The benthification of freshwater lakes: Exotic mussels turning ecosystems upside down

Collaborators

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Dreissenid Mussels & Benthification

- High population density
- High filtration rate

↓

Increased water clarity

- Form clusters

↓

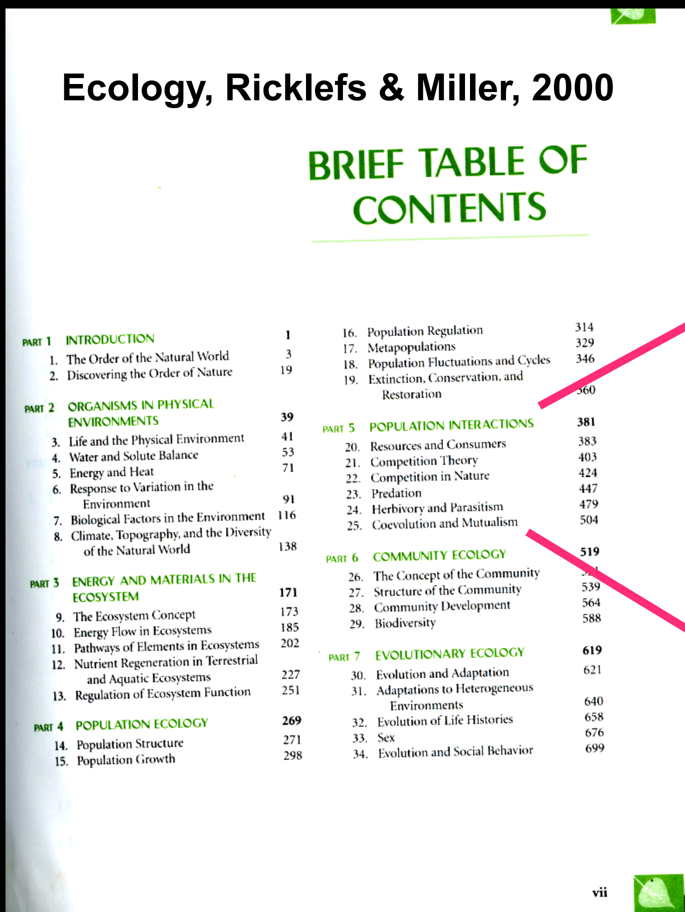
Increased benthic structure

Dreissena are Ecosystem Engineers

Organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials.

Jones et al. 1994

Ecology, Ricklefs & Miller, 2000



BRIEF TABLE OF CONTENTS

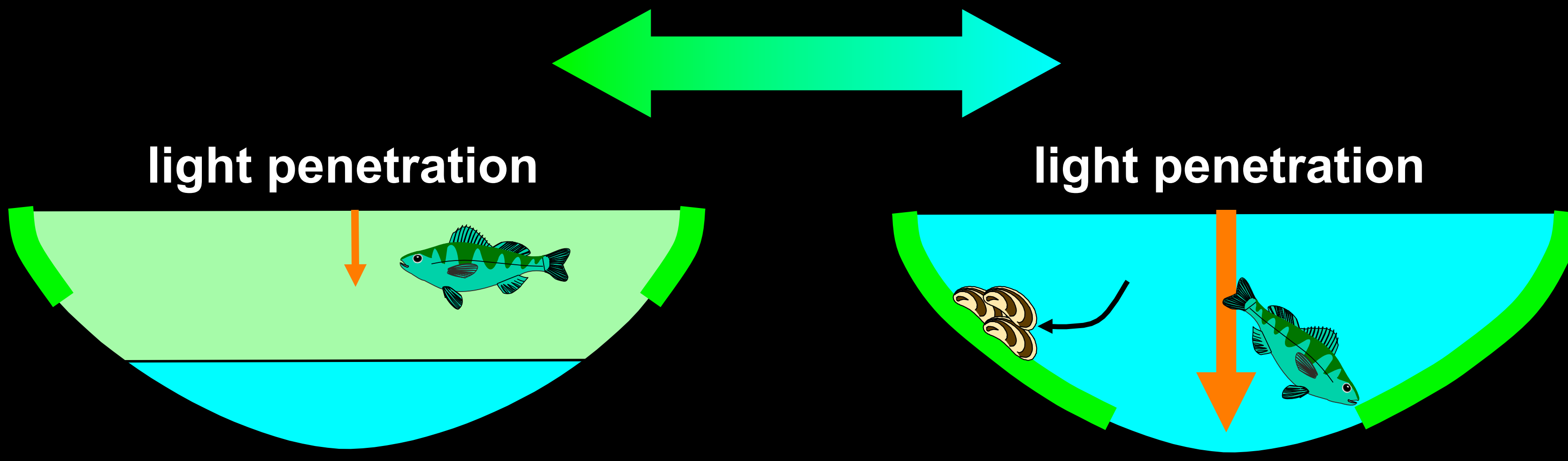
Population Interactions

- Resources and Consumers
- Competition Theory
- Competition in Nature
- Predation
- Herbivory and Parasitism
- Coevolution and Mutualism

Suite of expected changes with benthification

eutrophic

benthified



➔ **Limited** benthic production

➔ **Low** benthic complexity

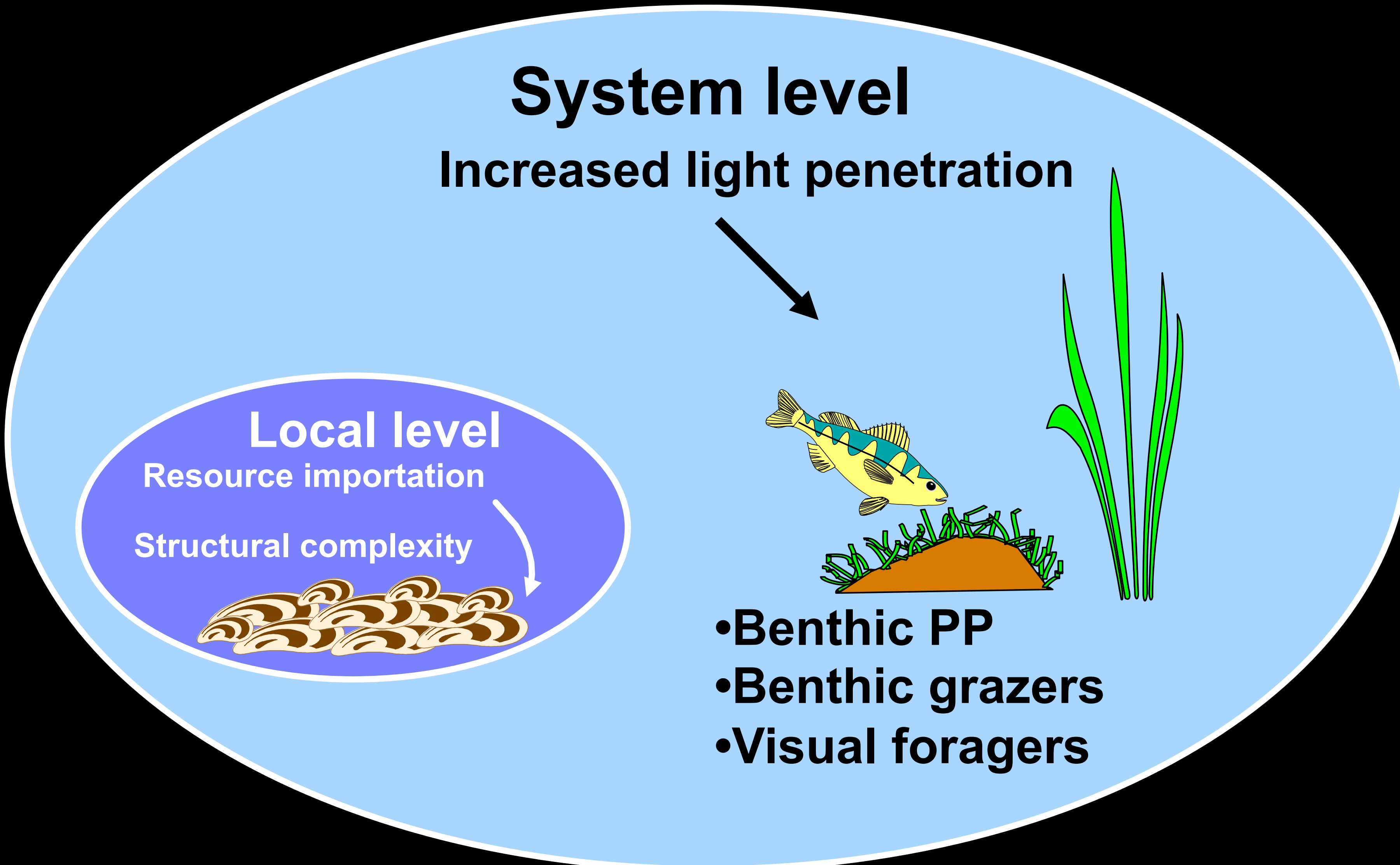
➔ Low foraging efficiency by benthic fish (**low** benthic to pelagic flux)

➔ **Extensive** benthic production

➔ **High** benthic complexity

➔ High foraging efficiency by benthic fish (**high** benthic to pelagic flux)

Dreissena affect lakes at multiple spatial scales and across trophic levels



Benthic Processes Affected by *Dreissena*

- **Primary production**
  - **Macrophytes: System-wide**
  - **Algae: System-wide & Local**

- **Benthic populations**
  - **Microbes: Local**
  - **Macroinvertbrates: System-wide & Local**

- **Visual foragers: System-wide & Local**

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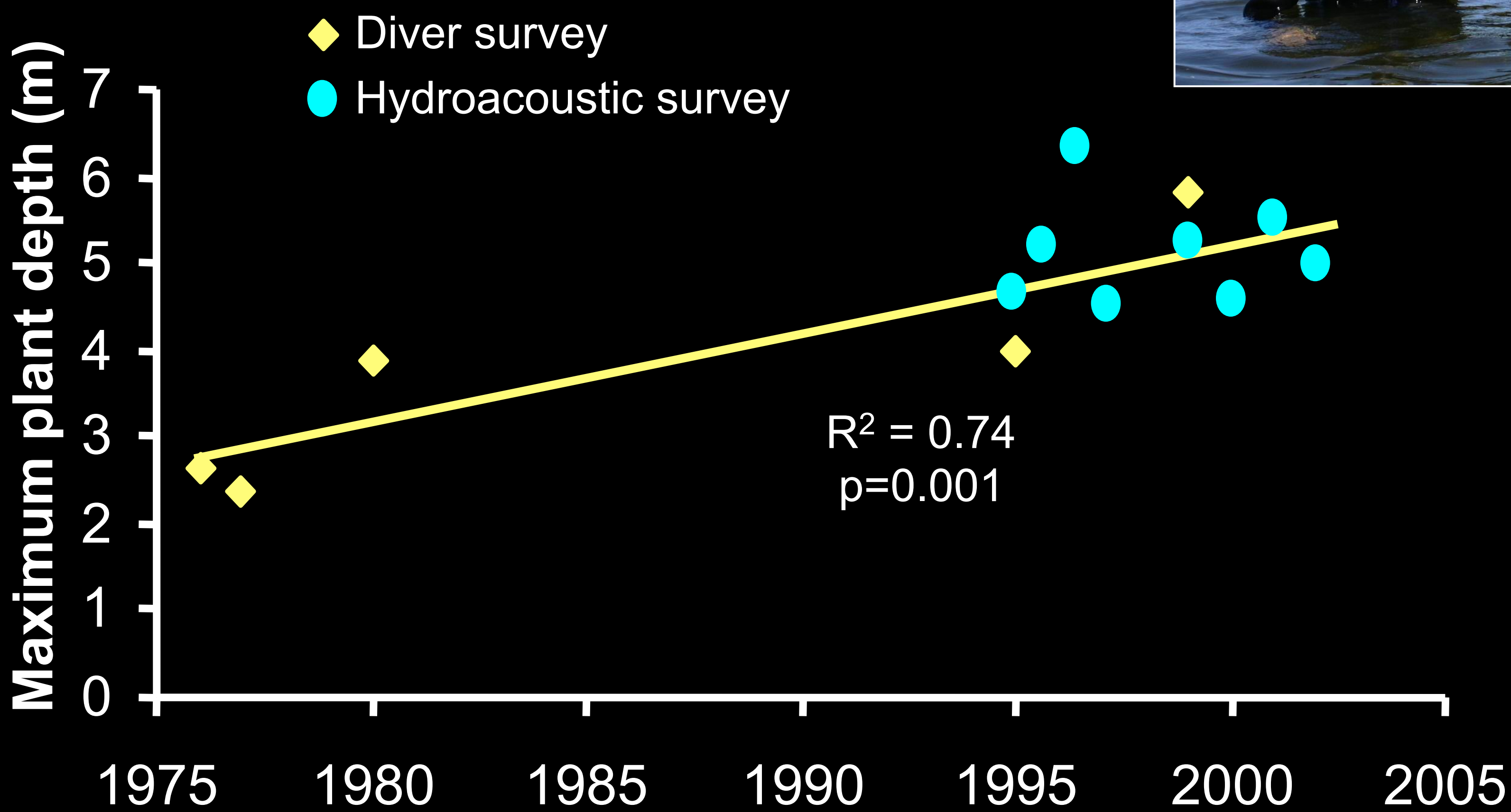
Oneida Lake
W. basin
you are here
Army Corps of Engineers, Detroit District

→**SAV maximum depth increased after *Dreissena***
→**Species evenness increased**
→**Myriophylum only spp to decrease**



Zhu et al. 2006 Ecosystems 9:1-12

Benthic Processes Affected by *Dreissena*

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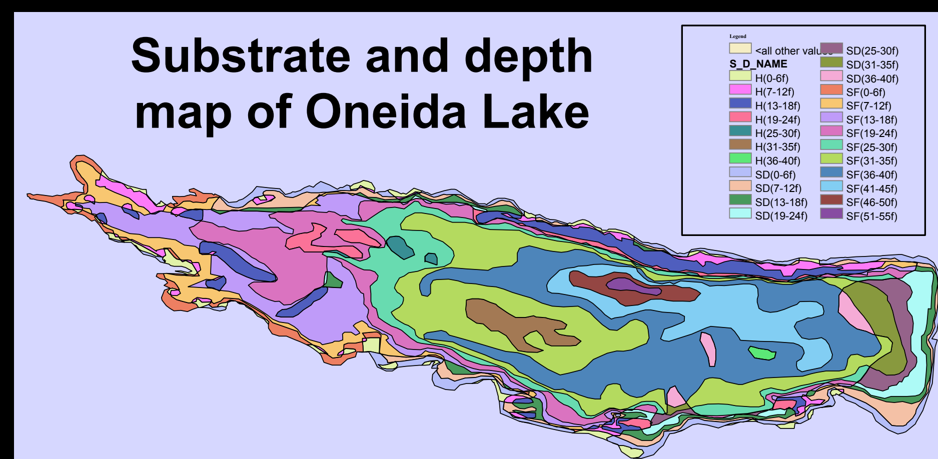
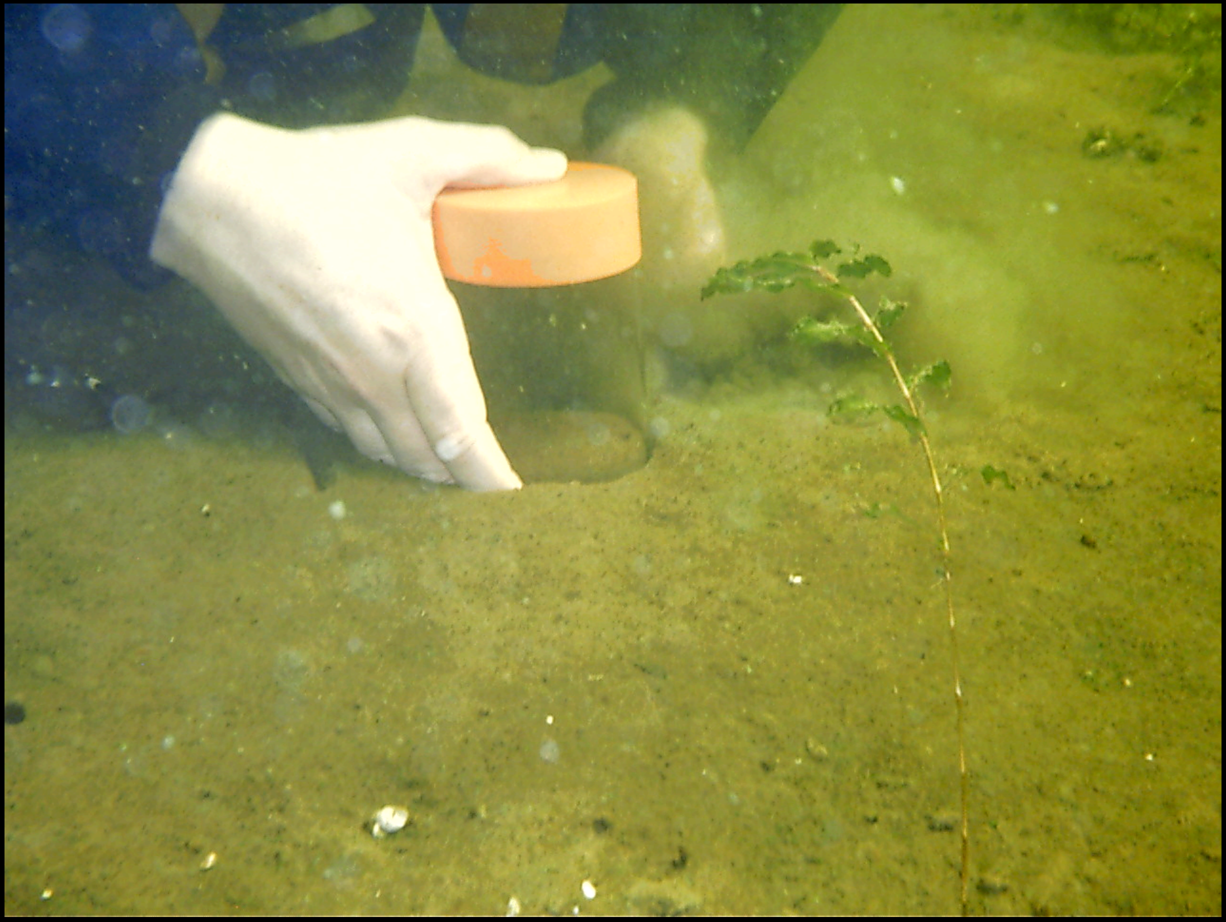
Response of benthic algal primary production to increased clarity in Oneida Lake

- Whole lake GPP 2003 & 2004
- Light response curves (N ~ 200) & modified Fee model to estimate production
- Back casting using long-term clarity data

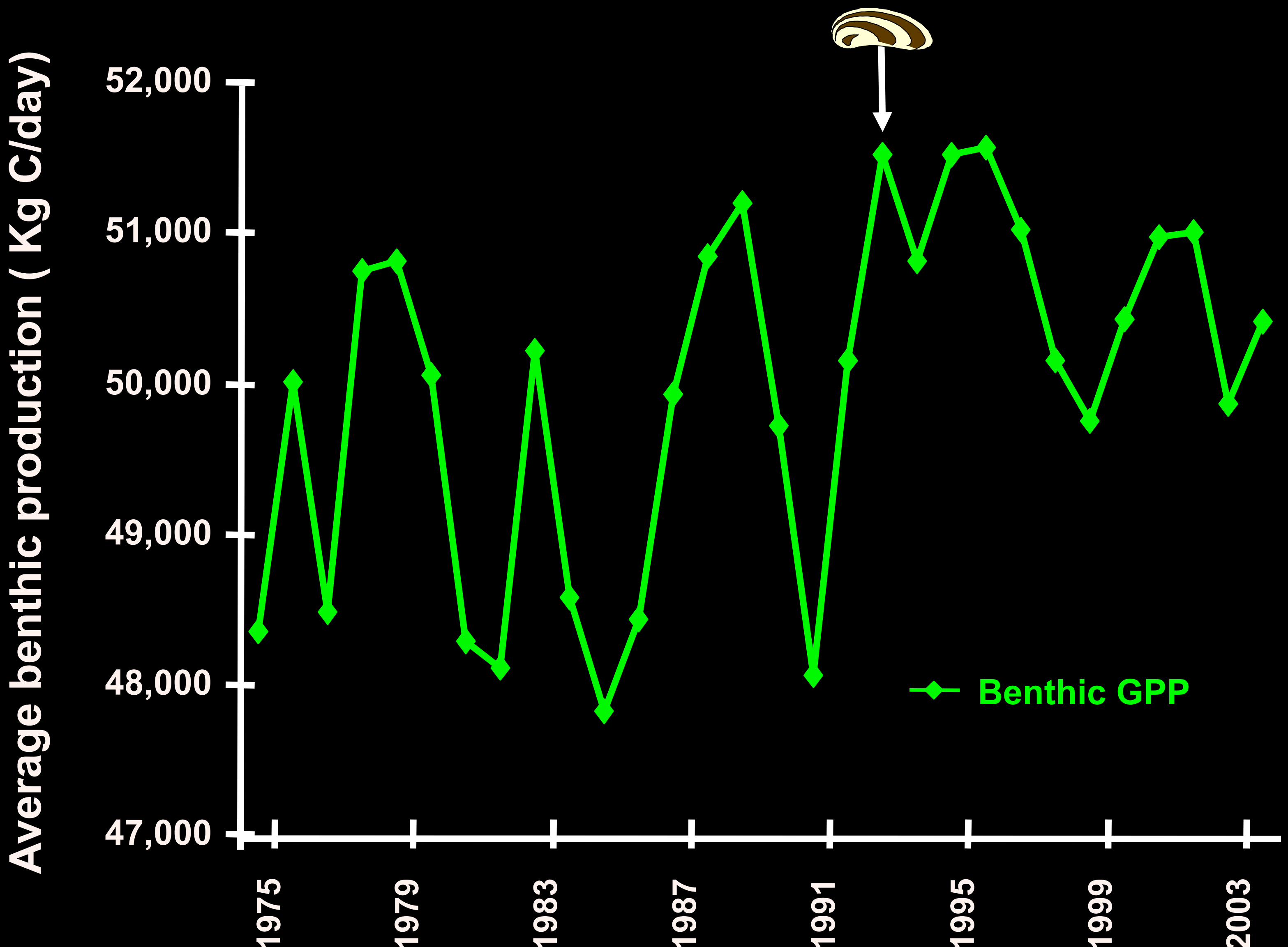


Becky Johnson-Cecala; Cecala et al. 2008. J. Integrated Plant Biology 50:1452-1466

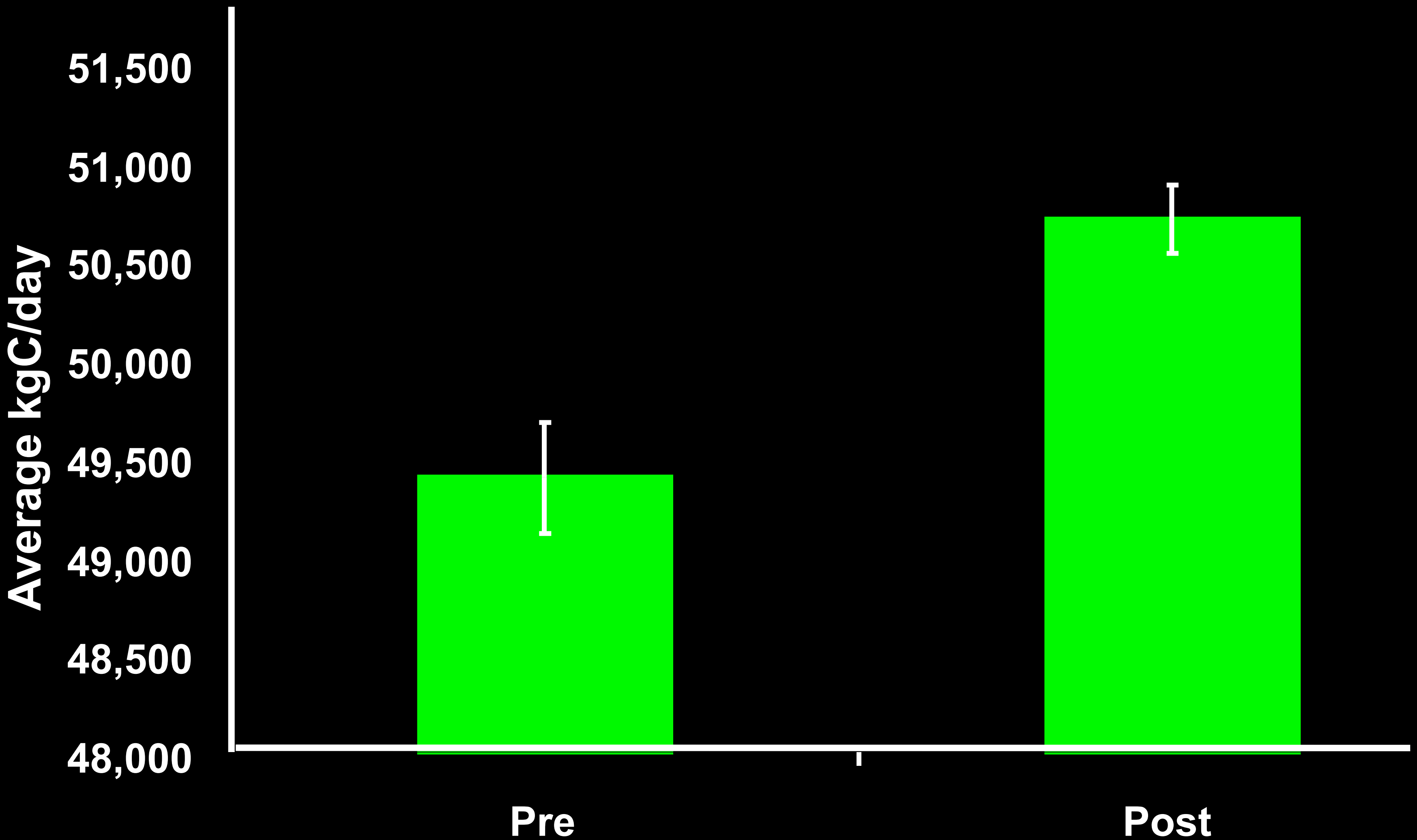
Diver collecting surface core to measure primary production on soft sediment



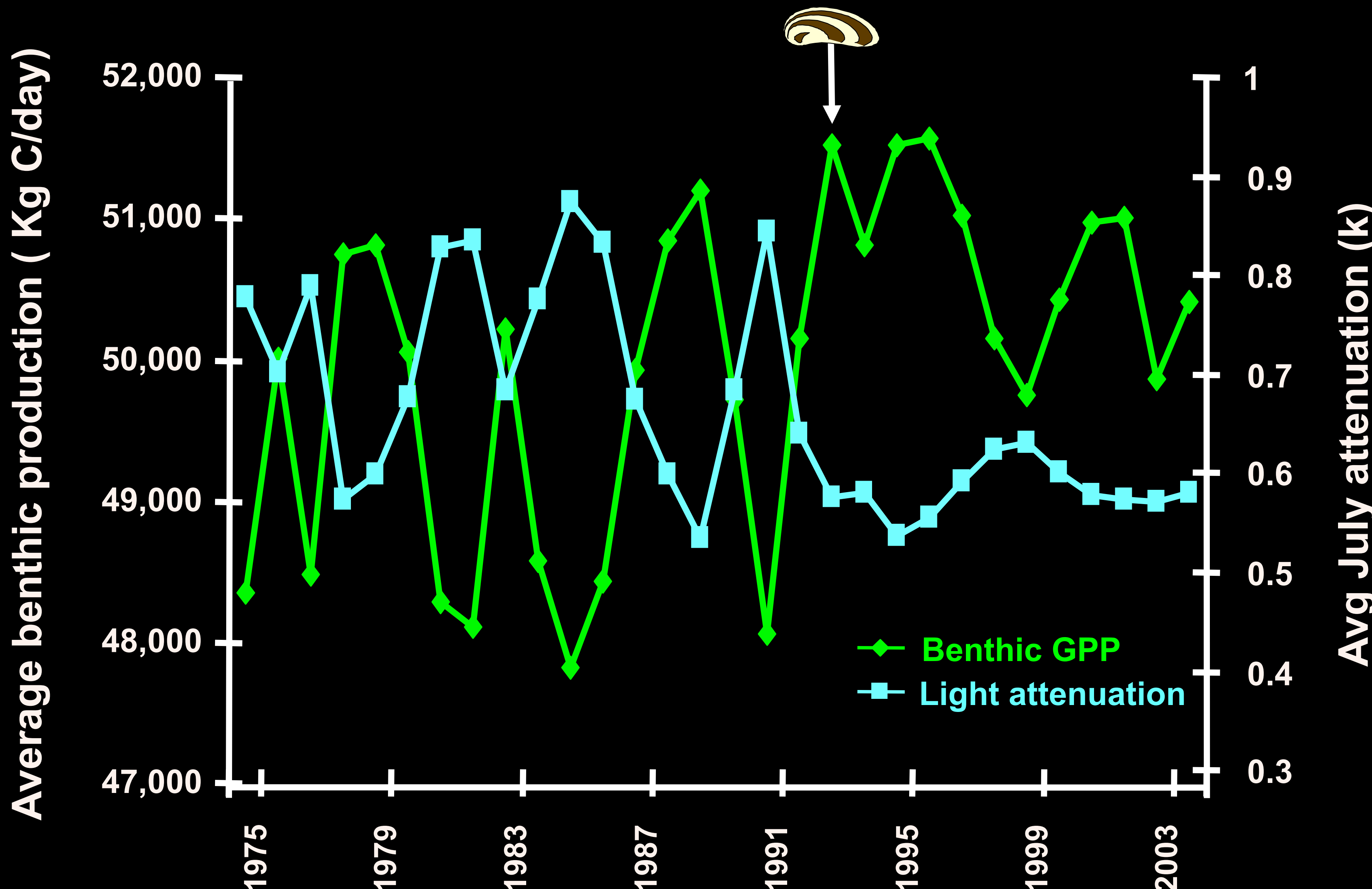
Whole-lake summer benthic GPP has increased and become less variable



~4% increase, was net change & included areas of reduced production due to photoinhibiton



Benthic GPP has become less variable following changes in attenuation



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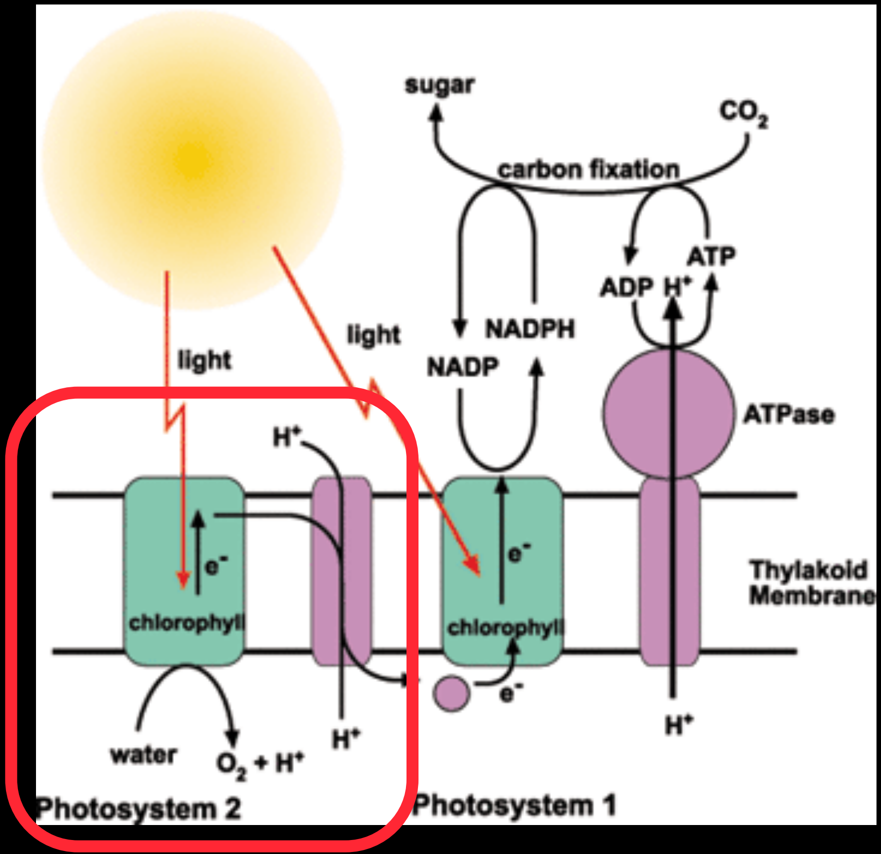
- ➔ Visual foragers: System-wide & Local

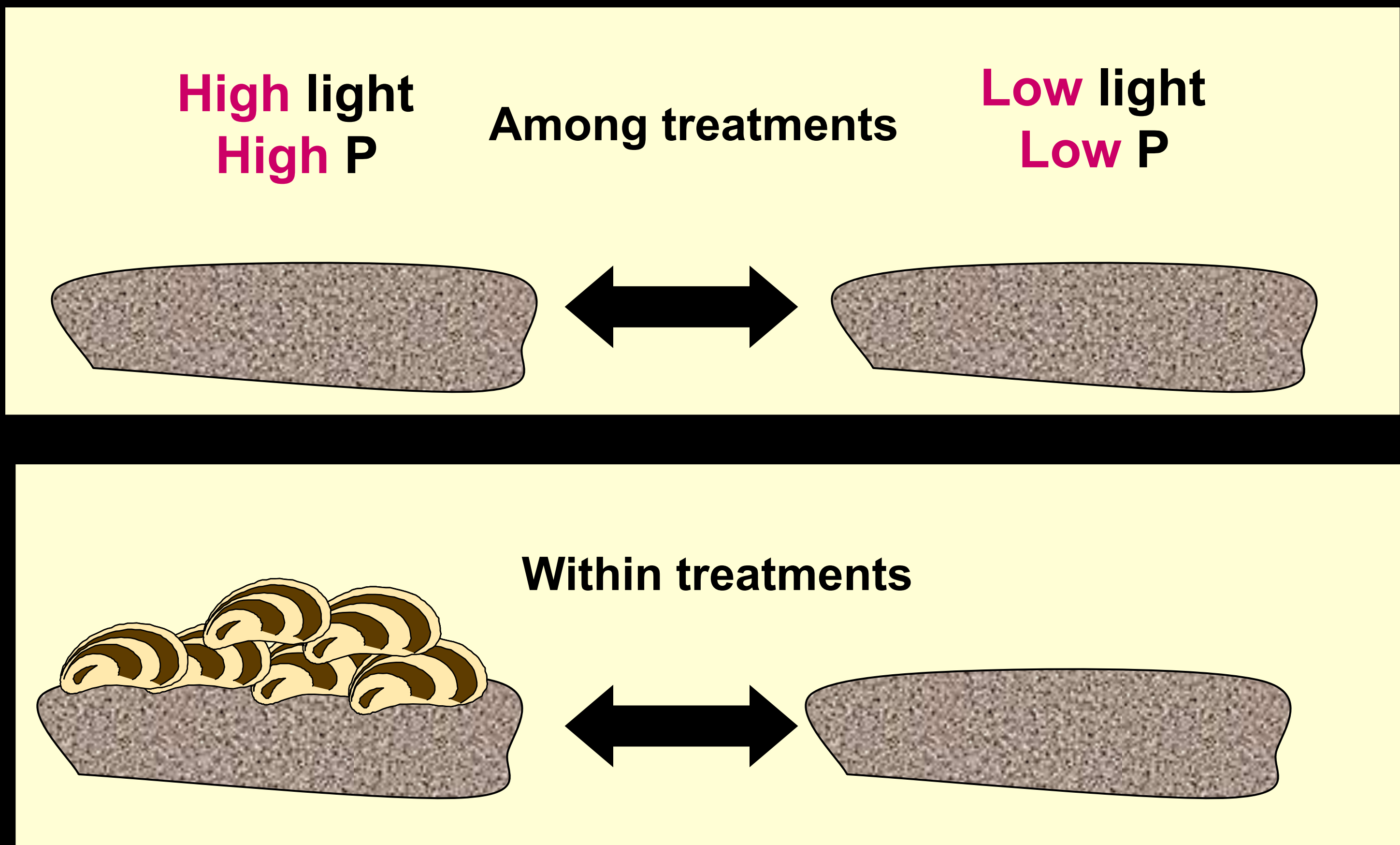
Experimental Approach: light x *Dreissena* x P x other grazers
w/ Kim Schulz, Peibing Qin, Xinli Xi

Fluorometric measure of photosynthesis



Electron Transport Rate (ETR) = proportional to photosynthesis

⇨ System wide and localized effects of *Dreissena* on *Cladophora*-dominated algal community

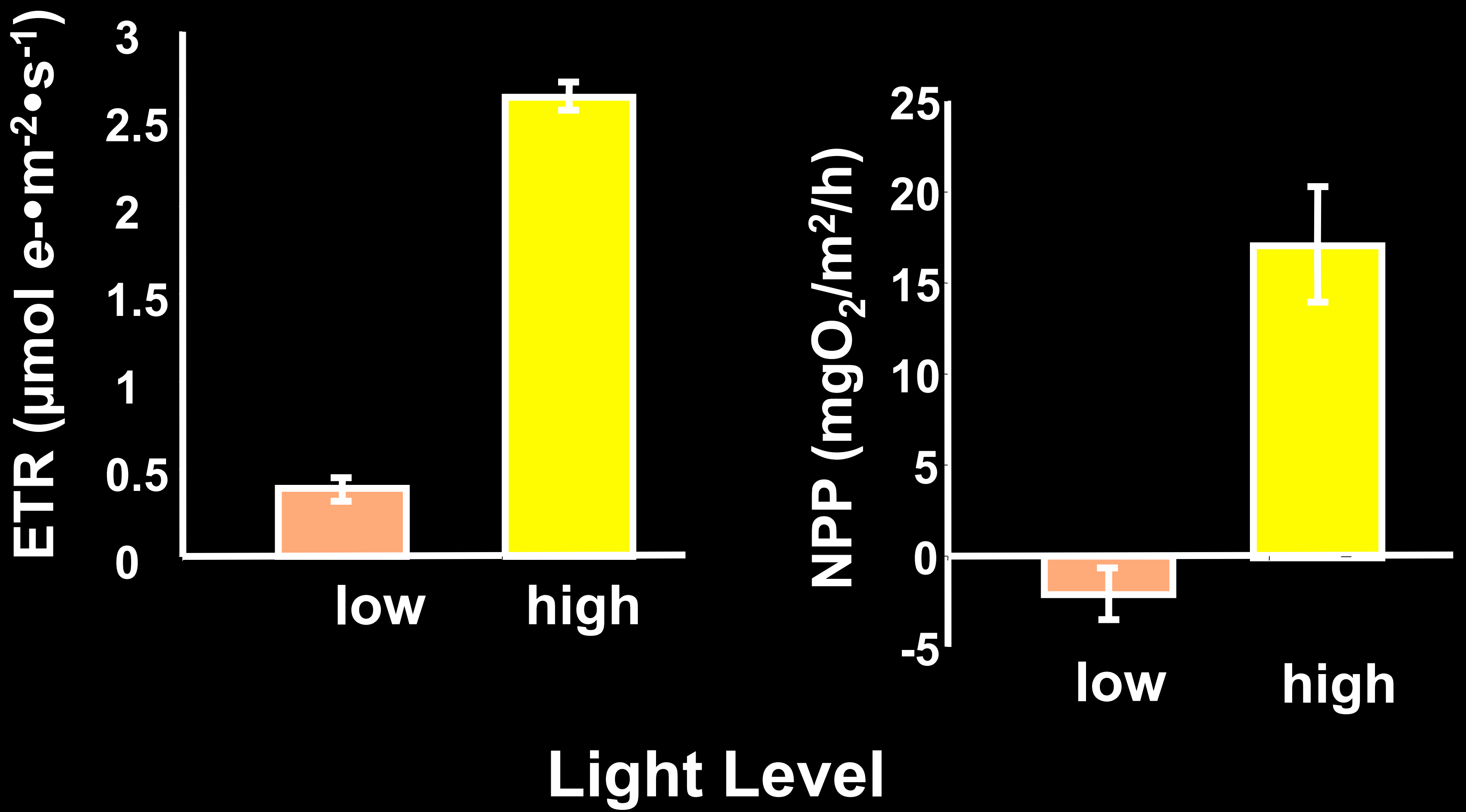


System-wide effects

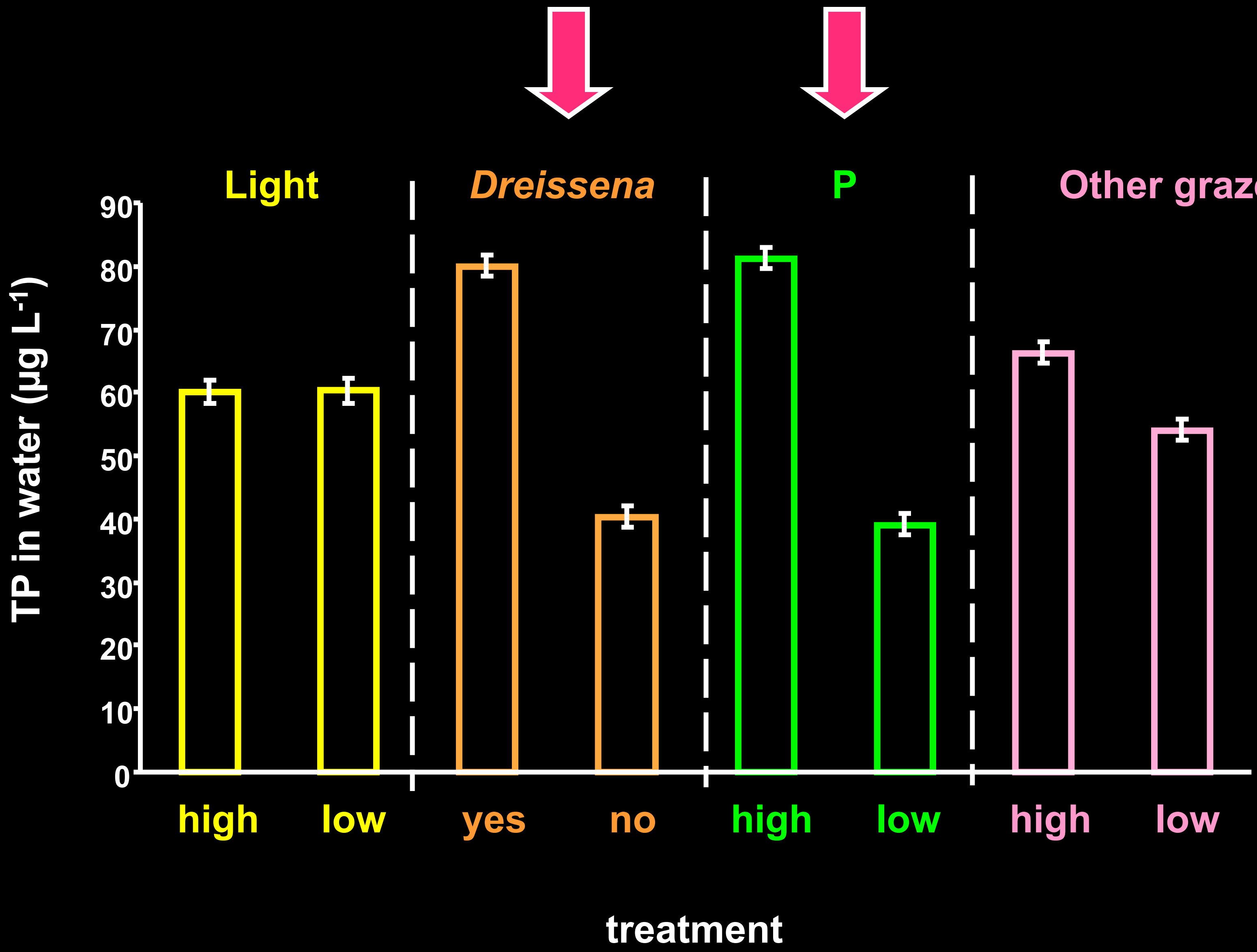
Localized effects

⇨ Light (but not P) strongly affected both NPP and ETR

Non-colonized rocks (system wide effect)

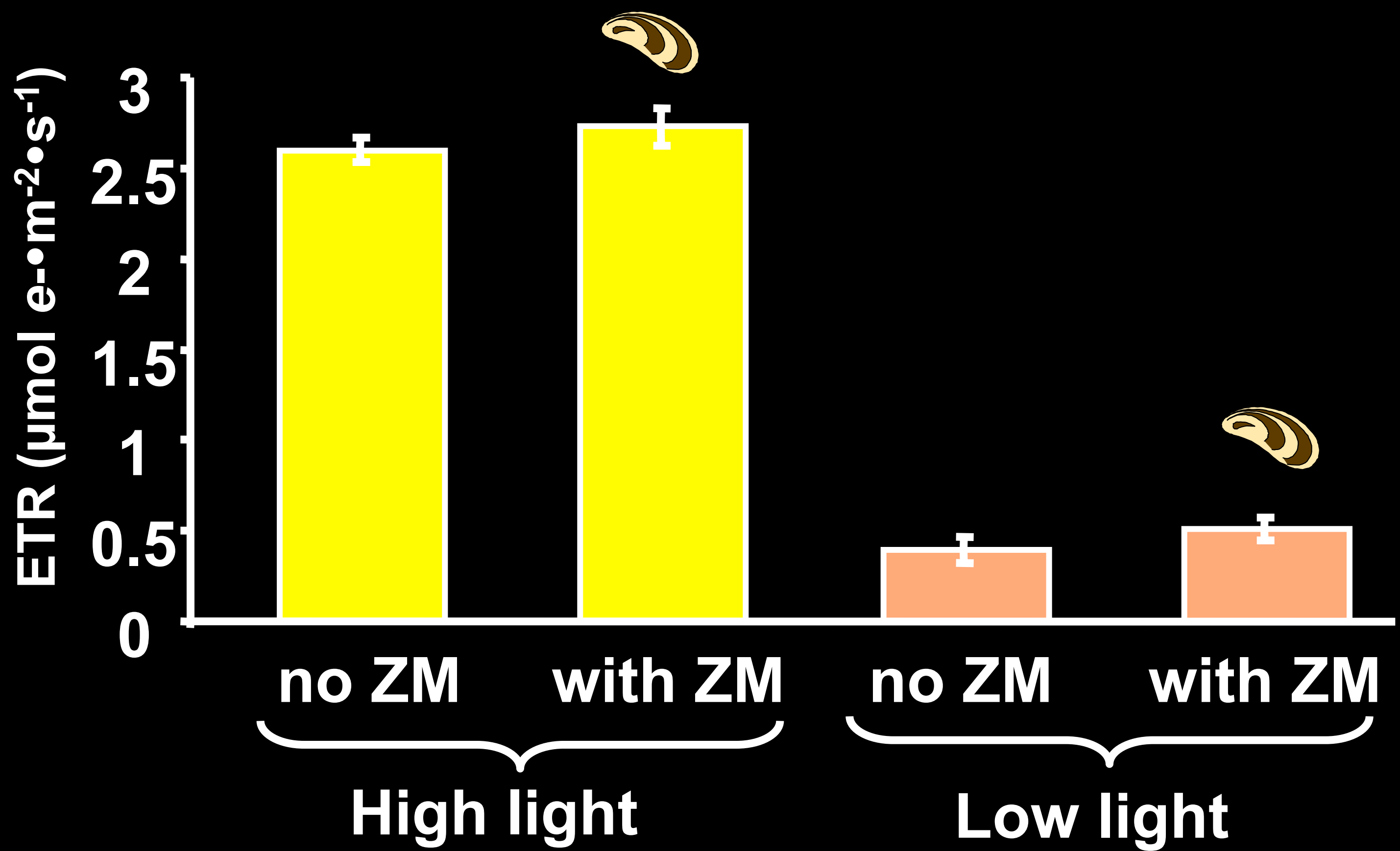


⇨ *Dreissena* sequestered P in experimental mesocosms, mimicking near shore shunt



Localized Effects

- ⇨ETR higher with *Dreissena* at both high & low light
- ⇨Statistical model accounts for other- treatment variance
- ⇨Difference small compared to light effect



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- Benthic populations
  - microbes: Local
  - macroinvertbrates: System-wide & Local
- Visual foragers: System-wide & Local

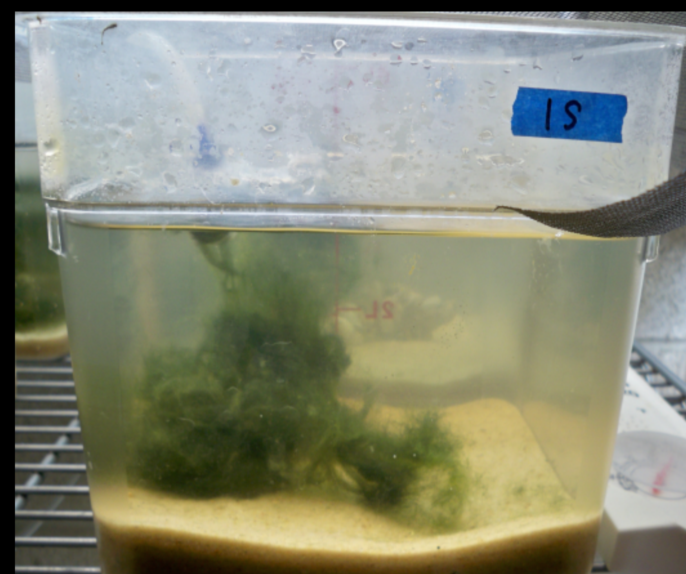
Do *Dreissena* contribute nutrients to promote algal blooms?
Manipulative experiment with *Lyngbya wollei*

Patricia Armenio; MS student U. Toledo

Live *Dreissena* (N=10)

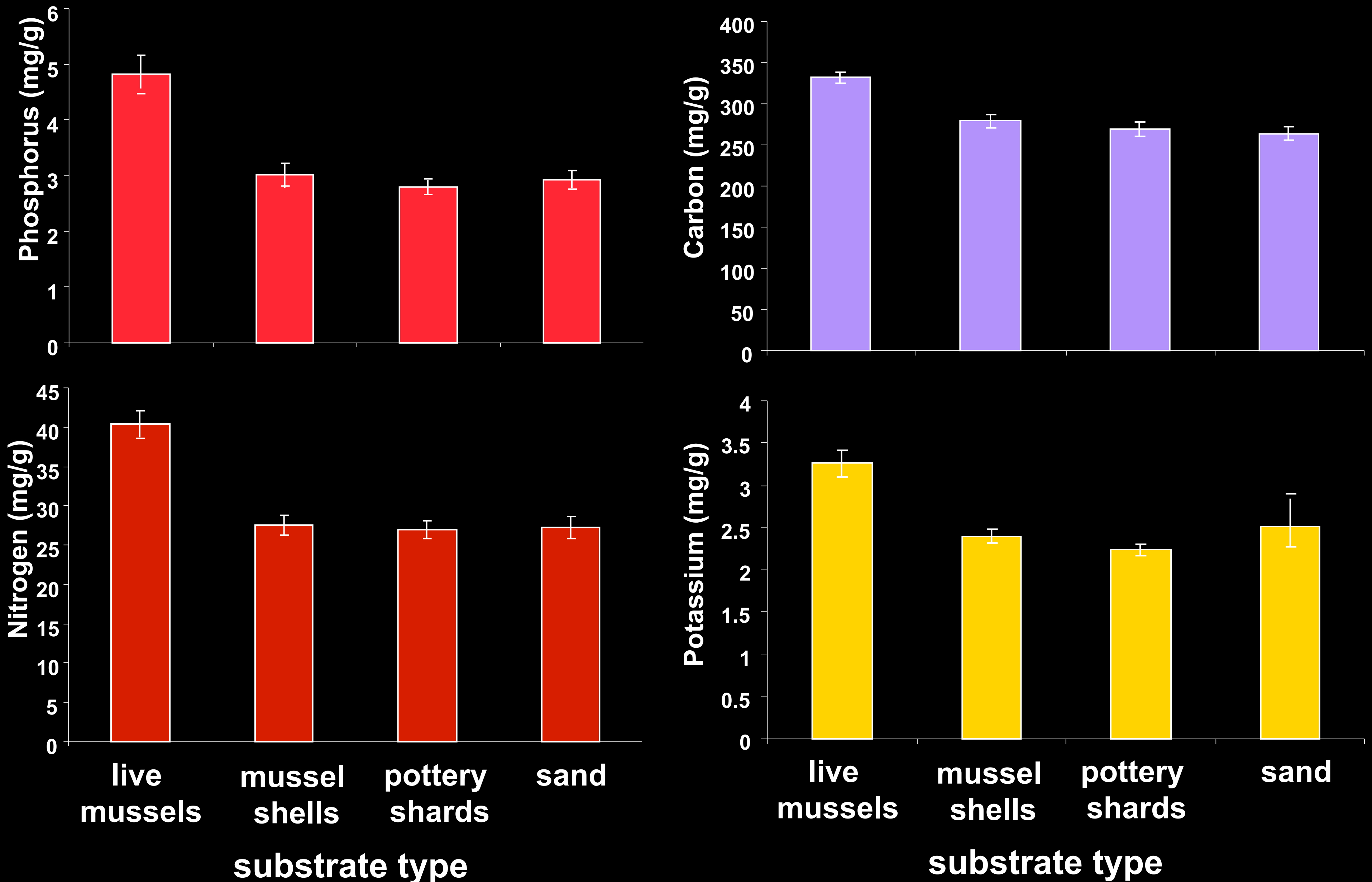
Pottery shards (N=10)

Dreissena shells (N=10)

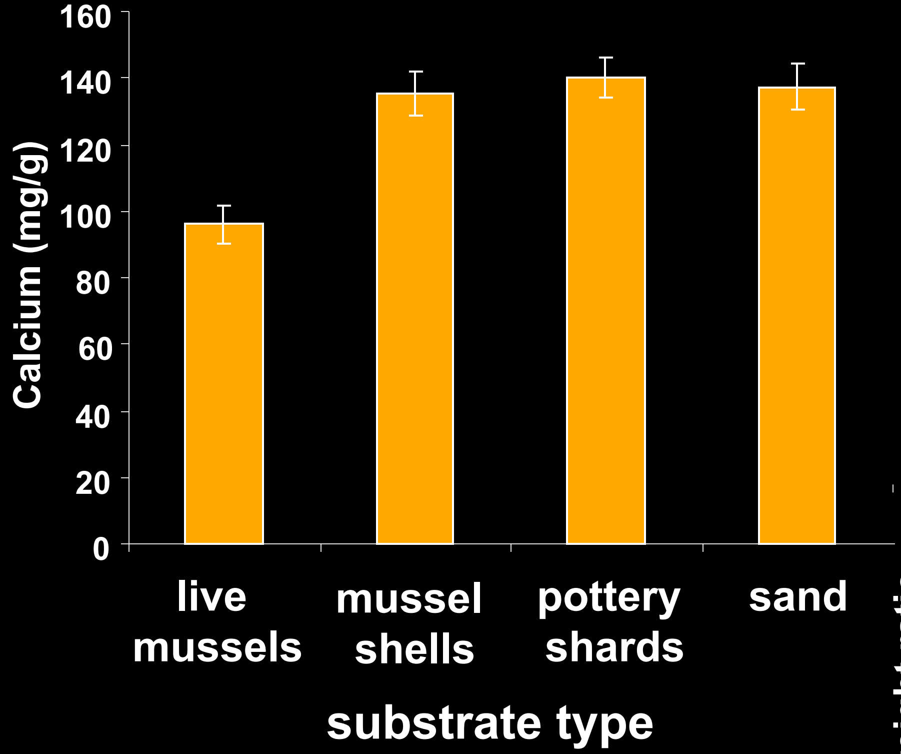


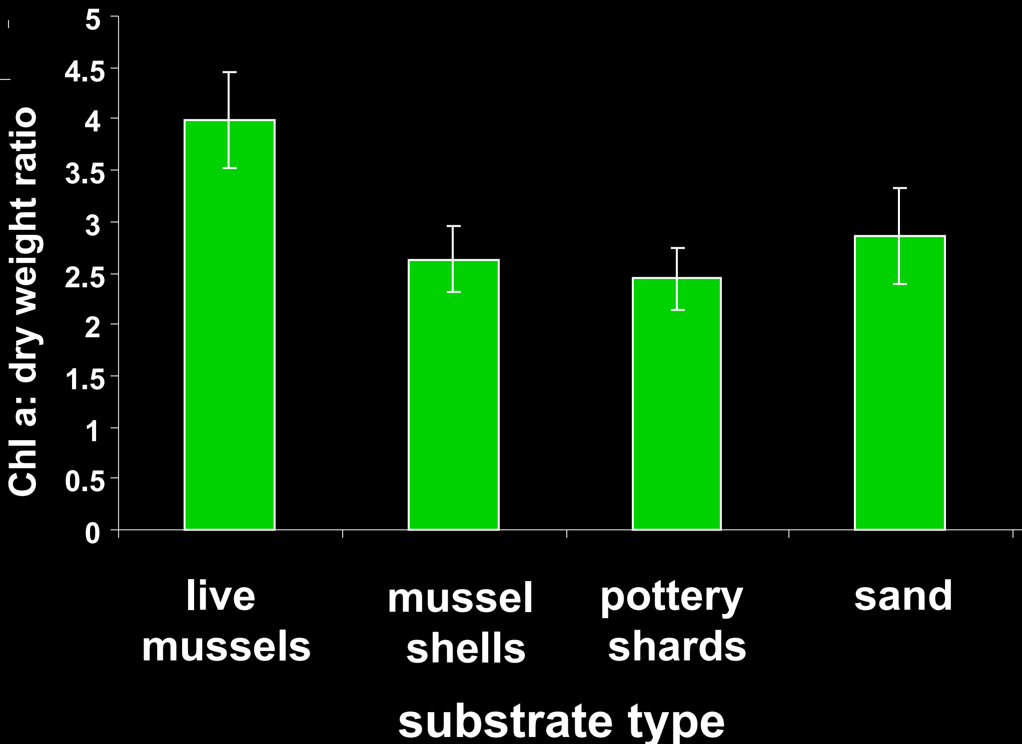
Sand (N=10)

No mass change, but *Dreissena* contributed some nutrients to *Lyngbya*

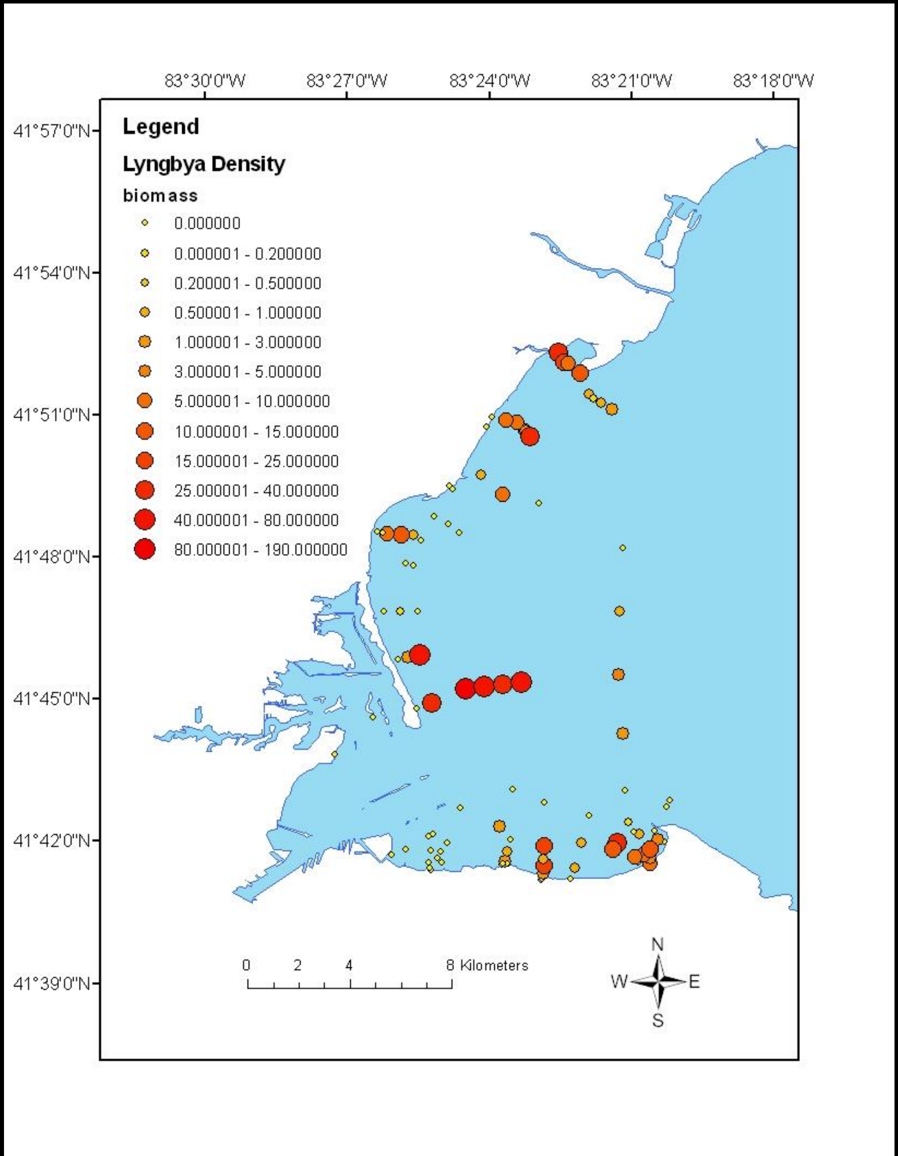


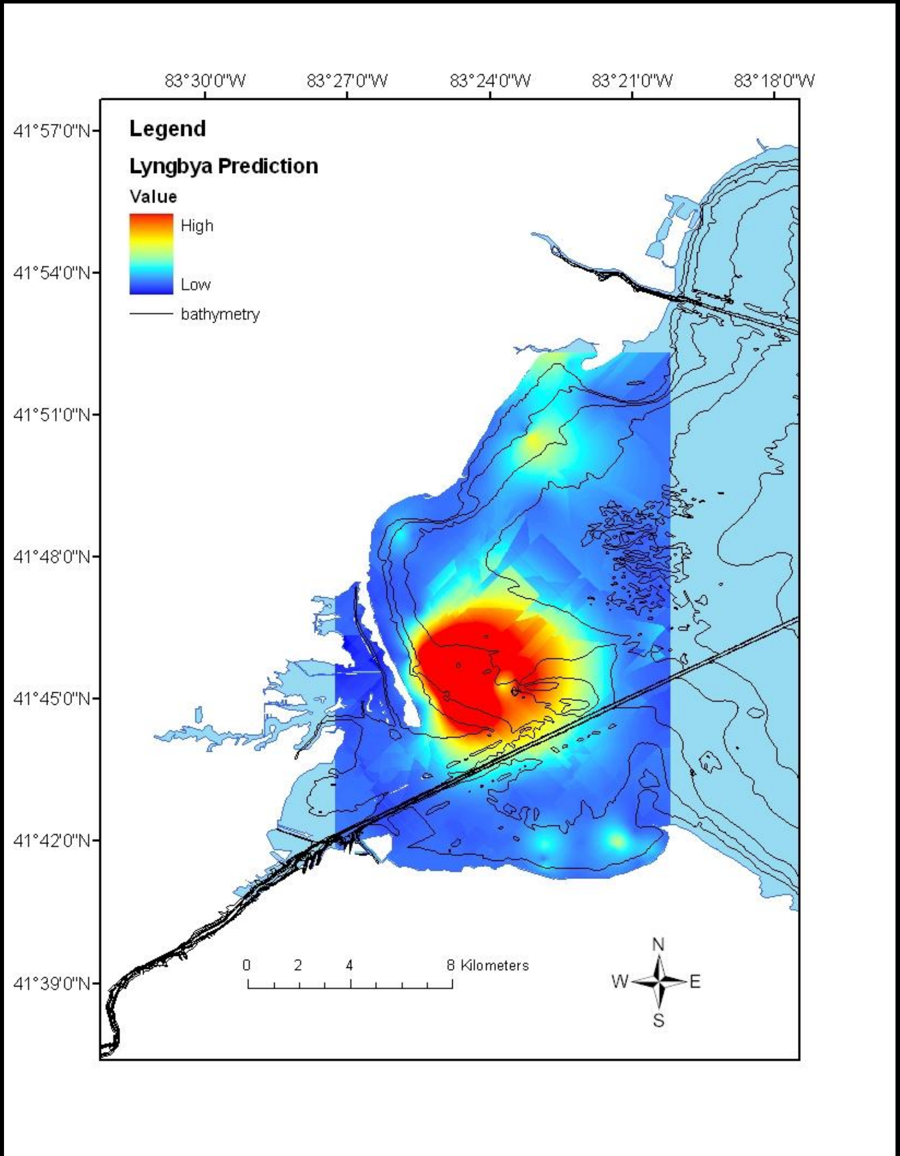
However…


160
140
120
100
80
60
40
20
0
Calcium (mg/g)
live mussels
mussel shells
pottery shards
sand
substrate type


5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Chl a: dry weight ratio
live mussels
mussel shells
pottery shards
sand
substrate type

Lyngbya density in western Lake Erie





Conclusions

1. Increased water clarity, hence bottom light promotes increased benthic PP, both plants and algae

2. *Dreissena* also increase benthic algal photosynthesis at local scale

3. Transfer of nutrients is a possible mechanism for local-scale effects– work in progress

4. When ZM aggregations are large, they may elevate water column P and other nutrients and thereby increase benthic algal photosynthesis, Near Shore Shunt

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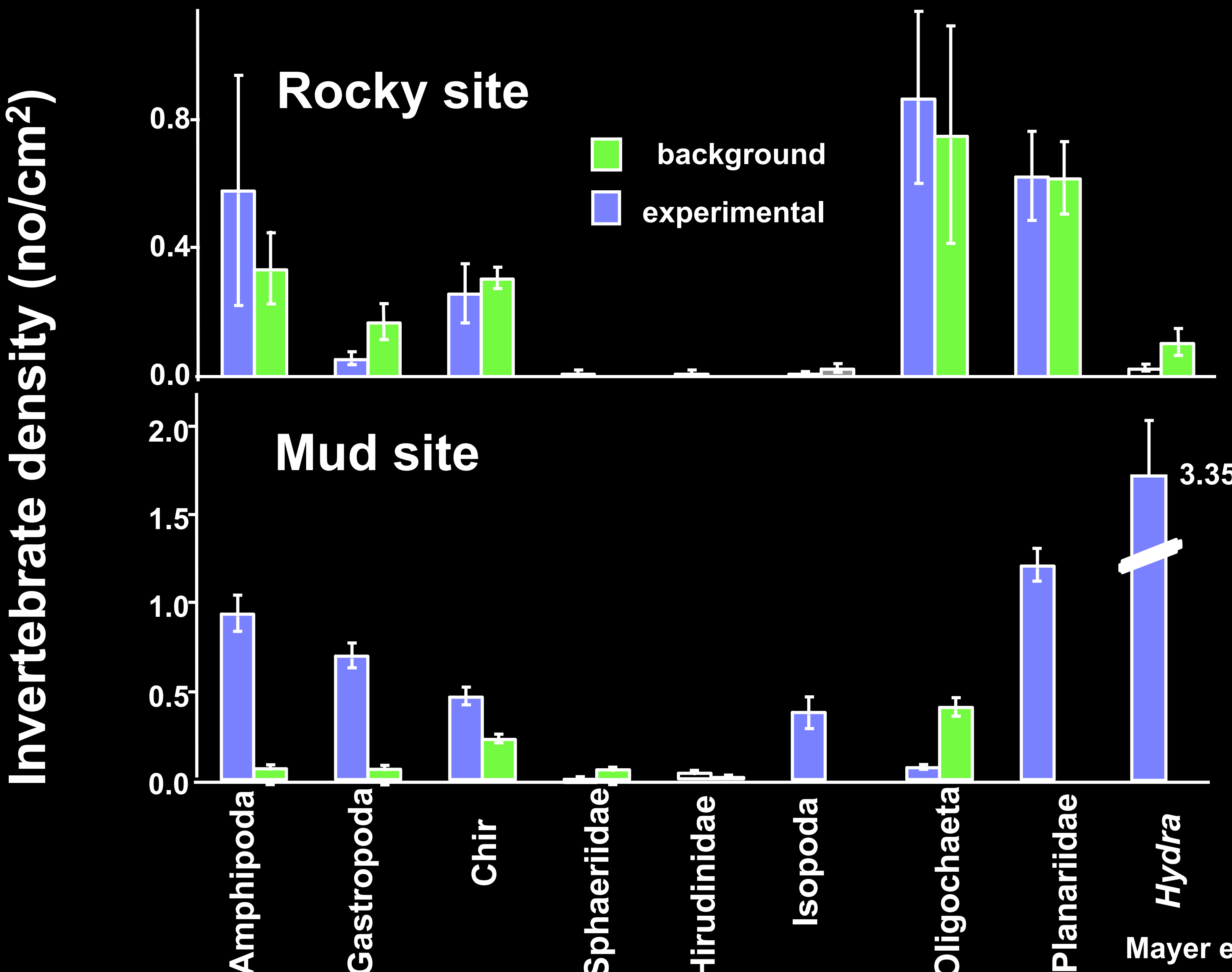
  - Macroinvertbrates: System-wide & Local
    - Hard substrate-Oneida Lake
    - Soft substrate-western Lake Erie

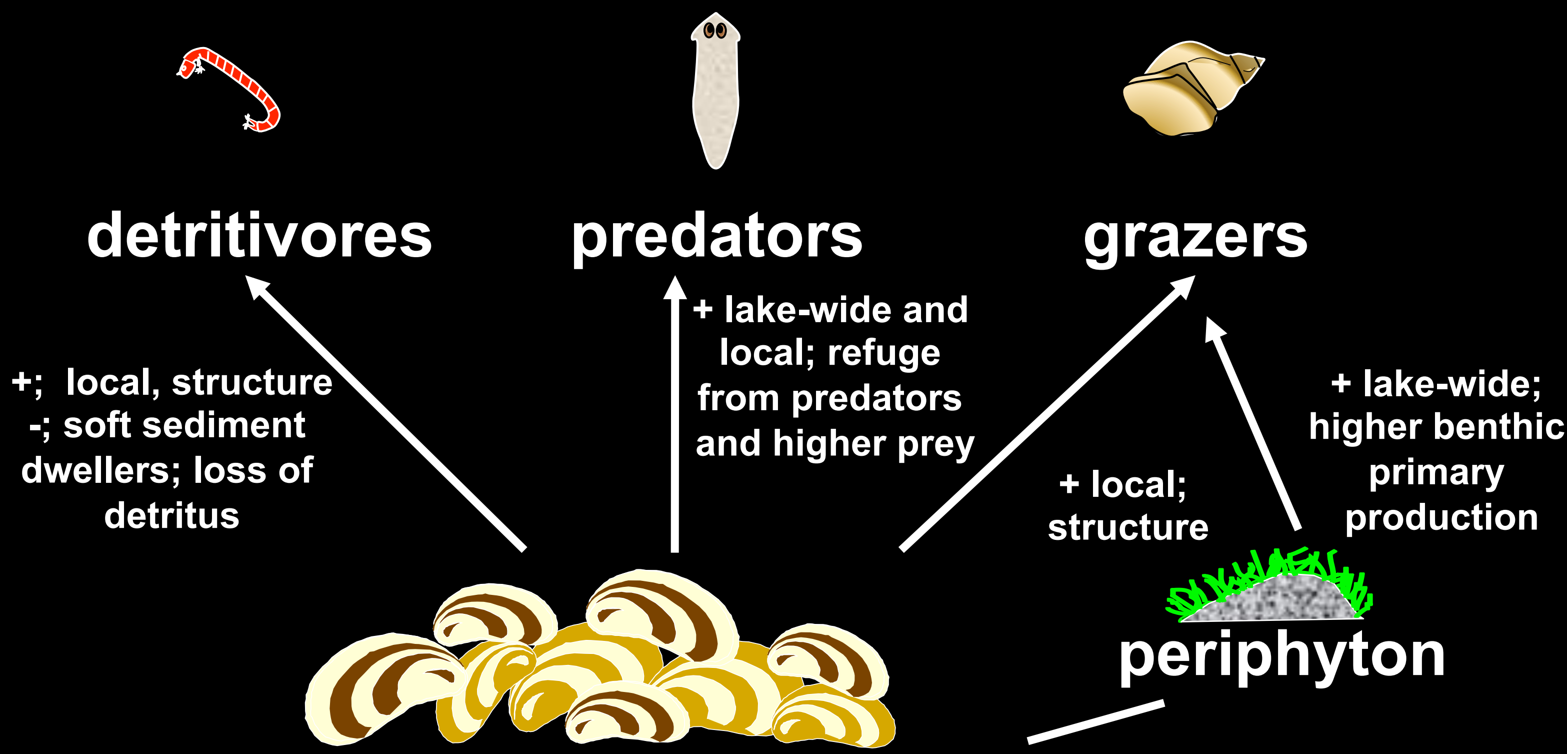
- ➔ Visual foragers: System-wide & Local

Dreissena attached to hard substrate increase invertebrate density, especially on soft background

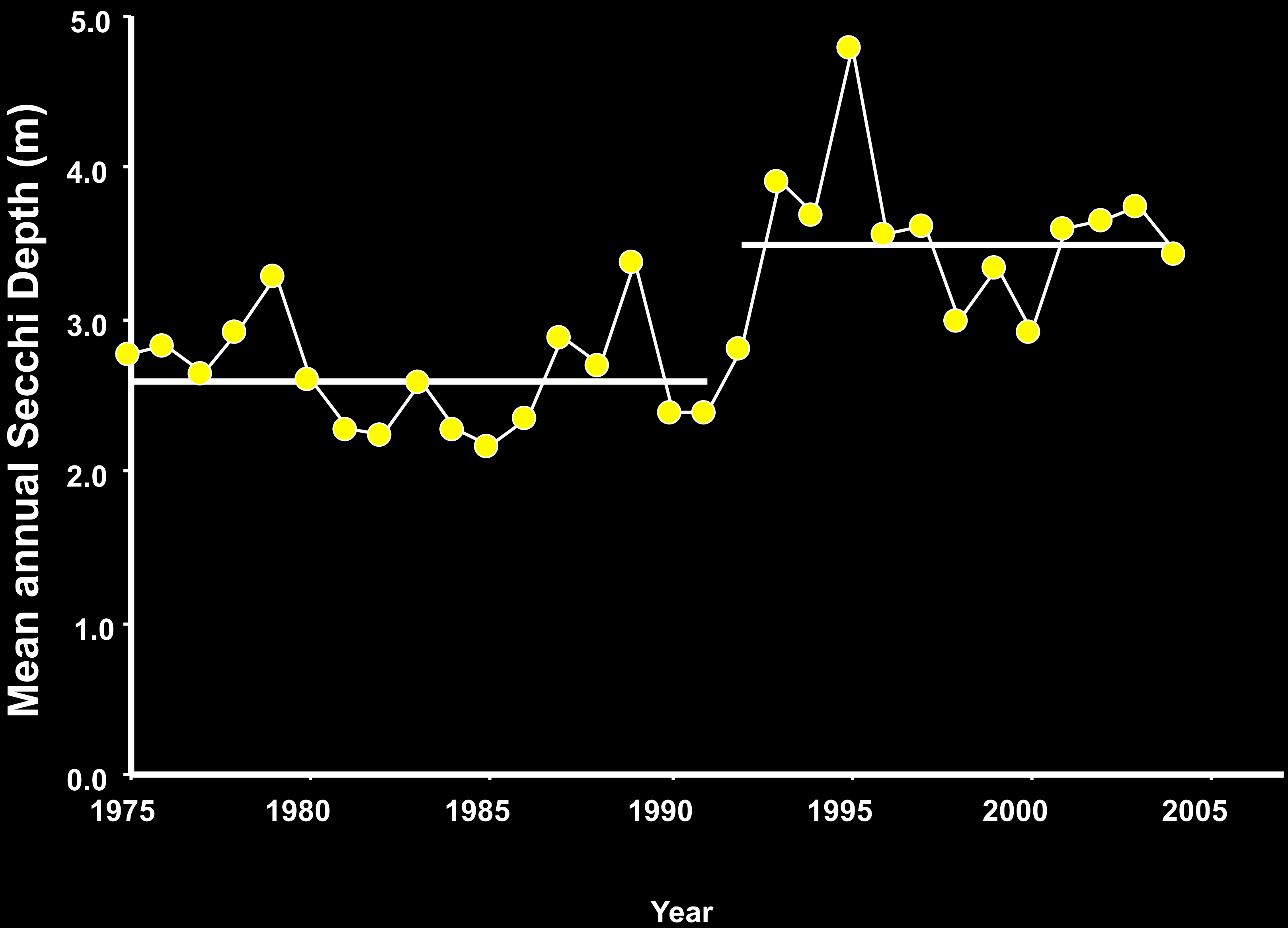


Mayer et al. 2002 JNABS

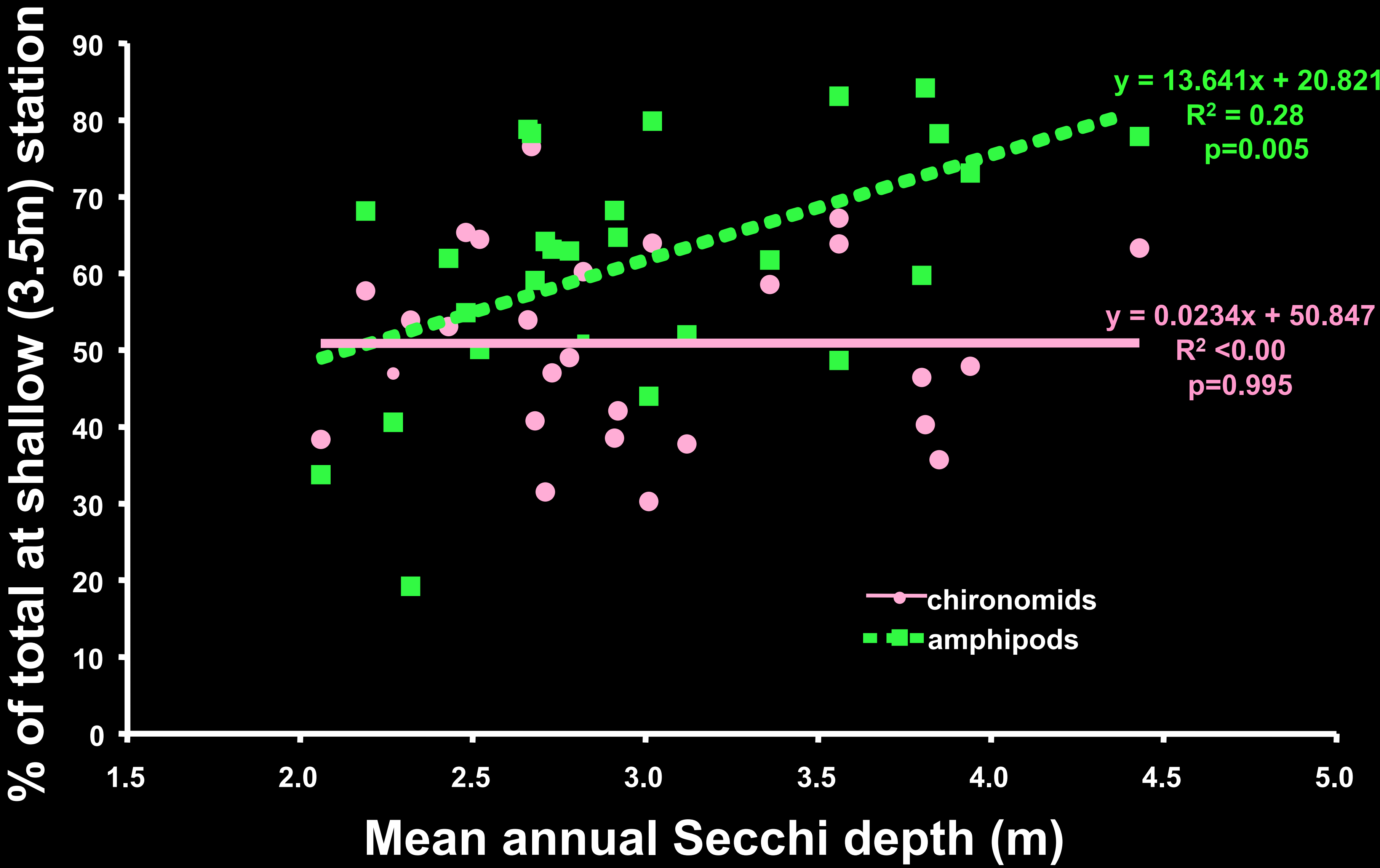
Combined lake-wide and local effects of *Dreissena* may favor grazers and predators



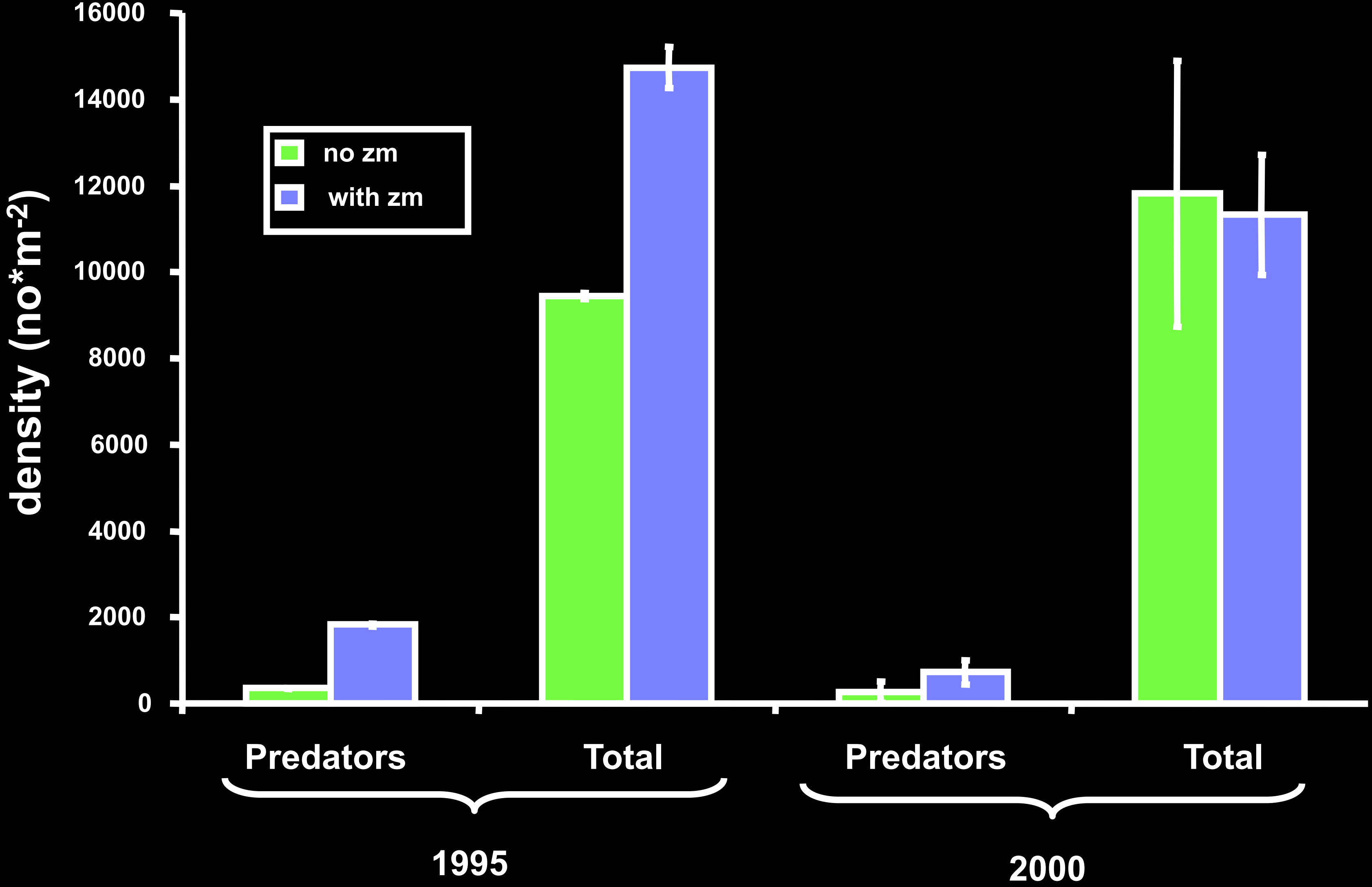
Water clarity and benthic GPP have increased in Oneida Lake



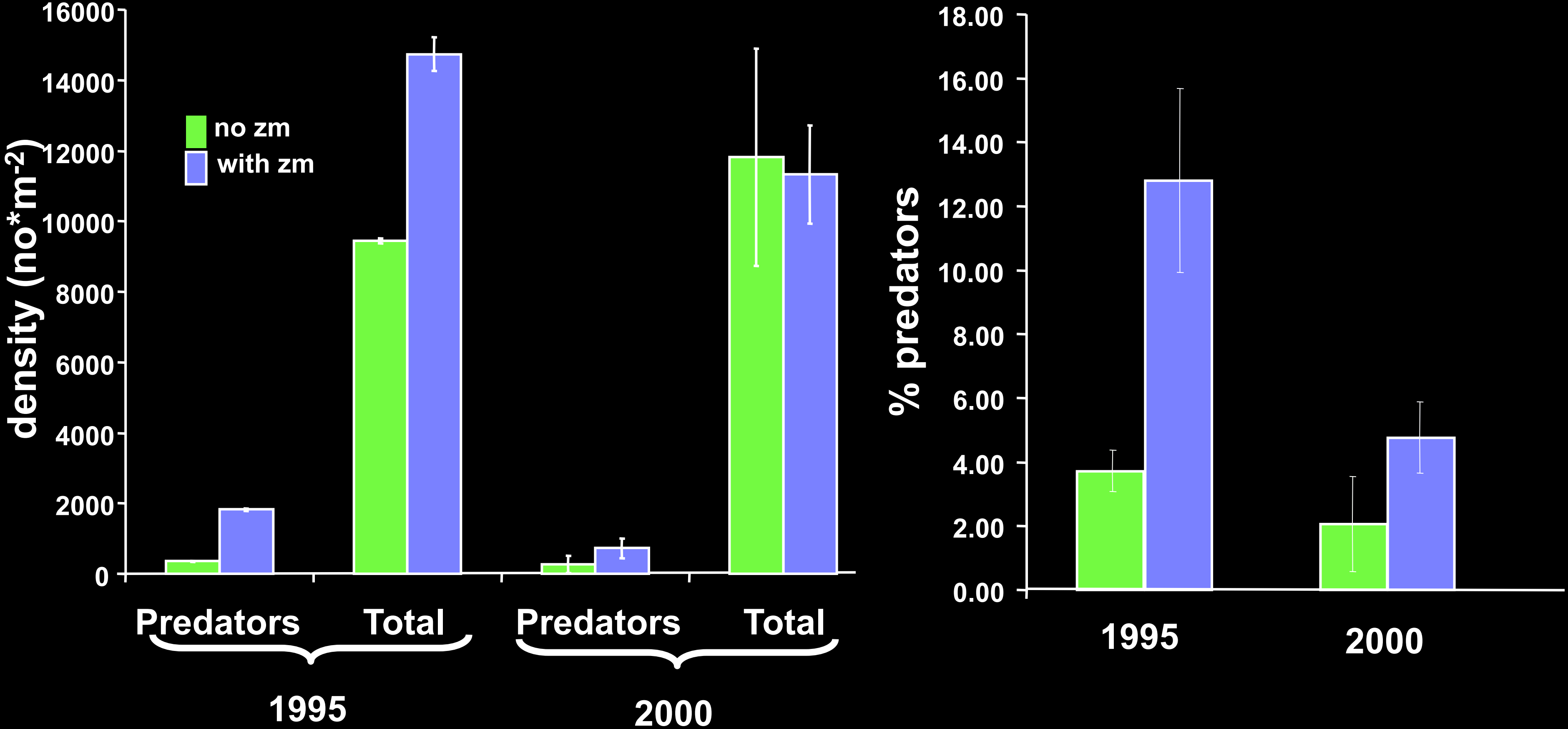
As water clears, relatively more amphipods, but not chironomids found at shallow station



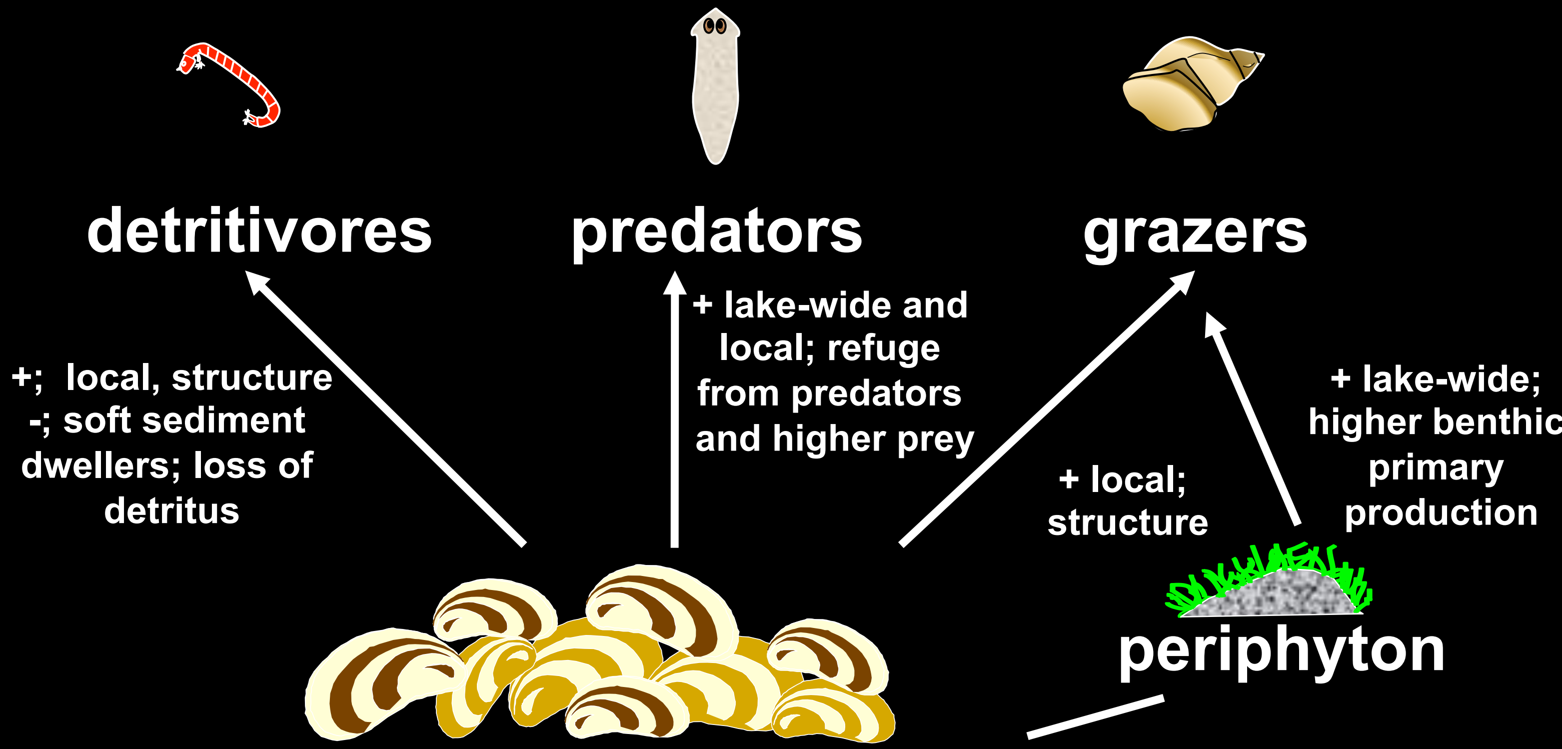
Periodic intensive survey of embayment shows predatory taxa higher in *Dreissena*-colonized habitats



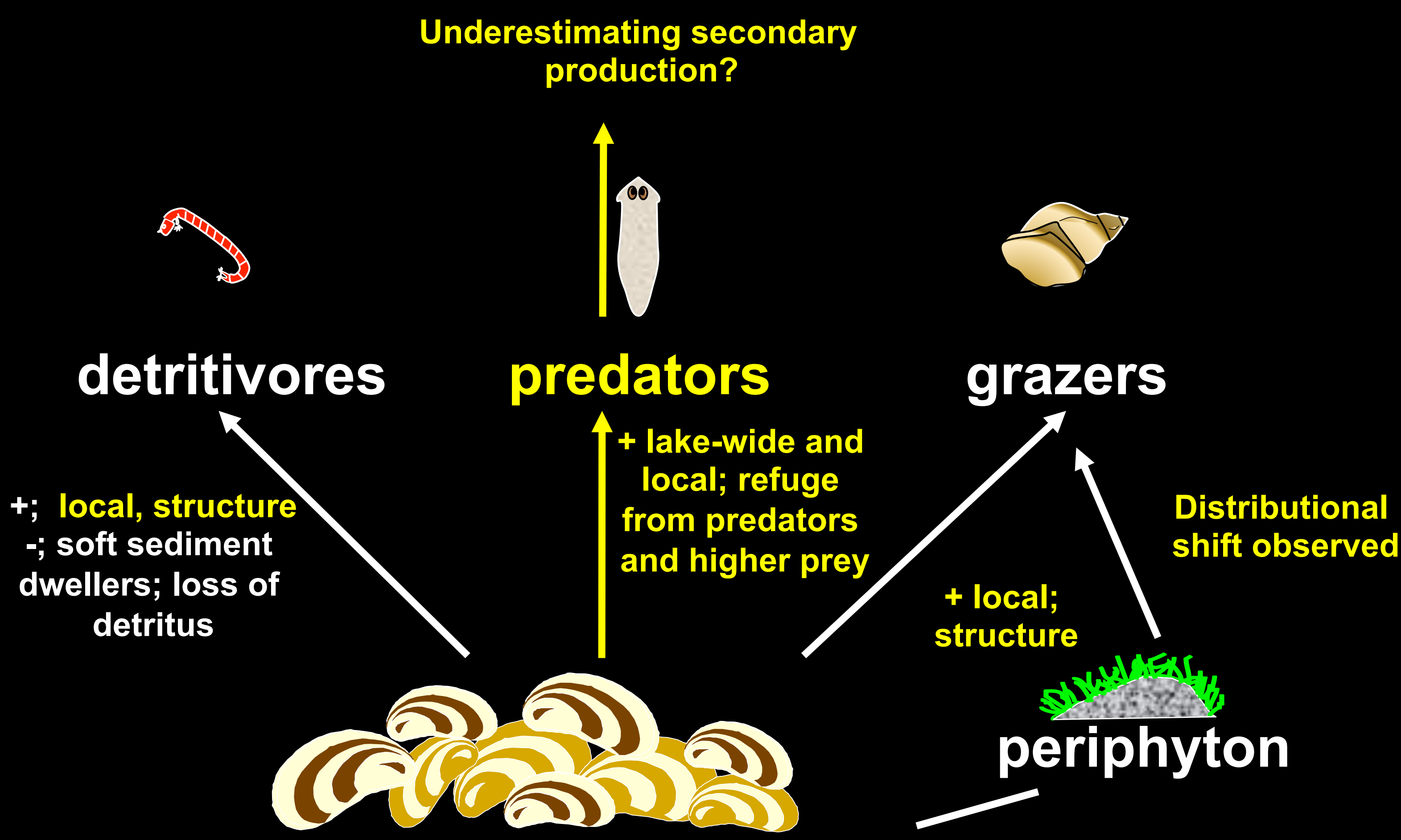
Percent predatory taxa consistently higher with *Dreissena*



Combined lake-wide and local effects of *Dreissena* may favor grazers and predators



Combined lake-wide and local effects of *Dreissena* may favor grazers and predators



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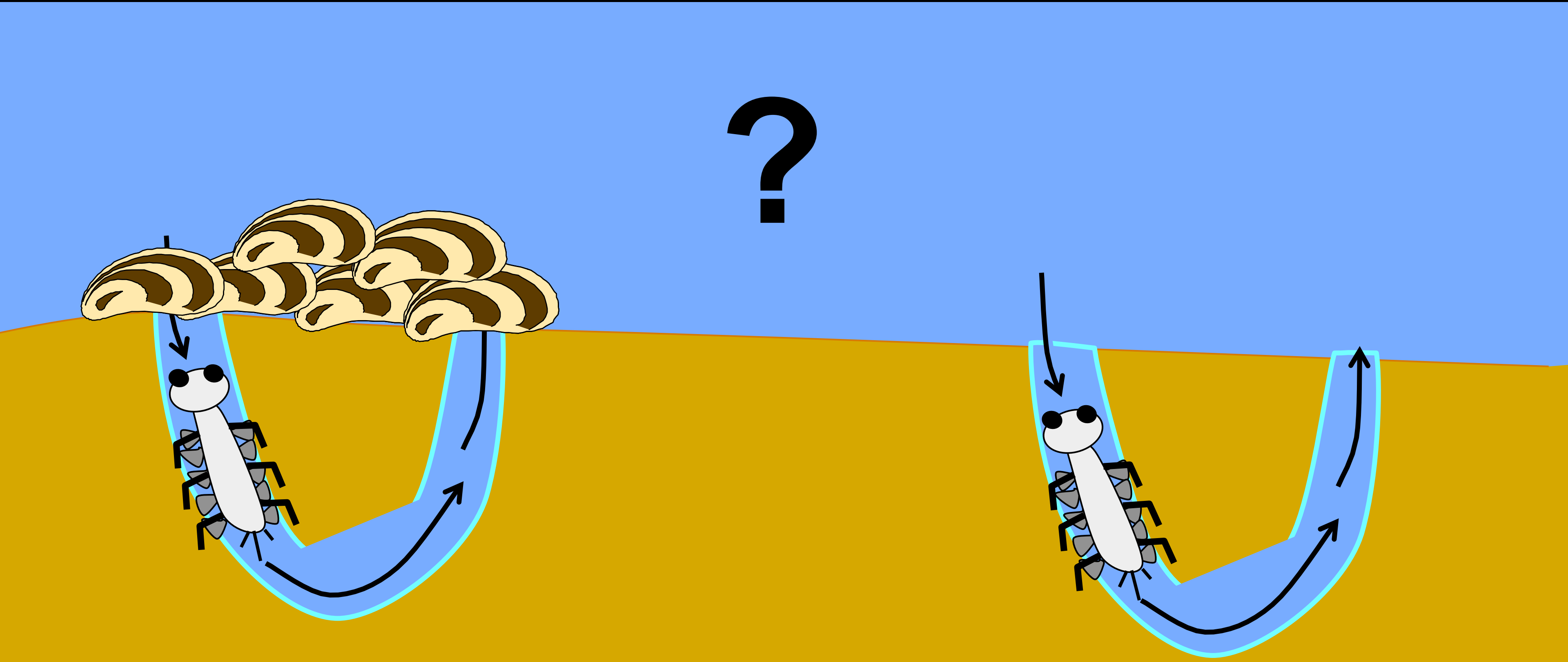
Kristen DeVanna; PhD student U. Toledo

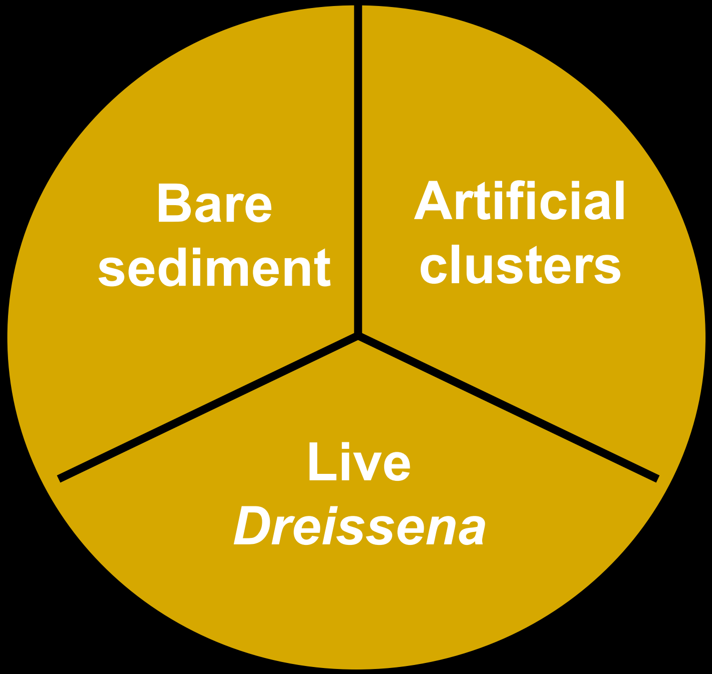
Dreissena clusters on hard substrate repeatedly shown to elevate localized invertebrate density

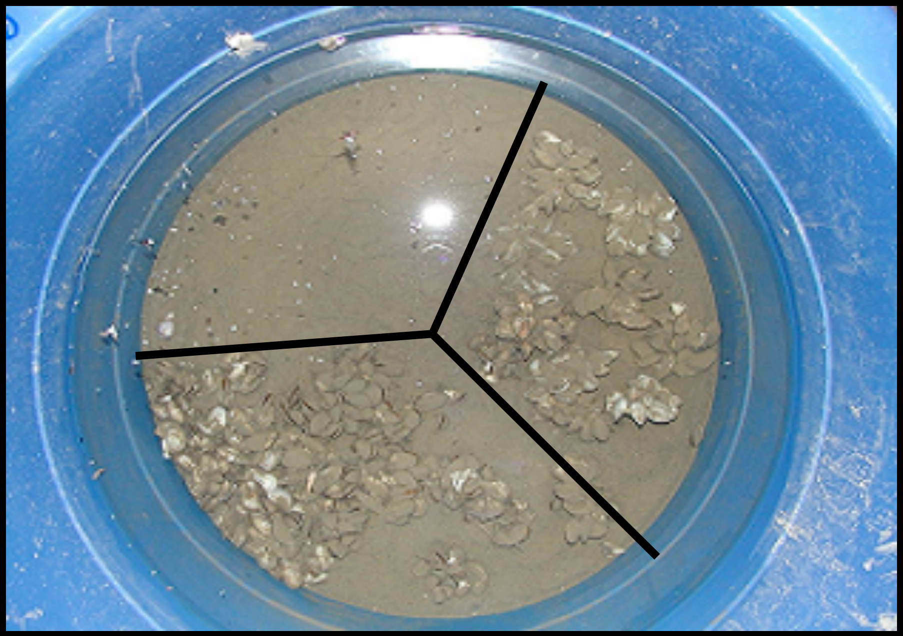
How do *Dreissena* affect soft sediment invertebrates such as *Hexagenia*?



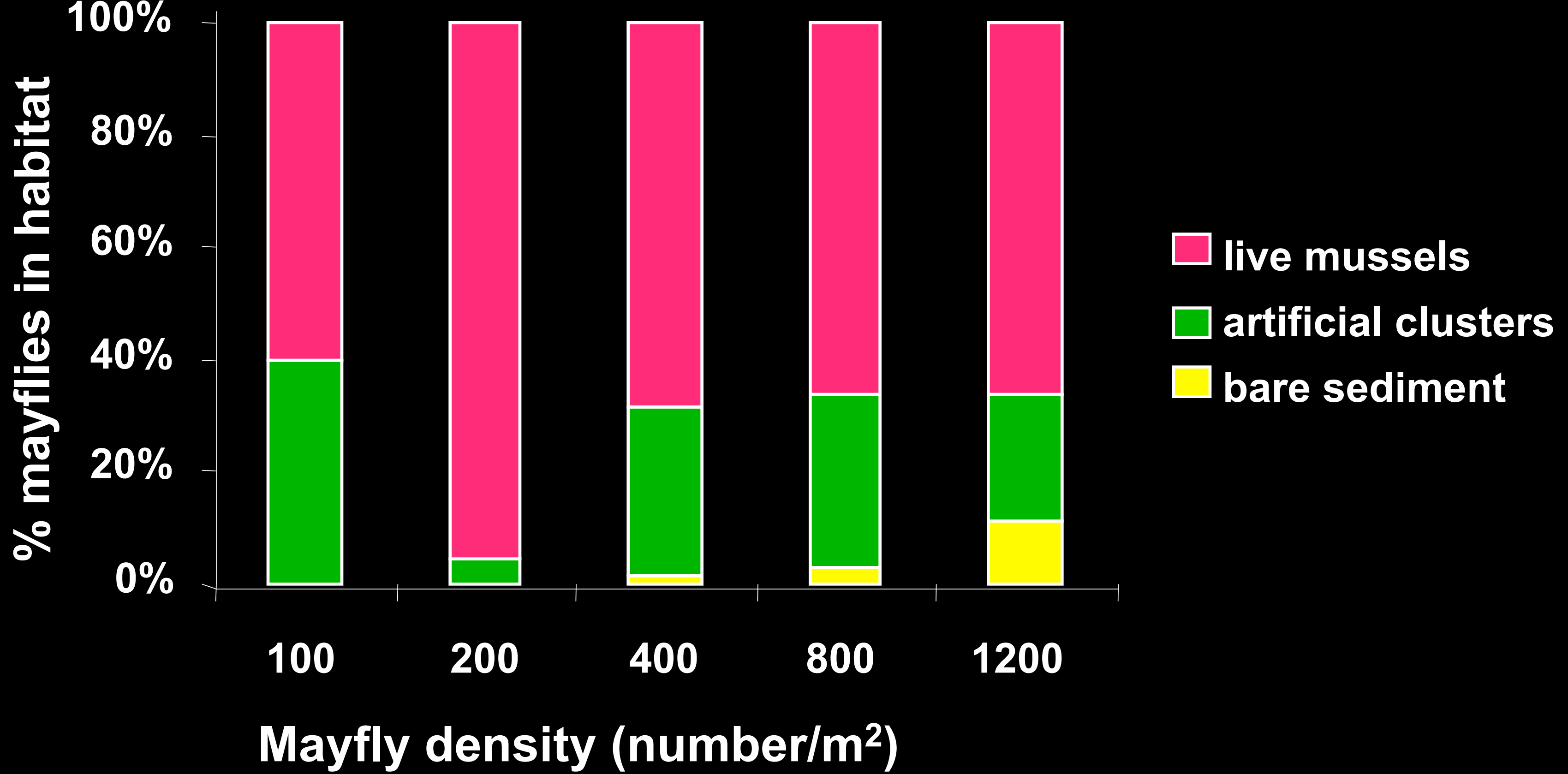
Hexagenia habitat selection experiments

5 mayfly densities; 100 -1200/m^2
Mayflies allowed to chose habitat
Removed after 48 hr



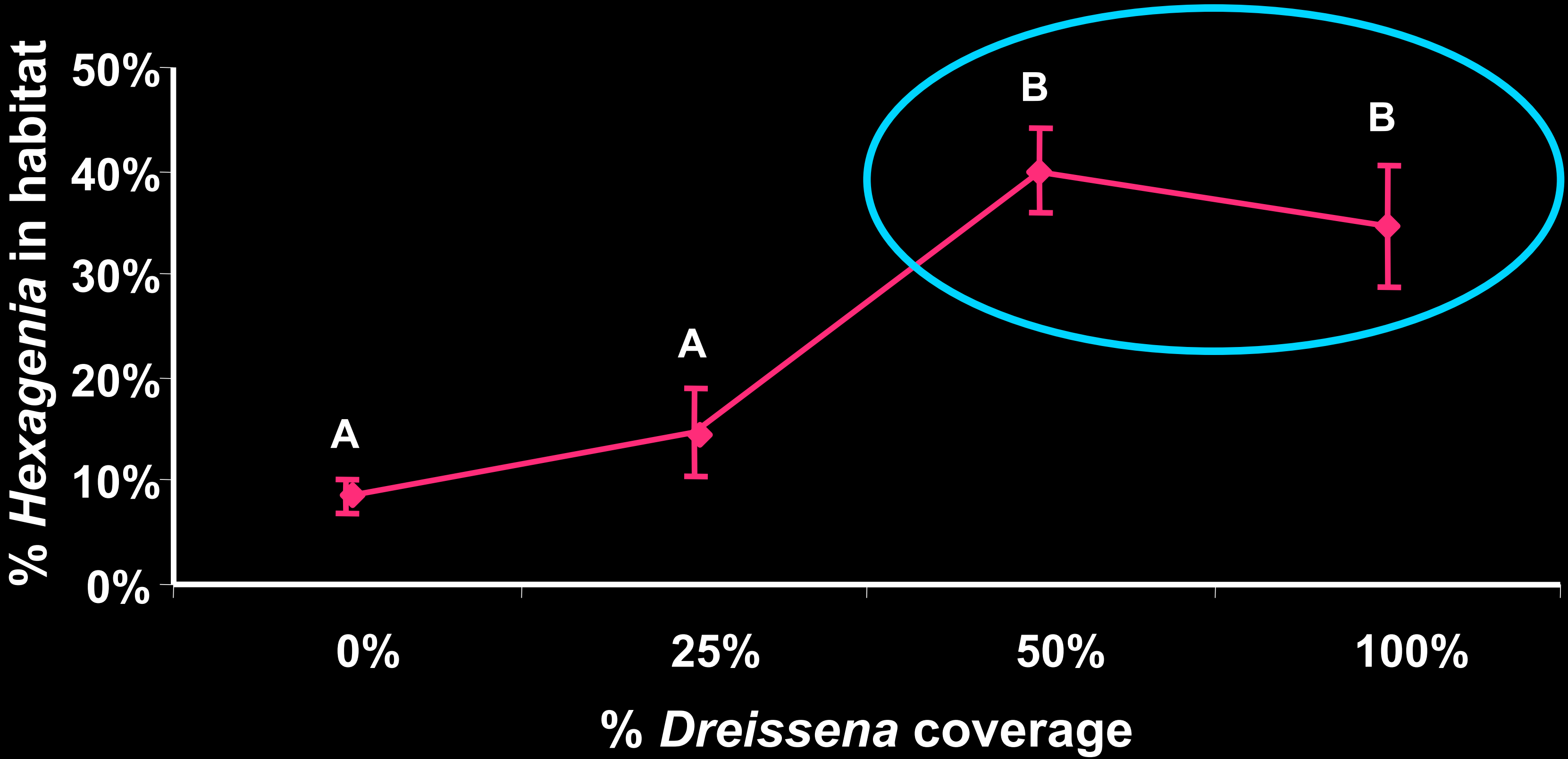


- *Hexagenia* prefer live *Dreissena* clusters
- Suggests resource importation
- Only go to bare sediment at high density



DeVanna et al. in review

75% of *Hexagenia* inhabited high-density *Dreissena* habitats

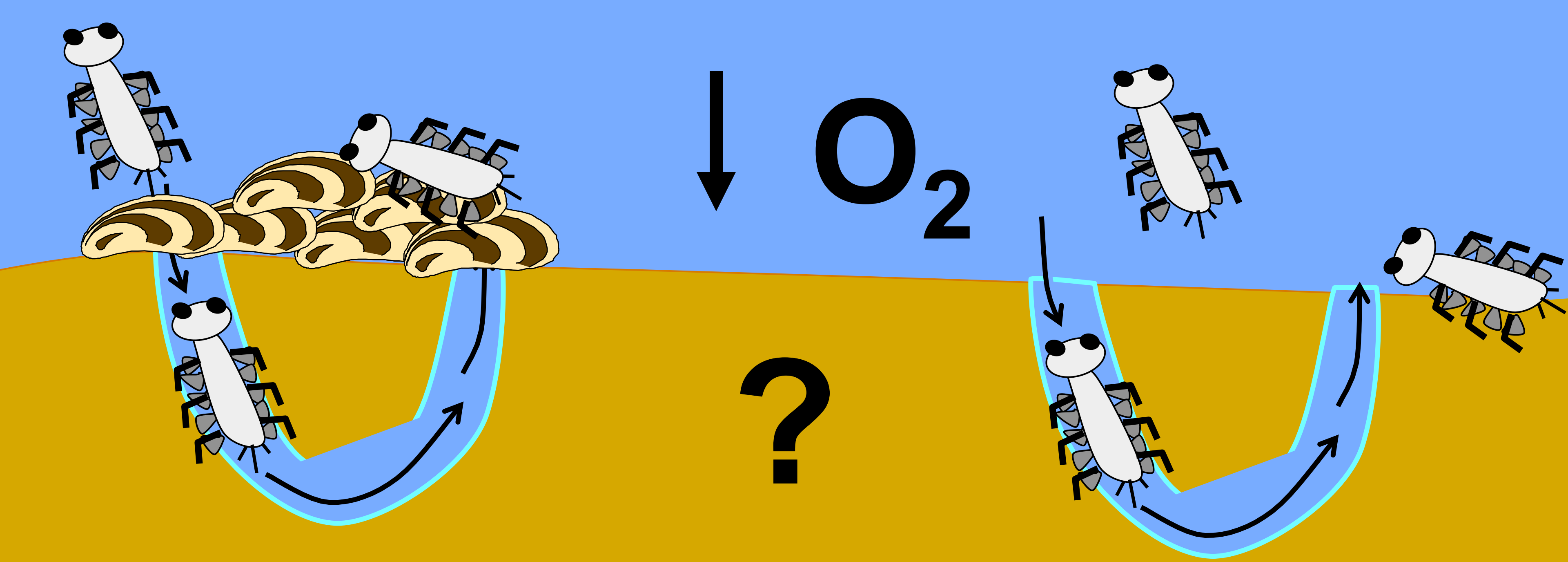


DeVanna et al. in review

Do Hexagenia always prefer Dreissena habitat: hypoxia ?

H_1 ⟶ *Hexagenia* avoid *Dreissena* clusters during hypoxic conditions

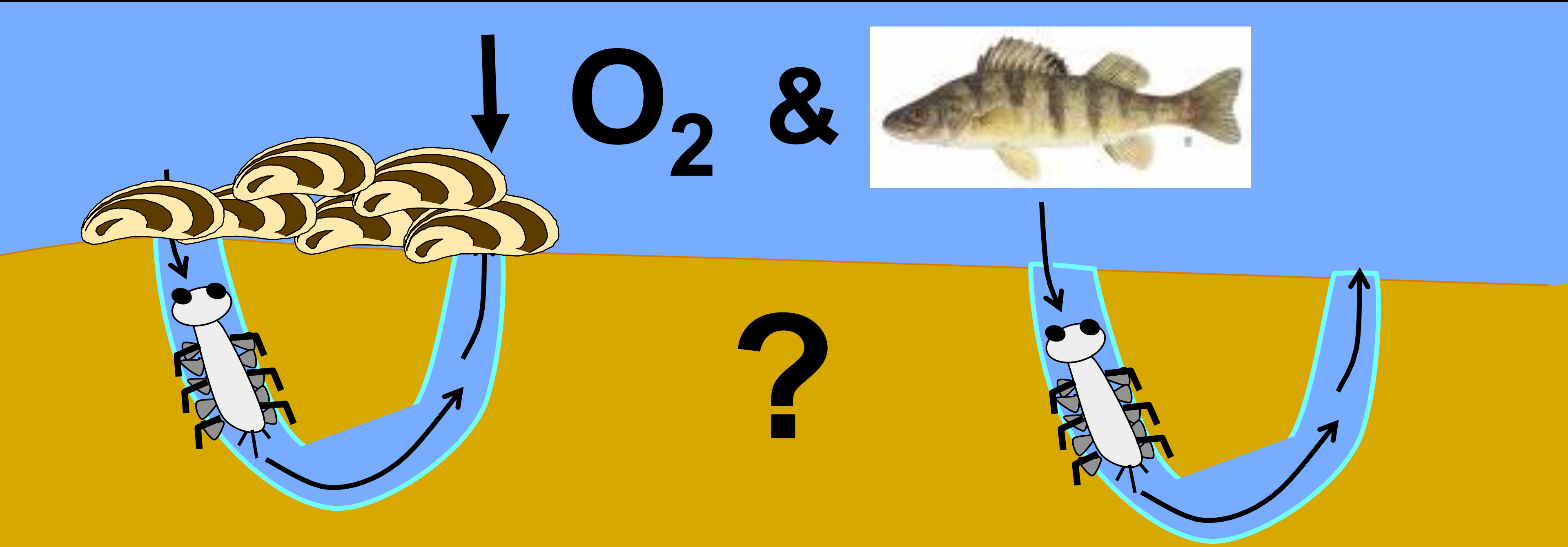
H_2 ⟶ *Hexagenia* leave burrows more often in hypoxic conditions compared to normoxic conditions



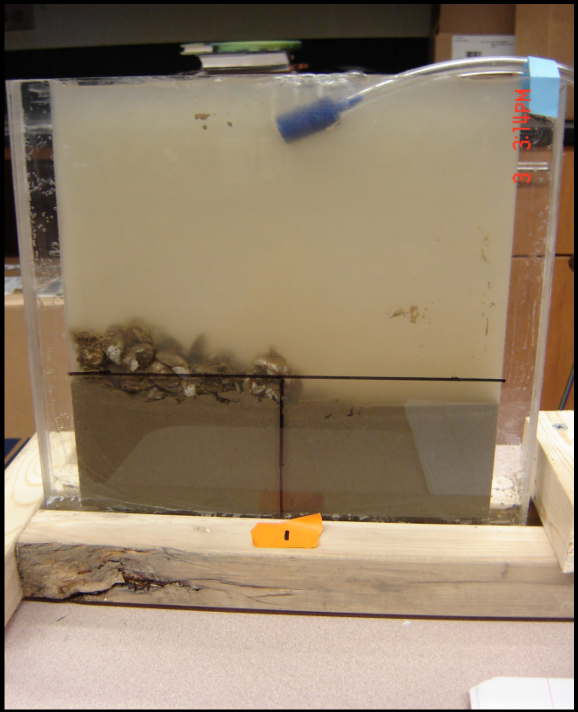
Does predation threat change *Hexagenia* behavior under different O_2 conditions?

H_1 *Hexagenia* select for *Dreissena* clusters and leave burrows less when fish predation threat is present

H_2 *Hexagenia* leave burrows under low O_2 even when predation threat is present



Methods

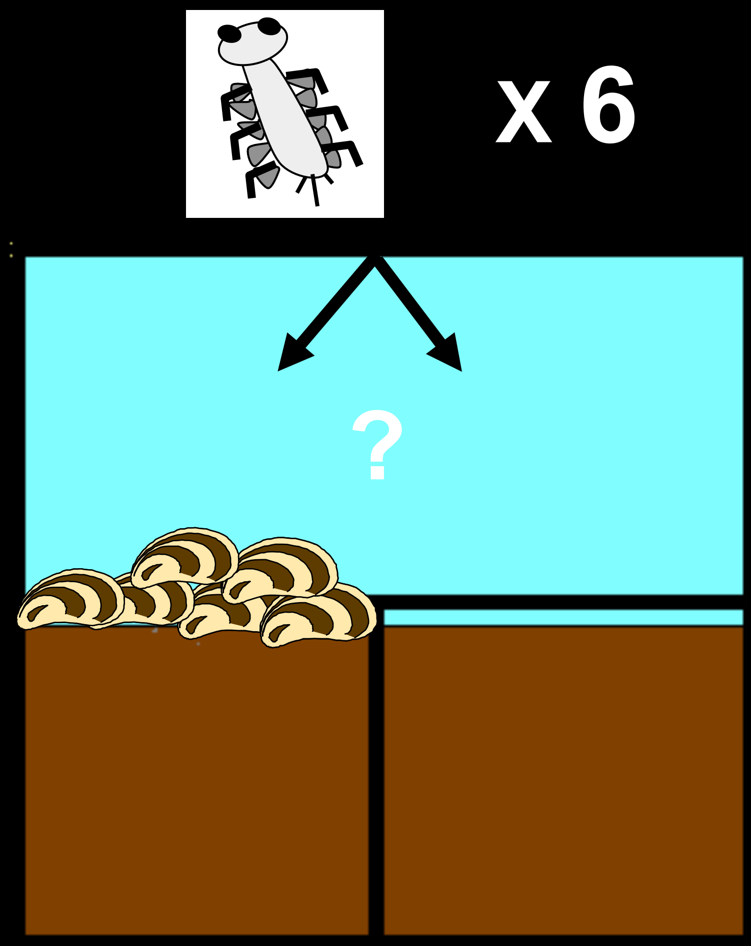


- *Hexagenia* Behavioral Arenas
  - 2 habitat types: *Dreissena* and sediment

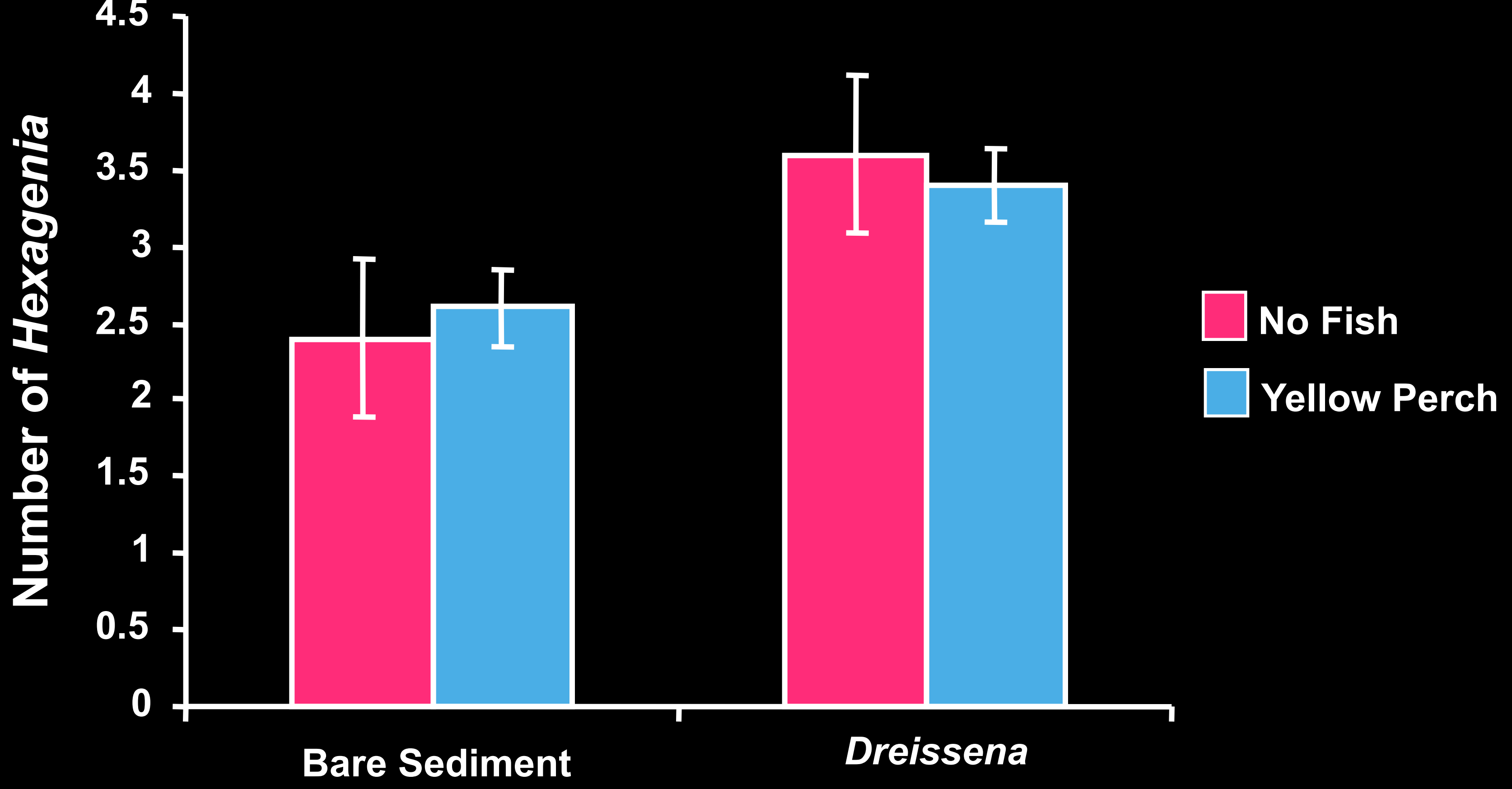
- **Treatments**
  - **Fish presence (N=5) vs. no fish (N=5)**
  - **High oxygen vs. hypoxia (imposed at 24 hr to both treatments)**

Methods

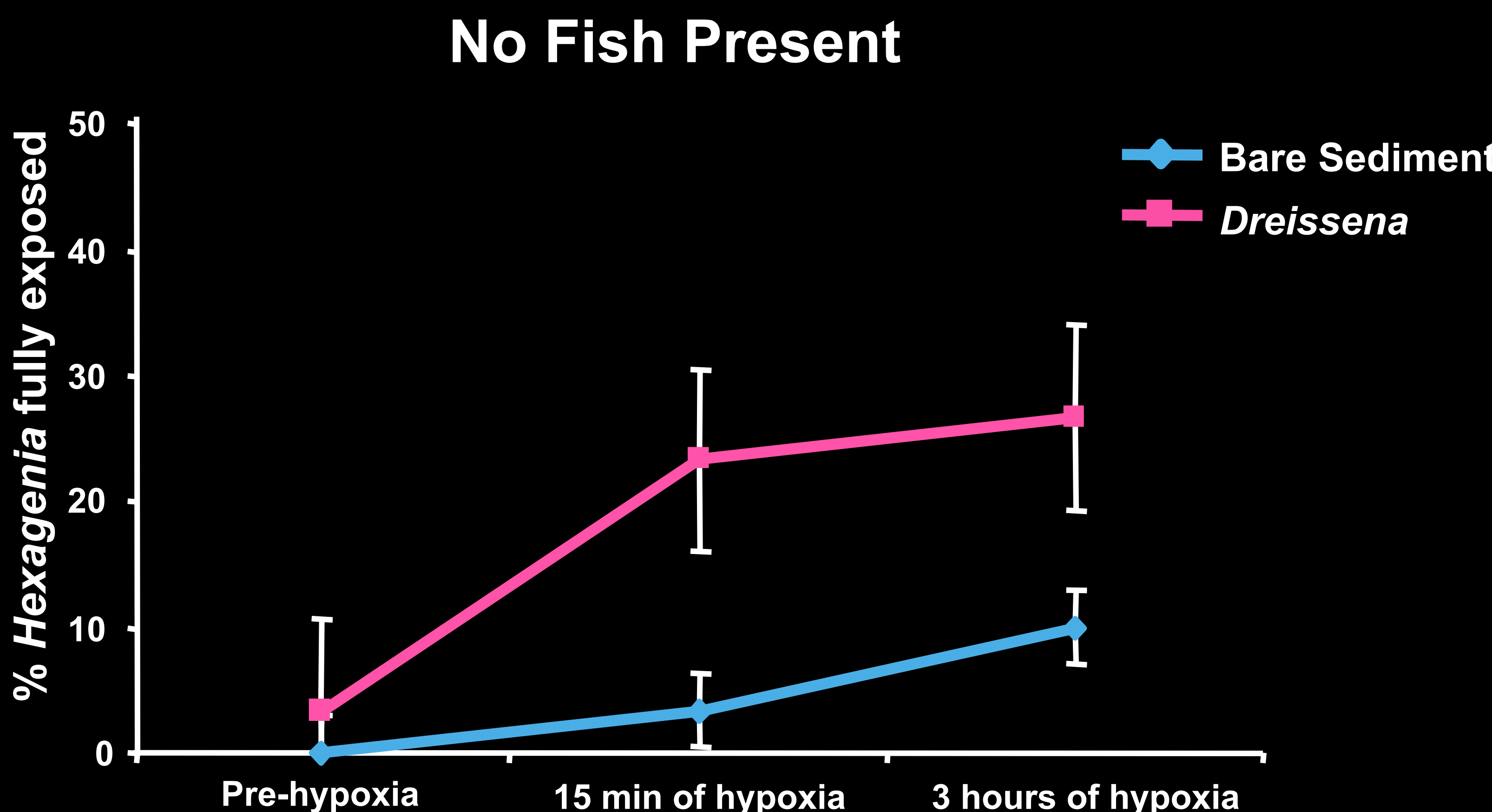
- Day 1
  - Introduced 6 mayflies
  - Observed for 15 minutes (Initial)
- Day 2
  - Initial Observations (Pre-hypoxia)
  - Lowered oxygen (<30% saturation)
  - Observed for 15 minutes (post-hypoxia)
  - Observed after 3 hours of hypoxia



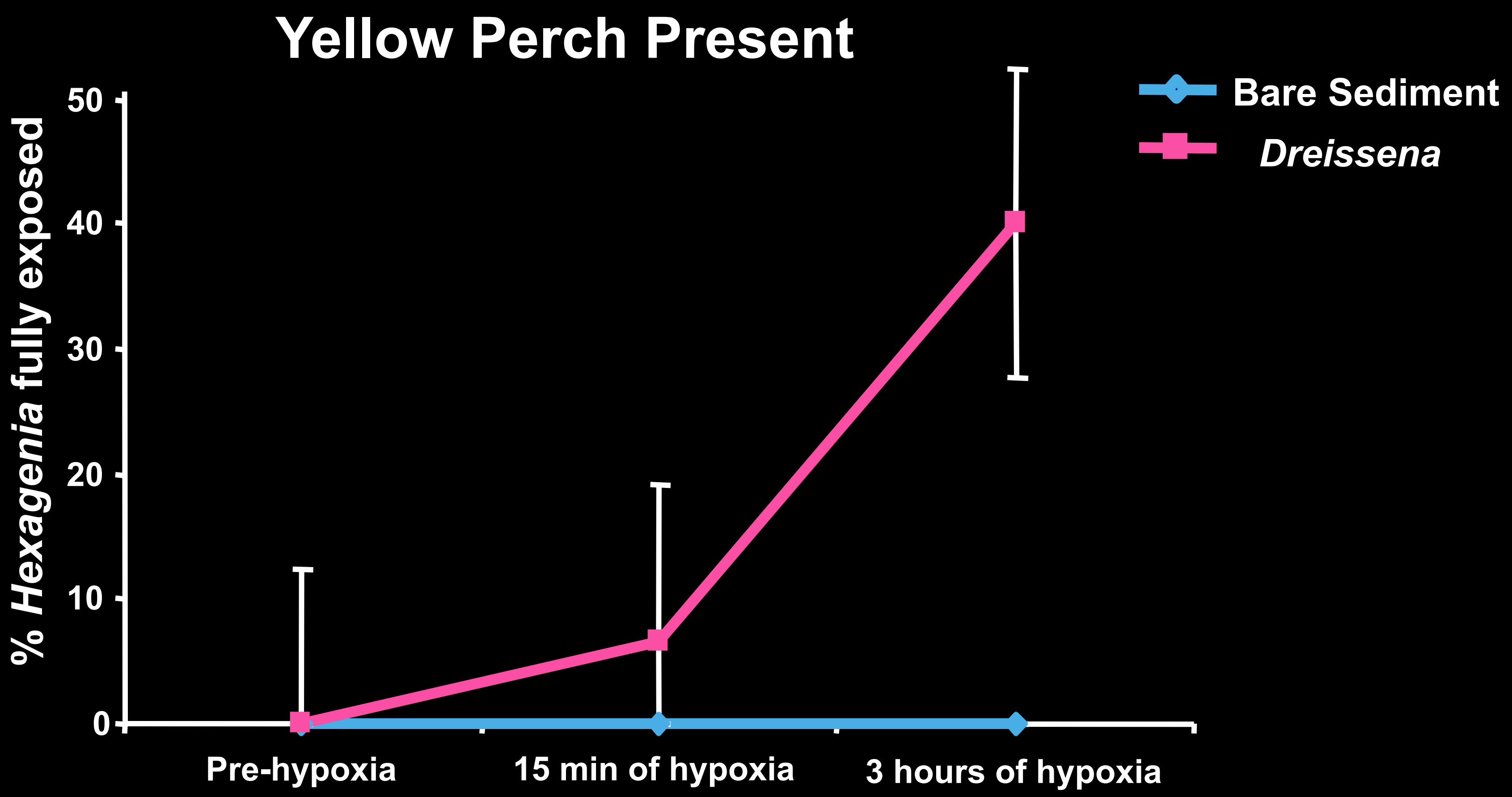
Initial Selection for *Dreissena*-covered sediment



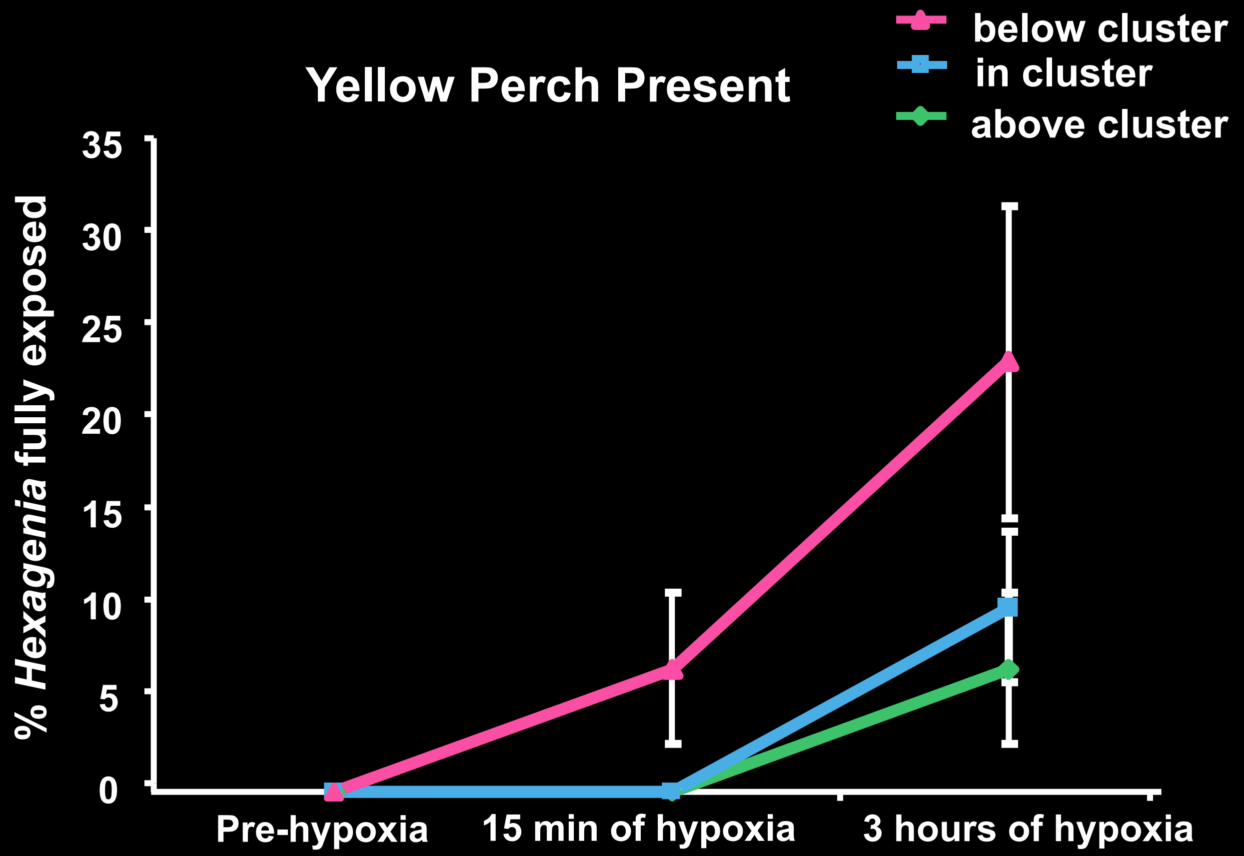
More *Hexagenia* were exposed in the structured habitat during hypoxia



Hexagenia waited longer to expose themselves when fish were present



Hexagenia left their burrows during hypoxia, but many were still sheltered beneath cluster



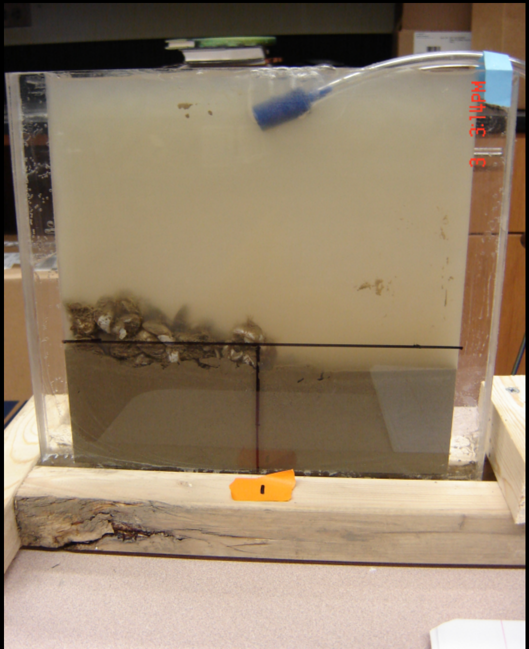
Conclusions:

➔ *Hexagenia* select for habitat with *Dreissena*

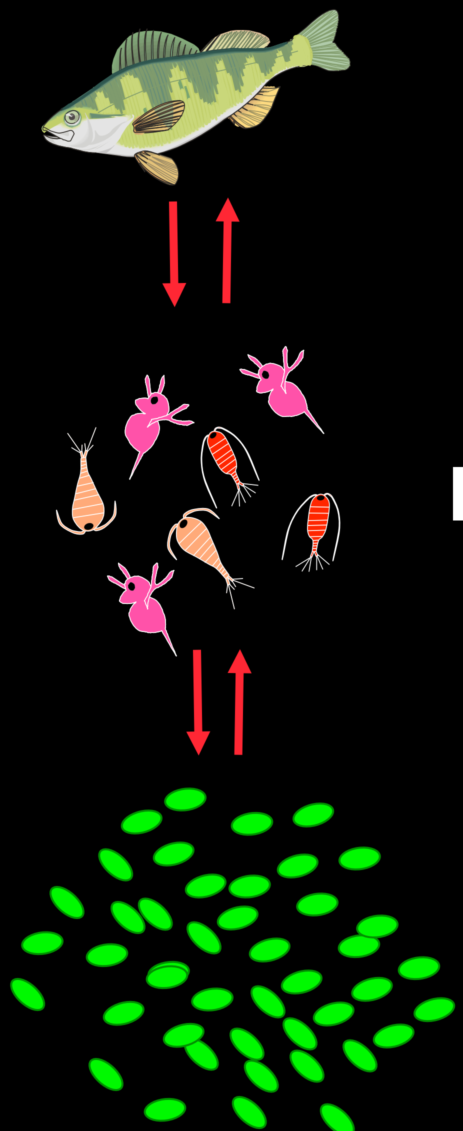
➔ May be exploiting microbial, algal or other resources in clusters

➔ Ongoing experiments to determine factors controlling habitat choice, *e.g.* fish predation, hypoxia

Preliminary results show that hypoxia results in neutral habitat selection and *Hexagenia* exit burrows and expose heads and bodies

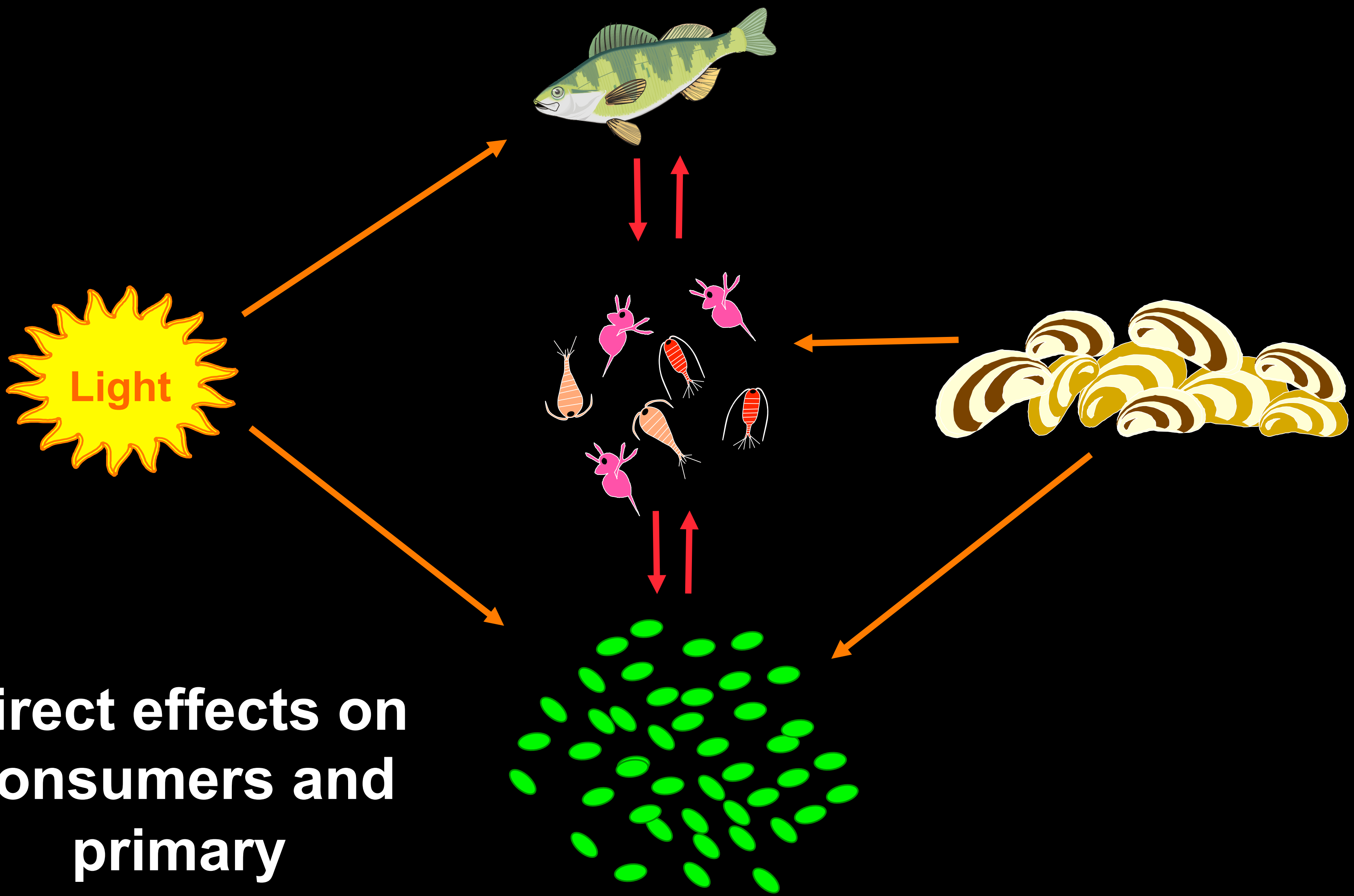


Trophic Cascade



Effects transmitted among trophic levels; up, down, or middle out

Ecosystem Engineering Cascade



Direct effects on consumers and primary producers