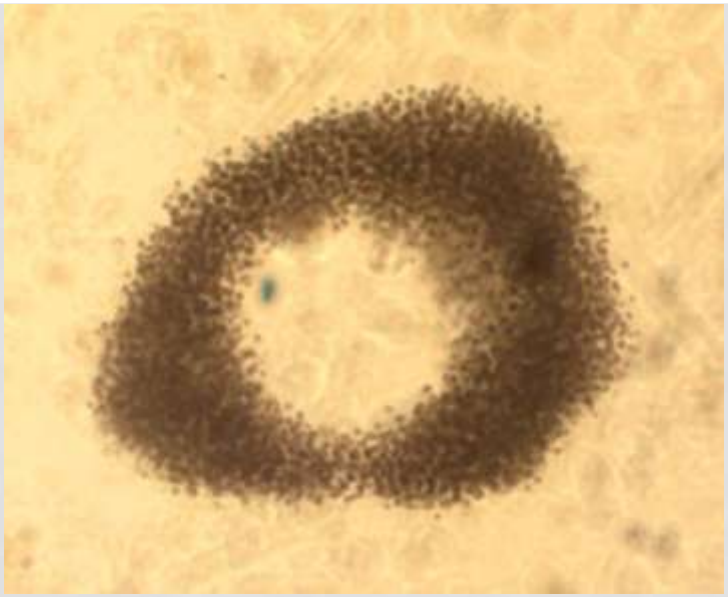

ZEBRA MUSSEL-*MICROCYSTIS* INTERACTIONS

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McNALMS 23 SEPTEMBER 2011

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Michigan State University

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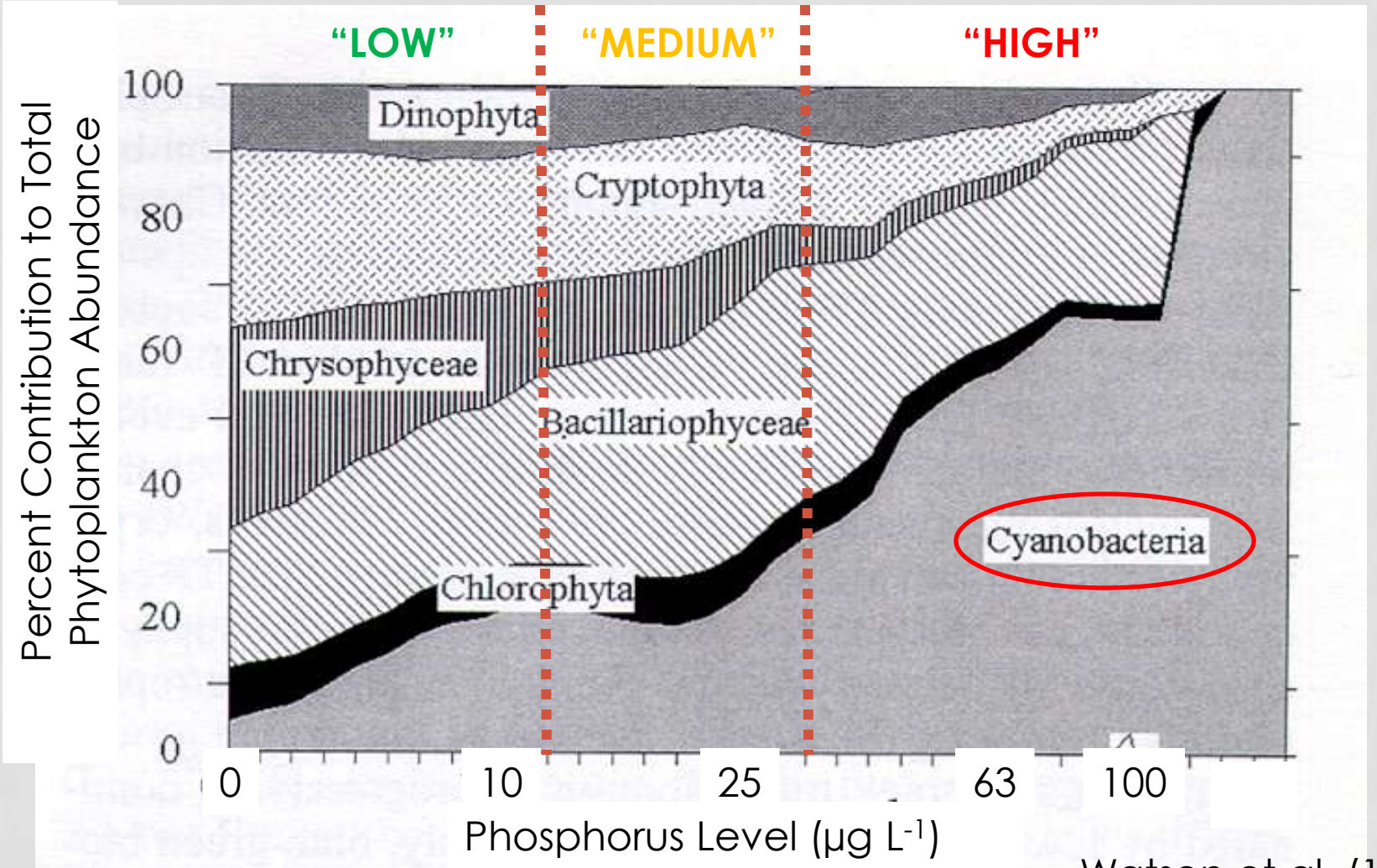
ZEBRA MUSSEL-*MICROCYSTIS* INTERACTIONS

- 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



Watson et al. (1997)

MICROCYSTIS AERUGINOSA

Microcystis aeurginosa

Colony-forming cyanobacterium

Floats: forms surface scums

Toxins (microcystin)

Harmful algal blooms (HABs)

ZEBRA MUSSELS *(DRIESSENA 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

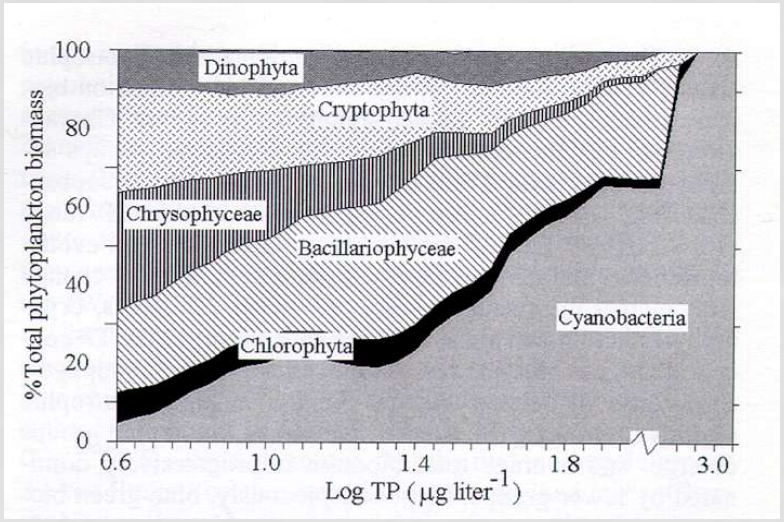
- *Microcystis* seemed to increase in abundance within 1-2 years of mussel establishment in some low-nutrient lakes

LAKE SURVEYS

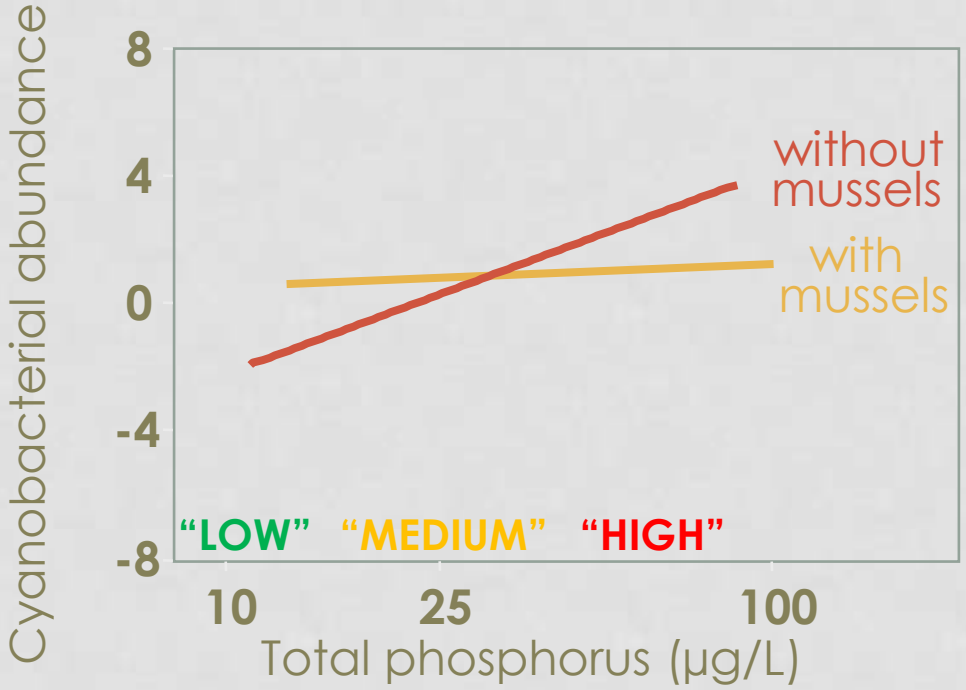
Michigan Inland Lakes

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

LAKE SURVEYS



Michigan Inland Lakes (1998-1999)



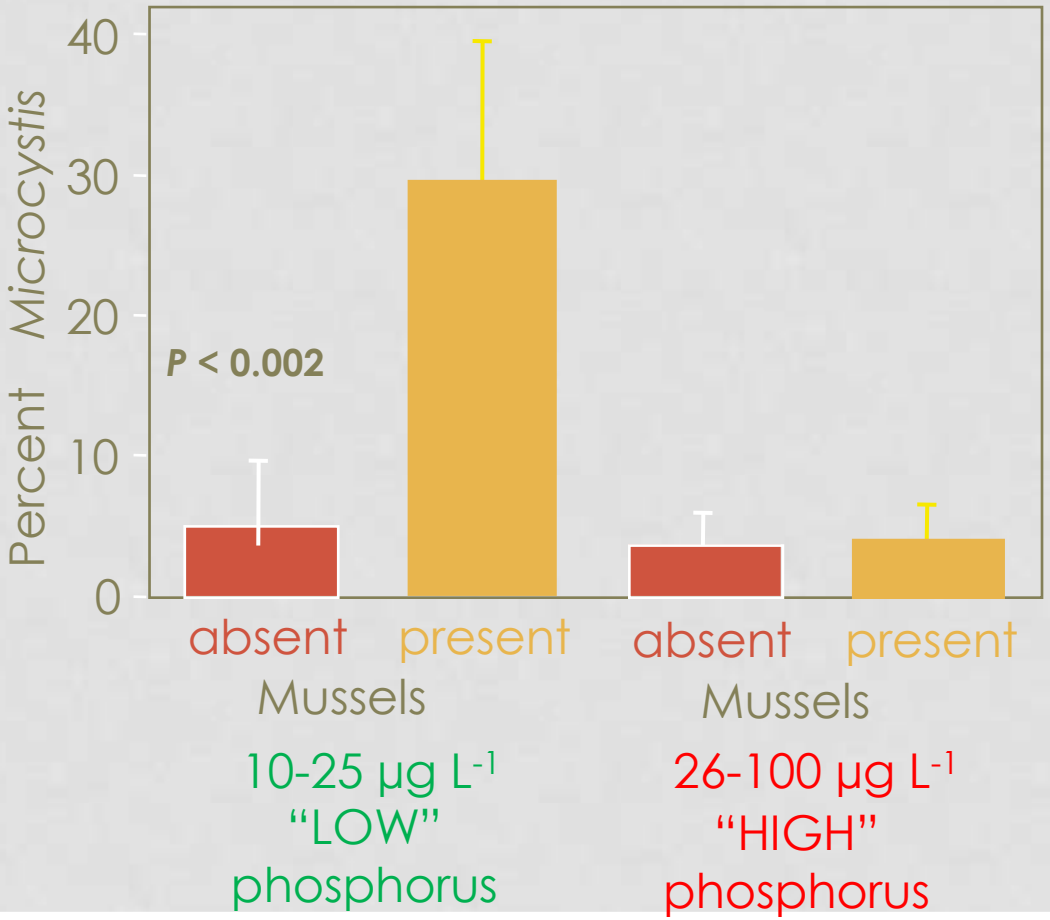
Cyanobacteria increase with phosphorus in non-invaded lakes, but not in lakes invaded by zebra mussels

Raikow et al. (2004), Sarnelle et al. (2010)

LAKE SURVEYS

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

Michigan Inland Lakes (1998-1999)

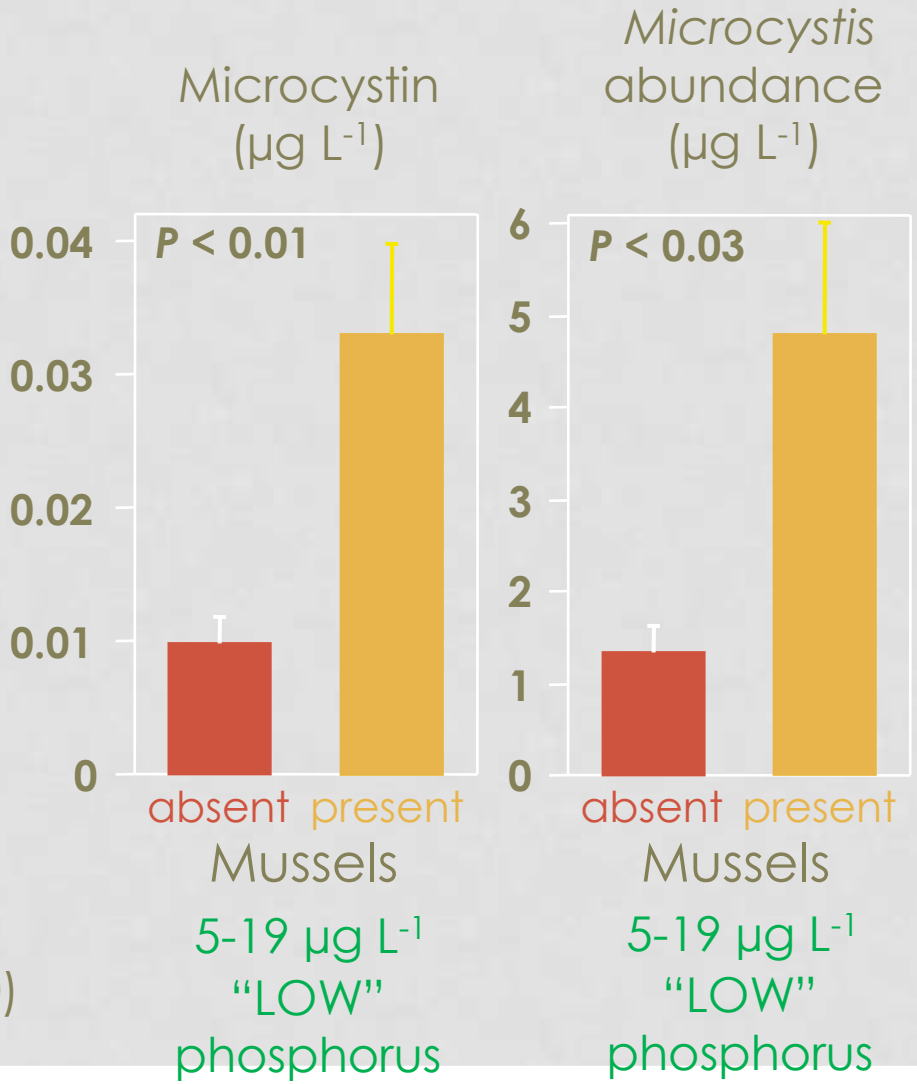


Raikow et al. (2004)

LAKE SURVEYS

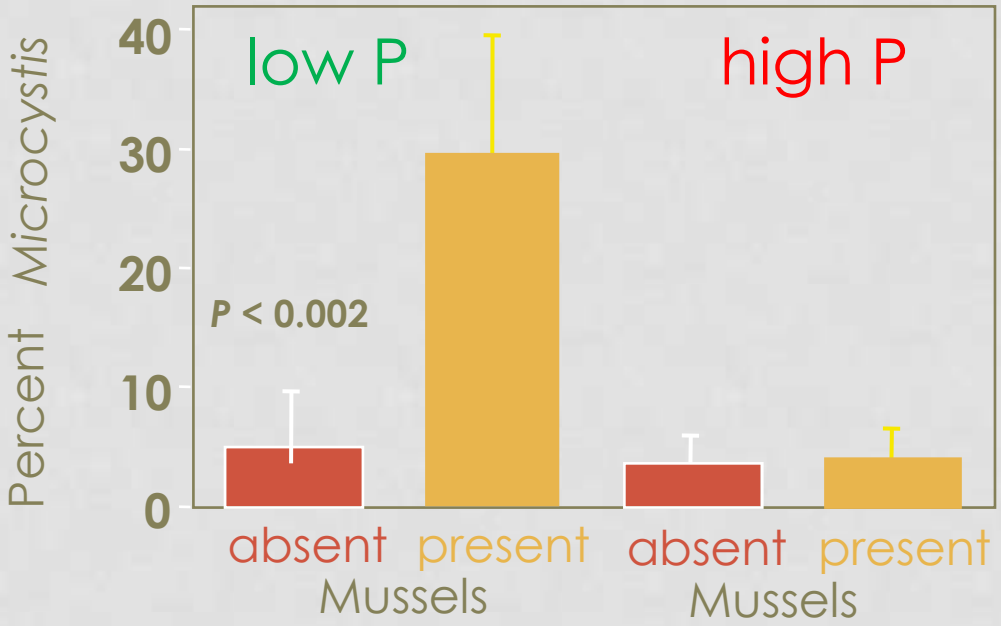
Michigan Inland Lakes (2002-2003, 2006)

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



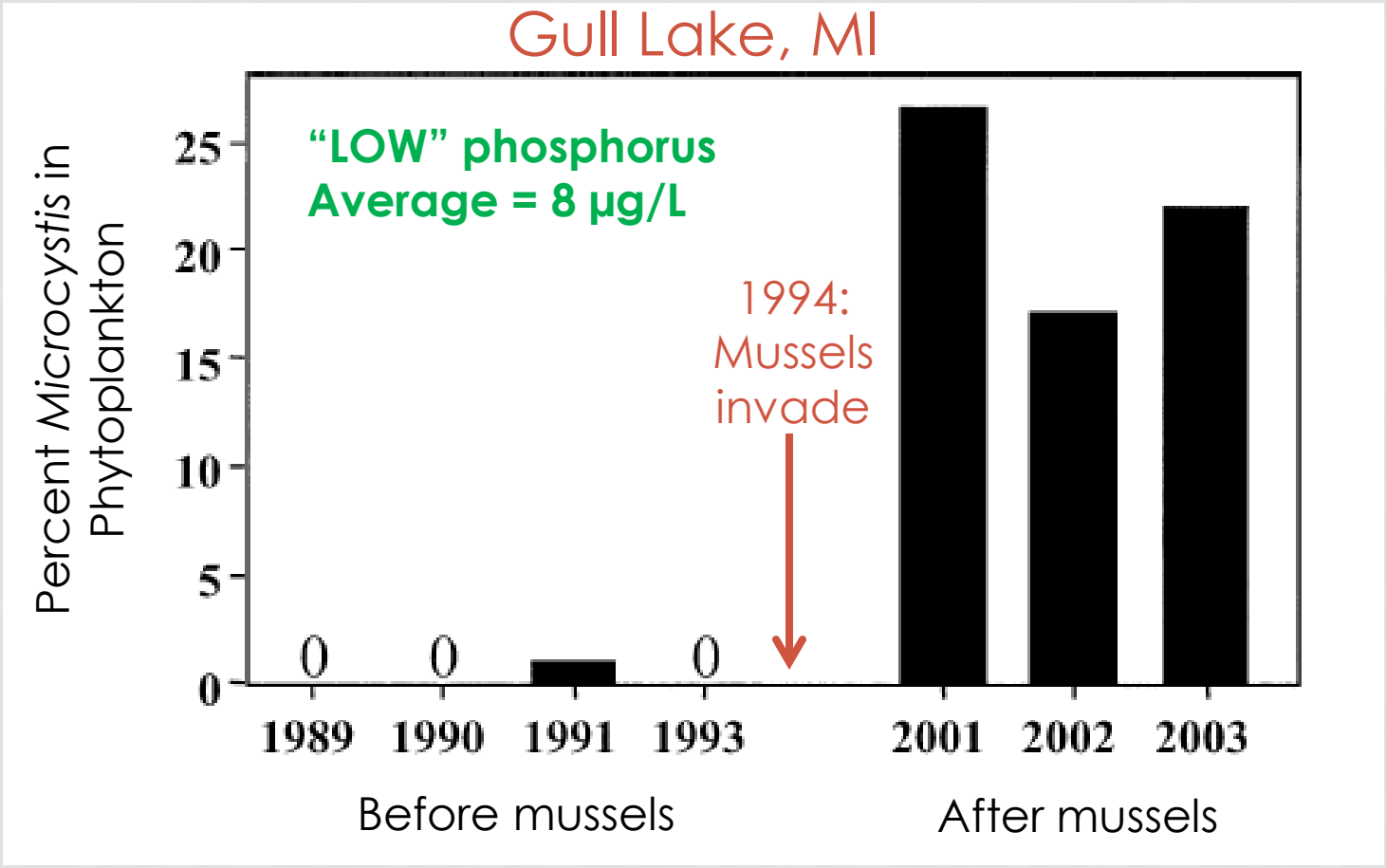
Hypothesis: Zebra mussel effects on *Microcystis* are dependent upon nutrient level

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



Sarnelle et al. 2005

FIELD EXPERIMENT

Zebra Mussel Experiment "ZMEX" 2008

FIELD EXPERIMENT

Zebra Mussel Experiment "ZMEX" 2008

Experimental design

mussels \ nutrients	low	medium	high
absent	N = 5	N = 5	N = 5
present (4 g/m^2)	N = 5	N = 5	N = 4

Sarnelle et al. submitted

FIELD EXPERIMENT

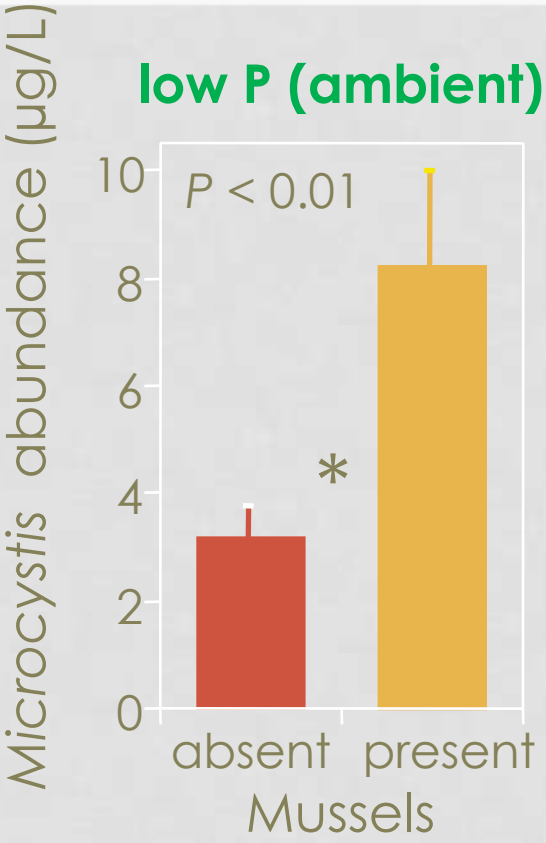
Zebra Mussel Experiment "ZMEX" 2008

FIELD EXPERIMENT

FIELD EXPERIMENT

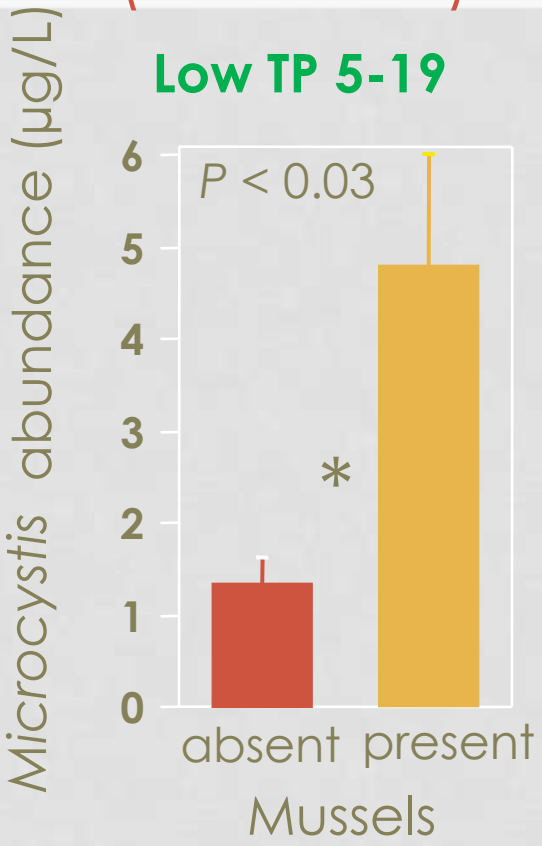
ZMEX 2008

low P (ambient)



Michigan lakes (2002-2003)

Low TP 5-19



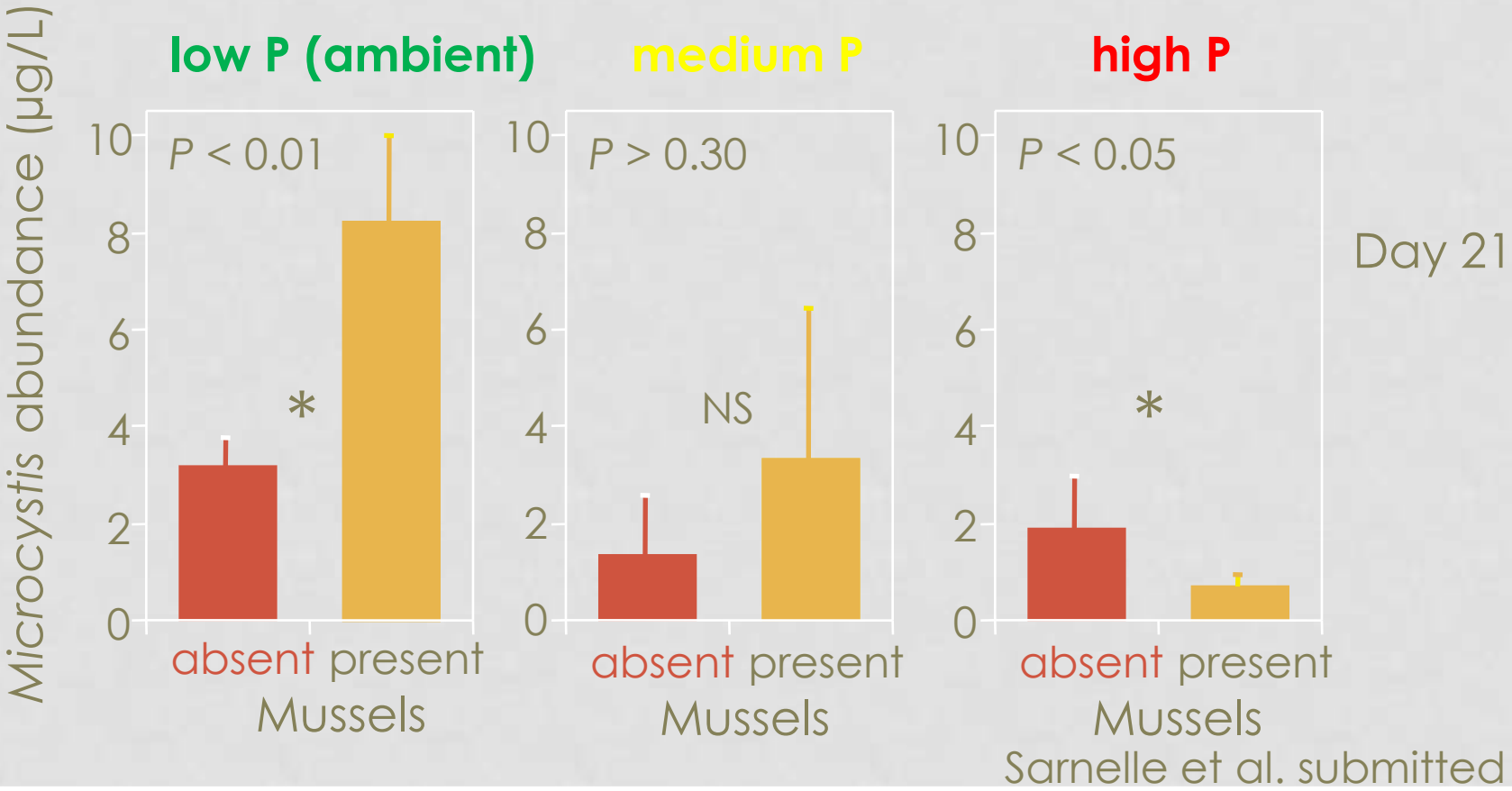
Experimental data closely resemble lake survey data

Sarnelle et al. submitted

FIELD EXPERIMENT

Zebra Mussel Experiment "ZMEX" 2008

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



Sarnelle et al. submitted

MECHANISMS?

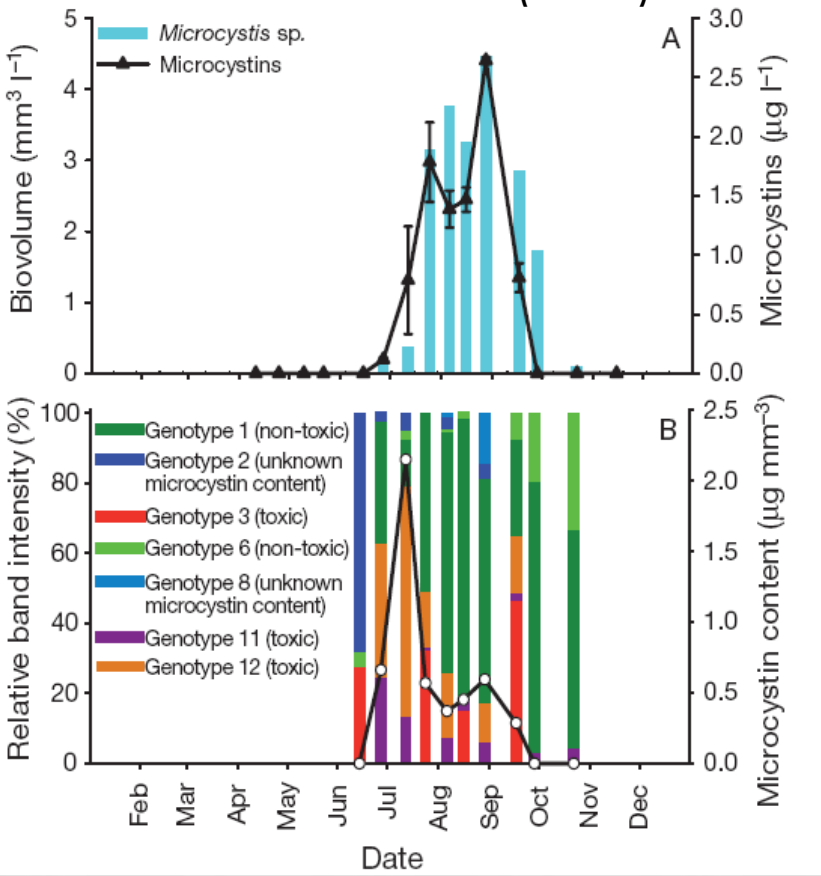
Why do nutrients modify the effect of mussels on *Microcystis*?

- 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?

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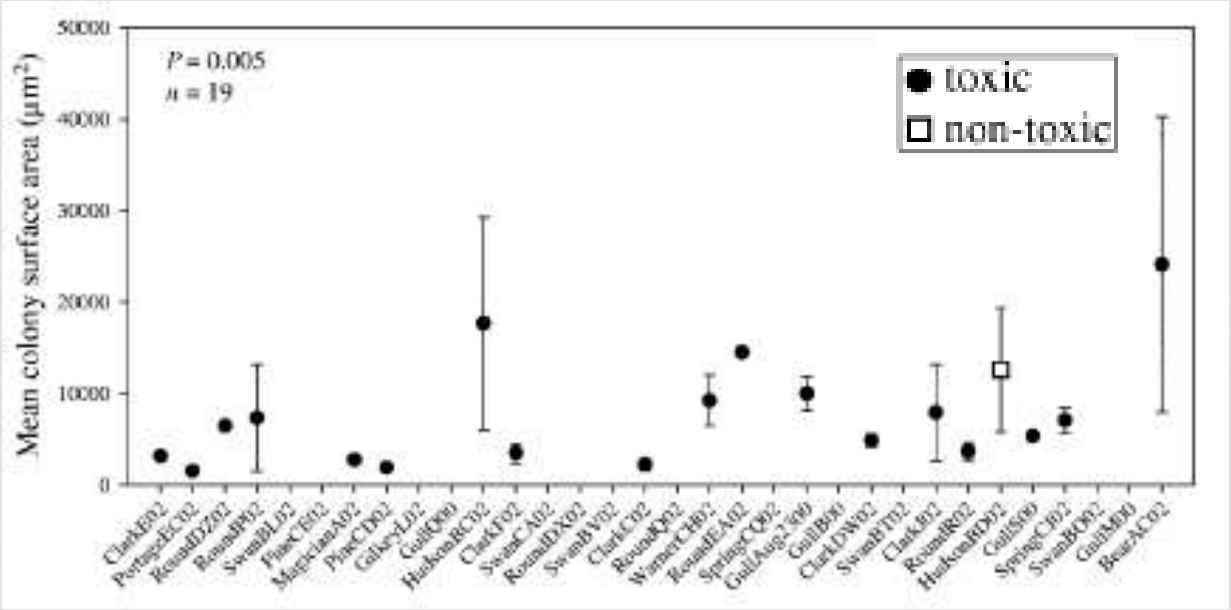
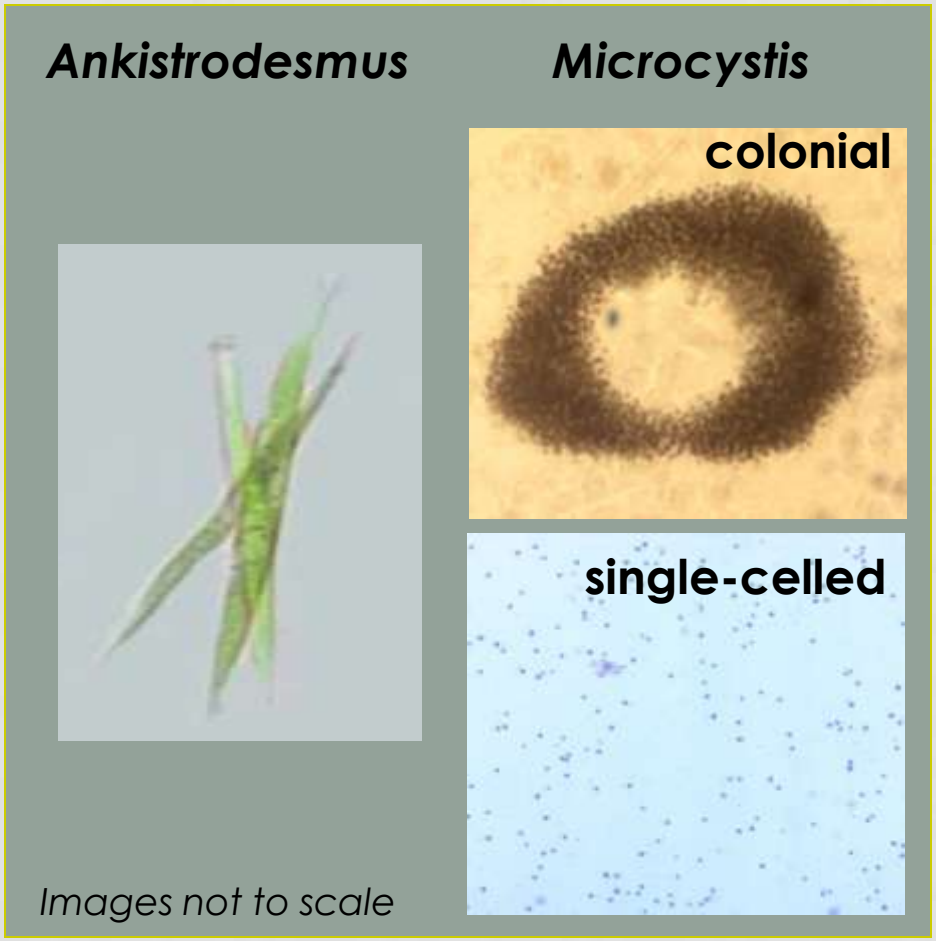


Wilson et al. 2006

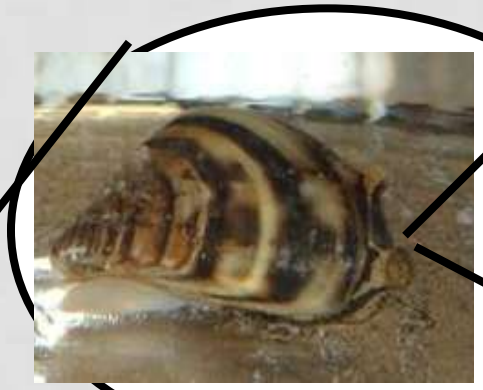
How might this biological variation affect vulnerability to mussel grazing?

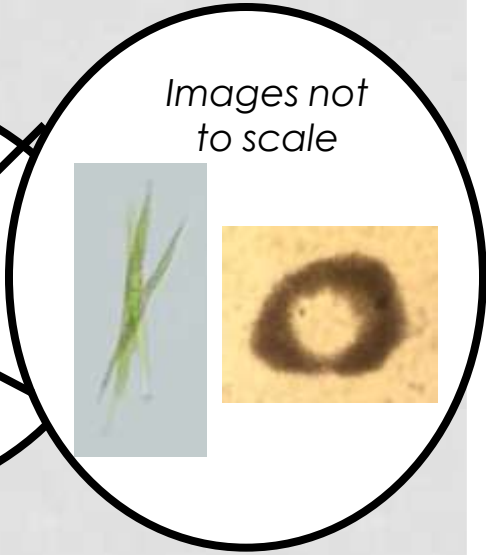
LABORATORY EXPERIMENTS

- 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*



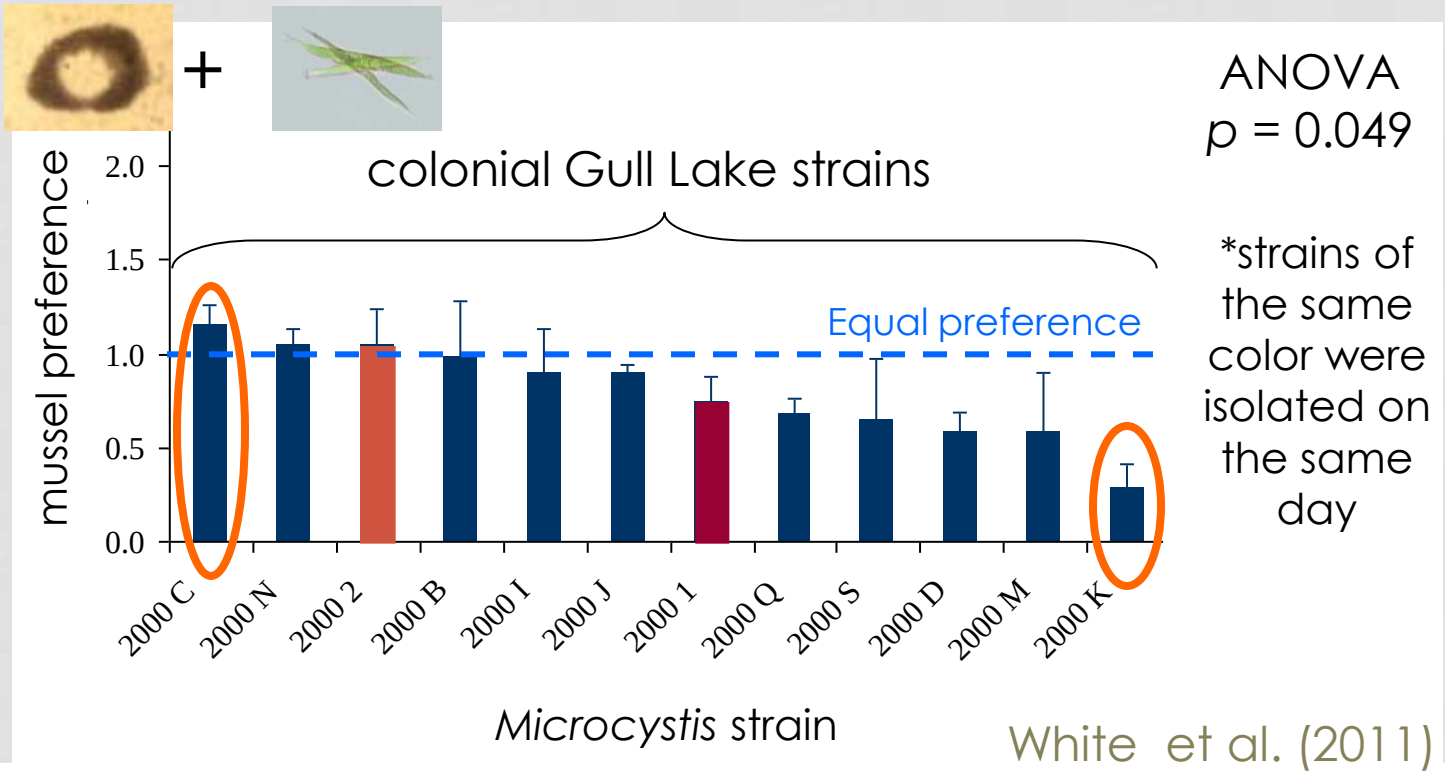
LABORATORY EXPERIMENTS





GENETIC VARIATION

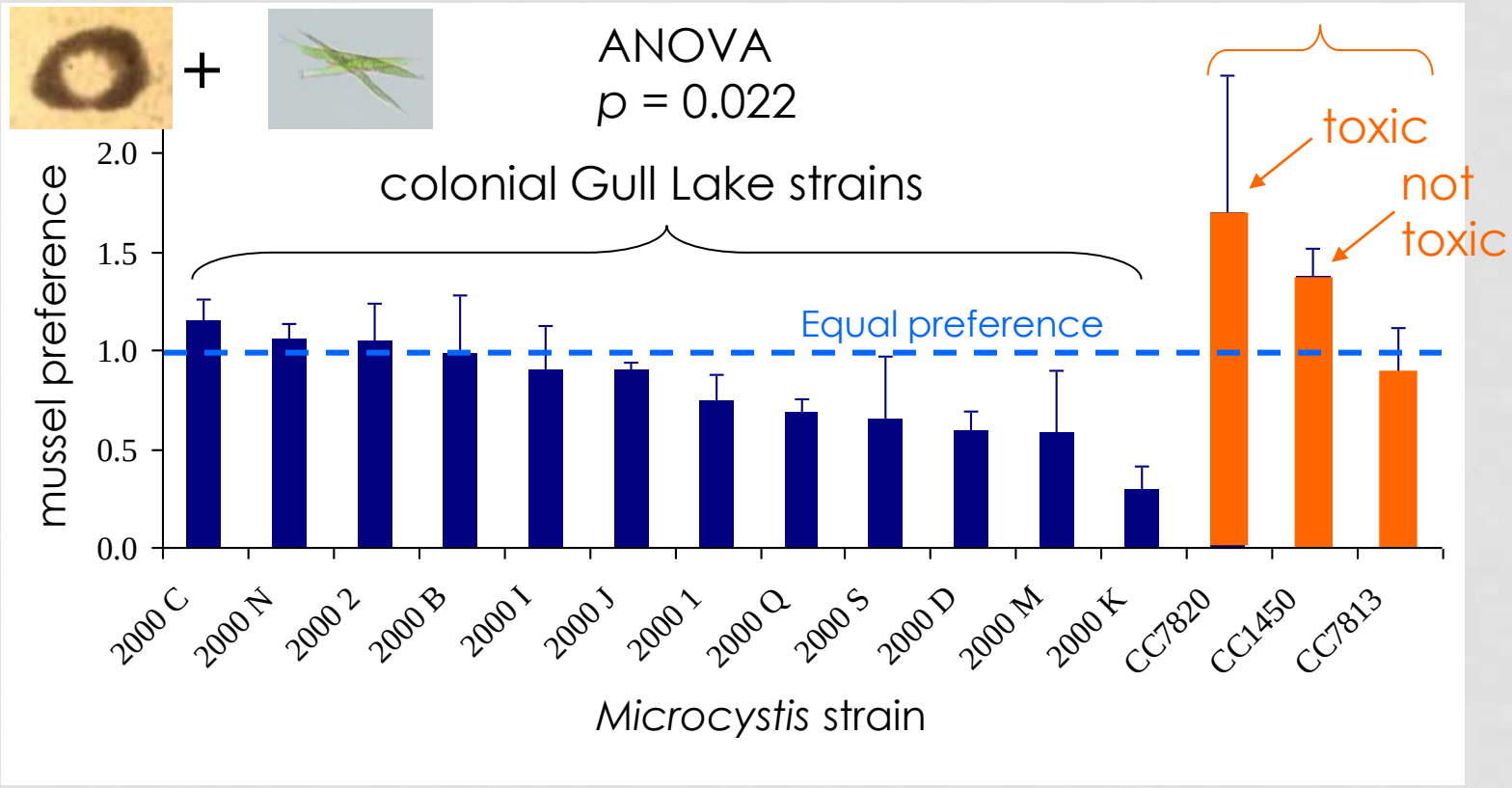
Significant differences in mussel preference for colonial strains isolated on the same date



White et al. (2011)

GENETIC VARIATION

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

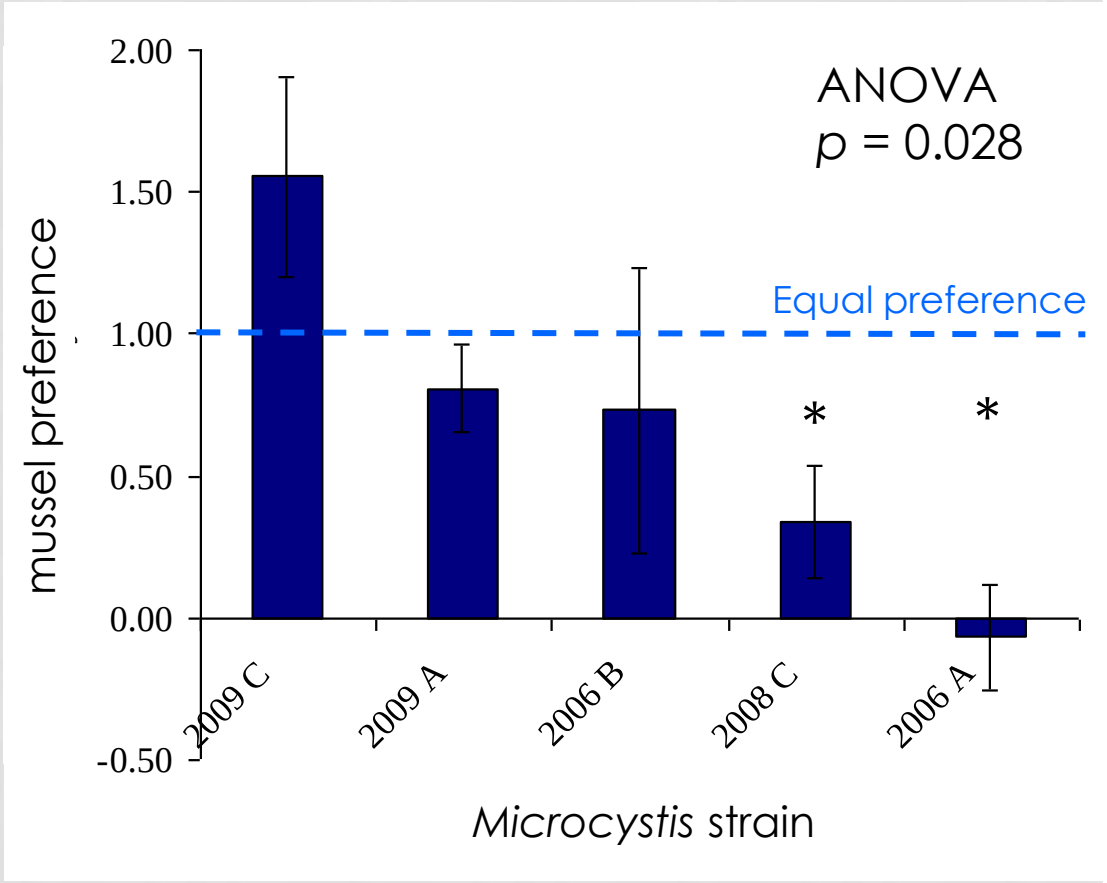


White et al. (2011)

GENETIC VARIATION

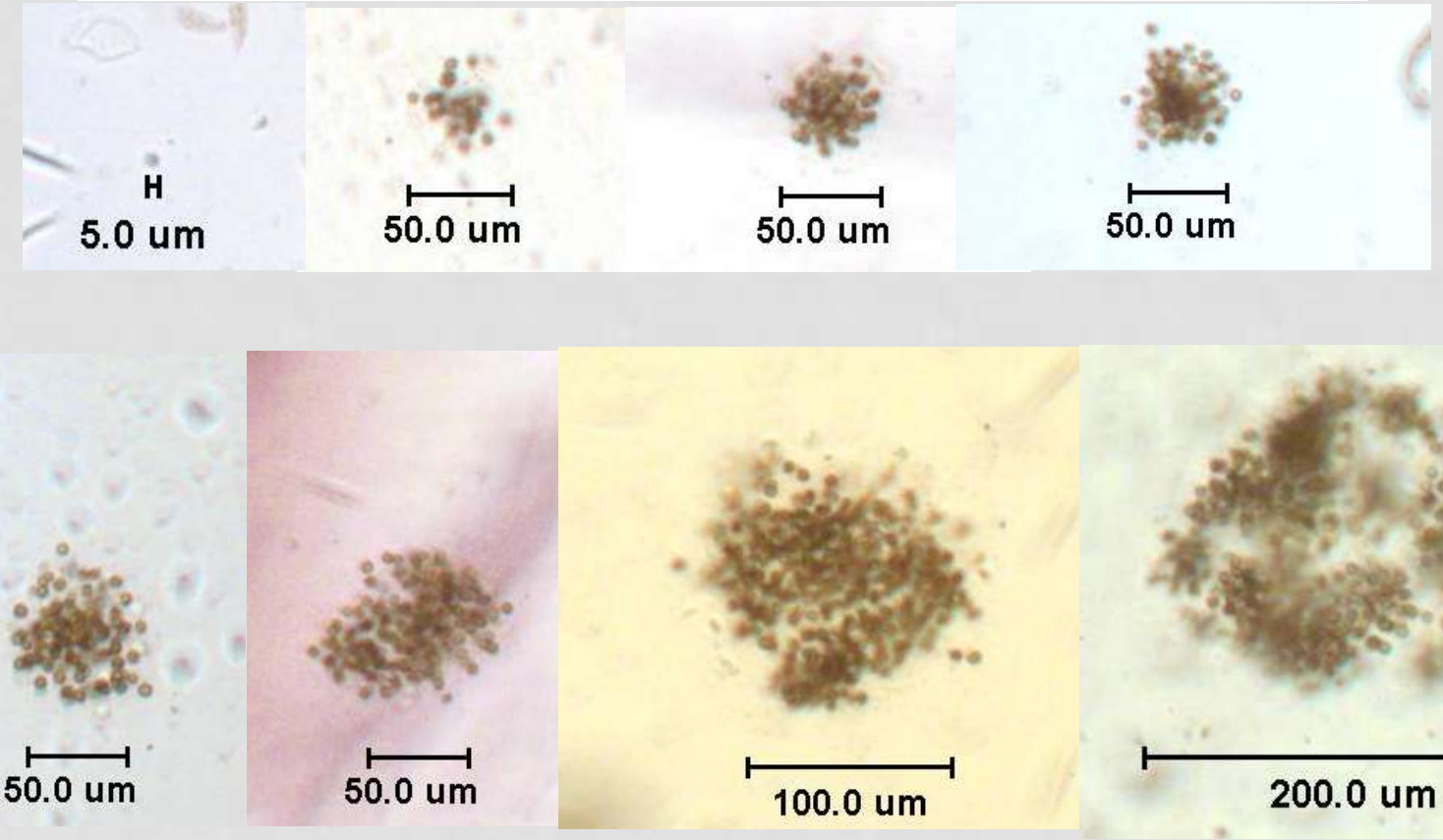
Significant differences and maximal variation in grazing vulnerability among colonial strains

White et al. (2011)



COLONY SIZE VARIATION

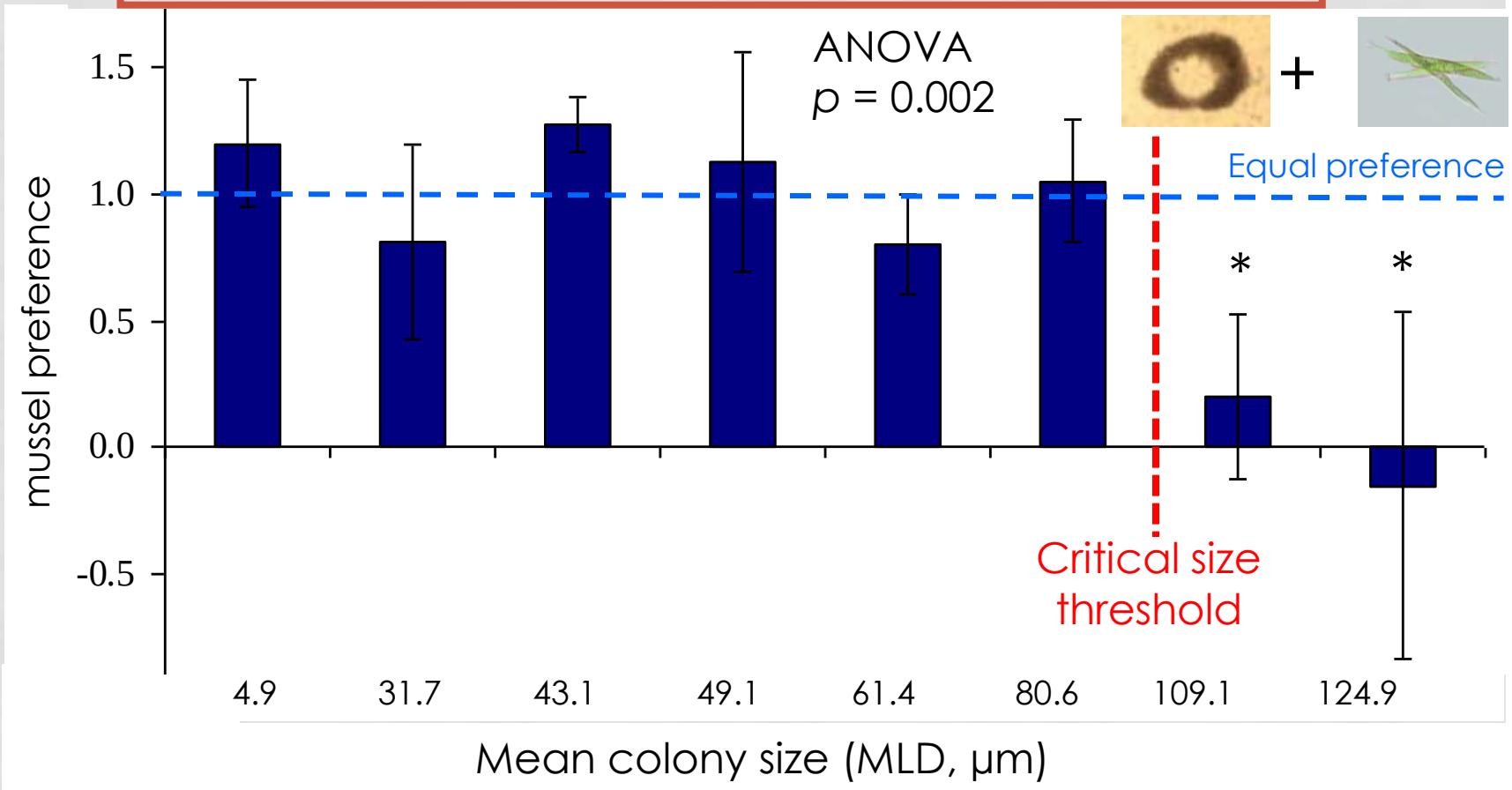
Variation in Colony Size of a Single Strain (2009C)



White and Sarnelle in preparation

COLONY SIZE VARIATION

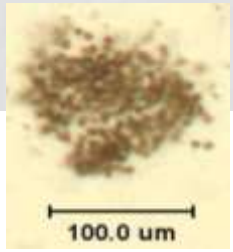
Mussels did not consume colonies ≥ ~110 µm MLD: vulnerability threshold to zebra mussels



White and Sarnelle in preparation

COLONY SIZE VARIATION

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



White and Sarnelle in preparation

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?