Update on Phosphorus and *Cladophora* in the Lake Michigan Nearshore Zone

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Nearshore TP and TDP Concentrations Since 1980, Near Milwaukee Harbor

![Graph showing nearshore TP and TDP concentrations from 1980 to 2005, with data points for each period.](chart)
Spring Total P (mean of all pelagic stations)

GLWQA Target for Lake Michigan: 7 μg/L

Michigan

Huron

20-Year Phosphorus Trend at River Junction

Data Source: MMSD
In Milwaukee River, dissolved P is becoming a larger fraction of TP

![Graph showing dissolved P : Total P Ratio from 1980 to 2005]

P in Wisconsin Cropland

![Bar chart showing average [P] (ppm) and soil P storage change (kg ha⁻¹) from 1968-73 to 1991-99]

Bundy and Sturgul 2001
Milwaukee River Transect, April 2005

SRP (μg L⁻¹)

Milwaukee River TP Concentrations have increased in late spring.

1982-87
Mean = 102

1988-95
Mean = 72

1996-2001
Mean = 120
Milwaukee River Discharge

- **1982-87**
  Avg. = 18.4

- **1988-95**
  Avg. = 13.1

- **1996-2001**
  Avg. = 14.3

Data source: USGS
Nearshore Phosphorus loads, May – July 2006

River load: 120 mg P m$^{-2}$
Mussel Excretion: 506 mg P m$^{-2}$
The Lake Michigan Phosphorus Cycle

Mussels have made nearshore water clear

Source: MMSD
Near-Bottom Total Dissolved Phosphorus
Atwater, Lake Michigan

TDP (μg/L)

Temperature (°C)

Water Temperature at 9 m
Lake Michigan Nearshore
Summer Temperature Trend

Optimum for *Cladophora* growth

no *Cladophora* growth

**TEMPERATURE**

**PHOSPHORUS**

*Quagga Mussel*

*Cladophora*
Lab Experiments:
Phosphorus Excretion by Quagga Mussels

Food Concentration (mg P ml\(^{-1}\))

μgP mgDW\(^{-1}\) hr\(^{-1}\)

Temperature (°C)

Biomass (gDW m\(^{-2}\))

Growth Rate (day\(^{-1}\))

μ

no mussels

mussels
P Flux Between Mussels and *Cladophora*

- Clean Mussels: 0.2 μg P mussel⁻¹ hr⁻¹
- Dirty Mussels: 0.1 μg P mussel⁻¹ hr⁻¹
- Mussels + Cladophora: -0.1 μg P mussel⁻¹ hr⁻¹

**LIGHT ?**
Current Needs

3. What is the botulism mechanism?

Photo: Alice Van Zoeren
4 minutes after dye injection
Effect of benthic respiration on thickness of anoxic layer

Depth of anoxic zone in mussel bed vs. $O_2$ uptake rate (mg m$^{-2}$ d$^{-1}$)
Benthic $O_2$ uptake by mussels

- $O_2$ uptake rate: $5,258$ mg $O_2$ m$^{-2}$ d$^{-1}$

Effect of benthic respiration on thickness of anoxic layer

- Depth of anoxic zone in mussel bed (cm) vs. $O_2$ uptake rate (mg m$^{-2}$ d$^{-1}$)
Above mussels:

- $K = 0.1 \text{ cm}^2 \text{s}^{-1}$

Mussel bed:

- $K = 0.01 \text{ cm}^2 \text{s}^{-1}$
PIV Image Analysis Results

Qian and Bootsma, in press
The Cladophora Solution