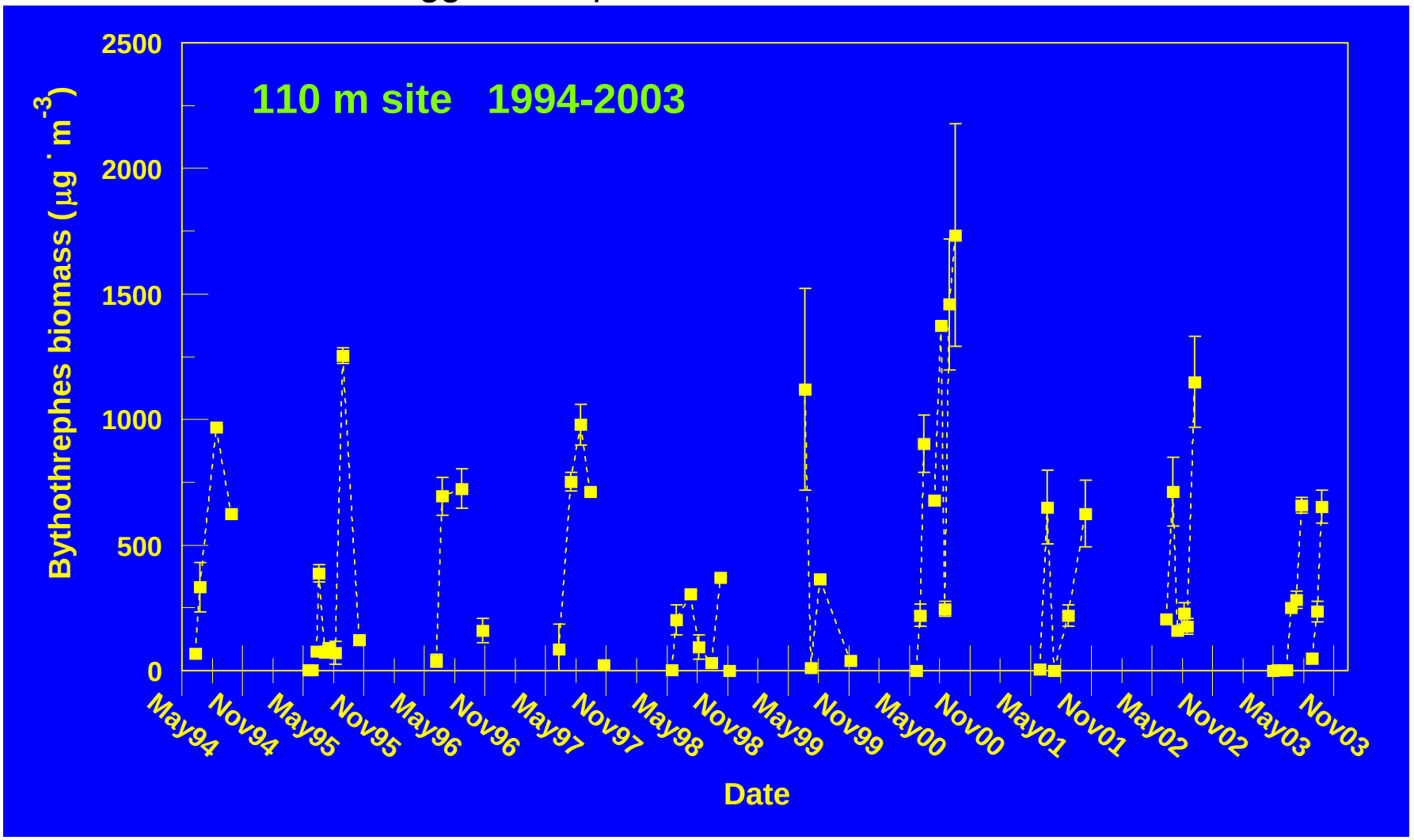
The system is also disrupted by *Bythotrephes* and *Cercopagis*



Emerging food web disruption story in Lake Michigan—does increase light heighten impact of visual predation by invasive predatory cladocerans?



Bythotrephes is highly variable with maximum concentration in fall—Recent data suggest this predator has not decreased



So while its prey the other zooplankton are down, this predator has not decreased—likely because the fish are down

Conclusions/Hypotheses

- Mussels and other non-indigenous species will react in surprising, unpredictable ways with climate warming.
- It is likely that projected warming and mussel filtering during the winter and winter-spring transition will exact a heavy toll on offshore phytoplankton, zooplankton, and fish communities.
- We anticipate synergies with Bythotrephes and Cercopagis will also be destructive.
- Altered spatial structure of the food web driven by light and altered chlorophyll patterns are likely to be negative.
- The extreme water clarity driven by the mussels will lead to greater penetration of ultraviolet radiation
- In inshore waters, increased temperature will stress the mussels and lessen their impacts.


Muskegon Field Station