

# ZEBRA MUSSEL-MICROCYSTIS INTERACTIONS

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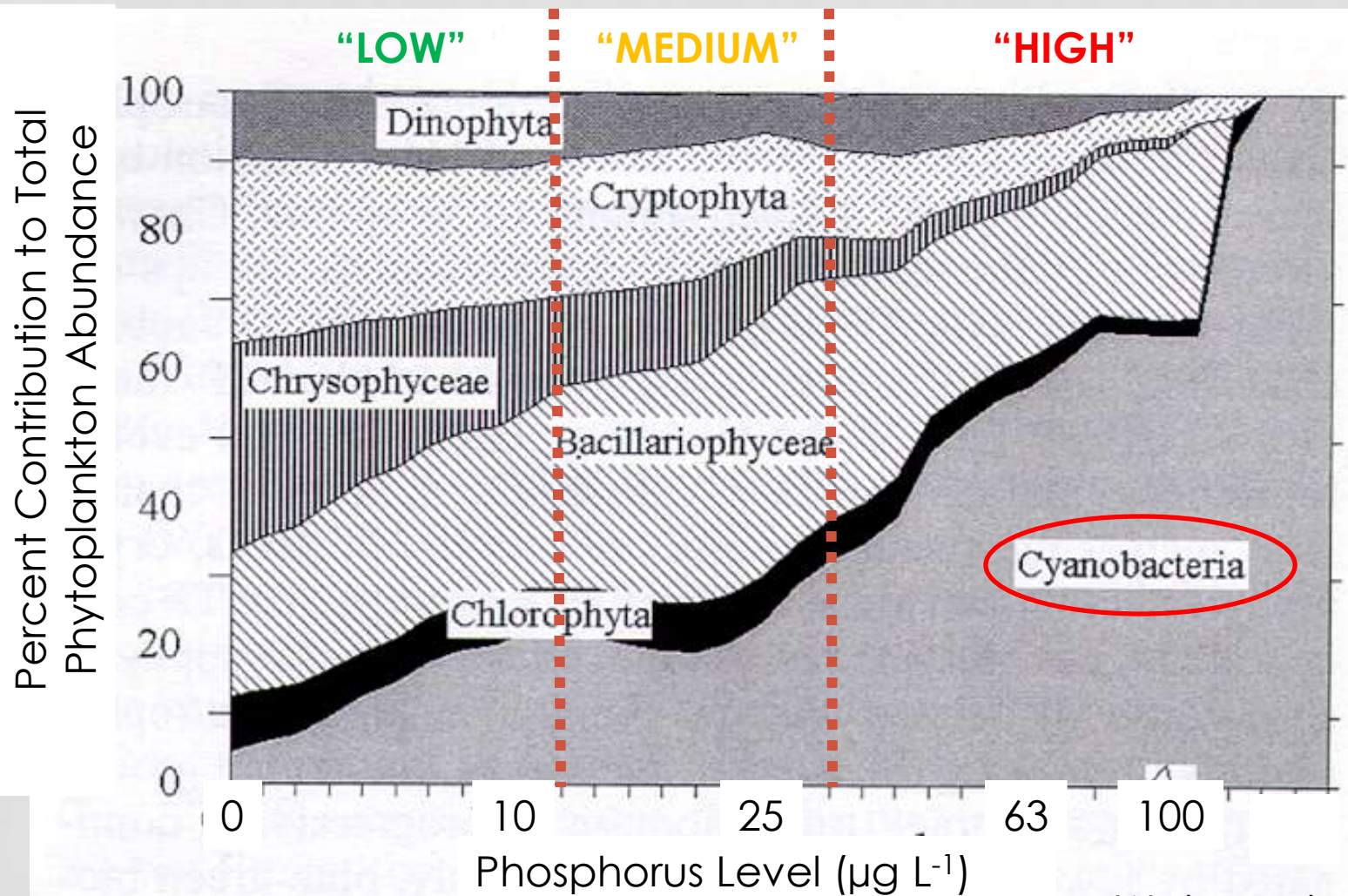
# ZEBRA MUSSEL-MICROCYSTIS INTERACTIONS

- Background
- Data
  - Lake Surveys: role of nutrients
  - Field Experiments: role of nutrients
  - Laboratory Experiments: role of biological variation in and among populations
- Summary
- Questions

# CYANOBACTERIA ("BLUE-GREEN ALGAE")



# CYANOBACTERIA AND LAKE NUTRIENT (PHOSPHORUS) LEVEL





# MICROCYSTIS AERUGINOSA

*Microcystis aeruginosa*

Colony-forming cyanobacterium

Floats: forms surface scums

Toxins (microcystin)

Harmful algal blooms (HABs)



Photo: Kerstin Bohm



# ZEBRA MUSSELS (*DREISSENA POLYMORPHA*)





# ZEBRA MUSSELS (*DRIESSENA POLYMORPHA*)



*Driessena polymorpha*

Prolific invader in N. America  
Bottom-dwelling filter feeder  
Capable of selective feeding



# ANECDOTAL OBSERVATION

## Michigan Inland Lakes, Mid 1990's

- *Microcystis* seemed to increase in abundance within 1-2 years of mussel establishment in some low-nutrient lakes

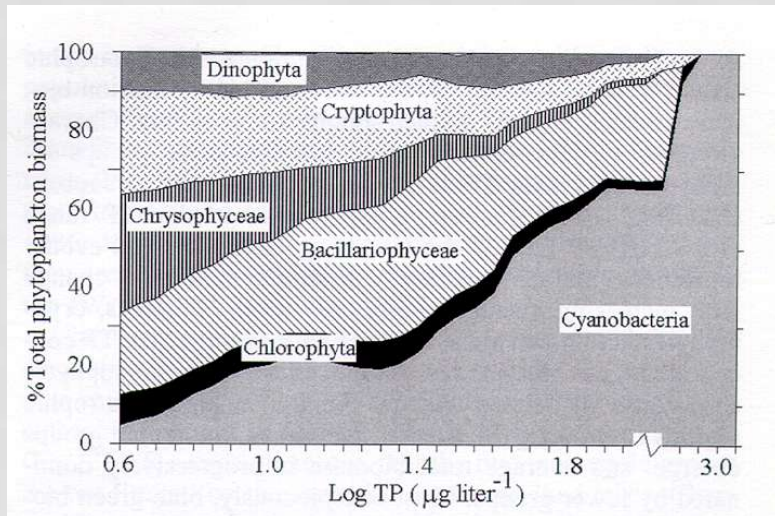
# LAKE SURVEYS

## Michigan Inland Lakes

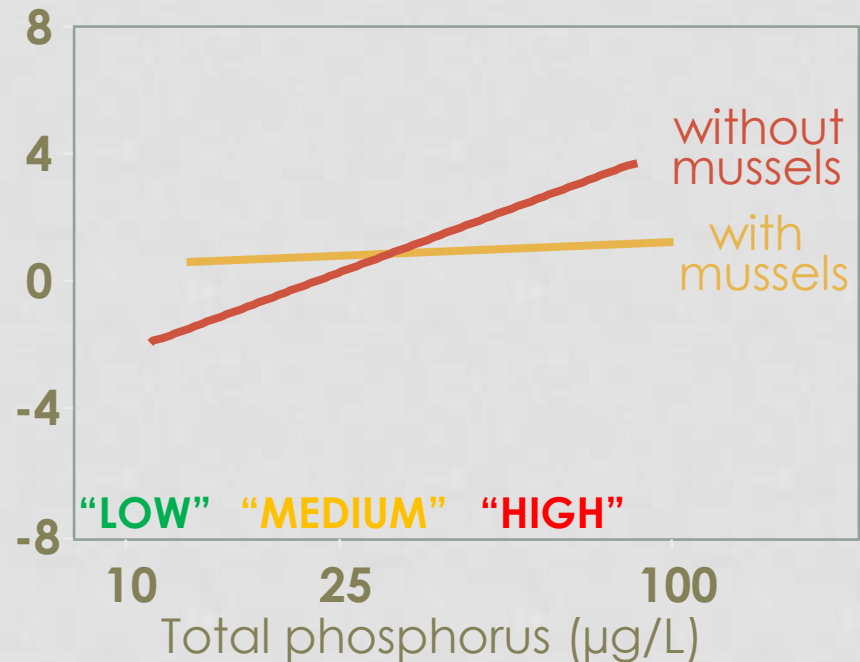
- 3 surveys from 1998-2006
- 39-75 lakes sampled each time
- Invaded and non-invaded lakes
- TP range: 1 - 117  $\mu\text{g L}^{-1}$
- Single-visit sampling (late summer)
- Phytoplankton species composition, microcystin toxin

# LAKE SURVEYS

## Michigan Inland Lakes (1998-1999)



Cyanobacterial abundance



Cyanobacteria increase with phosphorus in non-invaded lakes, but not in lakes invaded by zebra mussels



# LAKE SURVEYS

## Michigan Inland Lakes (1998-1999)

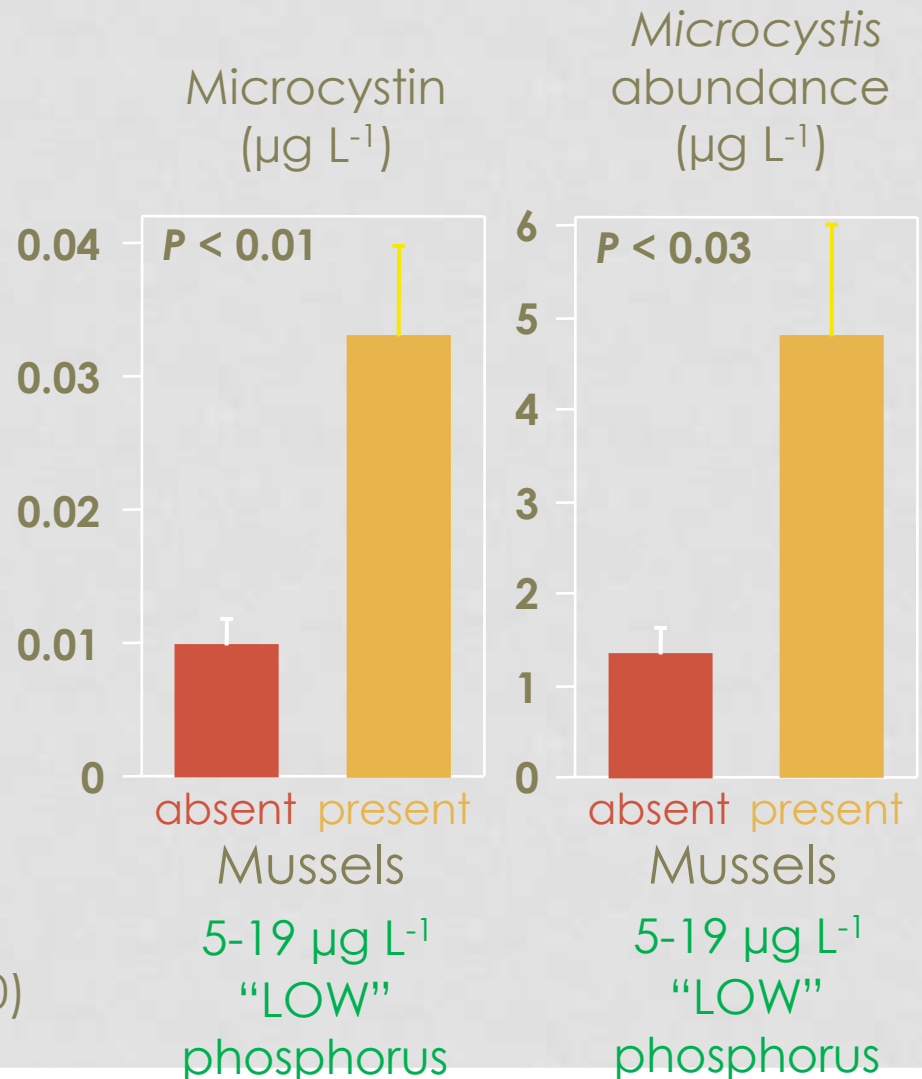
*Microcystis* comprises a greater proportion of the phytoplankton in low-nutrient inland lakes invaded by zebra mussels



# LAKE SURVEYS

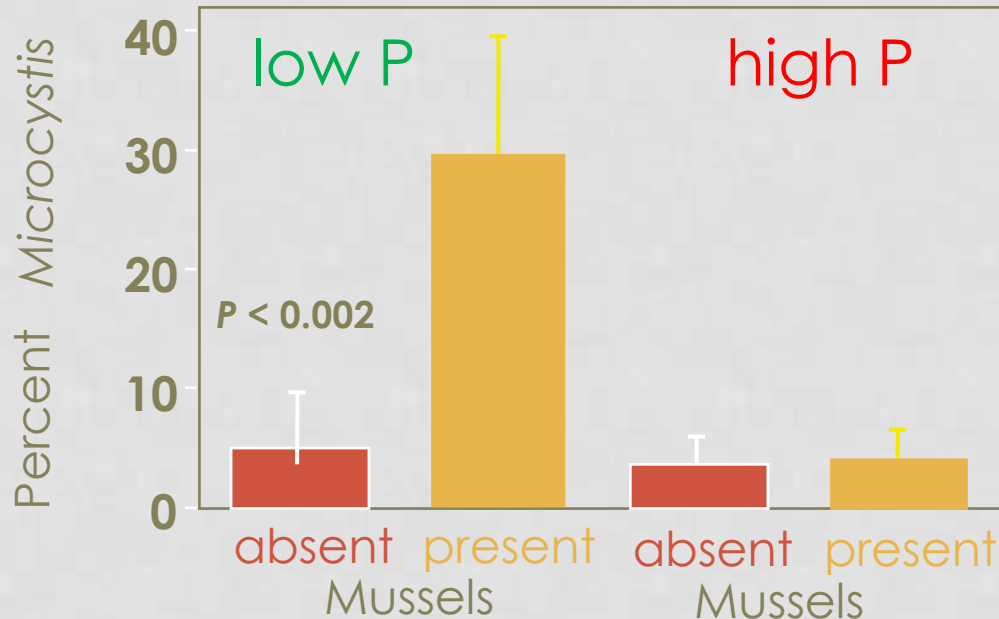
Michigan Inland Lakes (2002-2003, 2006)

Microcystin toxin is 3.3-8x higher and *Microcystis* is 3.6x more abundant in low-nutrient inland lakes invaded by zebra mussels



Knoll et al. (2008); Sarnelle et al. (2010)

# FIELD EXPERIMENT



**Hypothesis:** Zebra mussel effects on *Microcystis* are dependent upon nutrient level

**Hypothesis:** The positive effect of zebra mussels on *Microcystis* weakens with increasing nutrients



Gull Lake, MI  
Barry & Kalamazoo Co.

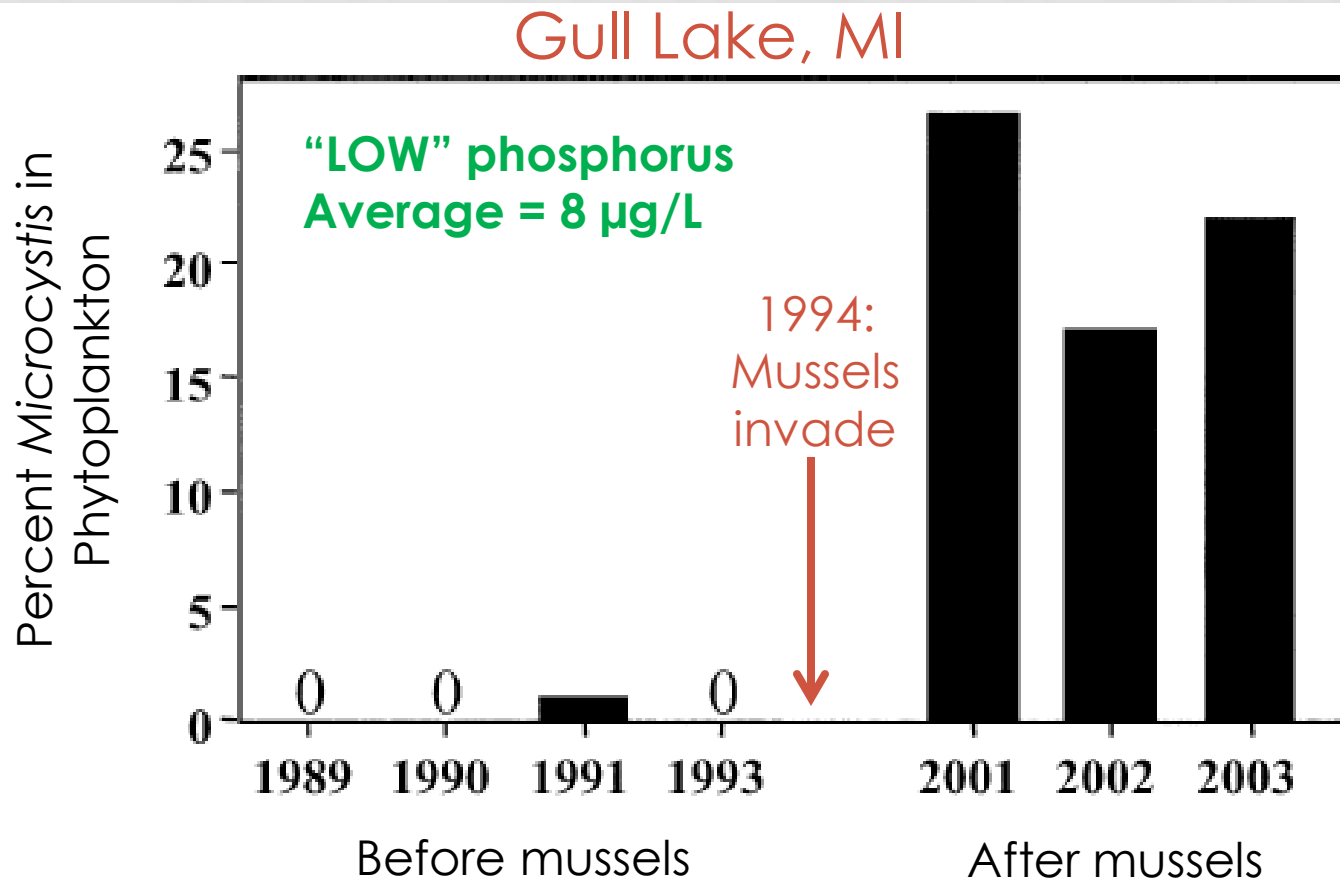


Gull Lake, MI  
Barry & Kalamazoo Co.

**W. K. Kellogg Biological Station (MSU)**



# FIELD EXPERIMENT





# FIELD EXPERIMENT

Zebra Mussel Experiment "ZMEX" 2008



# FIELD EXPERIMENT

Zebra Mussel Experiment “ZMEX” 2008

Experimental design

nutrients

low

medium

high

mussels

absent

N = 5

N = 5

N = 5

present  
(4 g/m<sup>2</sup>)

N = 5

N = 5

N = 4

# FIELD EXPERIMENT

Zebra Mussel Experiment "ZMEX" 2008



**Phosphorus**



**Mussels**

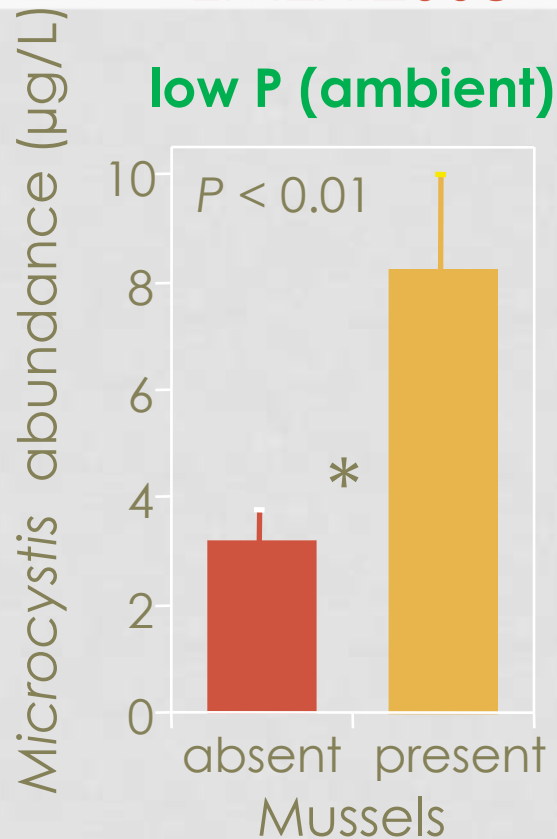


# FIELD EXPERIMENT

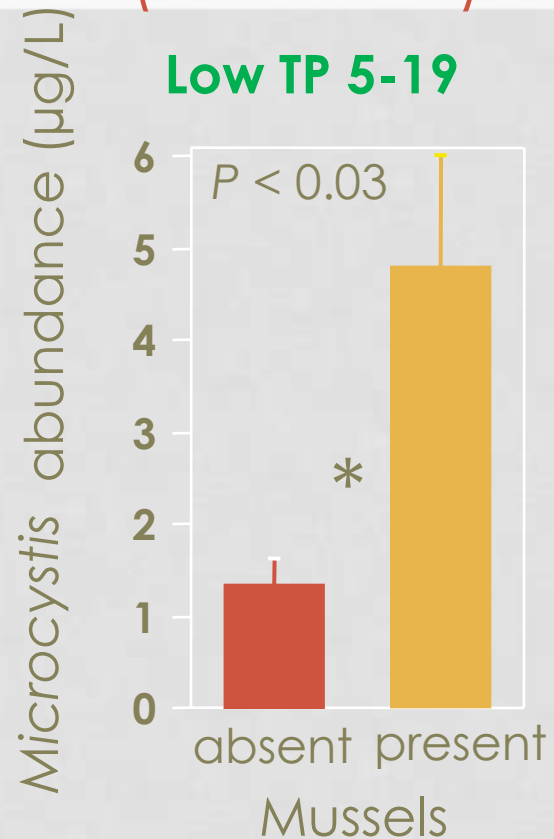


# FIELD EXPERIMENT

ZMEX 2008



Michigan lakes  
(2002-2003)

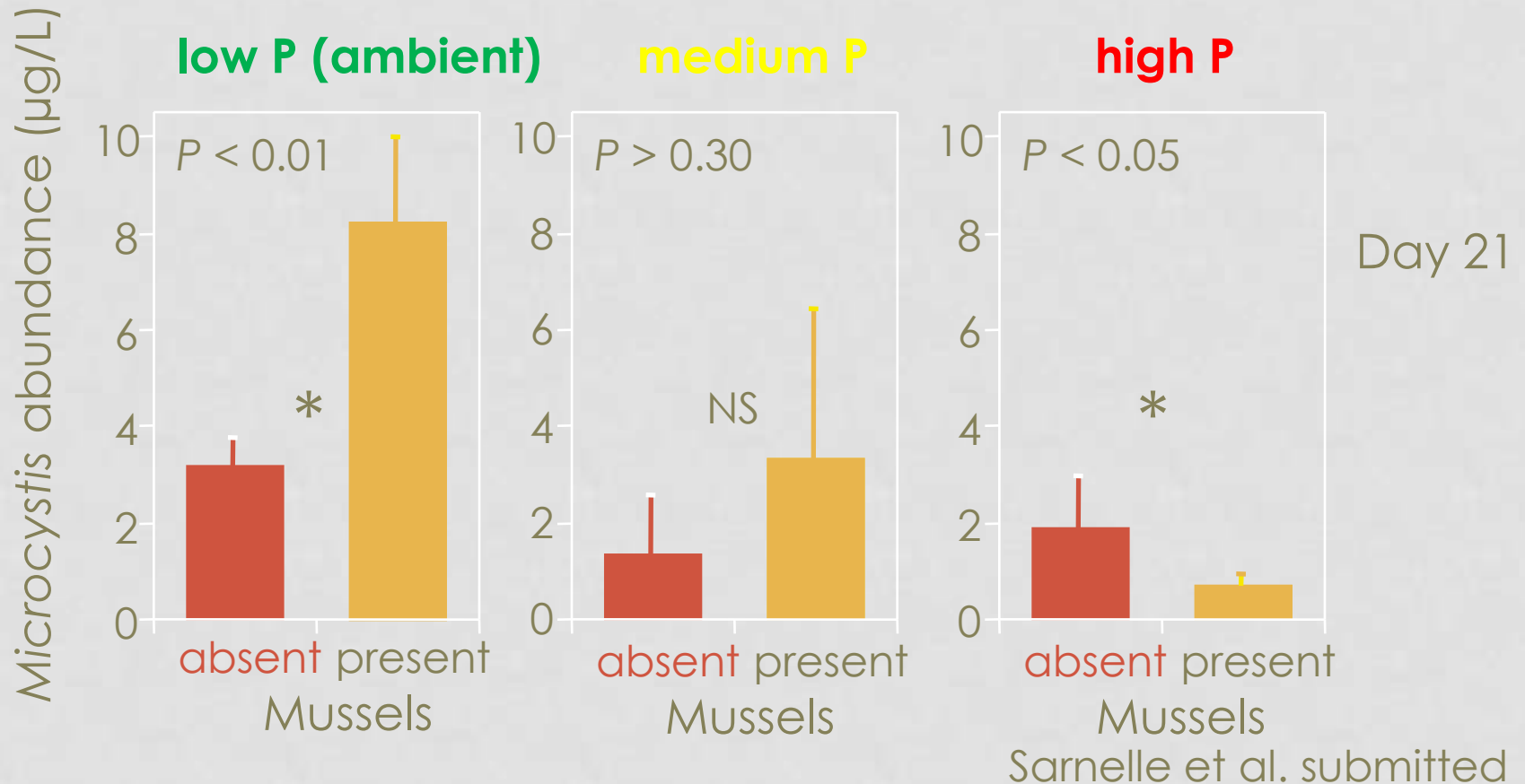


Experimental data closely resemble lake survey data

# FIELD EXPERIMENT

## Zebra Mussel Experiment "ZMEX" 2008

Phosphorus addition reverses the effect of zebra mussels on *Microcystis*



# MECHANISMS?

Why do nutrients modify the effect of mussels on *Microcystis*?

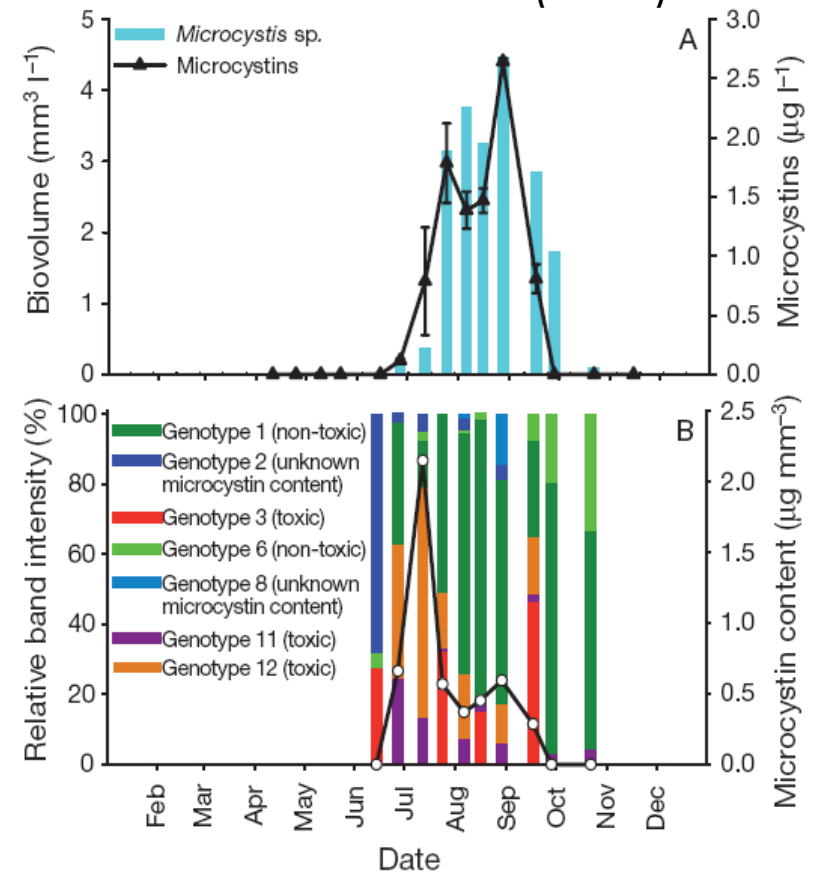
- Mussels modify the nutrient ratios of lake water
- Selective rejection of unpalatable or toxic *Microcystis* by mussels
- Biological variation in *Microcystis* populations (genetics, traits)



# VARIATION IN *MICROCYSTIS* POPULATIONS

- *Microcystis* populations are diverse
  - Genetically: **many unique strains**
  - Traits: size, **toxicity**, etc.

Kardinaal et al. (2007)



How might this biological variation affect vulnerability to mussel grazing?

# VARIATION IN *MICROCYSTIS* POPULATIONS

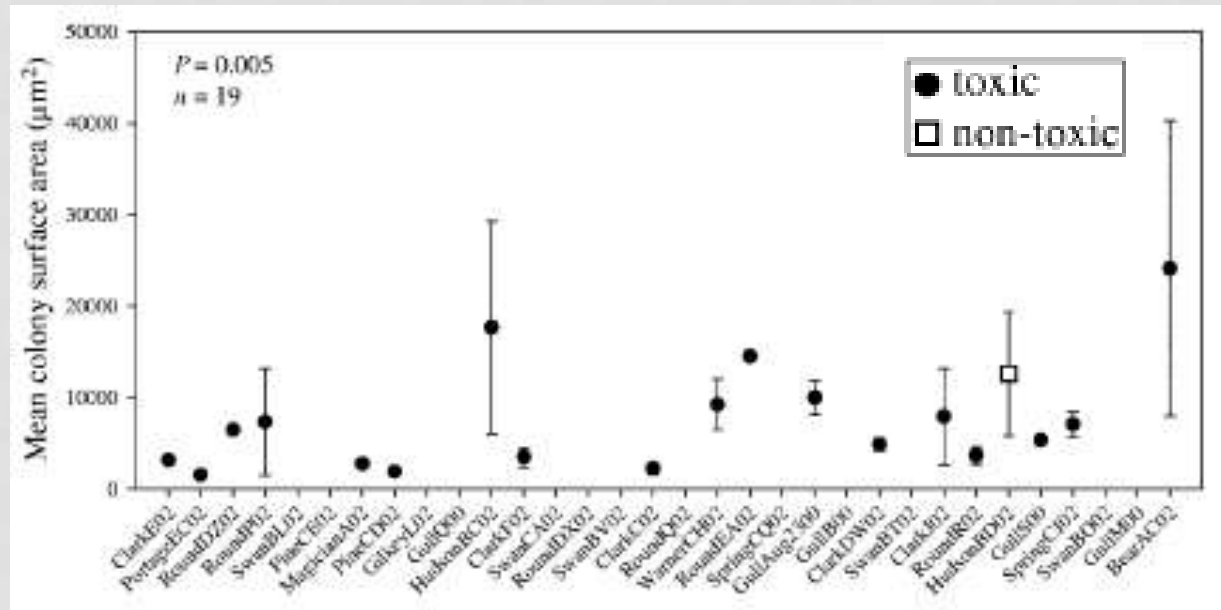
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# VARIATION IN *MICROCYSTIS* POPULATIONS

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Wilson et al.  
2006

How might this biological variation affect vulnerability to mussel grazing?

# LABORATORY EXPERIMENTS

- Gull lake mussels feeding on:
  - colonial Gull Lake *Microcystis* strains
  - Single-celled *Microcystis* strains
  - *Ankistrodesmus falcatus*
    - Preferred alga
- Mussels were fed mixtures of *Microcystis* and *Ankistrodesmus*

***Ankistrodesmus***



***Microcystis***



Images not to scale

# LABORATORY EXPERIMENTS



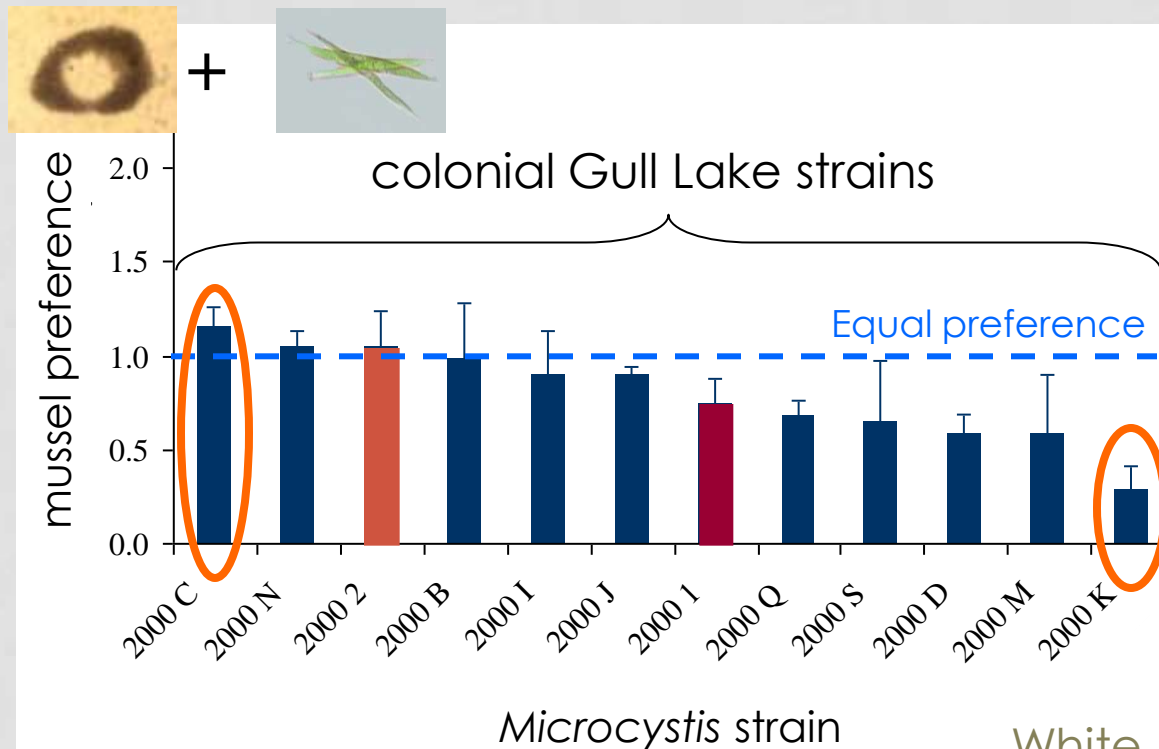
*Images not  
to scale*





# GENETIC VARIATION

Significant differences in mussel preference for colonial strains isolated on the same date

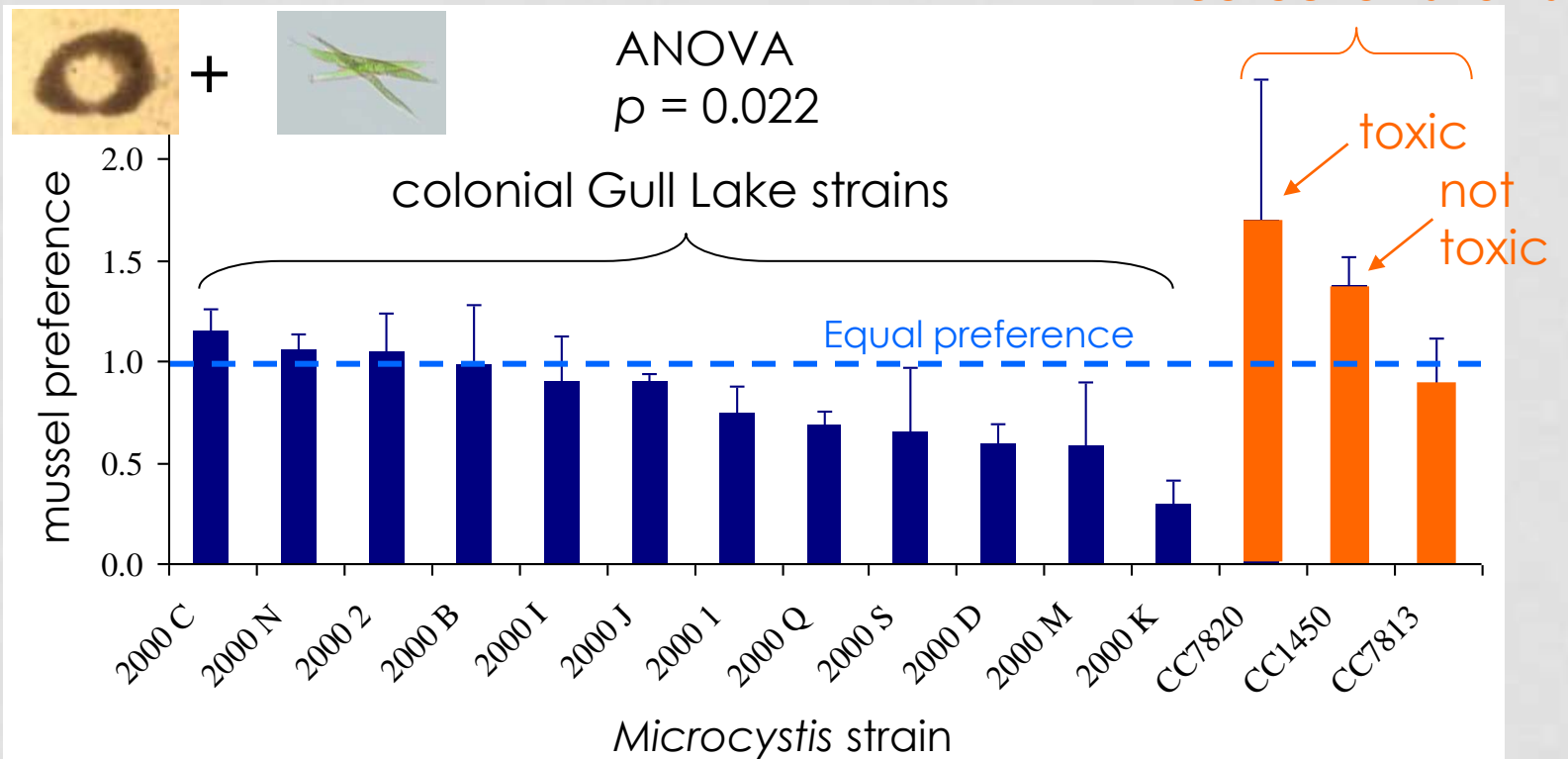


ANOVA  
 $p = 0.049$

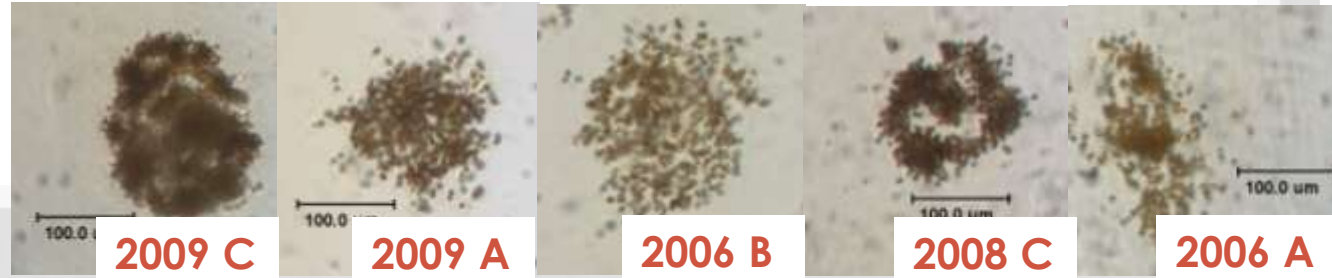
\*strains of the same color were isolated on the same day

# GENETIC VARIATION

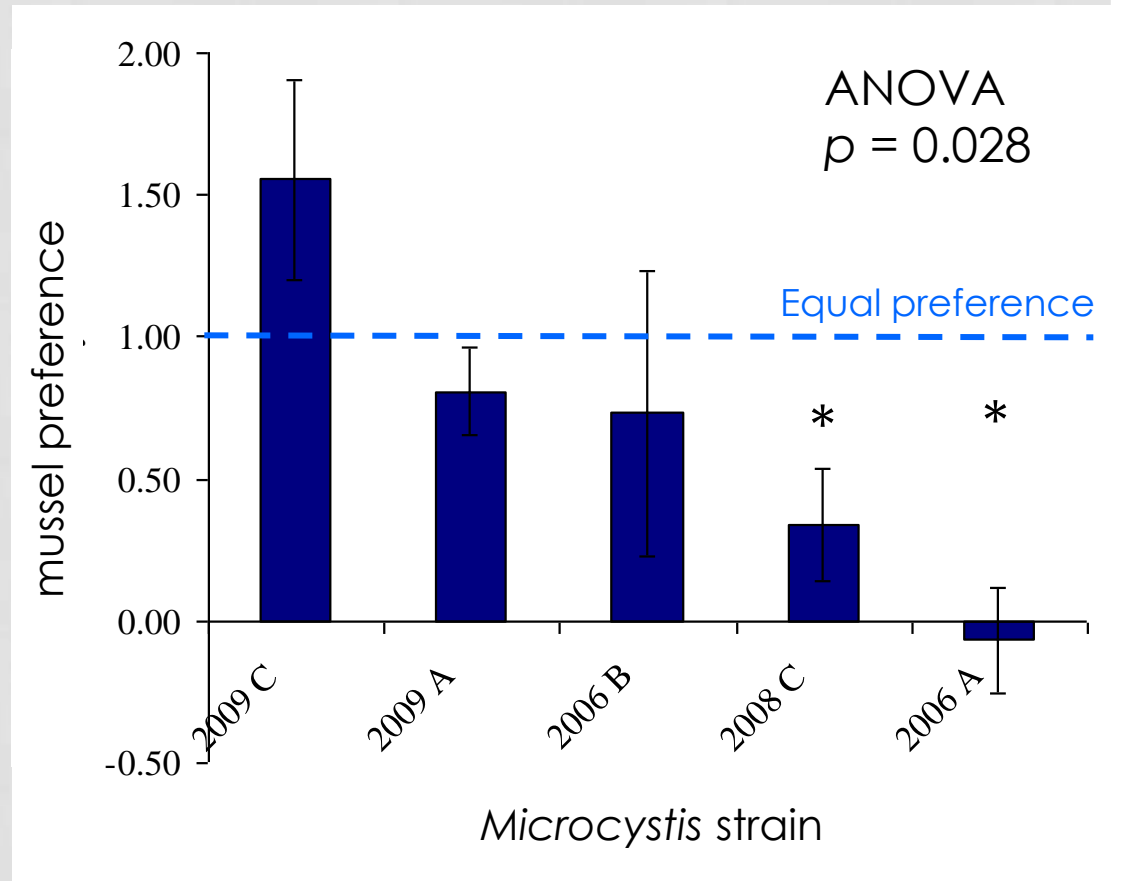
Preference high on single-celled strains, regardless of toxin content



# GENETIC VARIATION

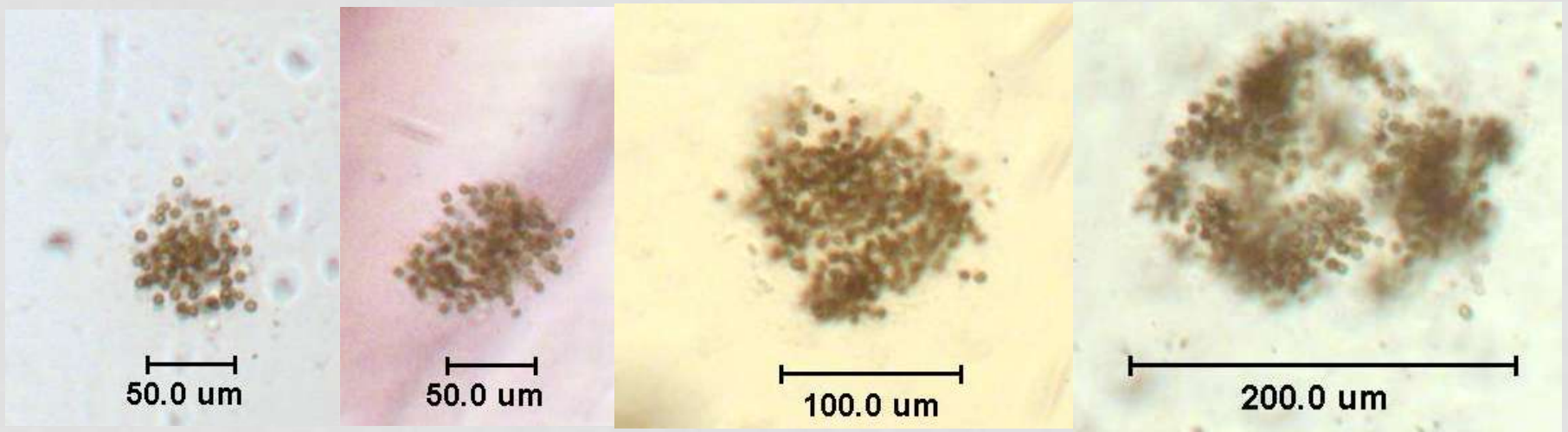
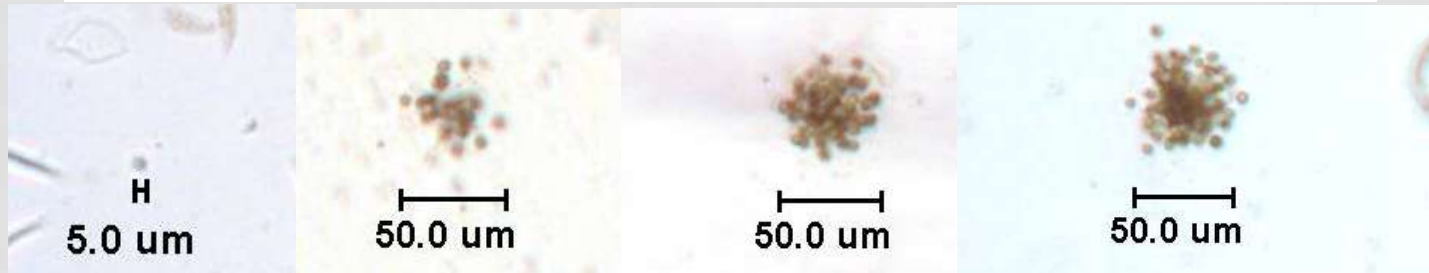


Significant differences and maximal variation in grazing vulnerability among colonial strains



# COLONY SIZE VARIATION

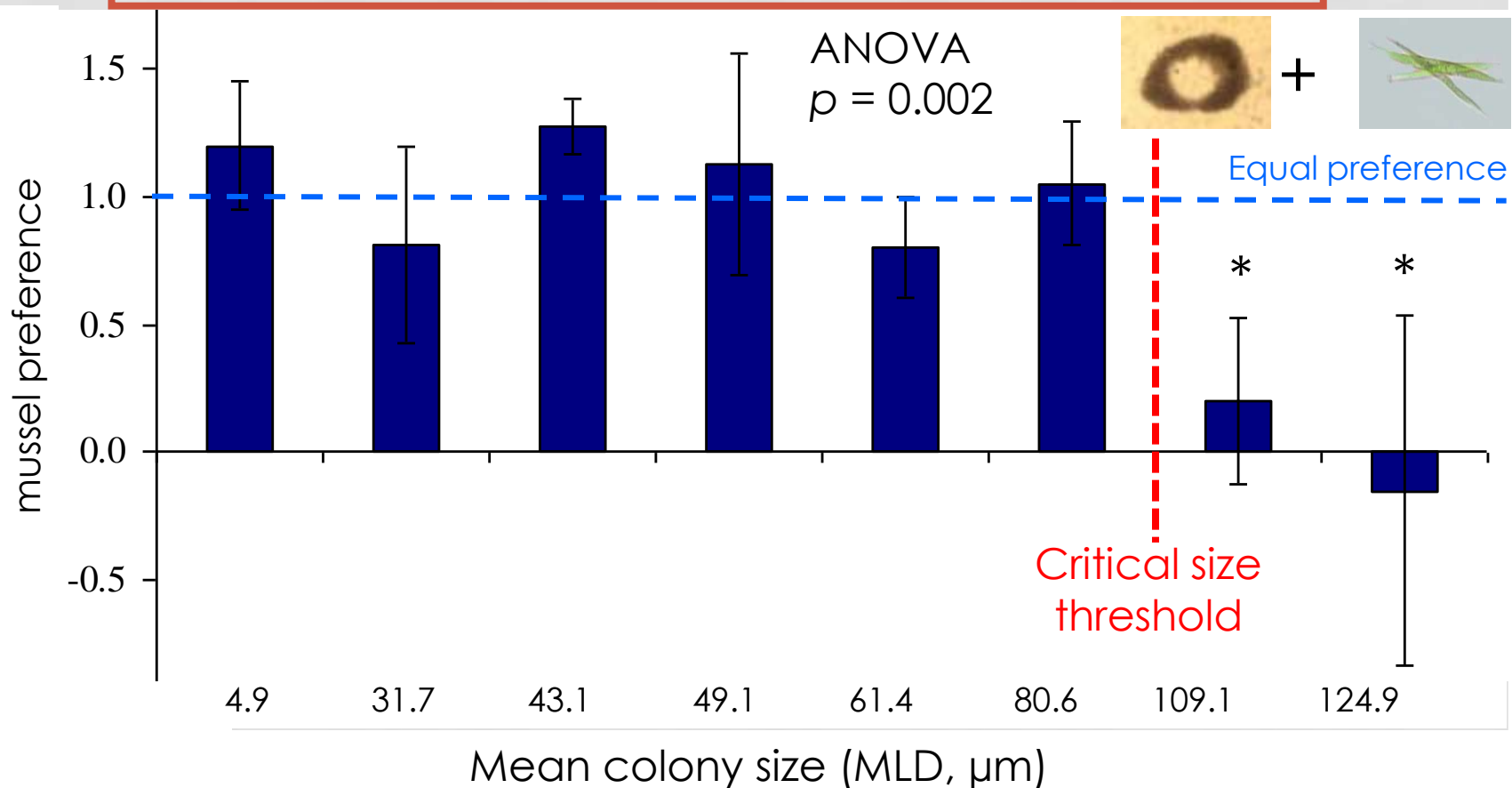
## Variation in Colony Size of a Single Strain (2009C)





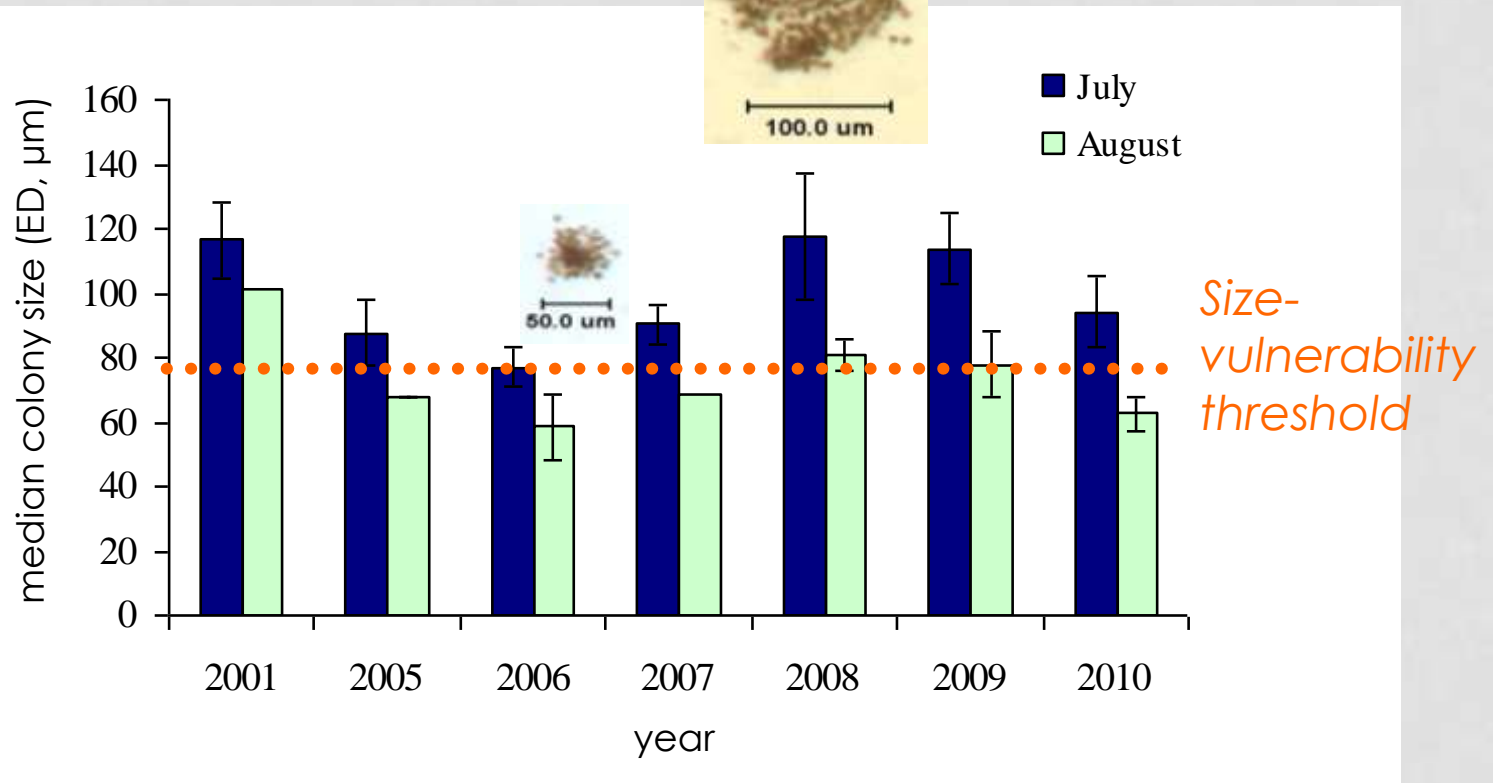
# COLONY SIZE VARIATION

Mussels did not consume colonies  $\geq \sim 110 \mu\text{m}$  MLD:  
vulnerability threshold to zebra mussels



# COLONY SIZE VARIATION

Gull Lake *Microcystis* colony size shifts seasonally from above to below the vulnerability threshold to zebra mussels



# ZEBRA MUSSEL-MICROCYSTIS INTERACTIONS: SUMMARY

1. Cyanobacterial dominance and microcystin concentrations increase with phosphorus enrichment, but only in lakes that have not been invaded by zebra mussels.
2. *Microcystis* abundance and microcystin concentrations are ~3-8 times higher in invaded than un-invaded lakes with low nutrients.
3. Positive, negative and no effects of zebra mussels on *Microcystis* were observed in a large-scale field experiment in Gull Lake.
4. Phosphorus addition reversed the effect of zebra mussels on *Microcystis* in the field experiment.
5. Biological variation (size, genetic, etc.) in *Microcystis* is large and may explain highly variable responses to mussel invasion.

# QUESTIONS?

