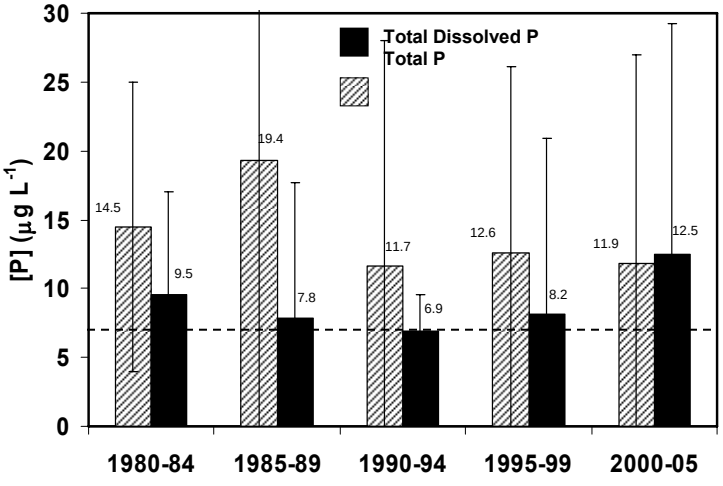
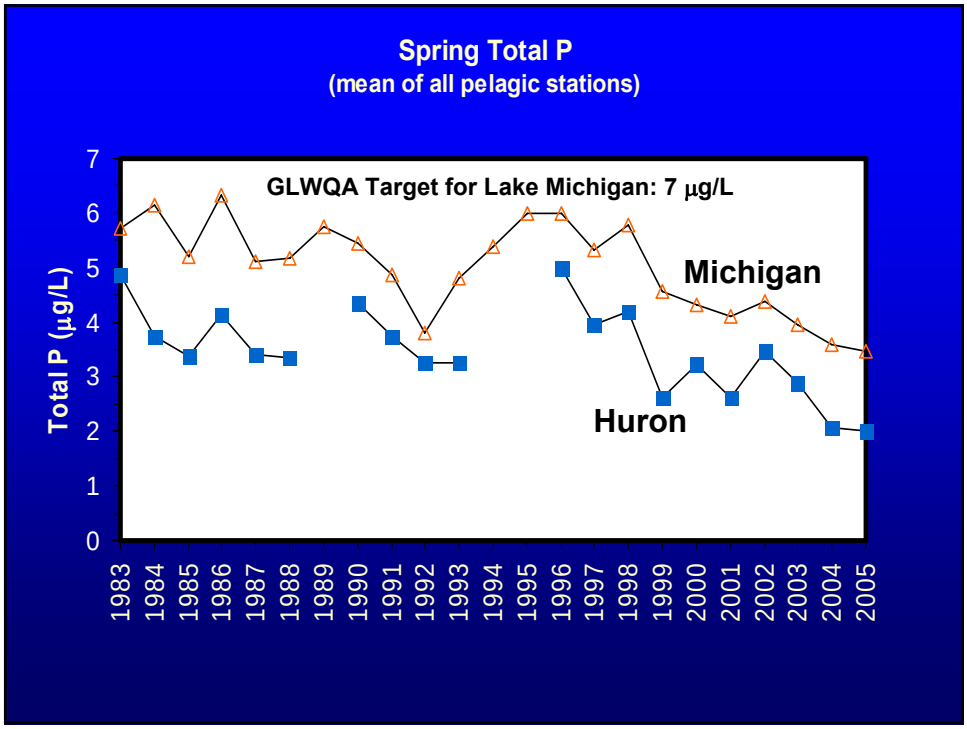
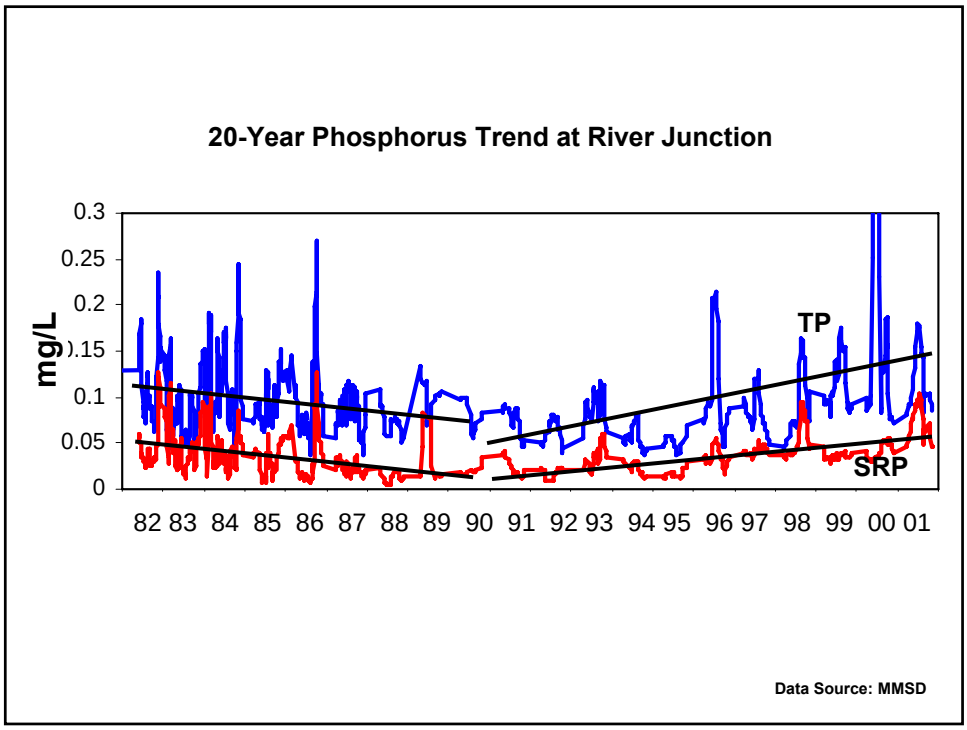
Update on Phosphorus and *Cladophora* in the Lake Michigan Nearshore Zone

Harvey Bootsma

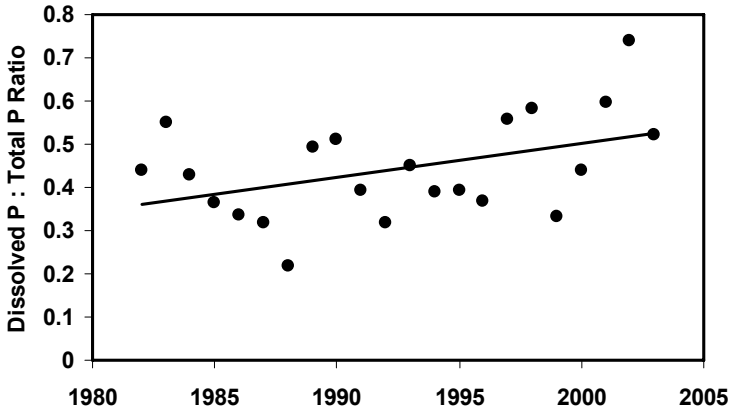
Nearshore TP and TDP Concentrations Since 1980, Near Milwaukee Harbor



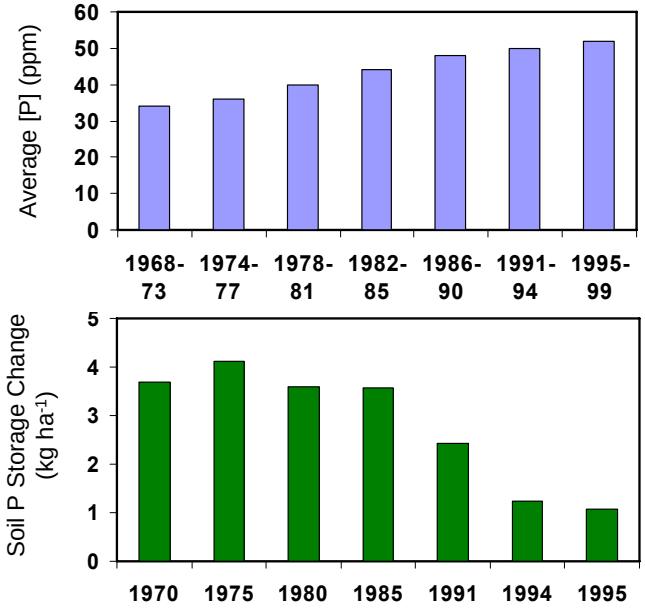

Spring Total P
(mean of all pelagic stations)
GLWQA Target for Lake Michigan: 7 µg/L
Total P (µg/L)
Michigan
Huron
0
1
2
3
4
5
6
7
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005


20-Year Phosphorus Trend at River Junction
mg/L
TP
SRP
0
0.05
0.1
0.15
0.2
0.25
0.3
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01
Data Source: MMSD

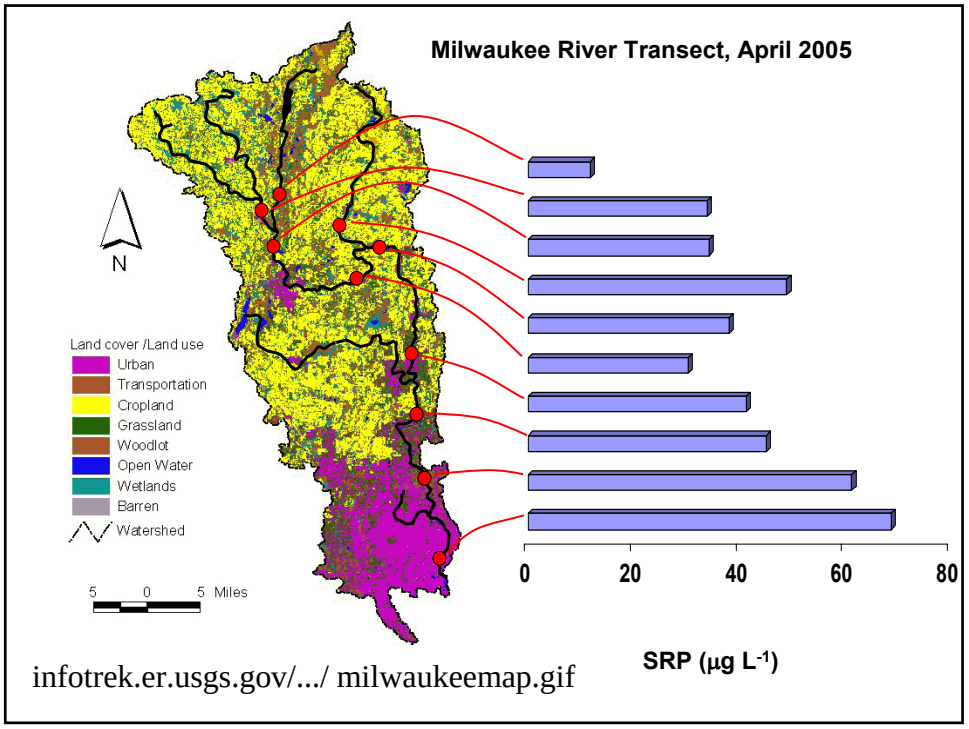
In Milwaukee River, dissolved P is becoming a larger fraction of TP



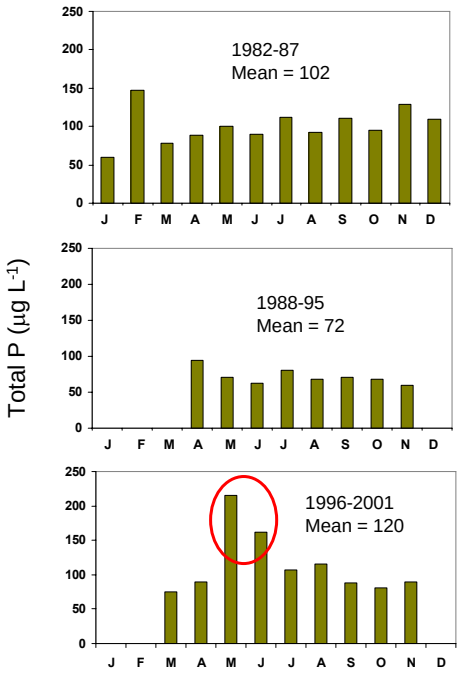
P in Wisconsin Cropland



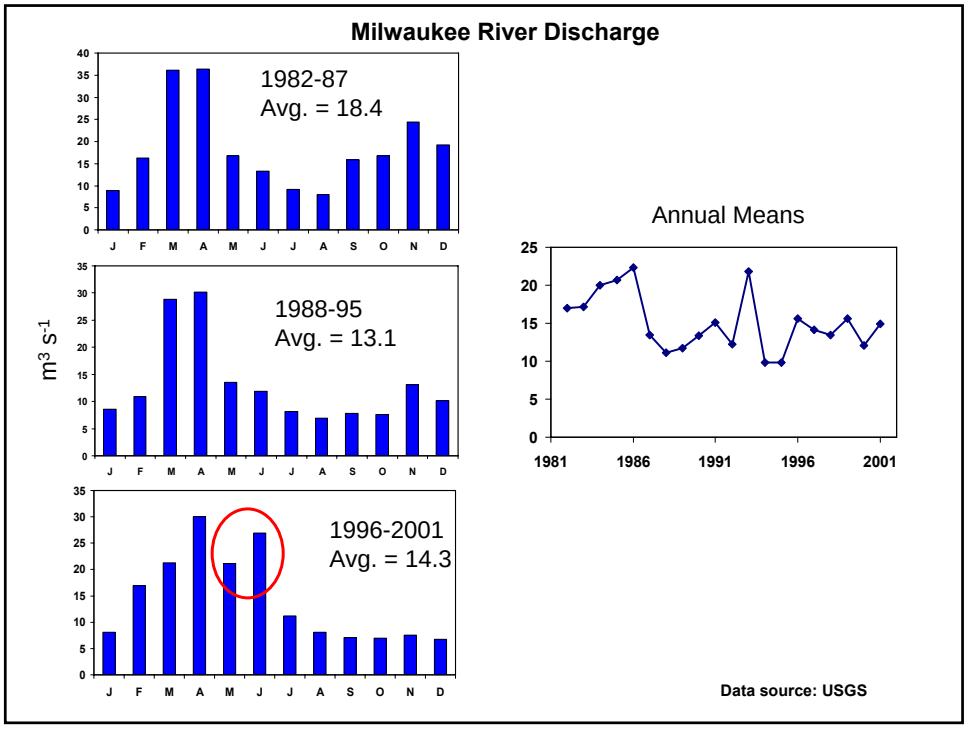
Bundy and Sturgul 2001

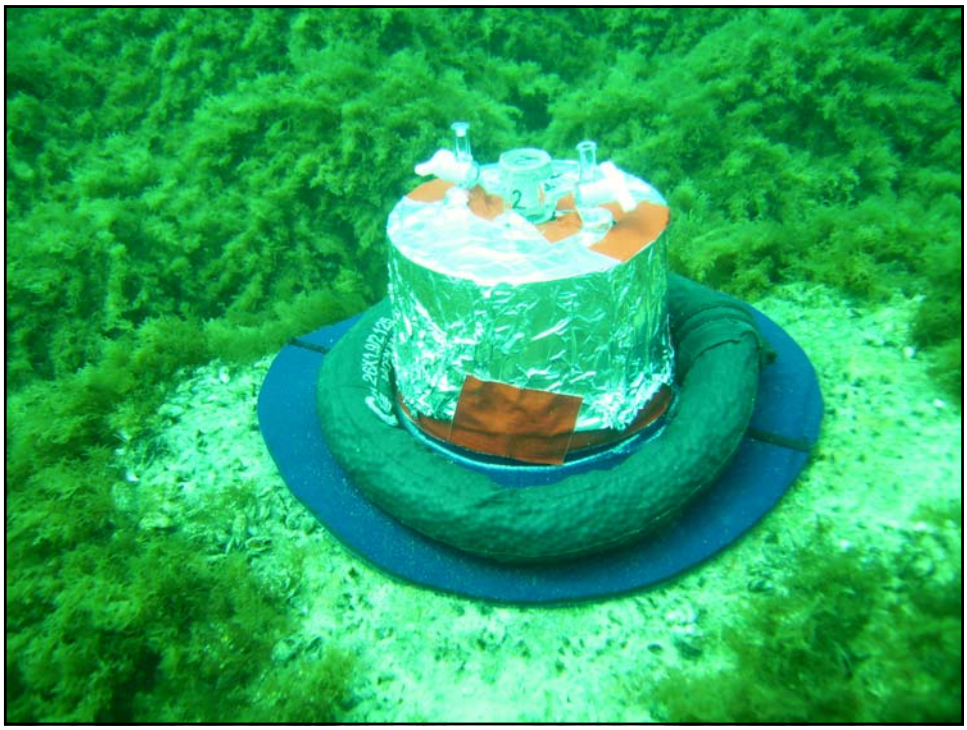


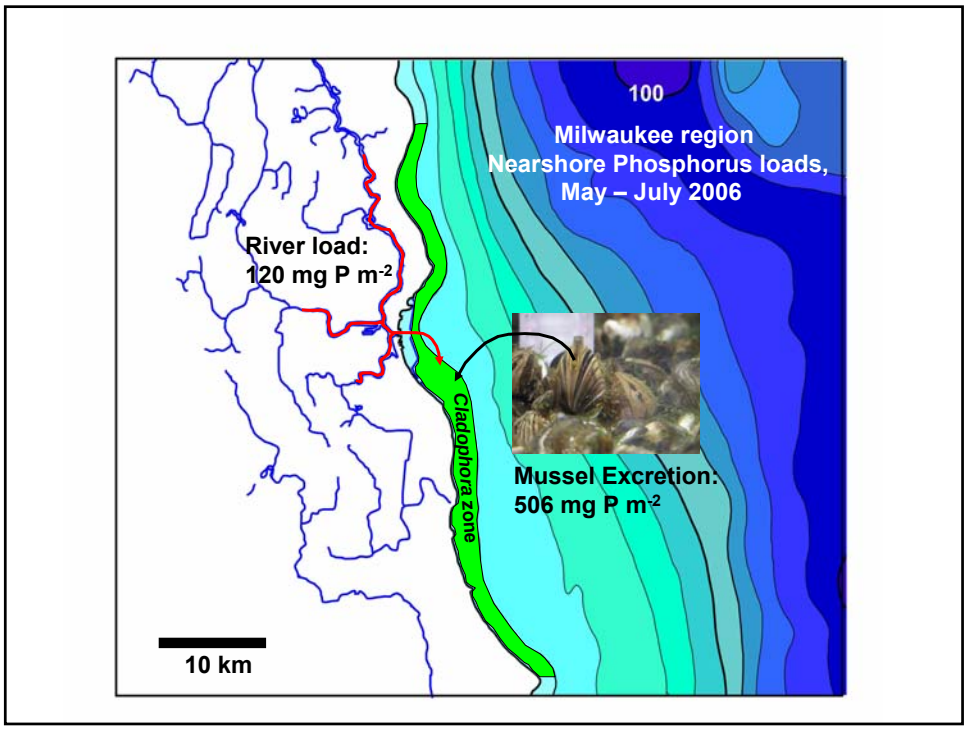
infotrek.er.usgs.gov/.../ milwaukeemap.gif



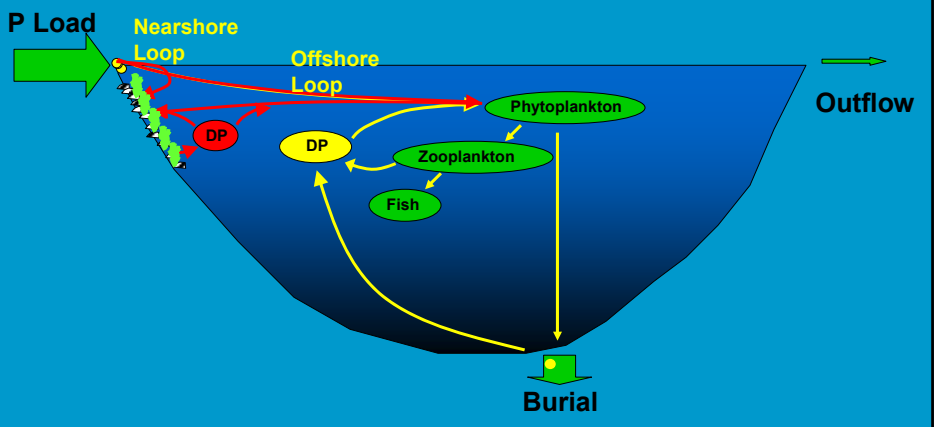
Milwaukee River TP Concentrations have increased in late spring.


Milwaukee River Discharge
1982-87
Avg. = 18.4
1988-95
Avg. = 13.1
1996-2001
Avg. = 14.3
m3 s-1
J F M A M J J A S O N D
Annual Means
1981
1986
1991
1996
2001
Data source: USGS

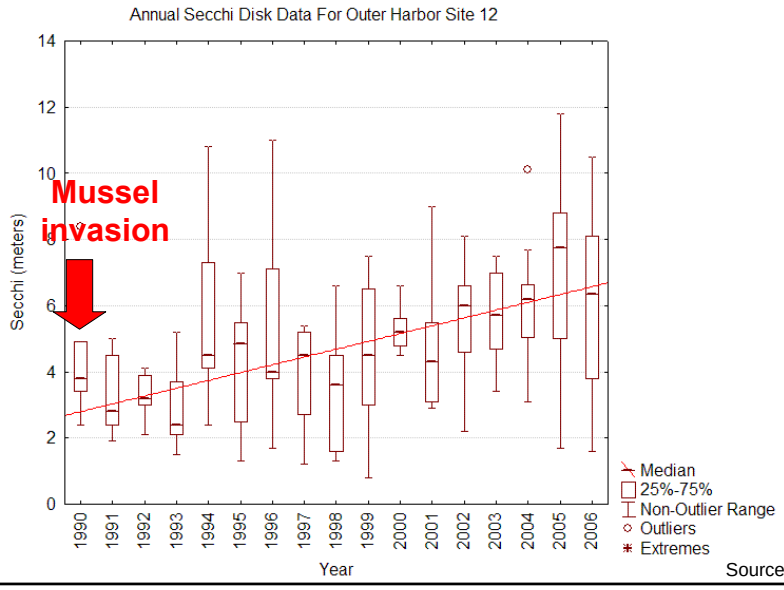



100
Milwaukee region
Nearshore Phosphorus loads,
May – July 2006
River load:
120 mg P m-2
Cladophora zone
Mussel Excretion:
506 mg P m-2
10 km

The Lake Michigan Phosphorus Cycle



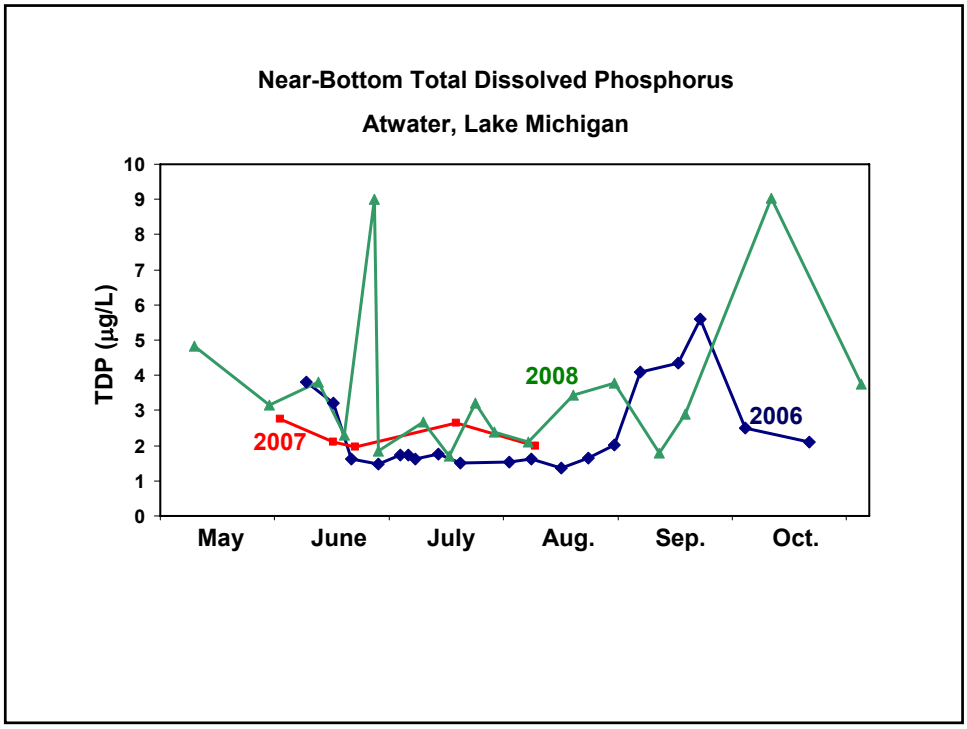
Mussels have made nearshore water clear

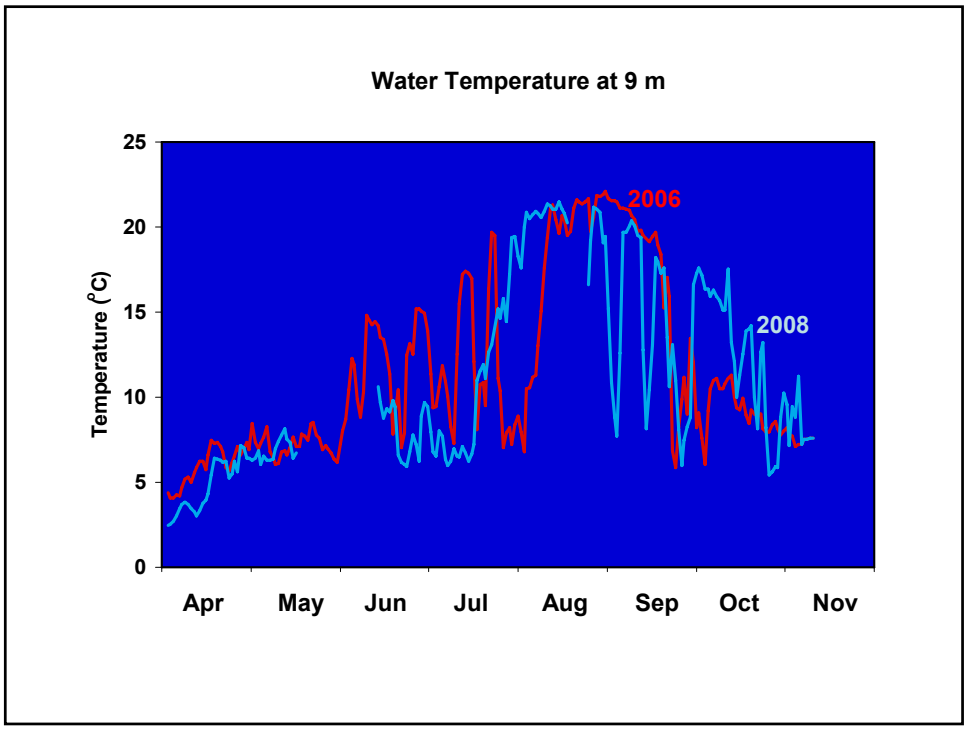


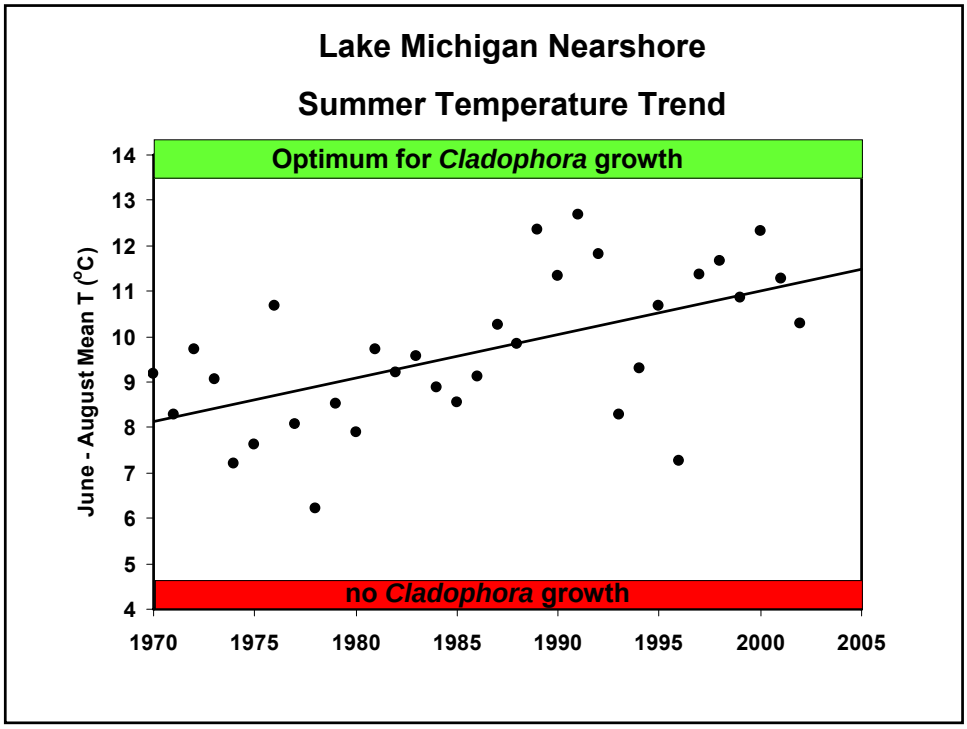
Source: MMSD

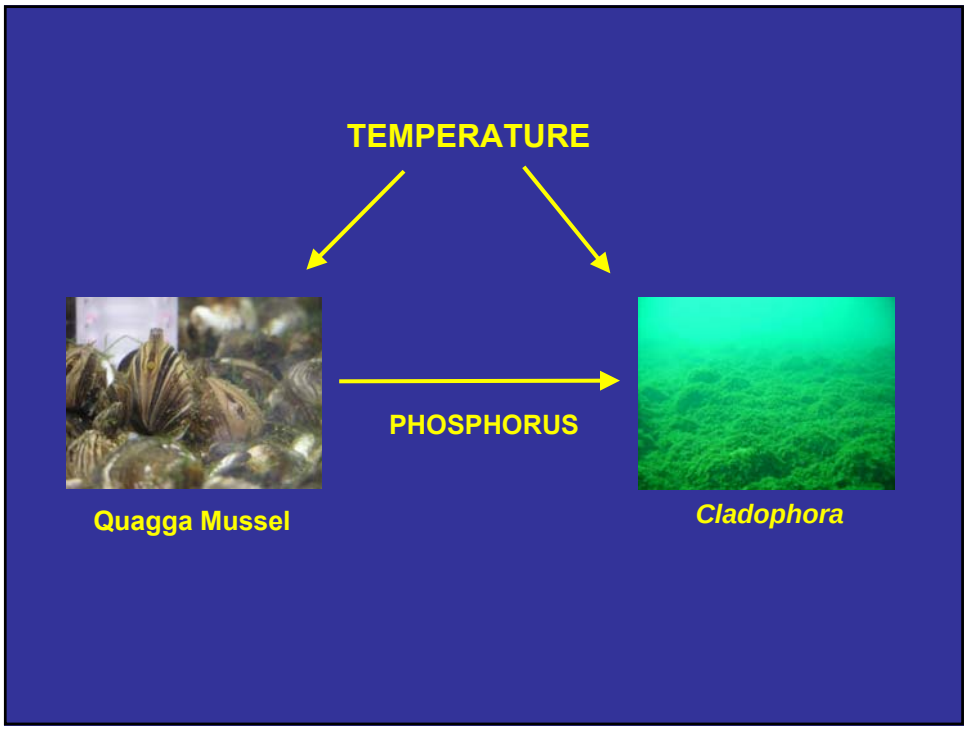

November 2007


November 2008


Near-Bottom Total Dissolved Phosphorus
Atwater, Lake Michigan
TDP (µg/L)
10
9
8
7
6
5
4
3
2
1
0
2008
2006
2007
May
June
July
Aug.
Sep.
Oct.

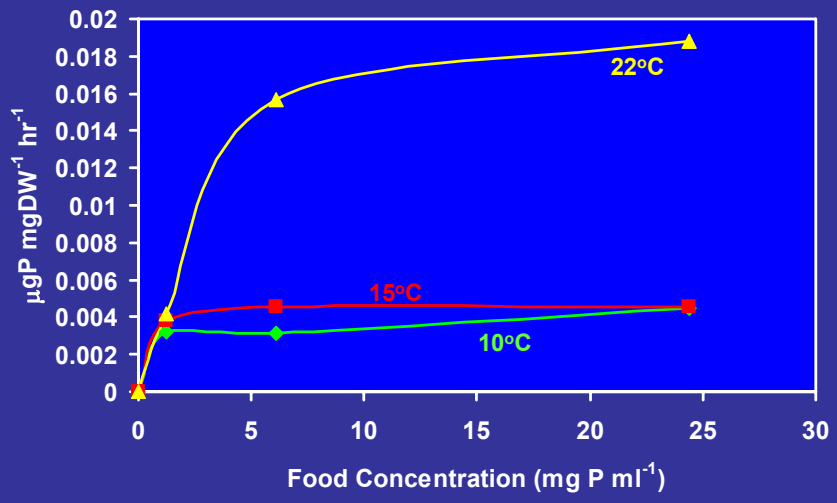

Water Temperature at 9 m
Temperature (°C)
25
20
15
10
5
0
2006
2008
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

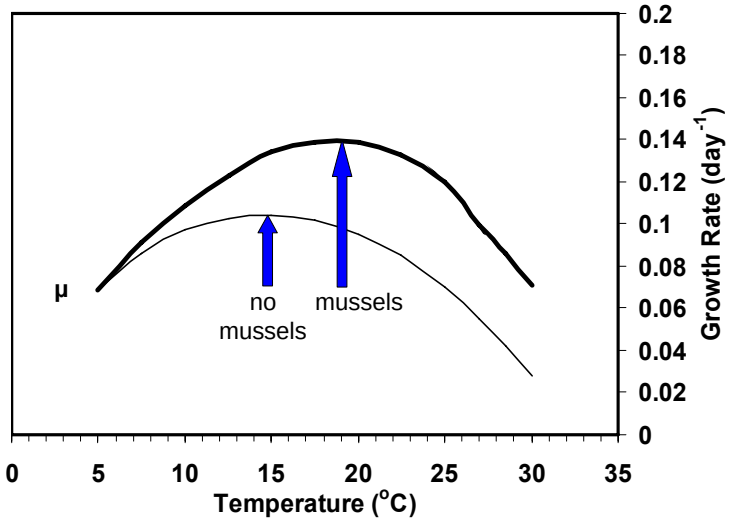

Lake Michigan Nearshore
Summer Temperature Trend
Optimum for *Cladophora* growth
no *Cladophora* growth
June - August Mean T (°C)
14
13
12
11
10
9
8
7
6
5
4
1970
1975
1980
1985
1990
1995
2000
2005


TEMPERATURE
PHOSPHORUS
Quagga Mussel
Cladophora

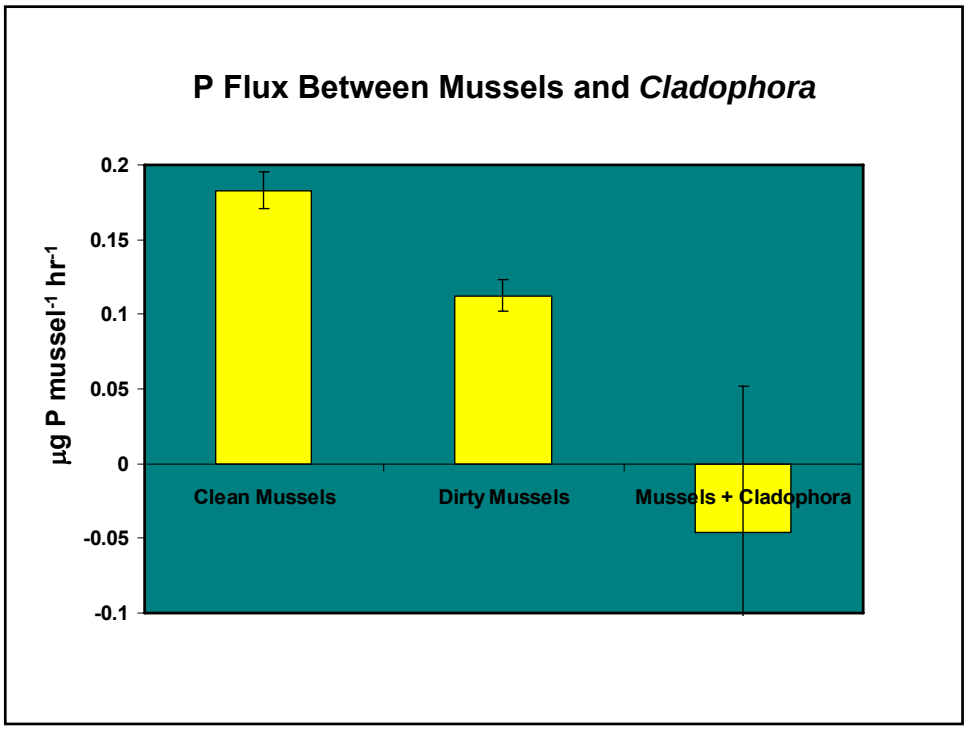
Lab Experiments:

Phosphorus Excretion by Quagga Mussels





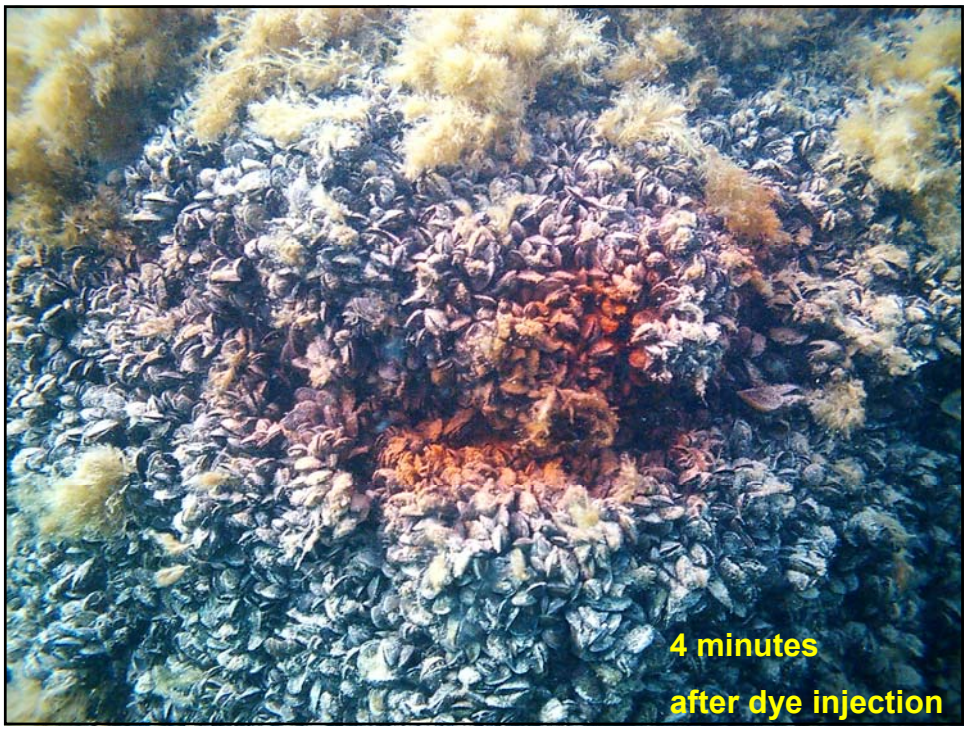
LIGHT ?

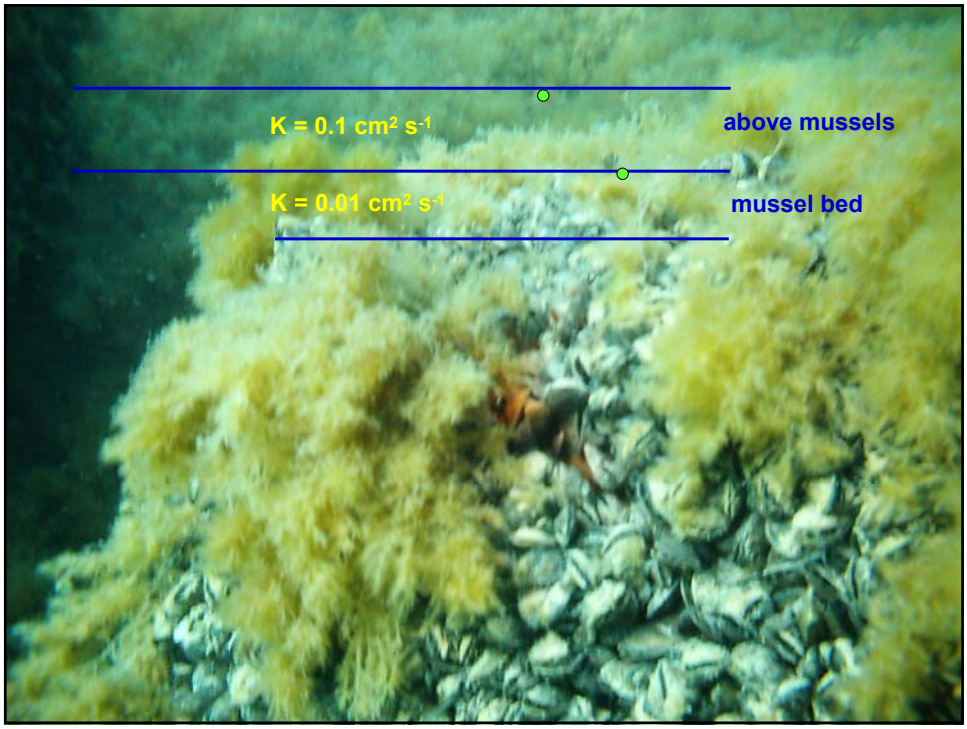

P Flux Between Mussels and *Cladophora*
µg P mussel-1 hr-1
0.2
0.15
0.1
0.05
0
-0.05
-0.1
Clean Mussels
Dirty Mussels
Mussels + Cladophora

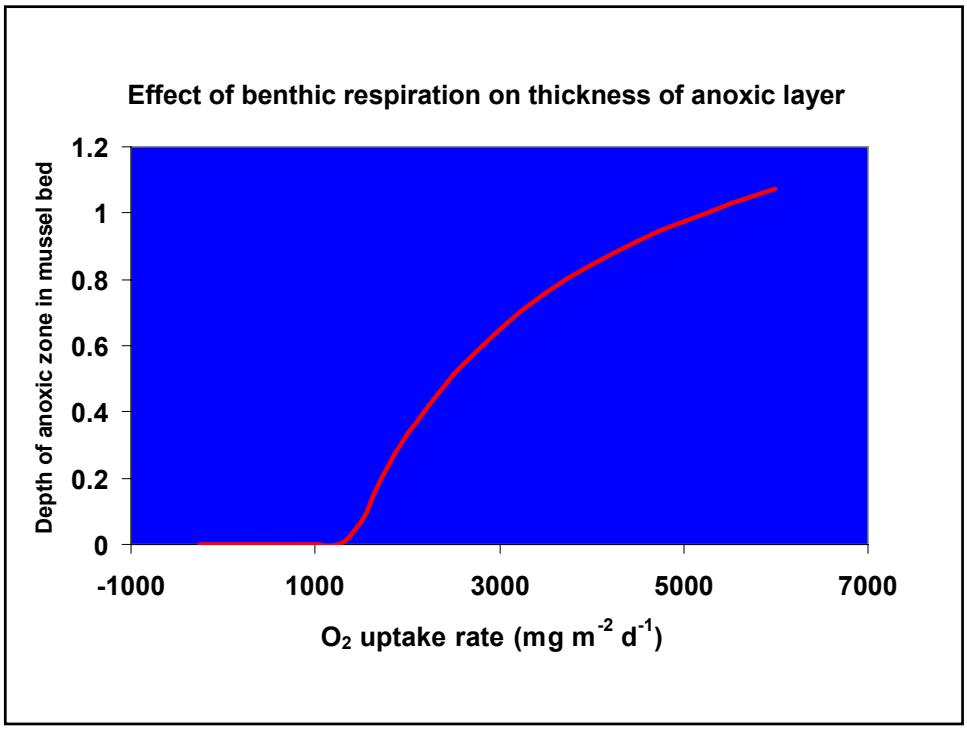
Current Needs

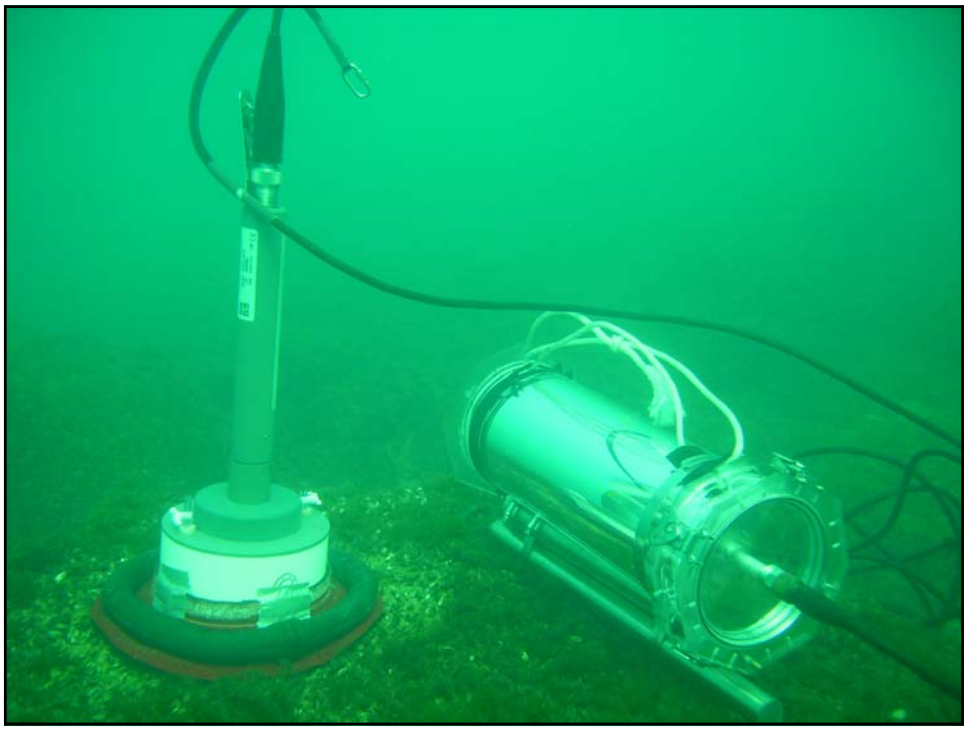
3. What is the botulism mechanism?

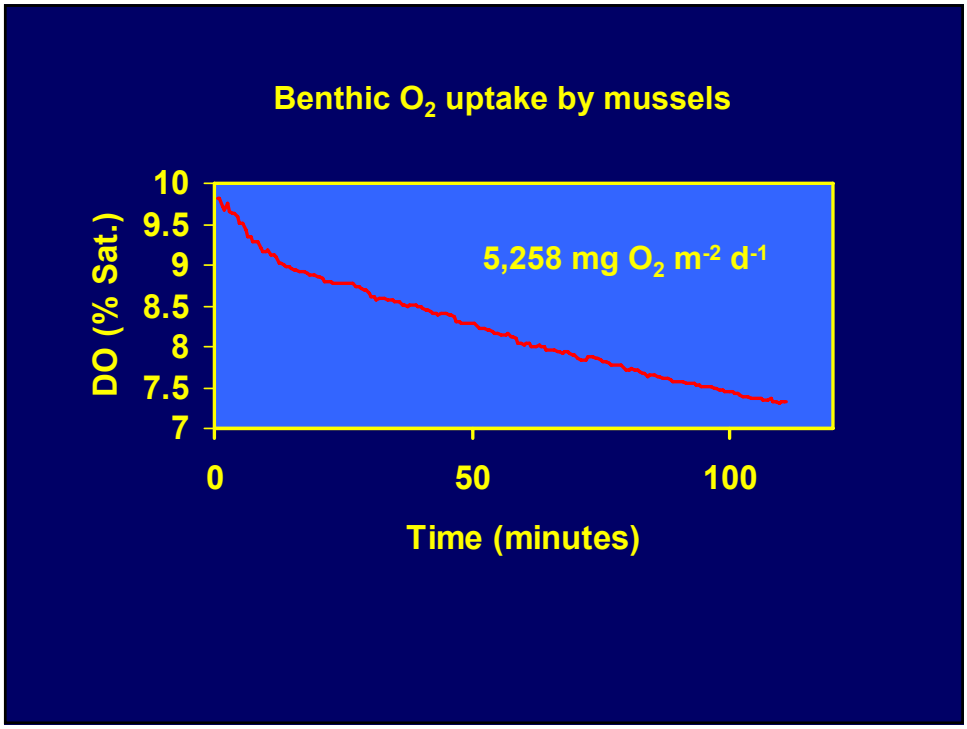
Photo: Alice Van Zoeren

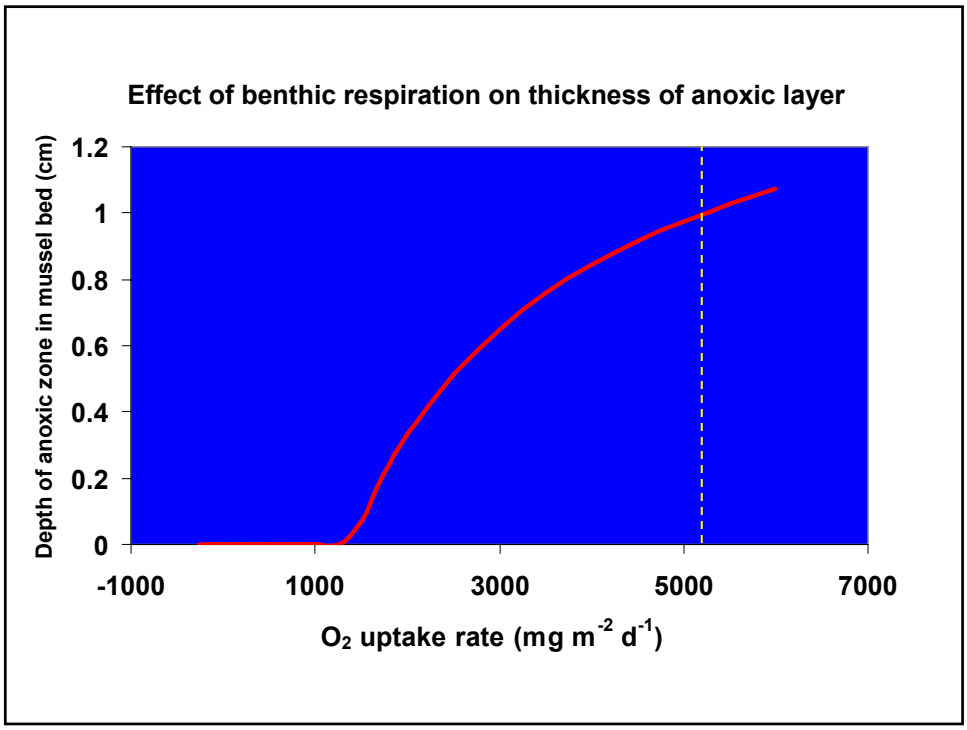

4 minutes
after dye injection

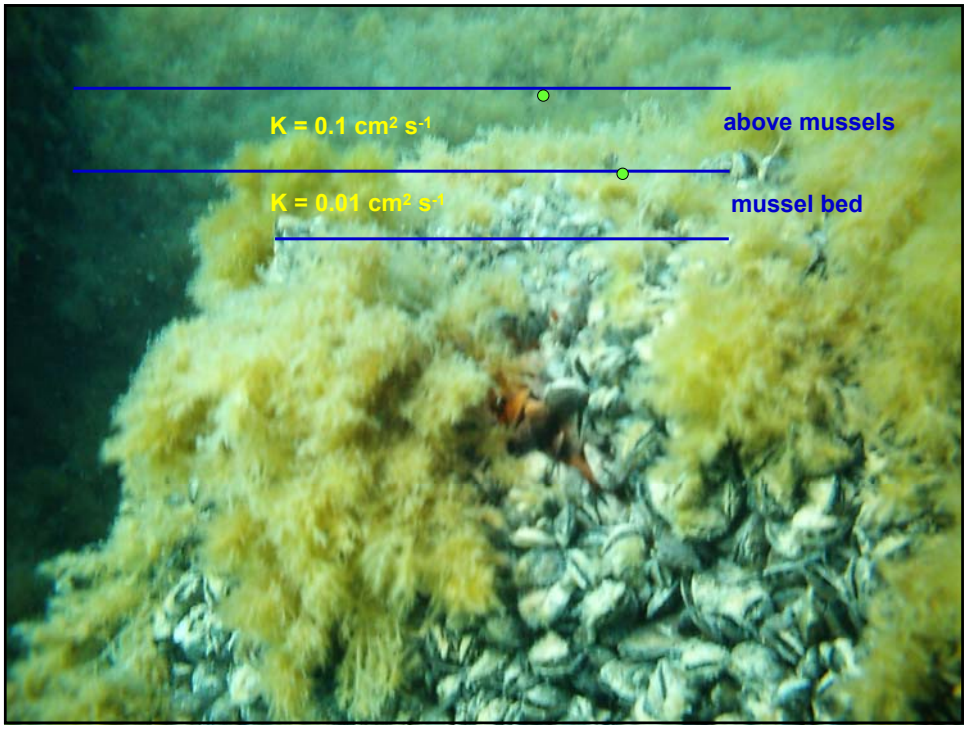

K = 0.1 cm² s⁻¹
above mussels
K = 0.01 cm² s⁻¹
mussel bed

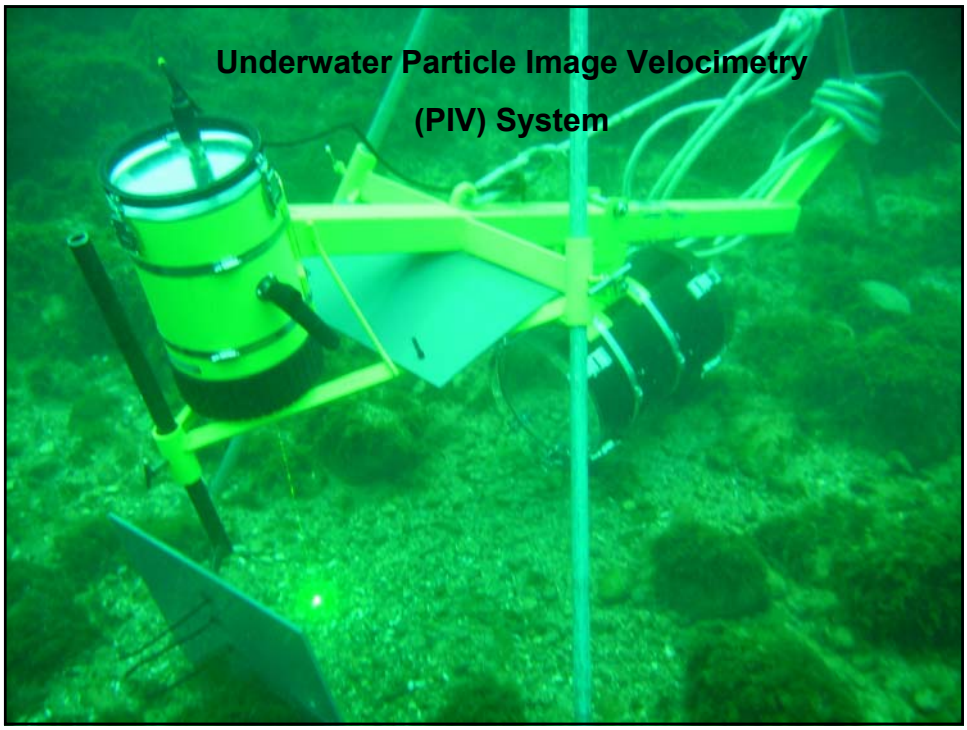

Effect of benthic respiration on thickness of anoxic layer
Depth of anoxic zone in mussel bed
1.2
1
0.8
0.6
0.4
0.2
0
-1000
1000
3000
5000
7000
O2 uptake rate (mg m-2 d-1)

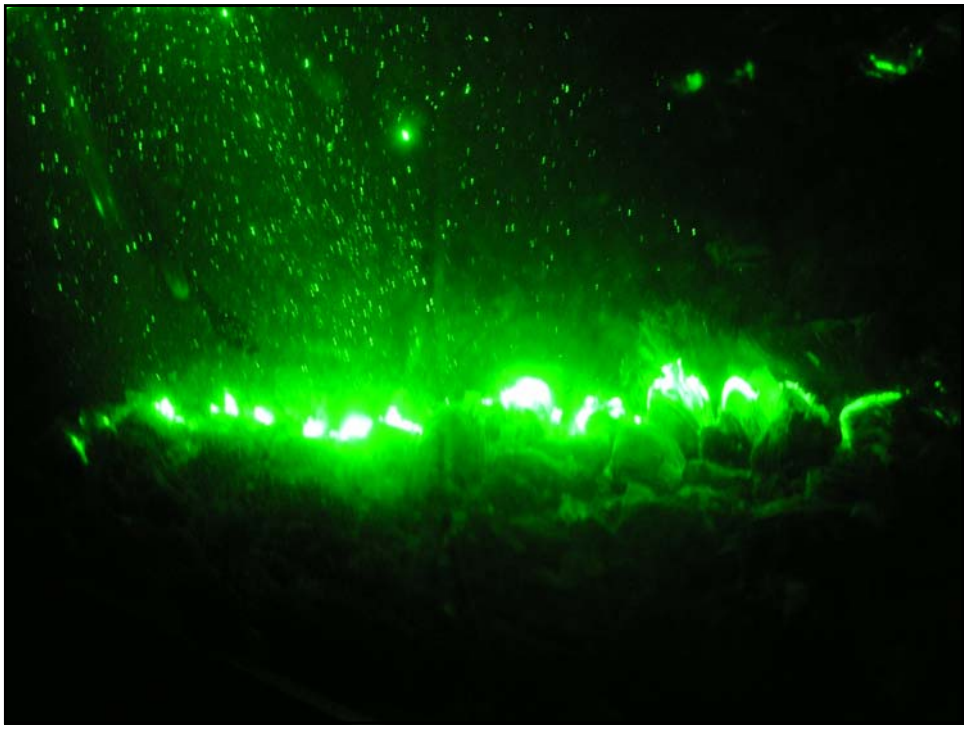



Benthic O_2 uptake by mussels
DO (% Sat.)
10
9.5
9
8.5
8
7.5
7
5,258 mg O_2 m^{-2} d^{-1}
0
50
100
Time (minutes)

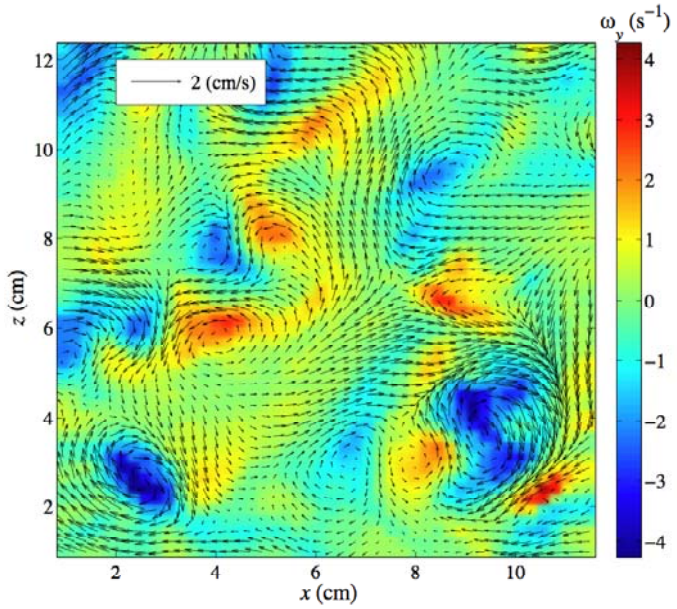

Effect of benthic respiration on thickness of anoxic layer
Depth of anoxic zone in mussel bed (cm)
1.2
1
0.8
0.6
0.4
0.2
0
-1000
1000
3000
5000
7000
O_2 uptake rate (mg m^{-2} d^{-1})


K = 0.1 cm² s⁻¹
above mussels
K = 0.01 cm² s⁻¹
mussel bed

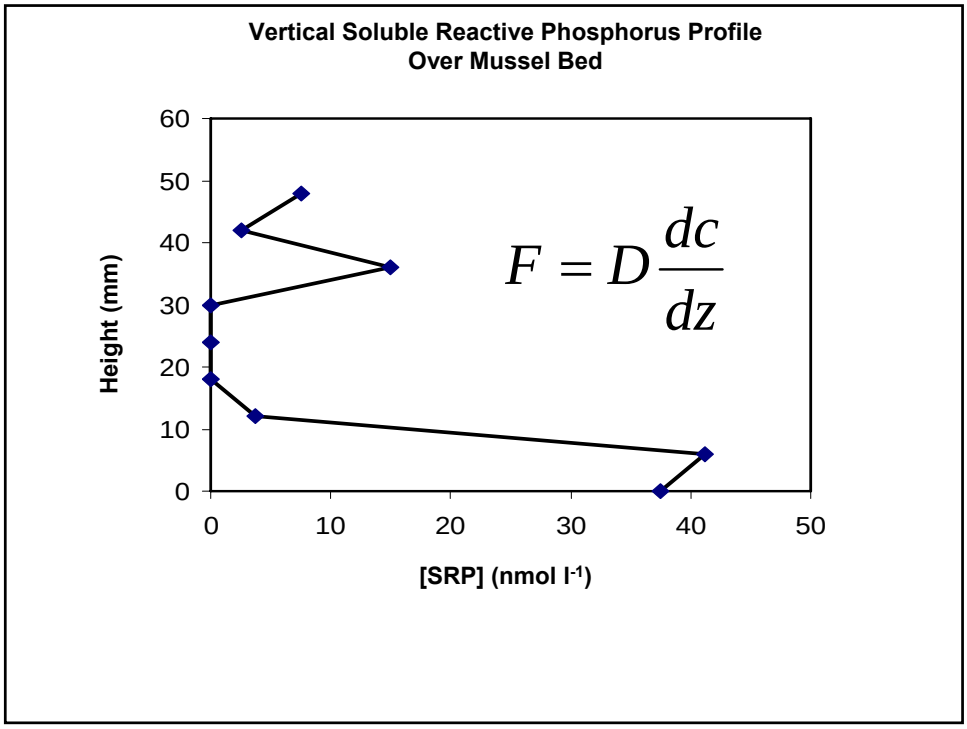

Underwater Particle Image Velocimetry
(PIV) System



PIV Image Analysis Results



Qian and Bootsma, in press



The *Cladophora* Solution


Bruce Mozert / University of Florida Press