Is there a threat of cyanobacteria to water or habitat quality in the Lower Columbia River?

Science Work Group meeting

April 23, 2013

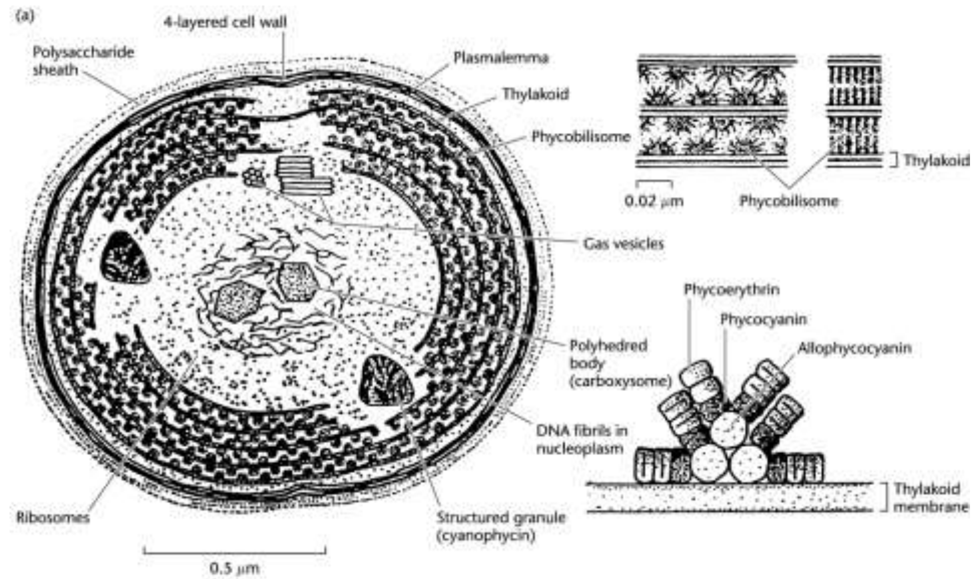
Topics

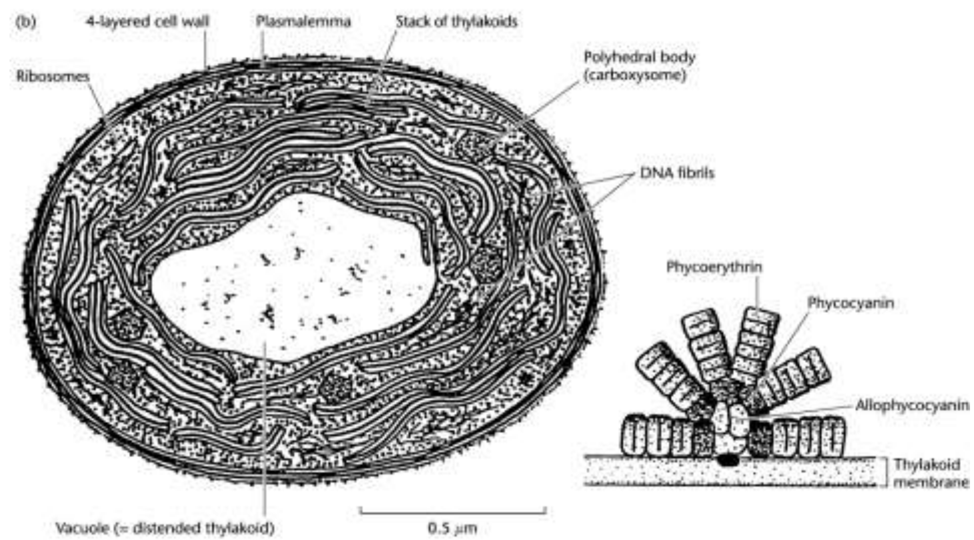
- Cyanobacteria – brief introduction
- Cyanobacteria, cyanotoxins, and water quality
- Do cyanobacteria pose a threat to ecosystems of the lower Columbia River?

Cyanophyceae

- Bacteria
- Chlorophyll, but no chloroplasts
- *Synechococcus*: Phycocyanin, Phycoerythrin, allophycocyanin
- *Prochlorococcus*: divinyl chlorophyll b
- Cell wall of murein

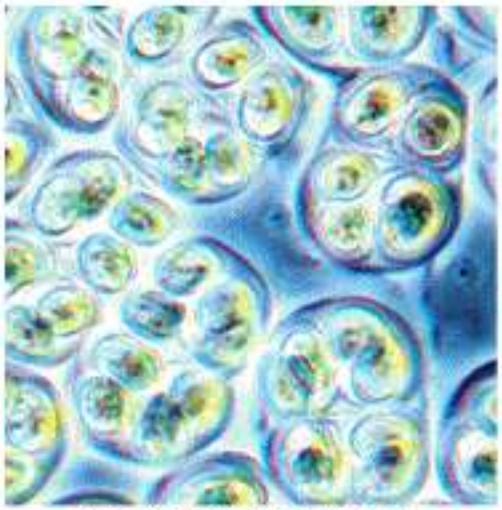
Synechococcus sp.





Prochlorococcus marinus

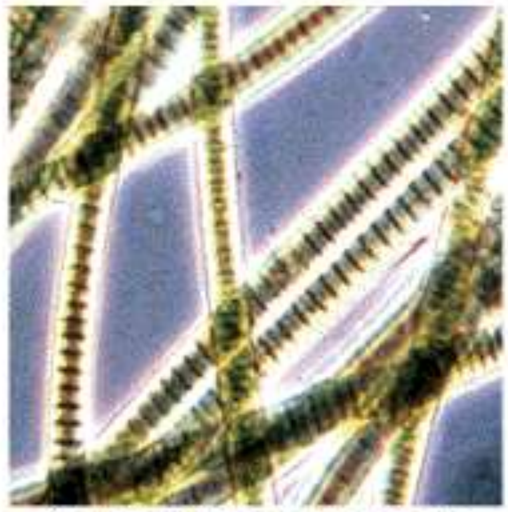
Diversity among the cyanobacteria



© R. Knauft/Biology Media/ Photo Researchers, Inc.

5 μm

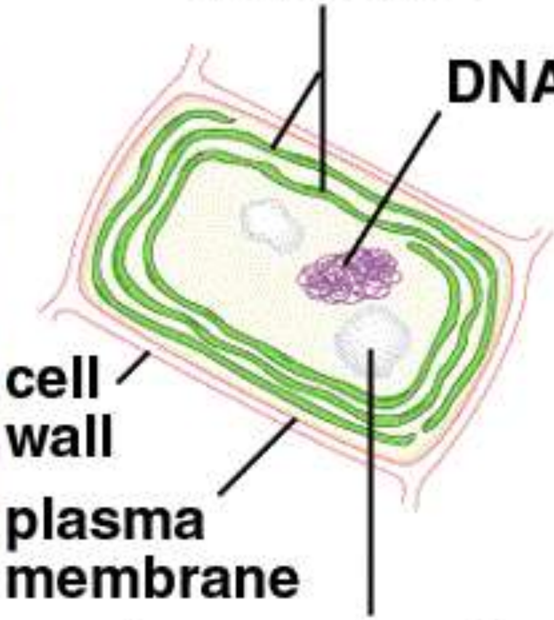
a. *Gloeocapsa*



© Eric Grave/Photo Researchers, Inc.

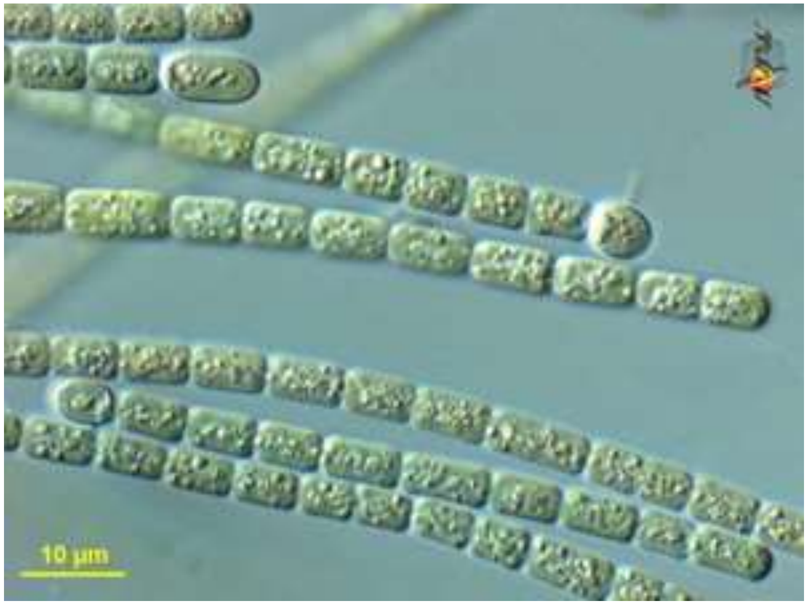
50 μm

b. *Oscillatoria*



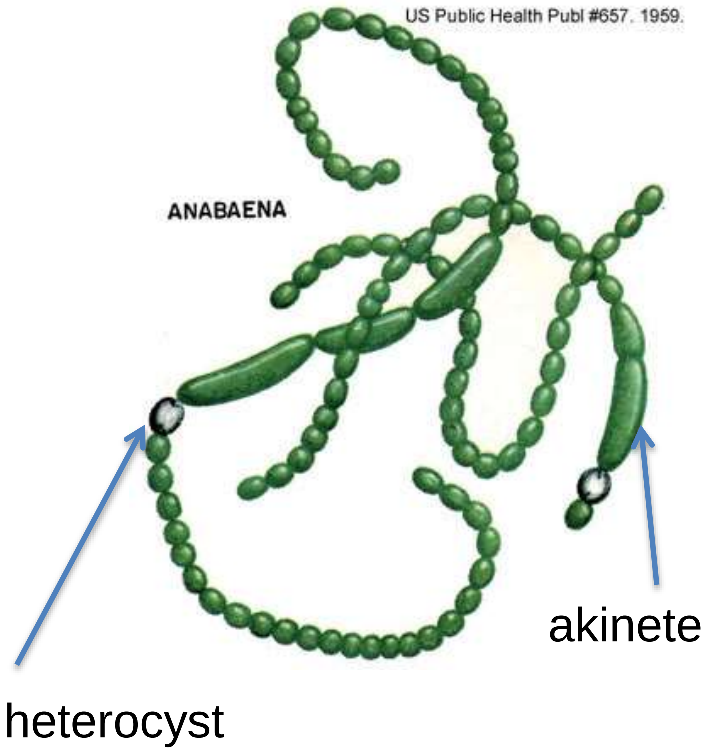
c. *Oscillatoria cell*

Cyanobacteria



http://serc.carleton.edu/details/images/2698.html

http://www.tutorvista.com



http://www.water.nsw.gov.au

Cyanotoxins

- At least 46 species of cyanobacteria produce toxins harmful to vertebrates, including *Microcystis, Anabaena, Aphanizomenon, Lyngbya, Nodularia, Planktothrix, Nostoc*, and *Cylindrospermopsis*(Chorus and Bartrum 1999)

- Hepatotoxins (affect the liver): produced by some strains of the cyanobacteria *Microcystis*, *Anabaena*, *Oscillatoria, Nodularia, Nostoc, Cylindrospermopsis* and *Umezakia*

- Neurotoxins (affect the nervous system): produced by some strains of *Aphanizomenon* and *Oscillatoria*

- Toxic alkaloids (gastrointestinal symptoms or kidney disease) *Cylindrospermopsis raciborski*

- Not all cyanobacteria of these species form toxins and it is likely that there are as yet unrecognized toxins.

Harmful Algae Blooms
- Algae Bloom Advisories
- Advisory Archive
- Frequently Asked Questions
- Program Guidelines
- Education and Outreach
- Partners

Algae Bloom Advisories

The 2012 algae bloom season

With the cool weather at the beginning of summer, we didn't have our first 2012 blue-green algae advisory until mid-July. Although we still have some advisories in place, we can expect to see the last remnants of summer disappear in the next couple of months.

With the change in seasons, exposure to harmful algae blooms declines due in part to the change in our recreational activities. Swimming, water skiing, tubing and other water activites shift to fall and winter fishing, hiking and hunting. if you participate in these activities, especially with your pet, we recommend you continue to be vigilant about potential exposure to waters that look suspicious - foamy, scummy, thick like paint, pea-green, blue-green or brownish red.

Get Advisory Notices
Subscribe to Email Alerts
View Recreational Advisories
Contact Us
Harmful Algae Bloom Surveillance Program

This year we had nine advisories, which is about half the number of advisories in recent years. The primary reason for the decrease was the decision by some waterbody managers to perform toxin testing when a bloom was first identified, and throughout the bloom lifecycle. This testing provided 'actual' toxin and exposure data rather than 'potential' for exposure to toxins that may or may not have been present at harmful levels.

When initial toxin data showed that health advisory guidelines for recreational waters were not exceeded and therefore not harmful to human health, no advisory was issued. This allowed the public to enjoy a lake or reservoir even though a bloom was present. When initial toxin testing was not performed, advisories were issued if lab analysis identified blue-green algae cell counts, among potentially toxigenic species, that were over guidelines for recreational waters. Remember, only a fraction of Oregon's waterbodies are monitored, so **when in doubt, stay out!**

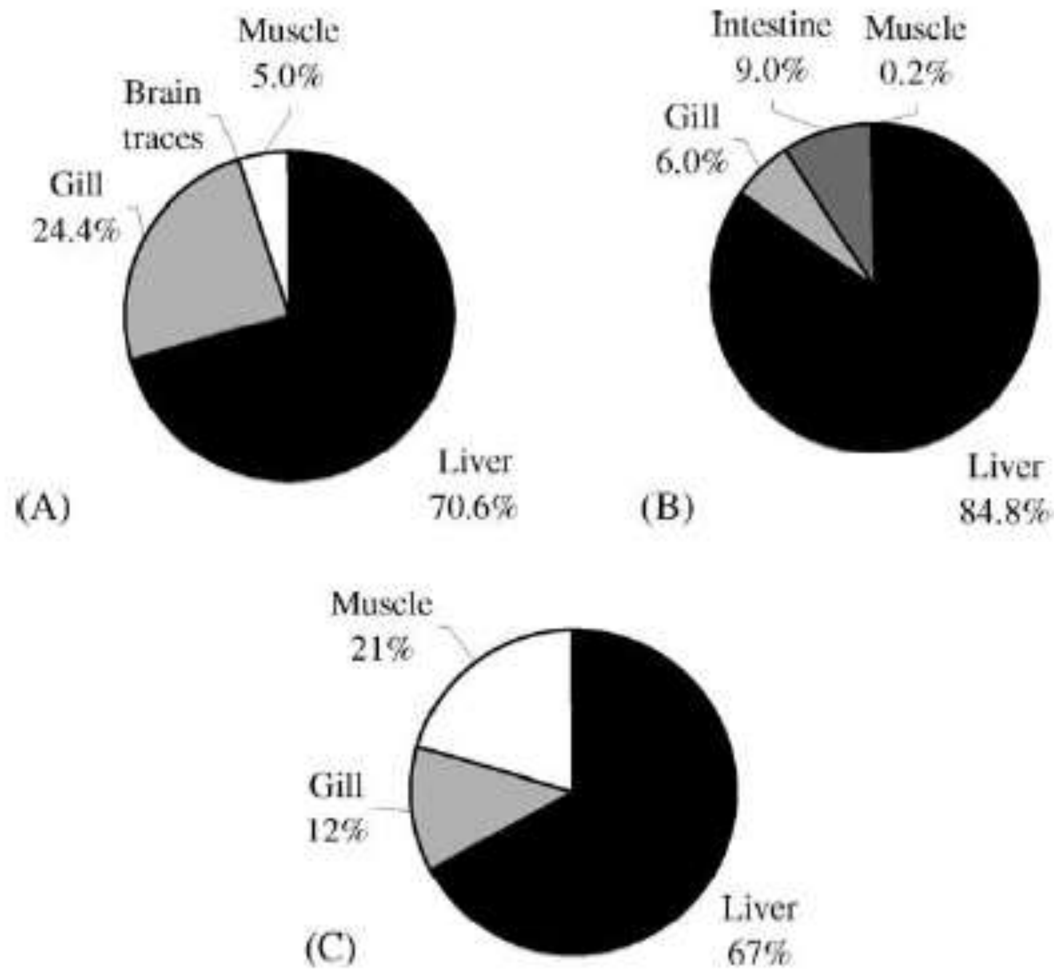
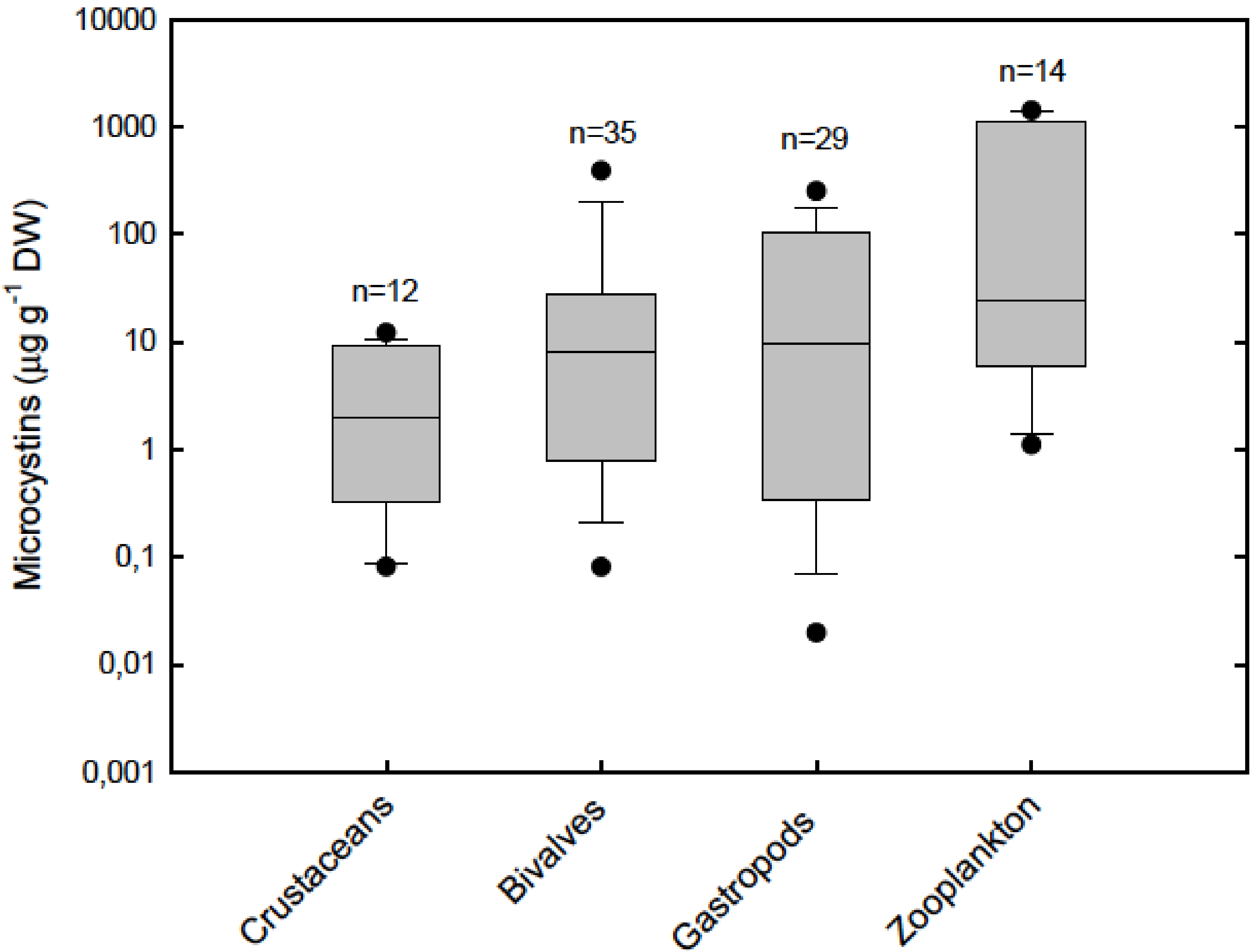


Fig. 1. Relative distribution of MC-RR in different tissues of fish: (A) *Jenynsia multidentata*, (B) *Corydoras paleatus* and (C) *Odontesthes bonariensis*.

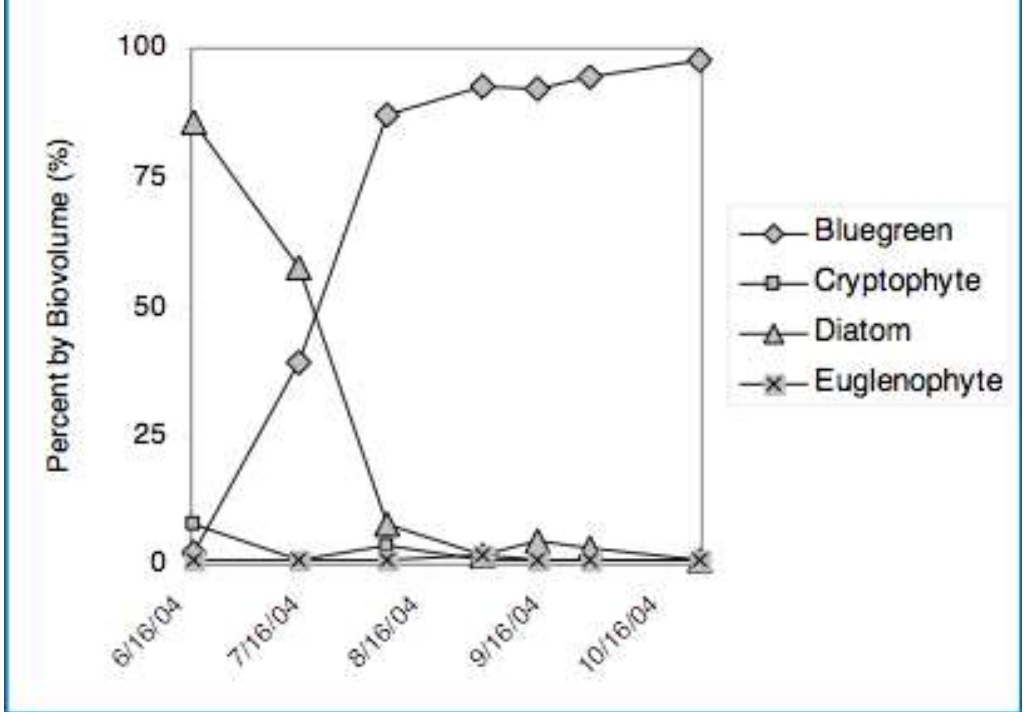
Cazenave et al., 2005

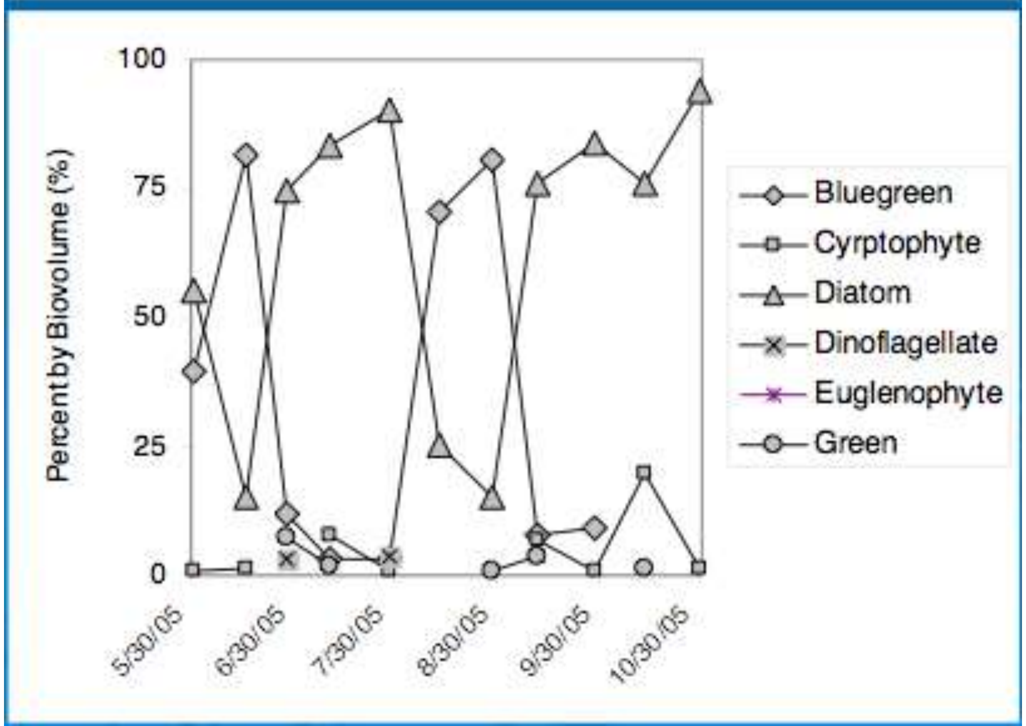
Microcystins accumulate in zooplankton



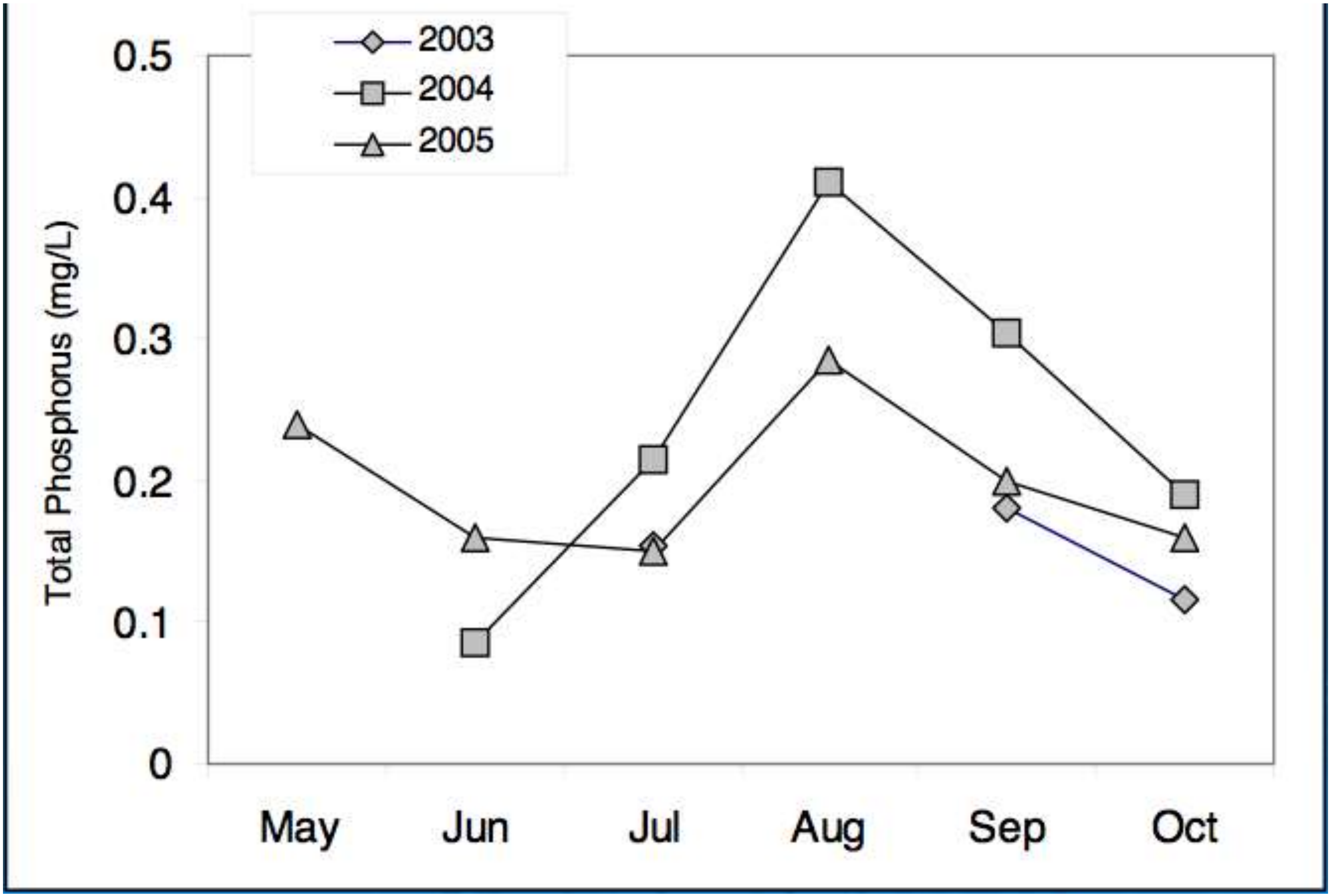
- Cyanotoxins can accumulate in zooplankton, upon which inverts feed
- higher mortality of *Chaoborus* (midge larvae) after preying on *Daphnia* fed toxic *Microcystis* than that fed non-toxic algae, suggesting that *Daphnia* transferred toxins from *Microcystis* to *Chaoborus* (Laurén-Määtä et al.)

Vancouver Lake, WA

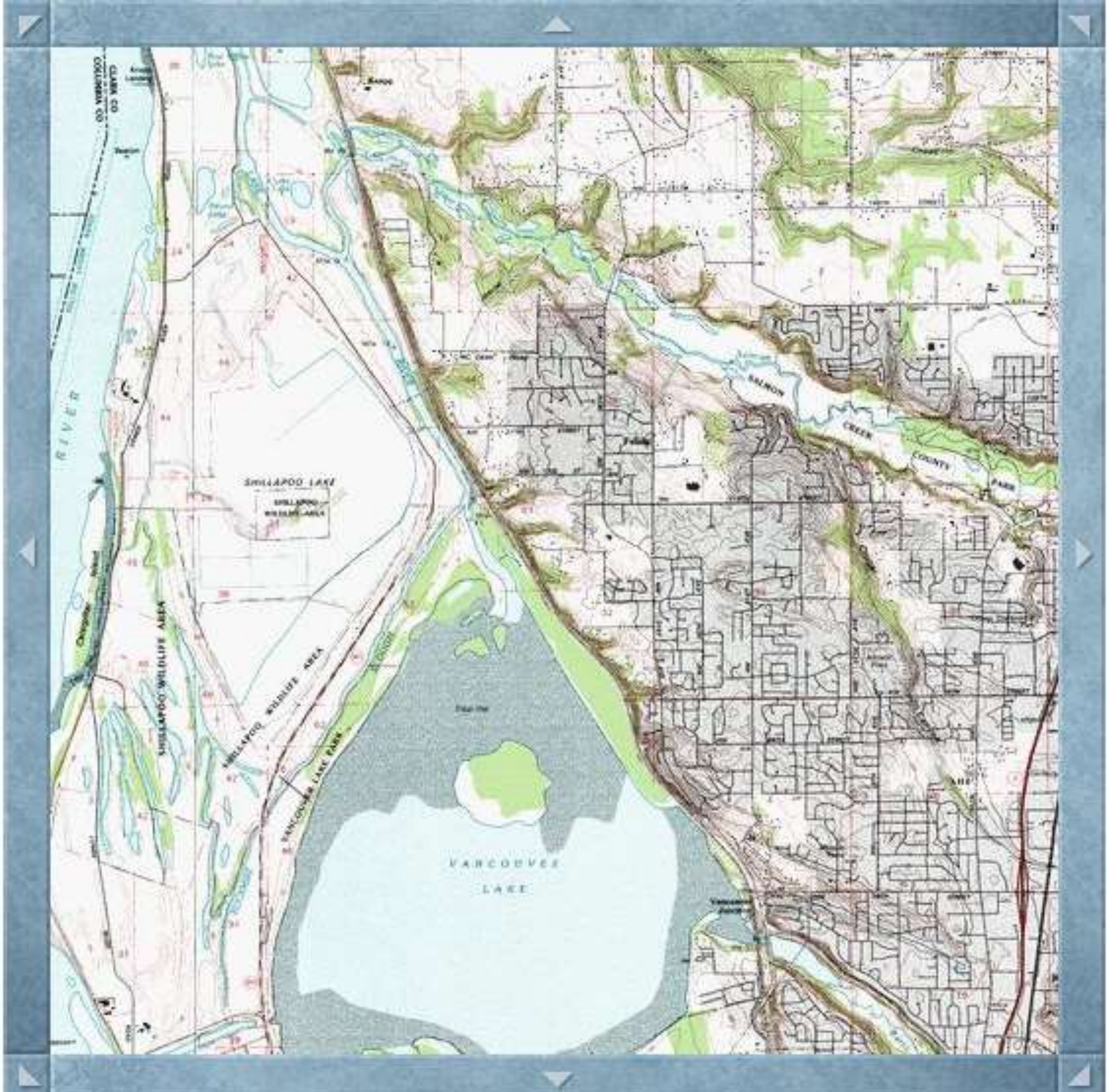




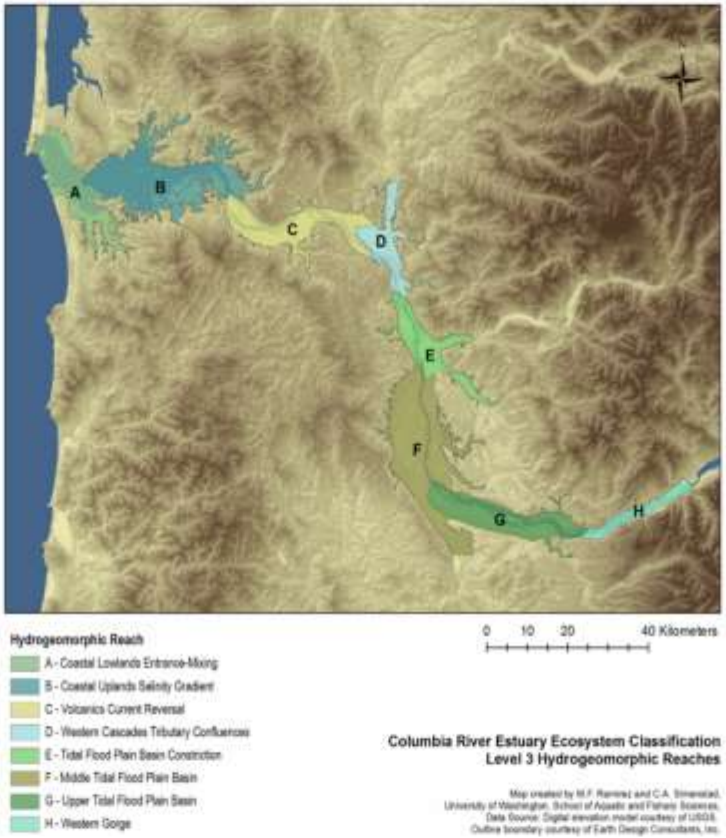
Wierenga, 2006

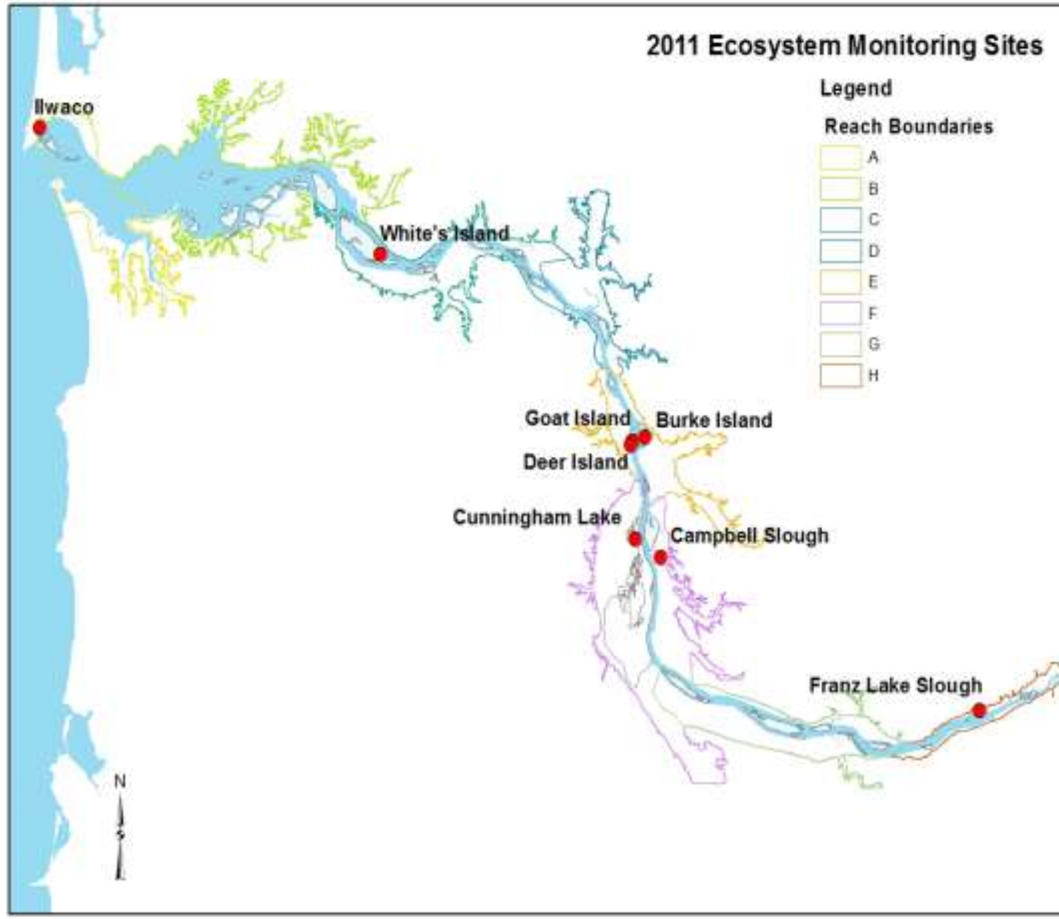


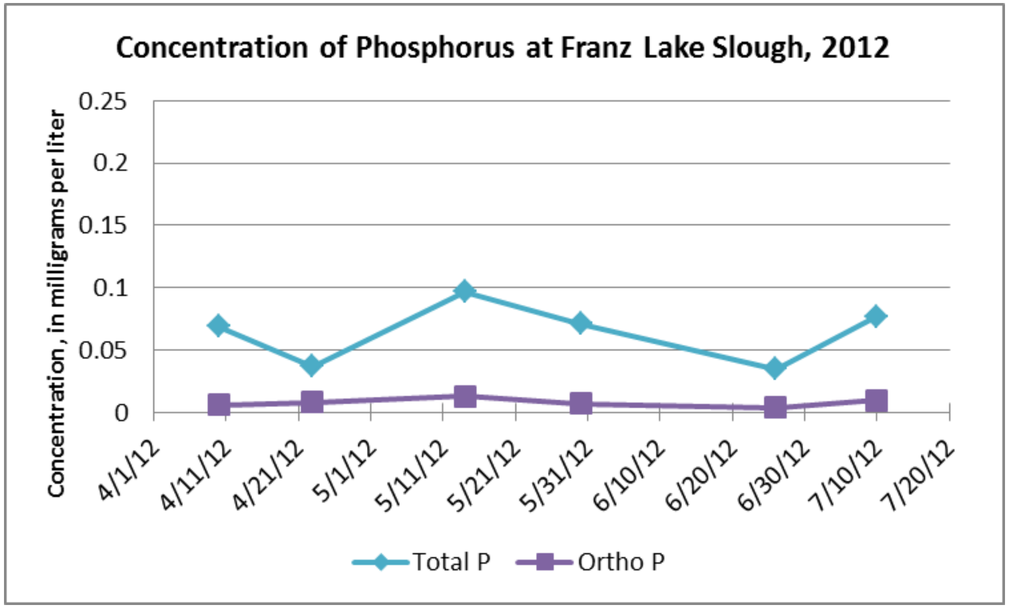
Wierenga, 2006

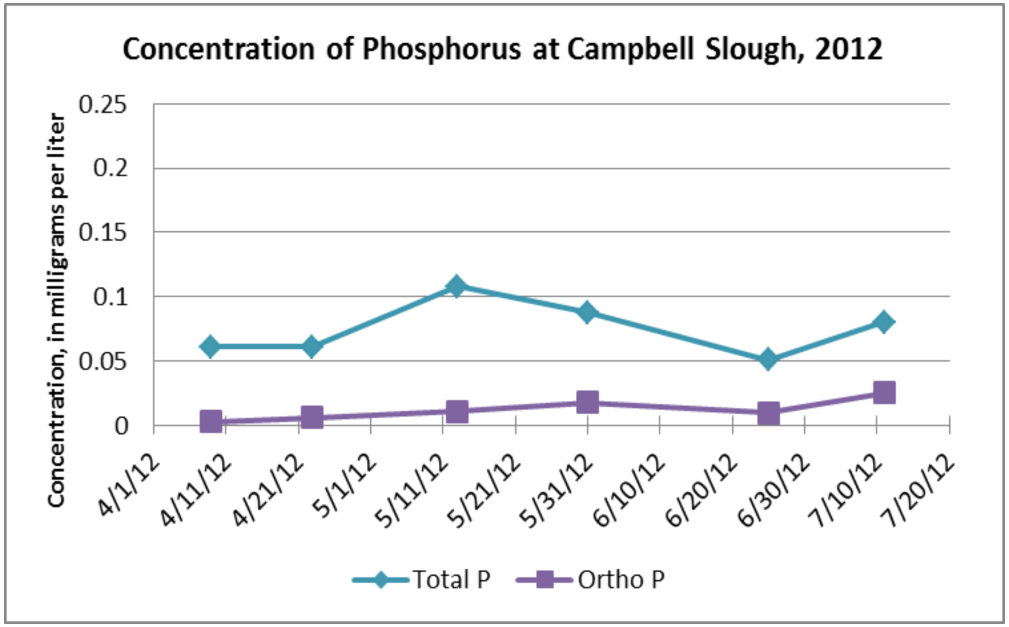


RIVER
SHILLAPOO LAKE
SHILLAPOO WILDLIFE AREA
SALMON
CREEK
COUNTY
PARK
VANCOUVER LAKE PARK
LAKE

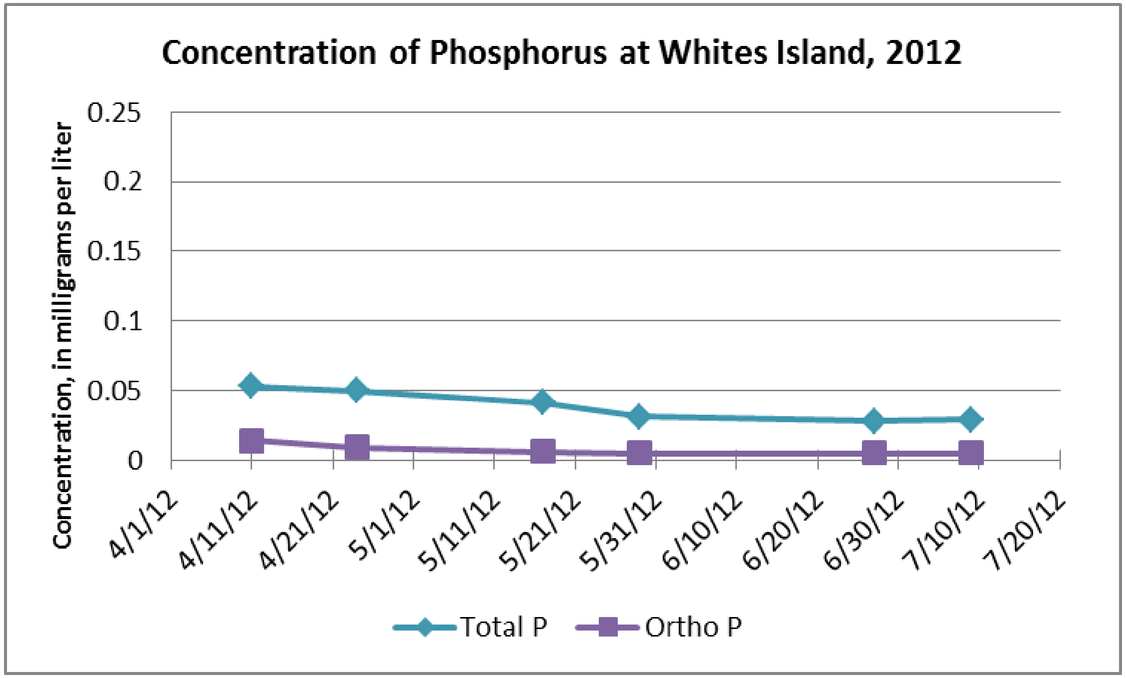

A
B
C
D
E
F
G
H
Hydrogeomorphic Reach
A - Coastal Lowlands Entrance-Mixing
B - Coastal Uplands Salinity Gradient
C - Volcanics Current Reversal
D - Western Cascades Tributary Confluences
E - Tidal Flood Plain Basin Constriction
F - Middle Tidal Flood Plain Basin
G - Upper Tidal Flood Plain Basin
H - Western Gorge
0 10 20 40 Kilometers
Columbia River Estuary Ecosystem Classification
Level 3 Hydrogeomorphic Reaches
Map created by M.F. Ramirez and C.A. Simenstad,
University of Washington, School of Aquatic and Fishery Sciences.
Data Source: Digital elevation model courtesy of USGS.
Outline boundary courtesy of Earth Design Consultants, Inc.

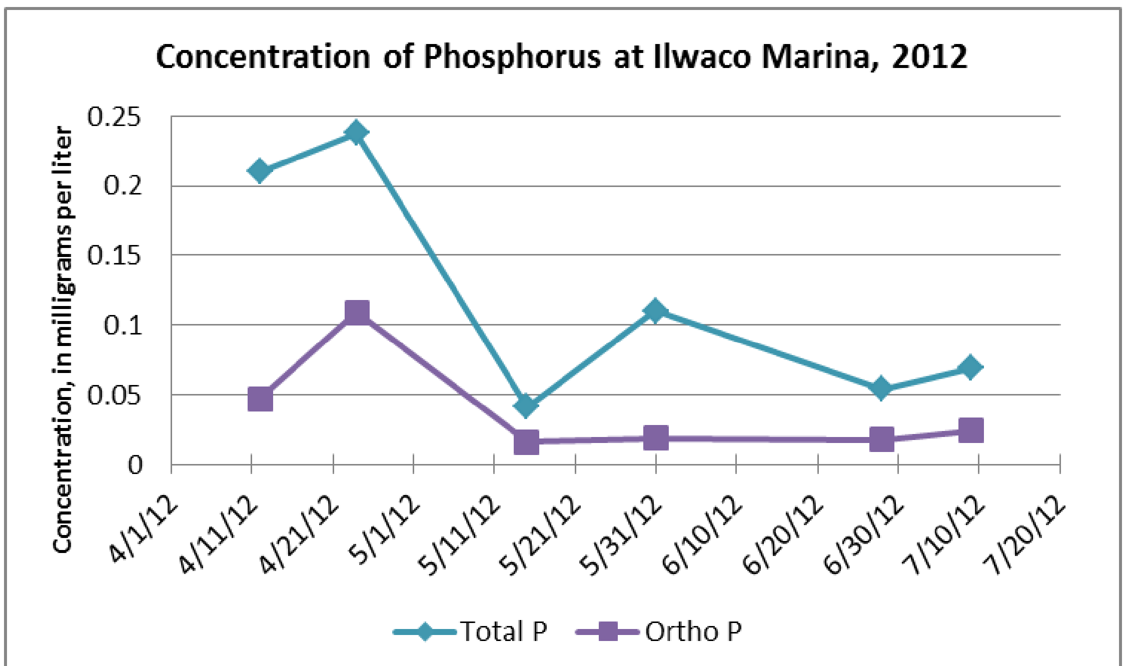

2011 Ecosystem Monitoring Sites
Legend
Reach Boundaries
A
B
C
D
E
F
G
H
Ilwaco
White's Island
Goat Island
Burke Island
Deer Island
Cunningham Lake
Campbell Slough
Franz Lake Slough
N



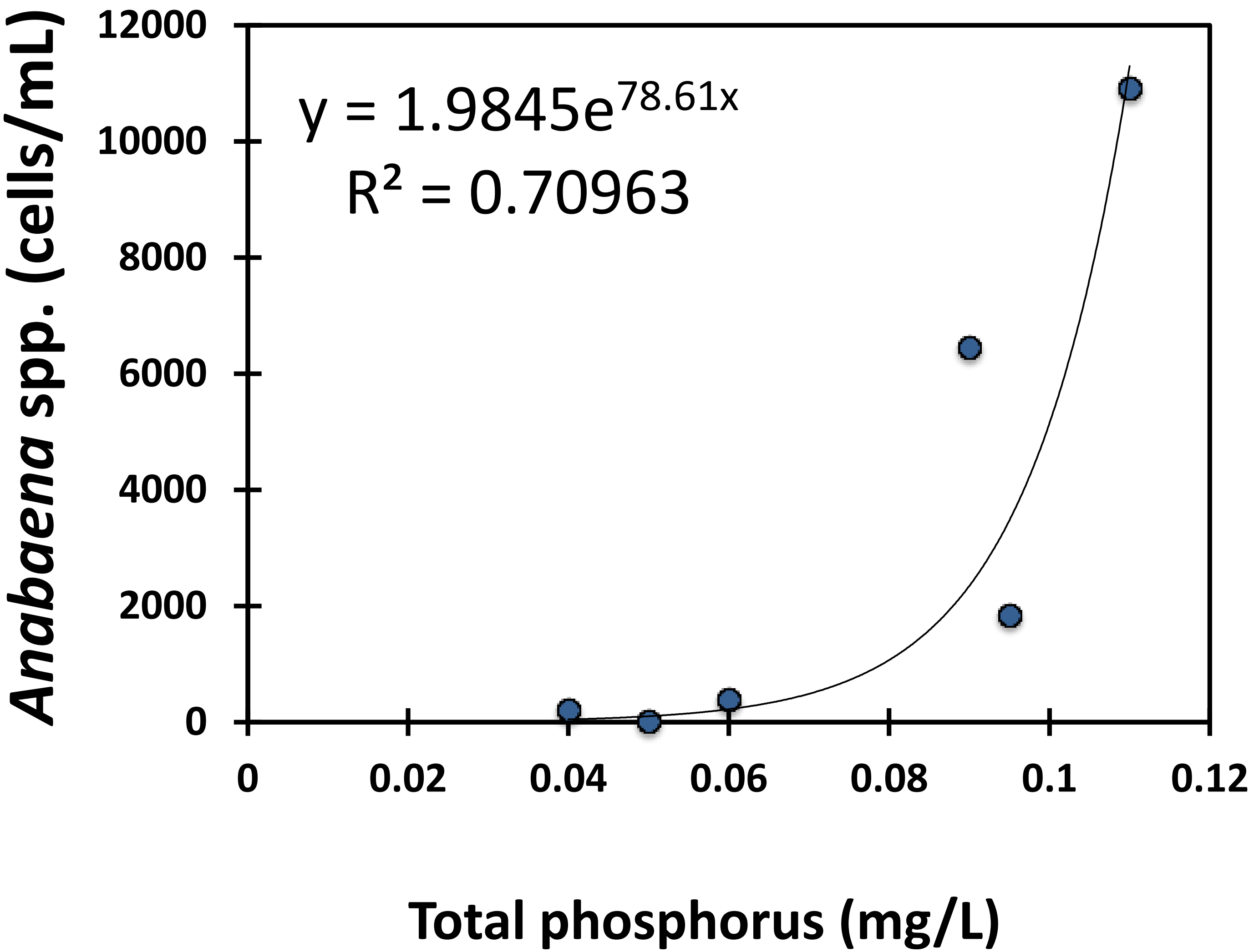


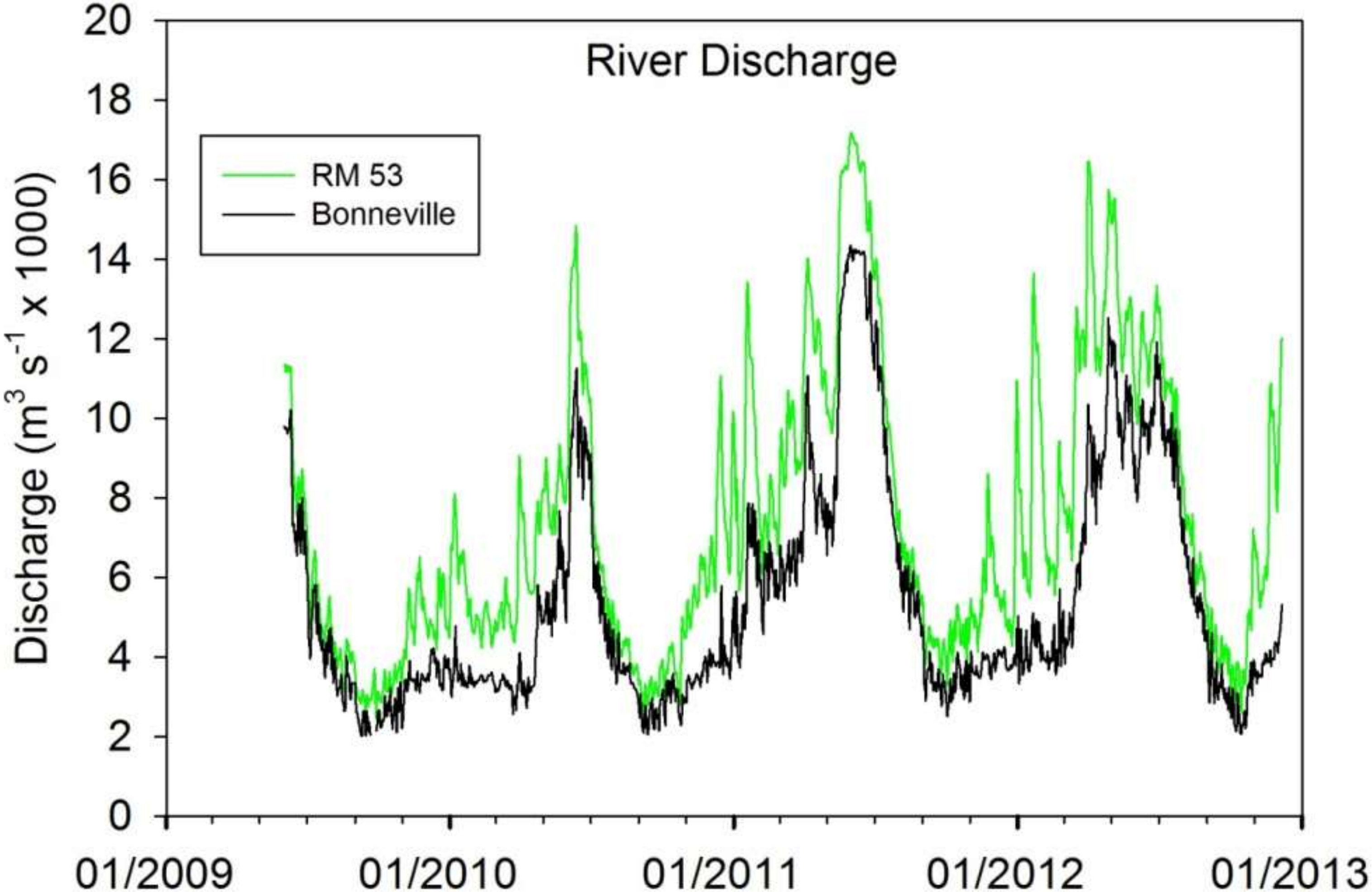
Whitney Temple and Jennifer Morace, USGS

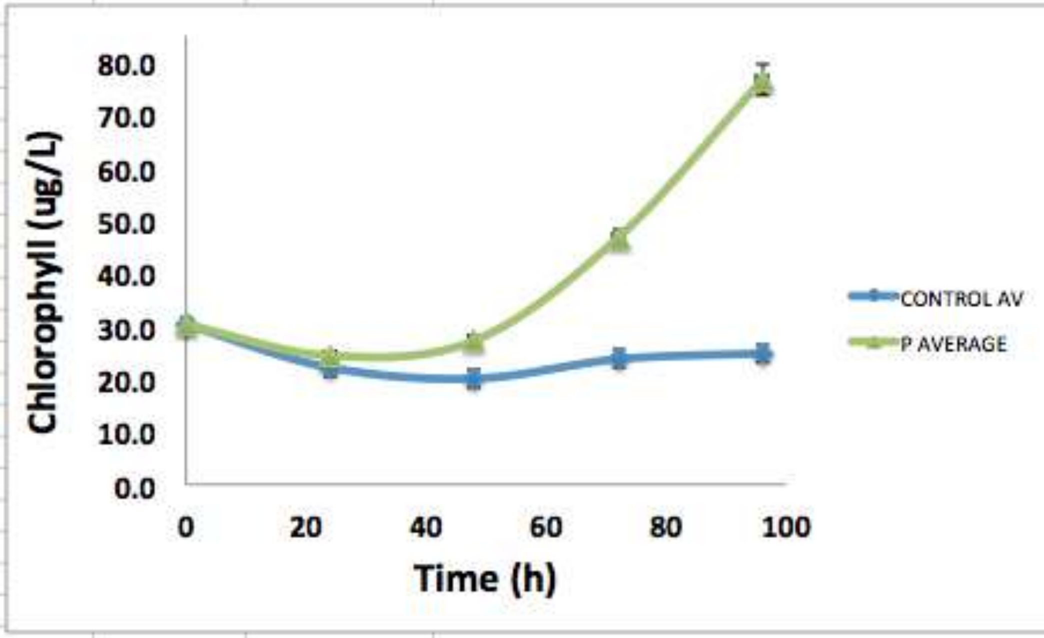




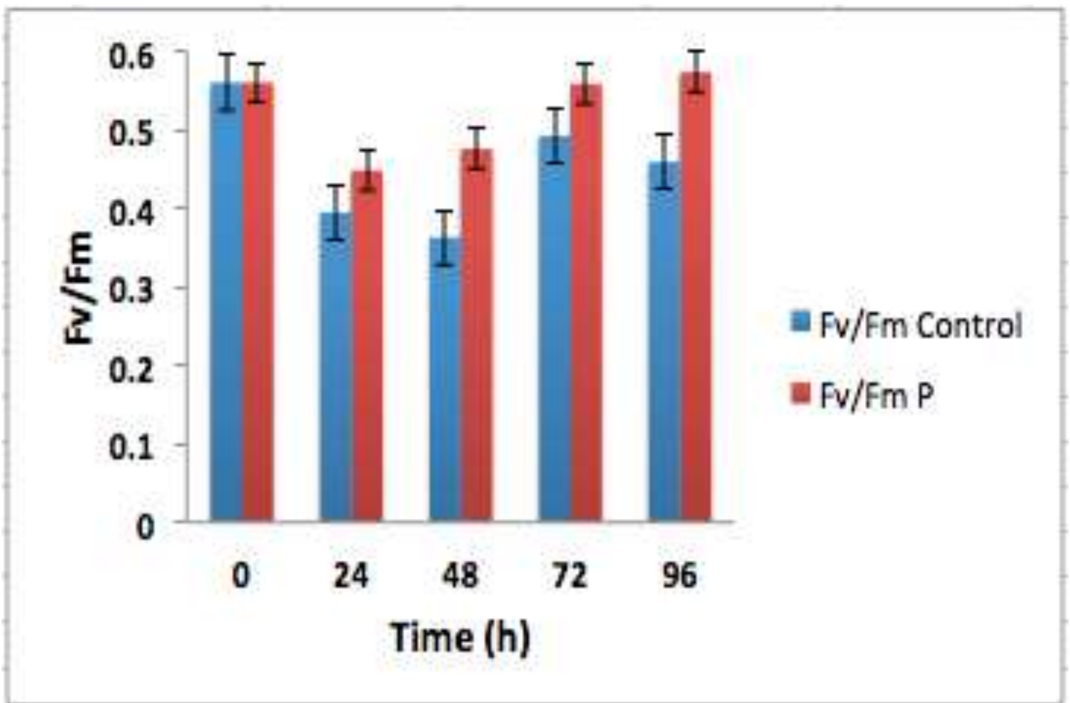
Whitney Temple and Jennifer Morace, USGS


y = 1.9845e^78.61x
R² = 0.70963
Anabaena spp. (cells/mL)
12000
10000
8000
6000
4000
2000
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Total phosphorus (mg/L)

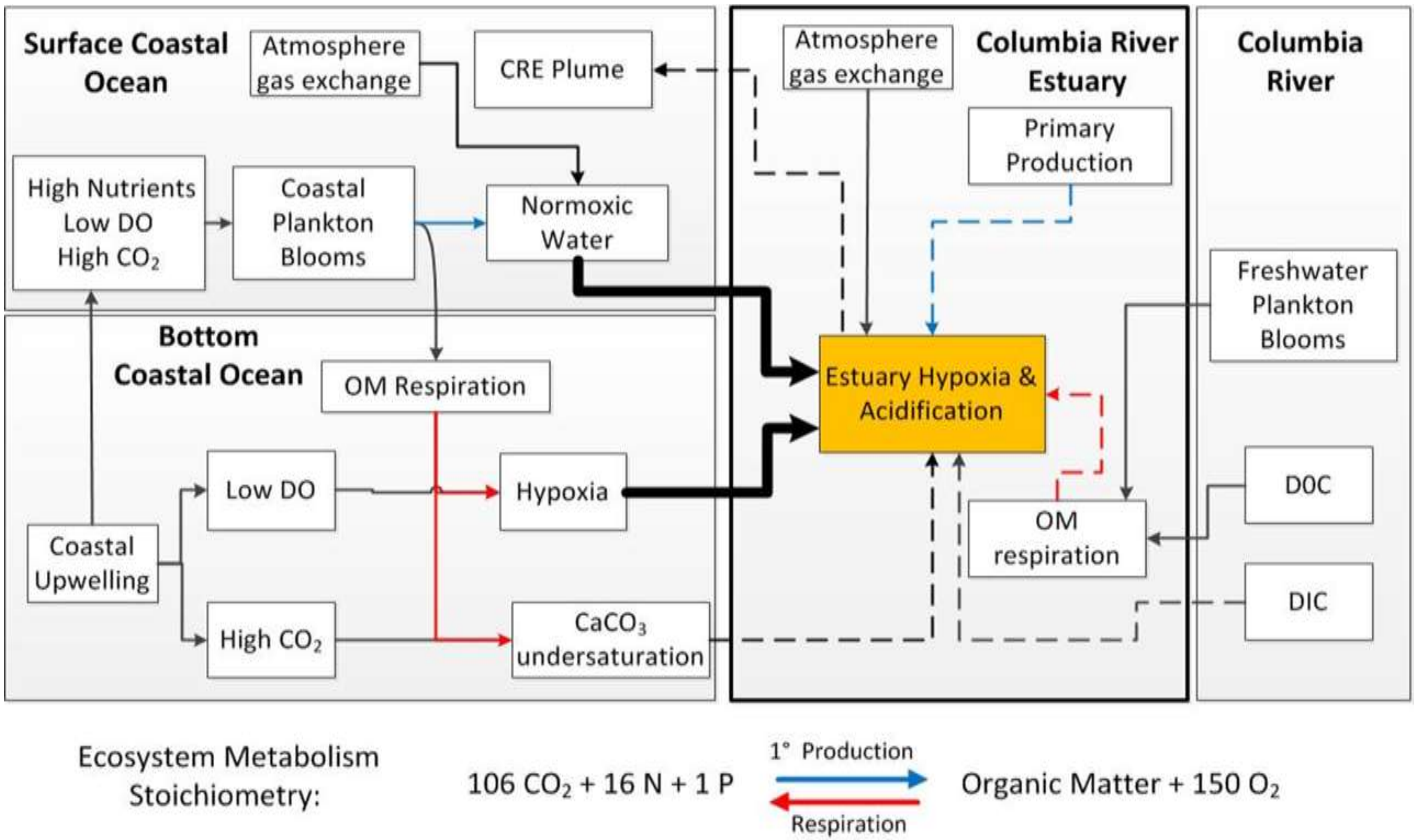

River Discharge
RM 53
Bonneville
Discharge ($m^3 s^{-1}$ x 1000)
0
2
4
6
8
10
12
14
16
18
20
01/2009
01/2010
01/2011
01/2012
01/2013



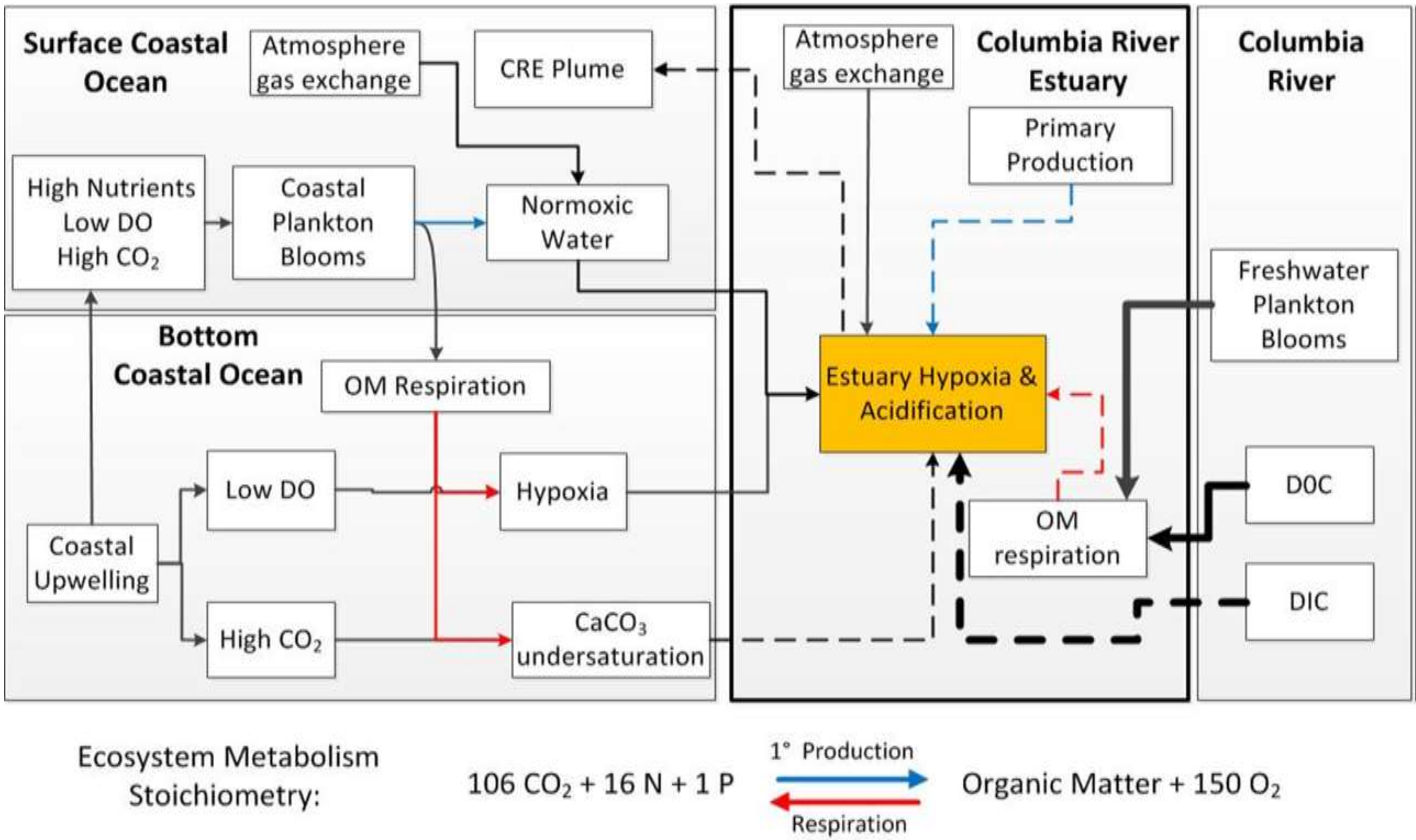
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Chlorophyll (ug/L)
0
20
40
60
80
100
Time (h)
CONTROL AV
P AVERAGE



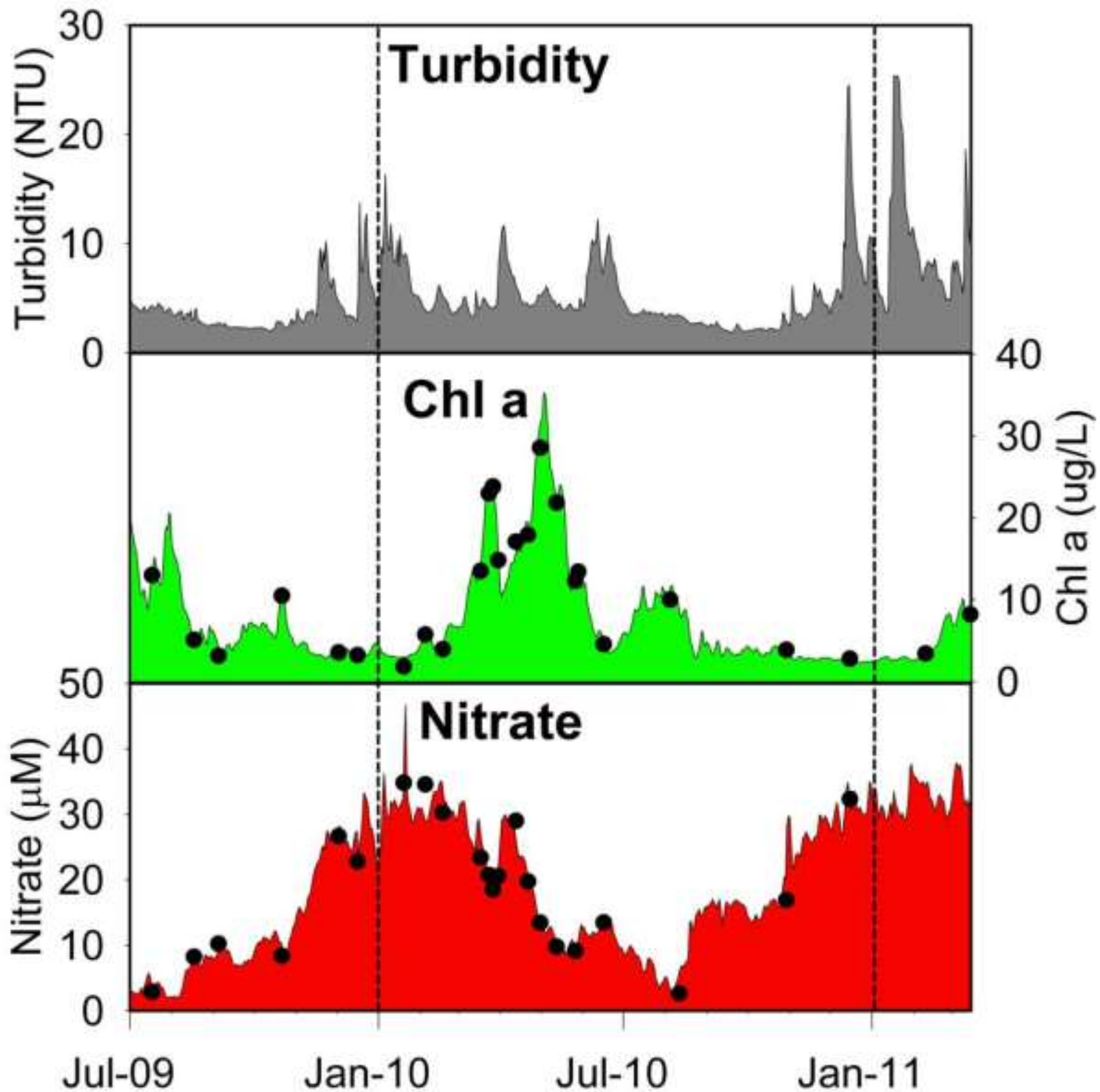
0.6
0.5
0.4
0.3
0.2
0.1
0
Fv/Fm
0
24
48
72
96
Time (h)
Fv/Fm Control
Fv/Fm P



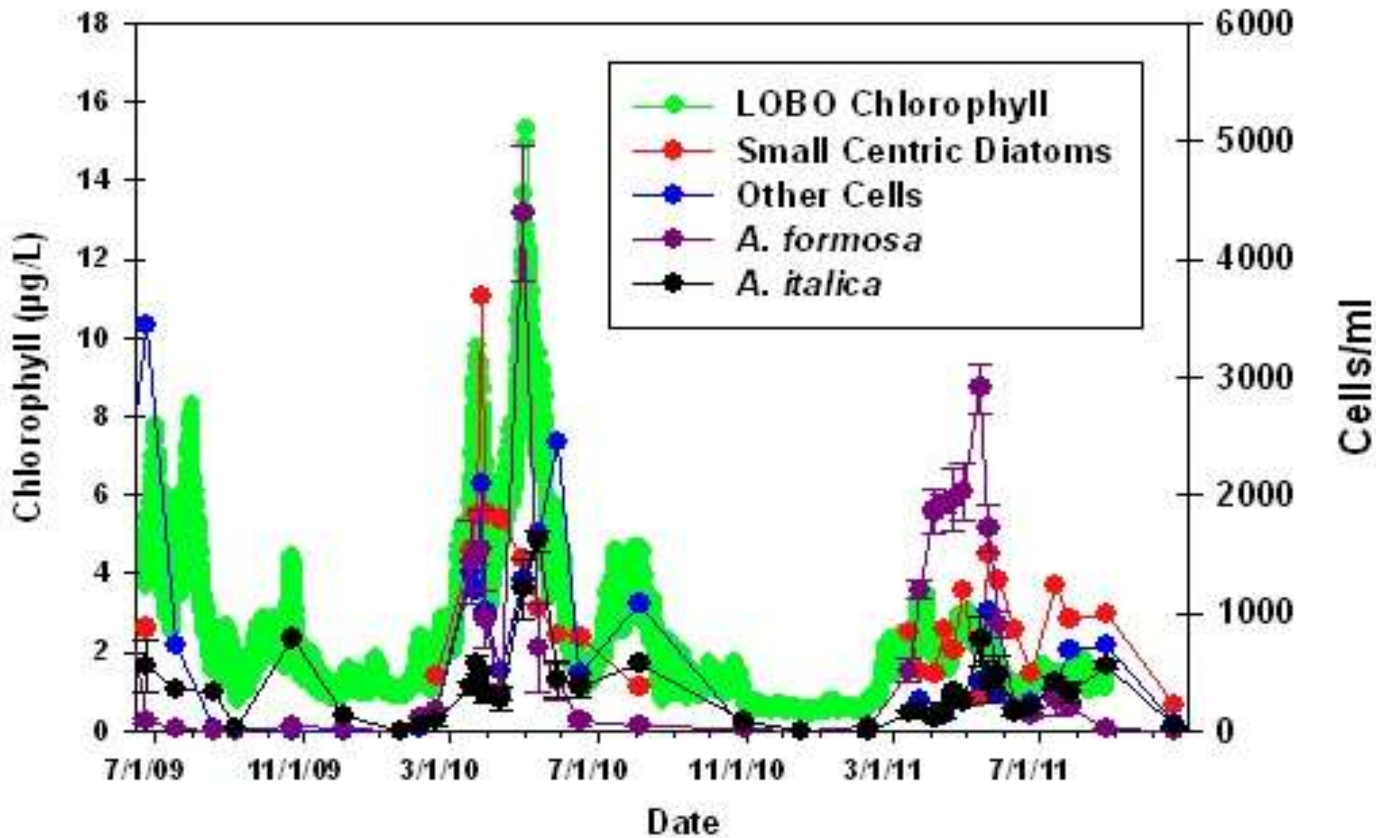
Surface Coastal Ocean
Atmosphere gas exchange
CRE Plume
High Nutrients Low DO High CO_2
Coastal Plankton Blooms
Normoxic Water
Bottom Coastal Ocean
OM Respiration
Low DO
Hypoxia
Coastal Upwelling
High CO_2
$CaCO_3$ undersaturation
Atmosphere gas exchange
Columbia River Estuary
Primary Production
Estuary Hypoxia & Acidification
OM respiration
Columbia River
Freshwater Plankton Blooms
DOC
DIC
Ecosystem Metabolism Stoichiometry:
$106\ CO_2 + 16\ N + 1\ P$
1° Production
Respiration
Organic Matter + 150 O_2


Surface Coastal Ocean
Atmosphere gas exchange
CRE Plume
High Nutrients
Low DO
High CO_2
Coastal Plankton Blooms
Normoxic Water
Bottom Coastal Ocean
OM Respiration
Low DO
Hypoxia
Coastal Upwelling
High CO_2
$CaCO_3$ undersaturation
Atmosphere gas exchange
Columbia River Estuary
Primary Production
Estuary Hypoxia & Acidification
OM respiration
Columbia River
Freshwater Plankton Blooms
DOC
DIC
Ecosystem Metabolism Stoichiometry:
$106\ CO_2 + 16\ N + 1\ P$
1° Production
Respiration
Organic Matter + $150\ O_2$

Autochthonous OM inputs to the estuary: SATURN-05 time series shows multiple phytoplankton blooms in a 'greened' river



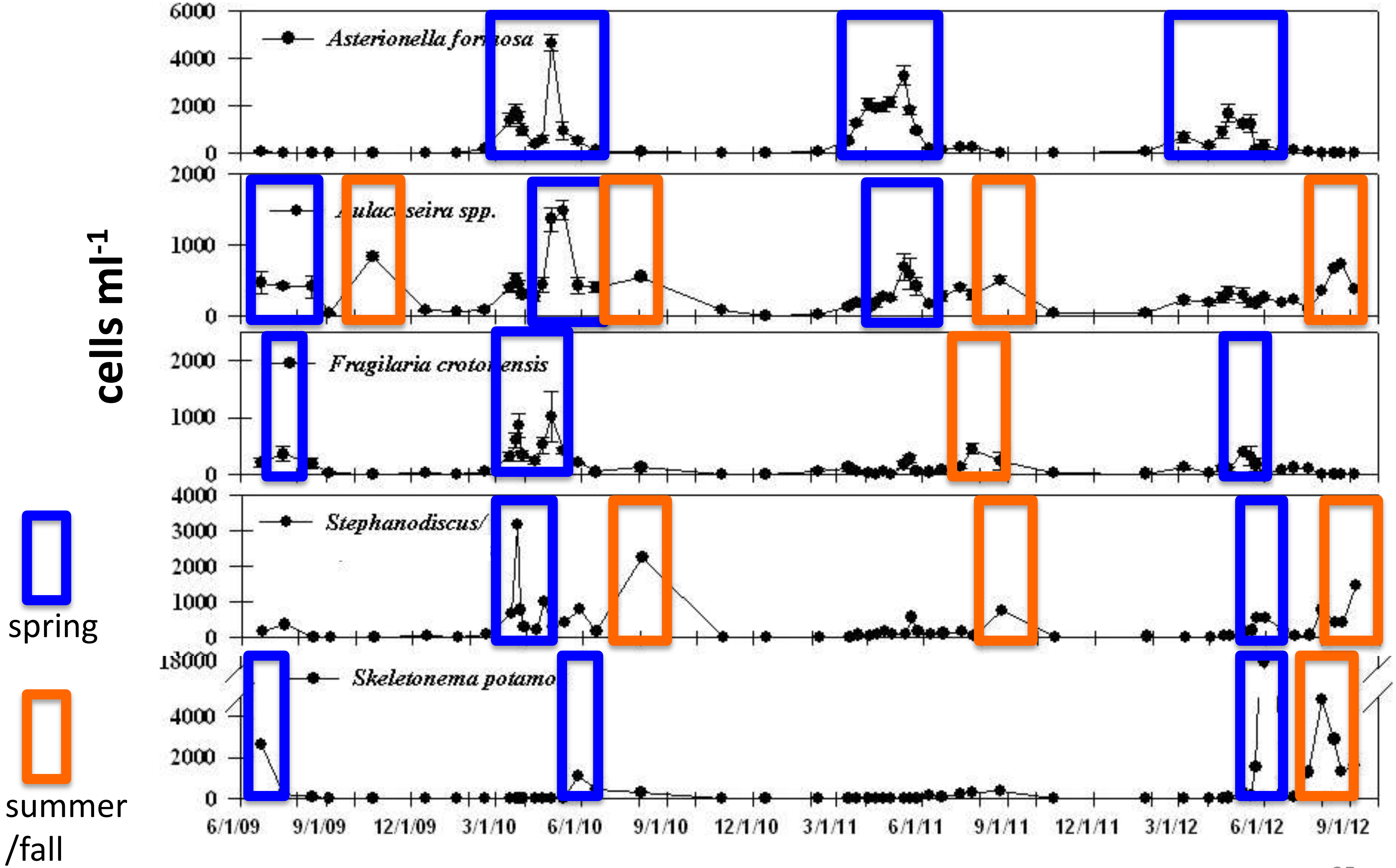
In situ chlorophyll peaks are dominated by diatoms



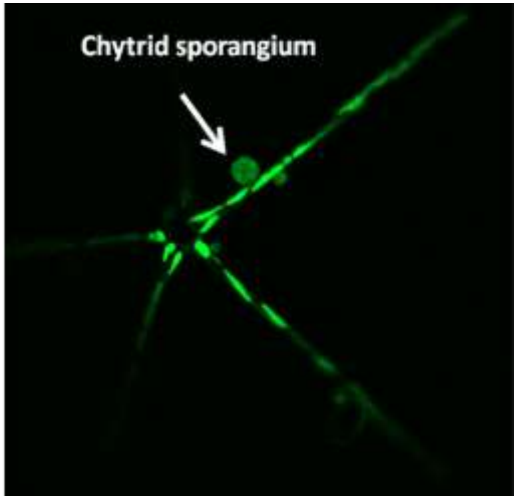
Asterionella formosa blooms during spring, *Aulacoseira italica* and other centric chain forming diatoms bloom in summer/autumn

Maier et al., in prep.

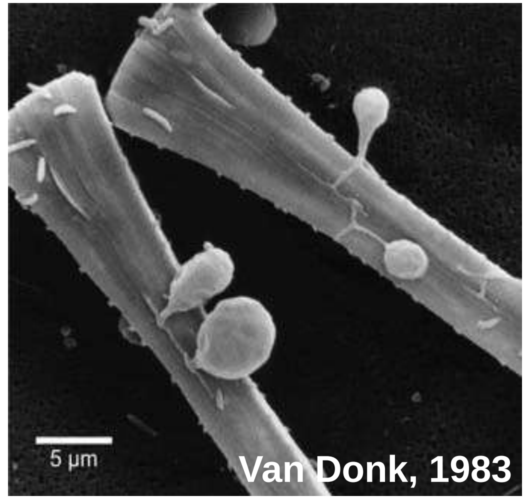
Diatom species exhibit seasonal patterns

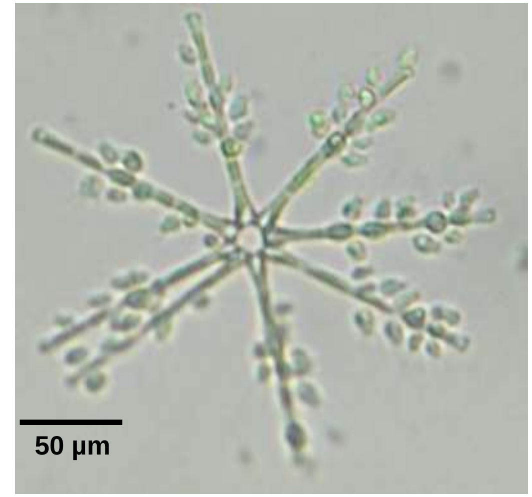


Asterionella formosa is susceptible to intense parasitism by zoosporic (chytrid) fungi



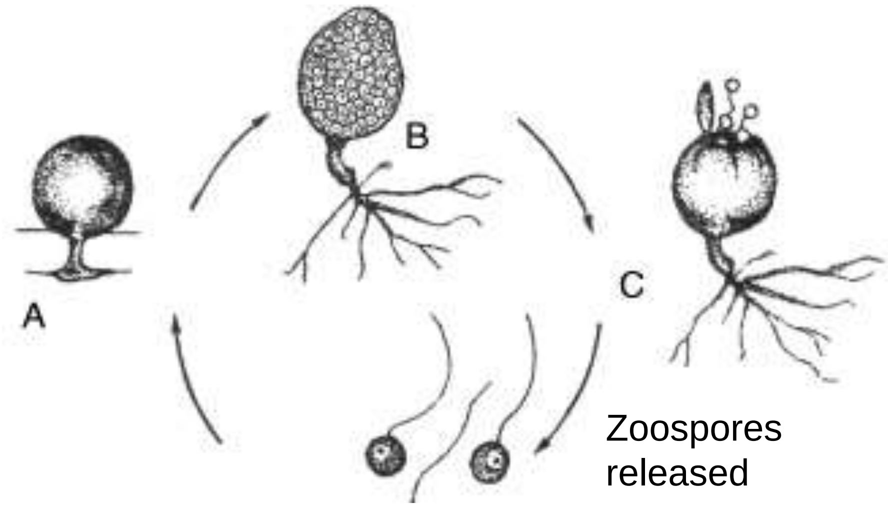
Columbia River *A. formosa*





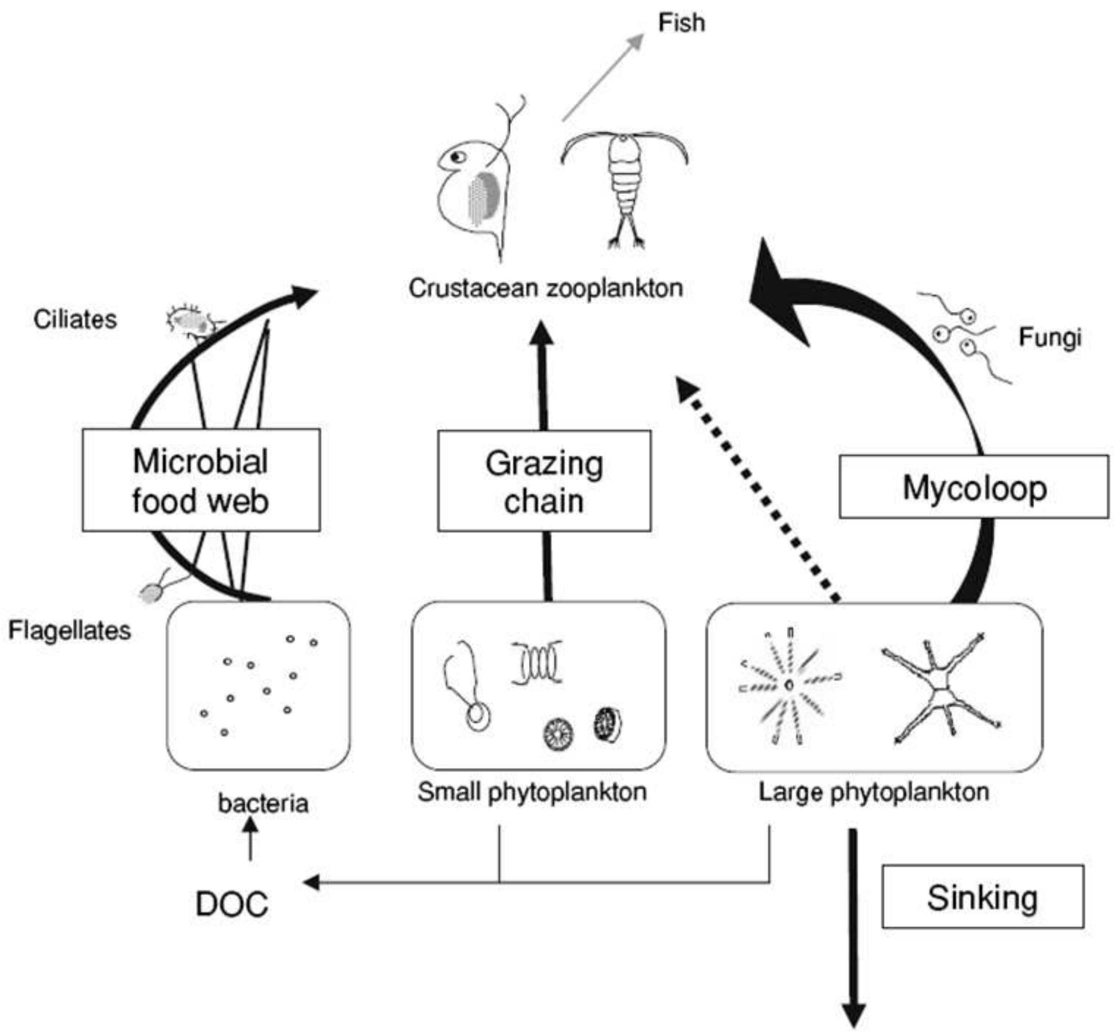
Columbia River *A. formosa*

Zygorhyzidium planktonicum identified using 18S rRNA gene sequences, ITS sequences



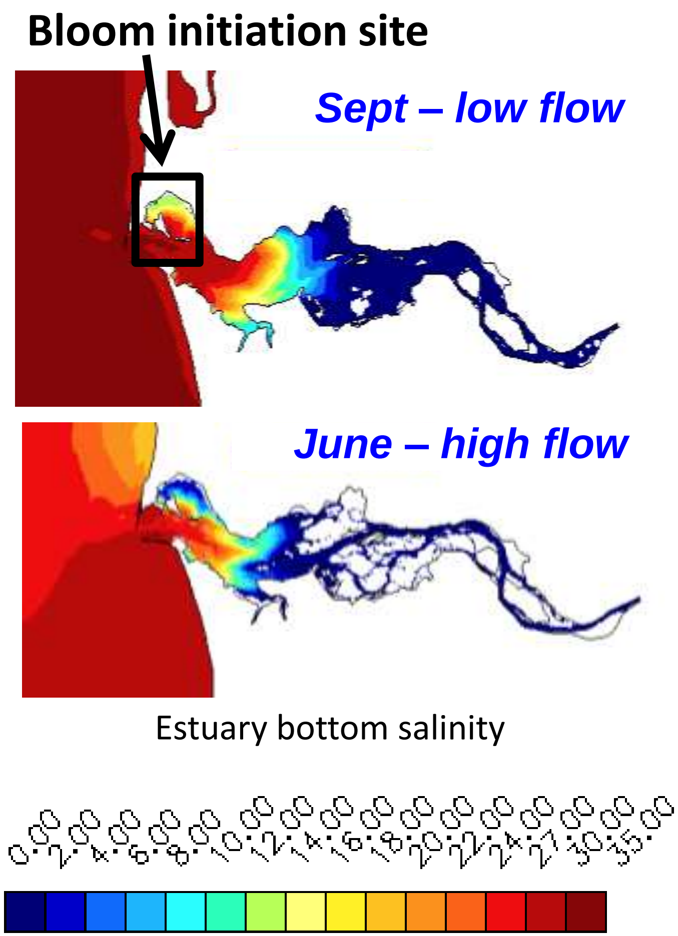
Van Donk (1983)

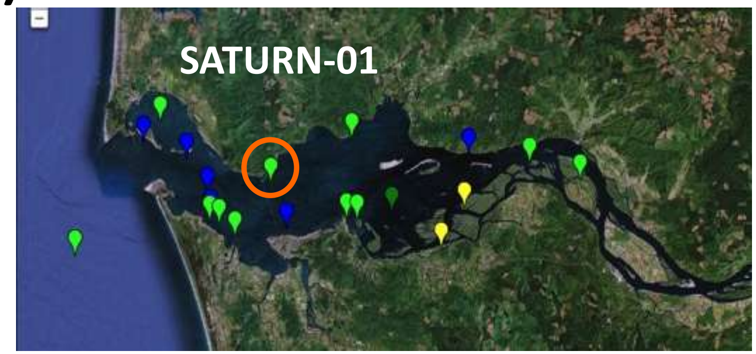
The ‘mycoloop’ shunts organic matter from diatoms into zoospores and alters food webs

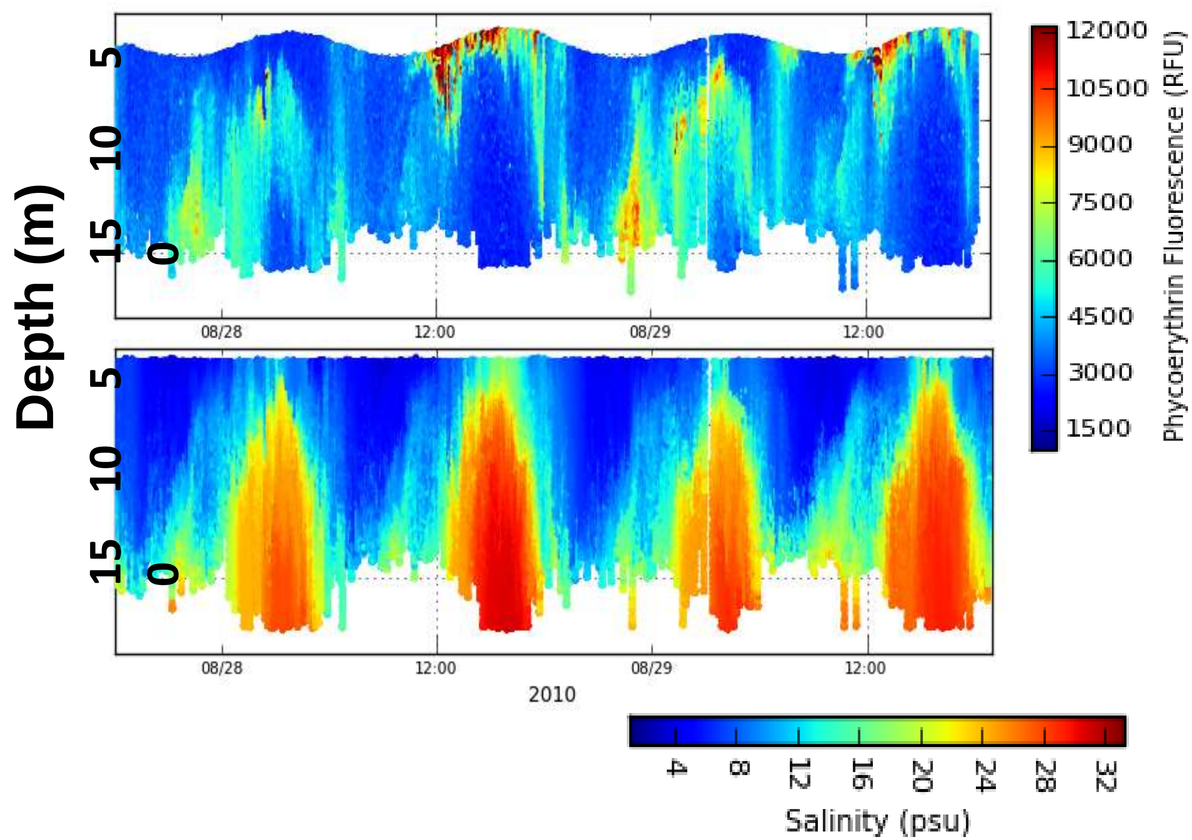


Kagami et al., 2007

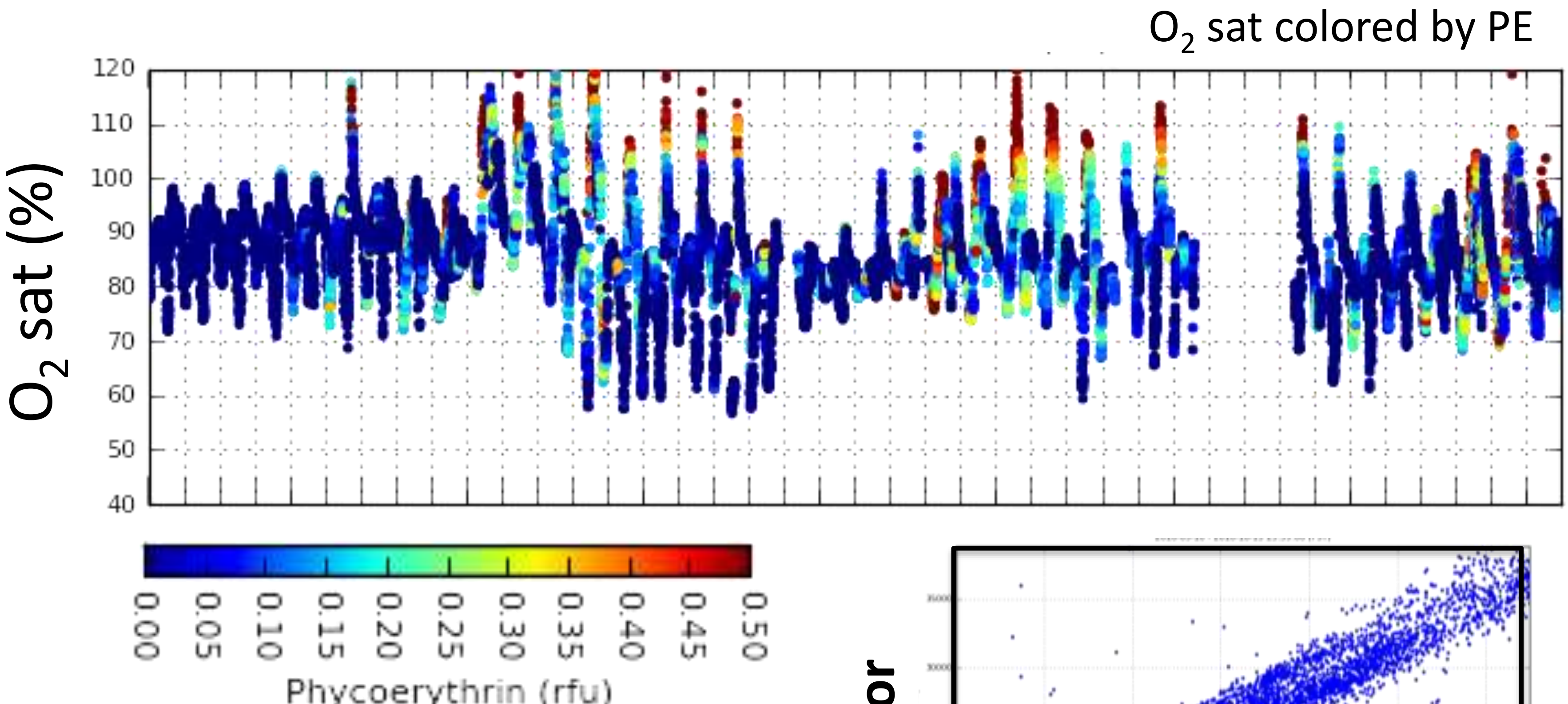
M. rubrum blooms occur when river discharge is low and ocean influence is significant (Aug – Oct)

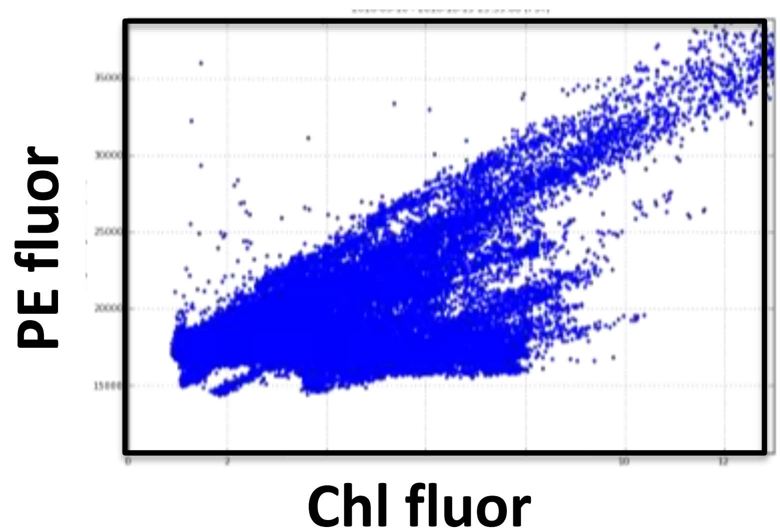




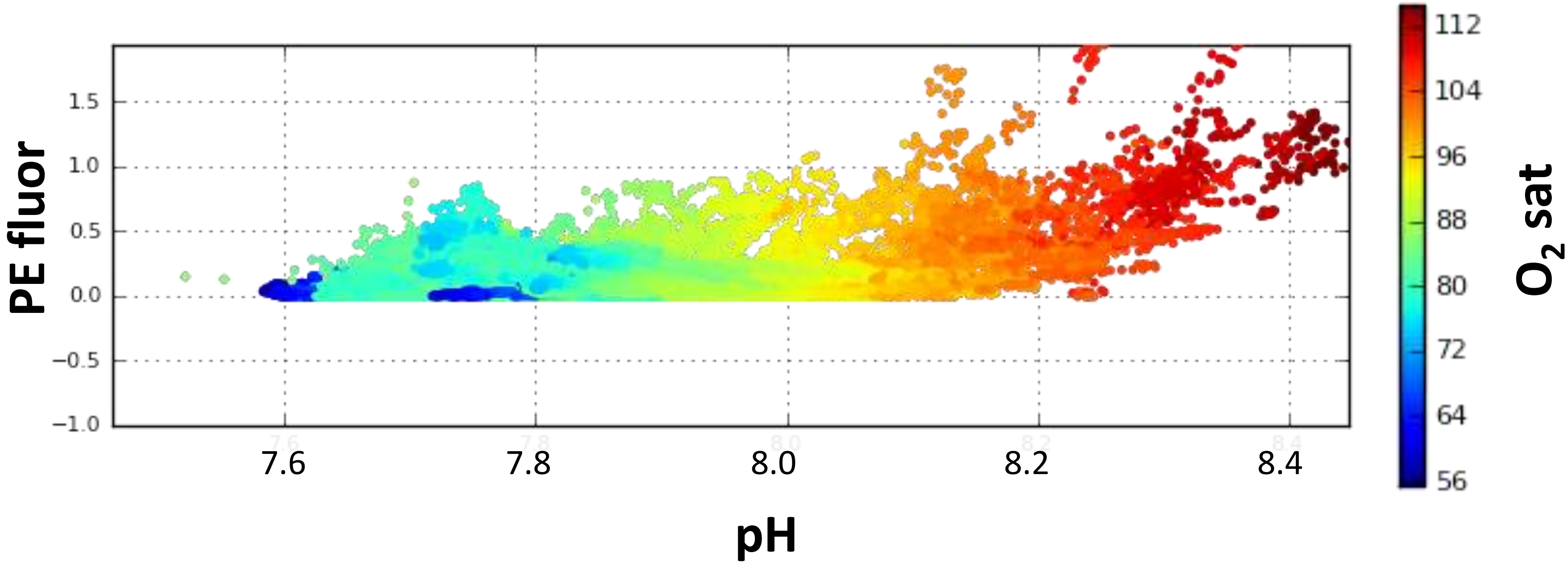


Oxygen saturation is highest where phycoerythrin and chlorophyll are highest

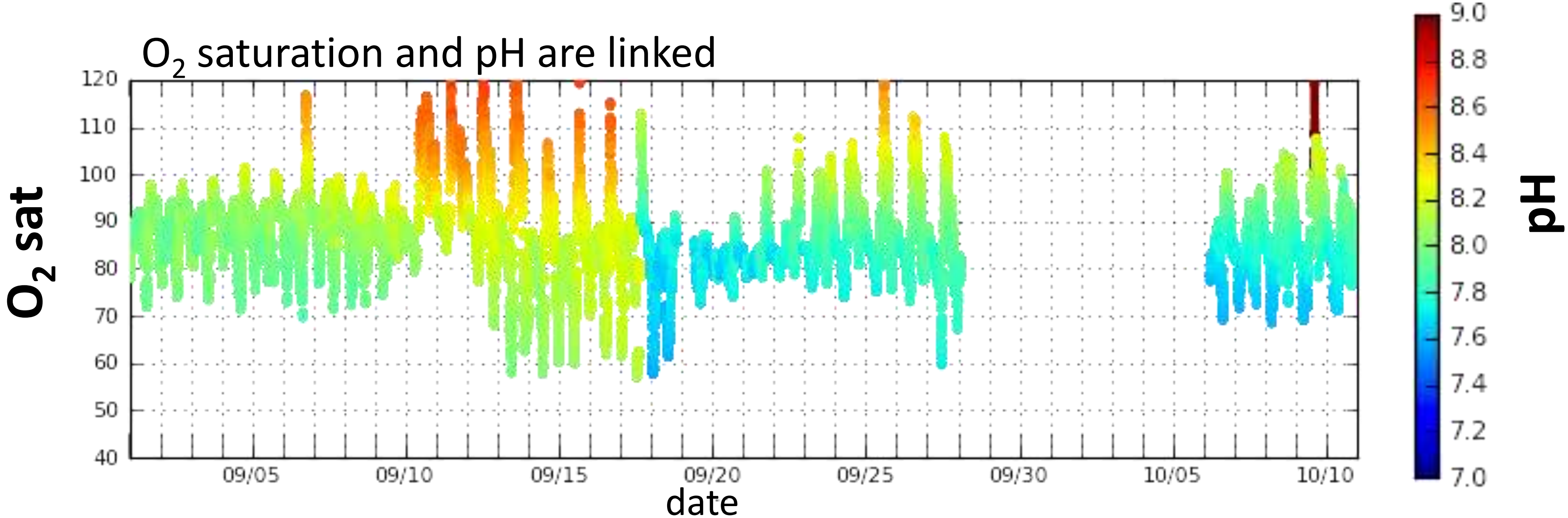


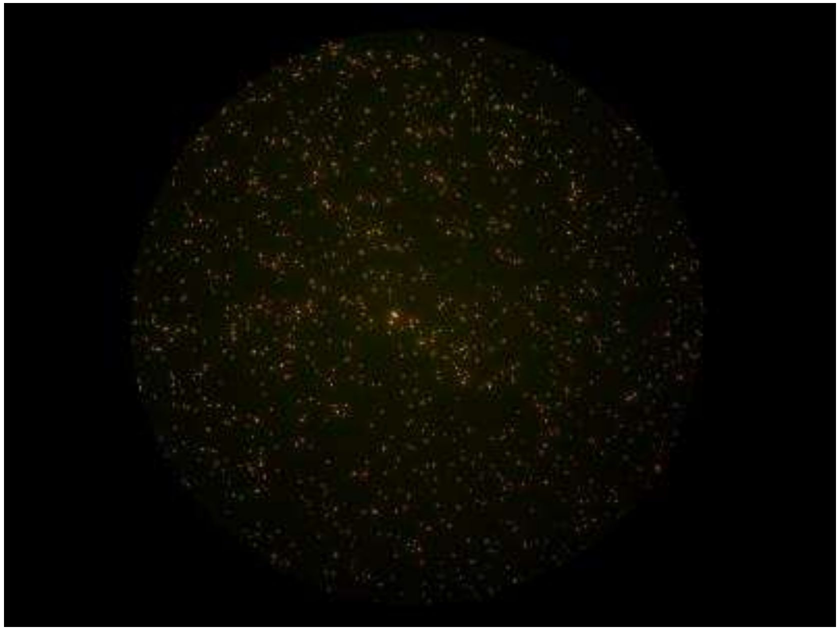


Phycoerythrin, O_2 saturation, and pH are linked, suggesting a potentially mitigating effect on hypoxia and acidification by *M. rubrum*



pH is highest where O_2 saturation is high; high pH and high O_2 sat occur where PE fluorescence is high



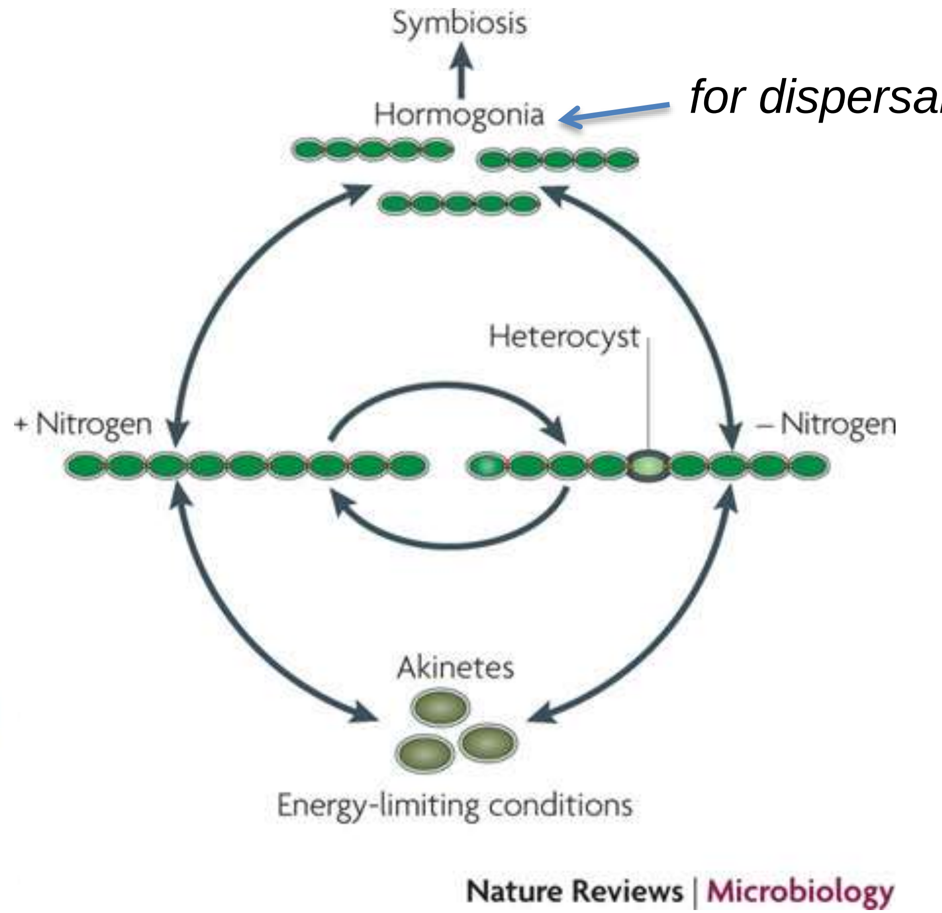


Unicellular cyanobacteria fix N_2 in the subtropical North Pacific Ocean

Jonathan P. Zehr*, John B. Waterbury†, Patricia J. Turner*, Joseph P. Montoya‡, Enoma Omoregie*, Grieg F. Steward*, Andrew Hansen§ & David M. Karl§

High rates of N_2 fixation by unicellular diazotrophs in the oligotrophic Pacific Ocean

Joseph P. Montoya[1], Carolyn M. Holl[1], Jonathan P. Zehr[2], Andrew Hansen[3], Tracy A. Villareal[4] & Douglas G. Capone[5]



Enrique Flores & Antonia Herrero; Nature Reviews Microbiology 8, 39-50 (January 2010)