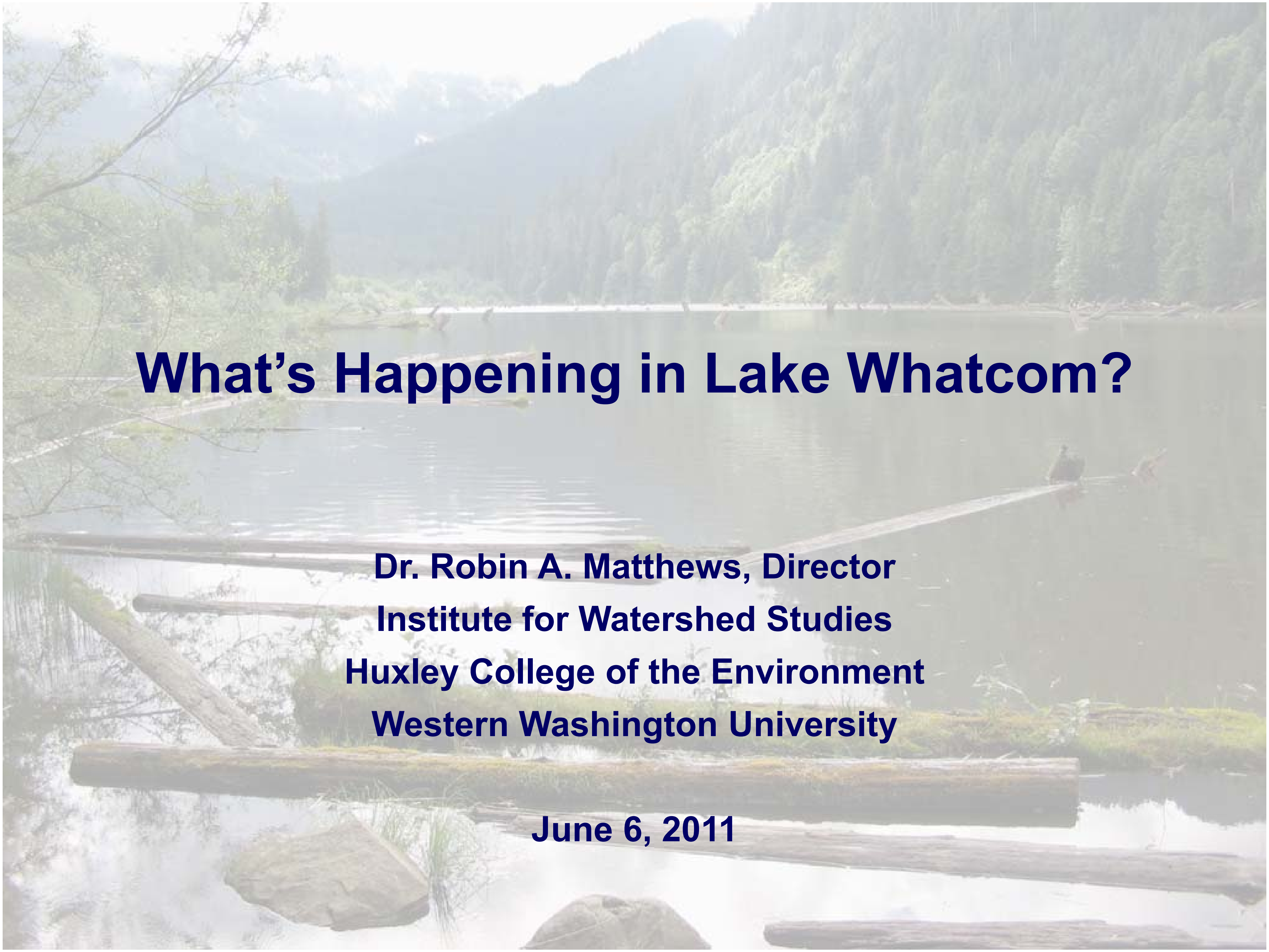

What’s Happening in Lake Whatcom?

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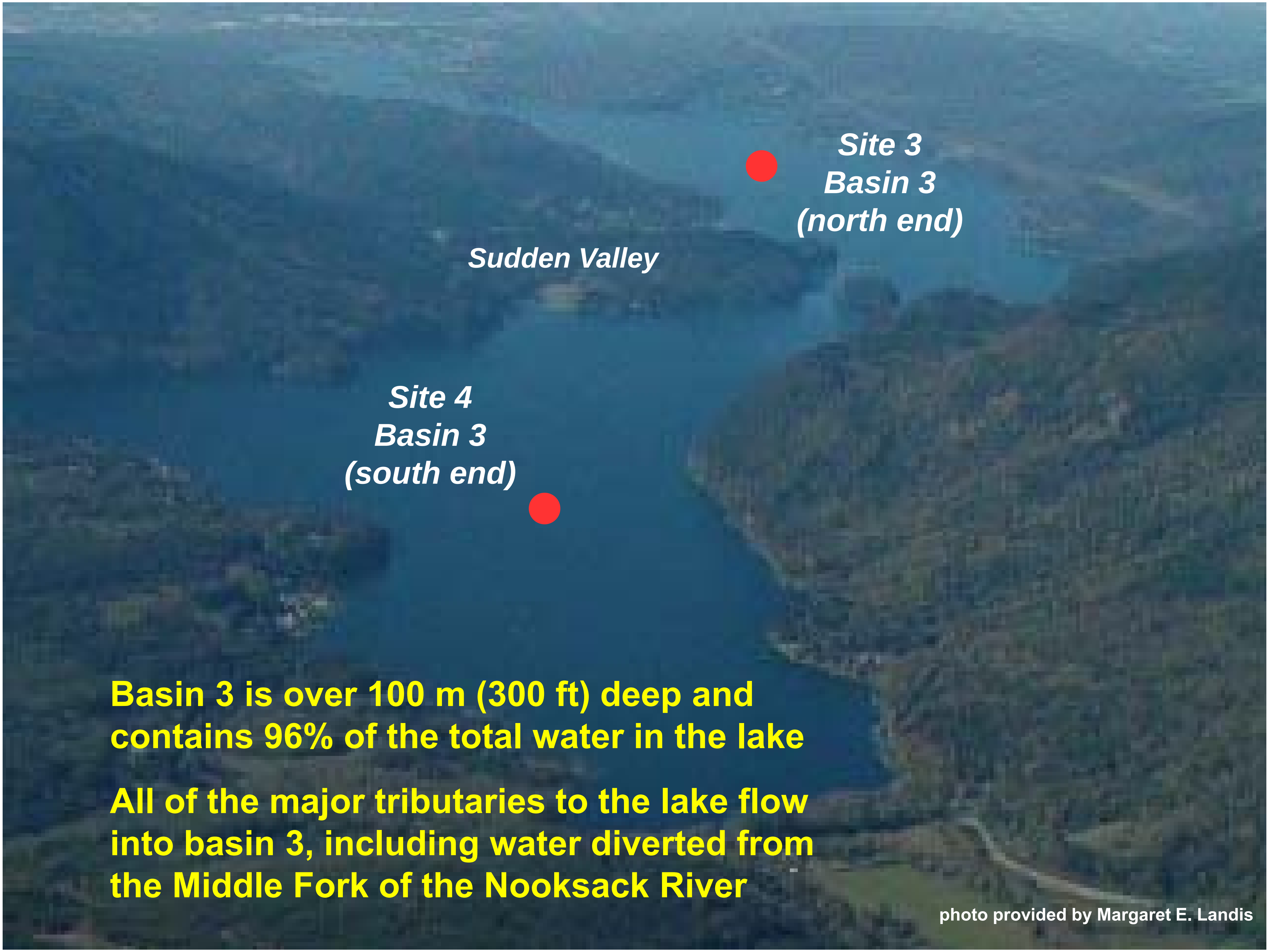
Institute for Watershed Studies

Huxley College of the Environment

Western Washington University

June 6, 2011

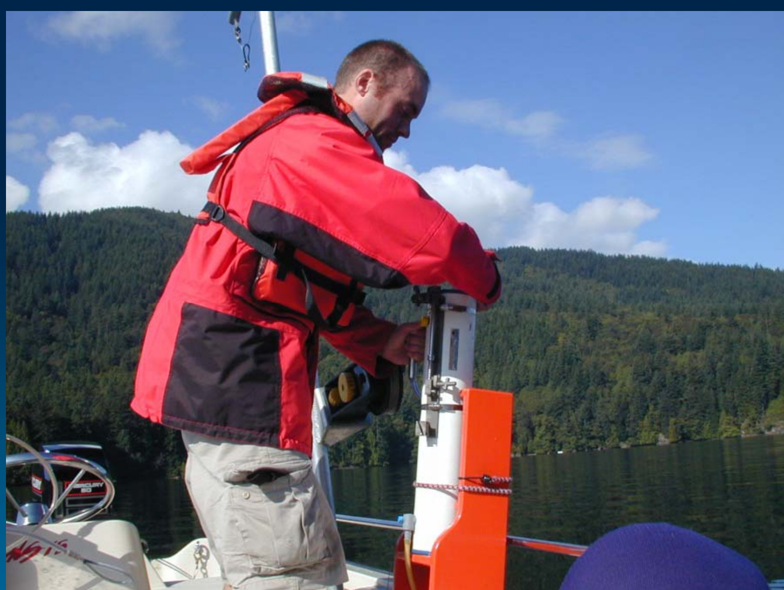

Site 2
Basin 2
Site 1
Basin 1
Bloedel/
Donovan
Park
Lake Whatcom is
comprised of 2 small,
shallow basins and one
large, deep basin
Each shallow basin is only
~20 m (60 ft) deep and
contains about 2% of the
total water in the lake
photo provided by Margaret E. Landis


Site 3
Basin 3
(north end)
Sudden Valley
Site 4
Basin 3
(south end)
Basin 3 is over 100 m (300 ft) deep and contains 96% of the total water in the lake
All of the major tributaries to the lake flow into basin 3, including water diverted from the Middle Fork of the Nooksack River
photo provided by Margaret E. Landis

Lake Whatcom Monitoring Objectives

- Conduct long-term lake and stream monitoring
  - emphasis on lake monitoring
- Collect lake and stream hydrologic data
  - annual water balance model
  - annual hydrographs for Austin and Smith Creeks
    - ➔other tributaries monitored by USGS
- Evaluate effectiveness of storm water treatment systems in watershed
  - objectives changed in 2010 to focus on Silver Beach Creek and Northshore

Long-Term Lake Monitoring



Lake Sampling

(Annual report available at http//www.wwu.edu/iws)

Monthly samples:

conductivity	alkalinity	nutrients
dissolved oxygen	turbidity	(TN, NH_3, NO_3, TP, SRP)
pH	Secchi depth	chlorophyll
temperature	plankton	bacteria (coliforms)

new: algae counts at gatehouse, Intake-10 m, Site 2-10 m

Annual/biannual samples:

total metals (As, Cd, Cr, Co, Fe, Pb, Hg, Ni, Zn)

total organic carbon

hydrogen sulfide (summer)

Dissolved Oxygen as an Indicator

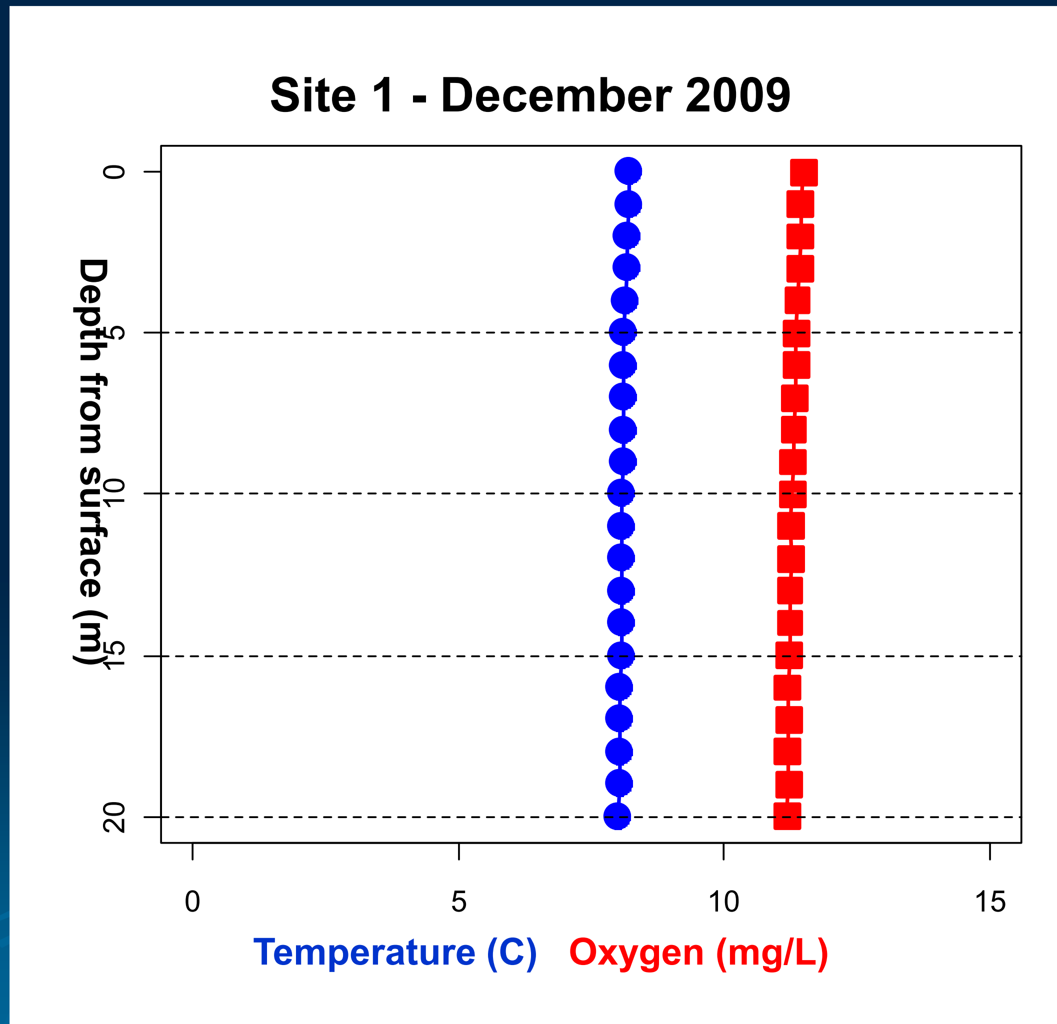
- The primary source of dissolved oxygen in lakes is the atmosphere
  - Algae produce oxygen during photosynthesis (daytime), but consume oxygen at night
- When the lake stratifies, epilimnetic oxygen levels remain high because of contact with the atmosphere
- The hypolimnion is isolated from the atmosphere during stratification, so no additional oxygen is introduced until late fall when the lake cools enough to destratify

Winter Water Quality in Lake Whatcom

Lake is cold and **unstratified**; water column mixes from surface to bottom … even basin 3 (100 m)

Temperature is nearly uniform from surface to bottom

Dissolved oxygen and most other compounds are nearly uniform from surface to bottom

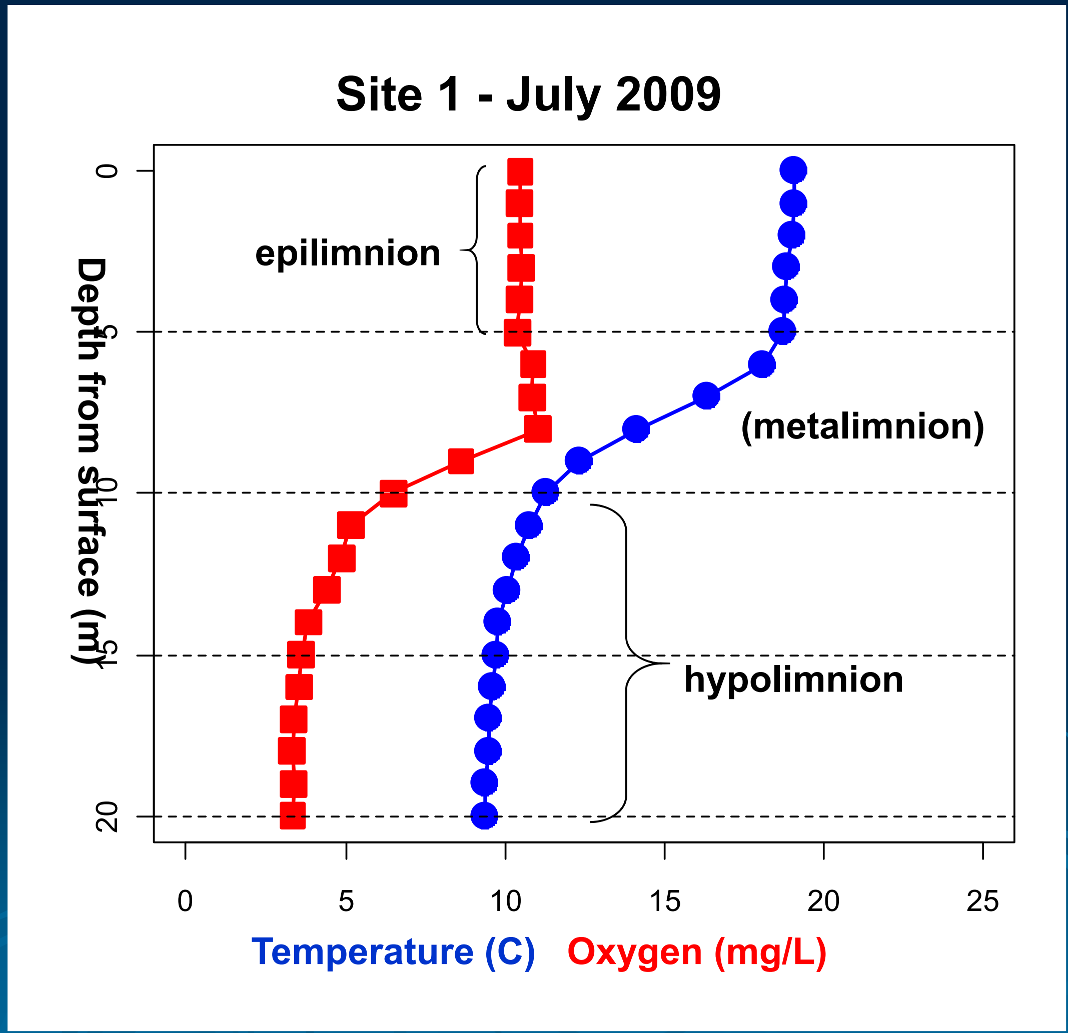


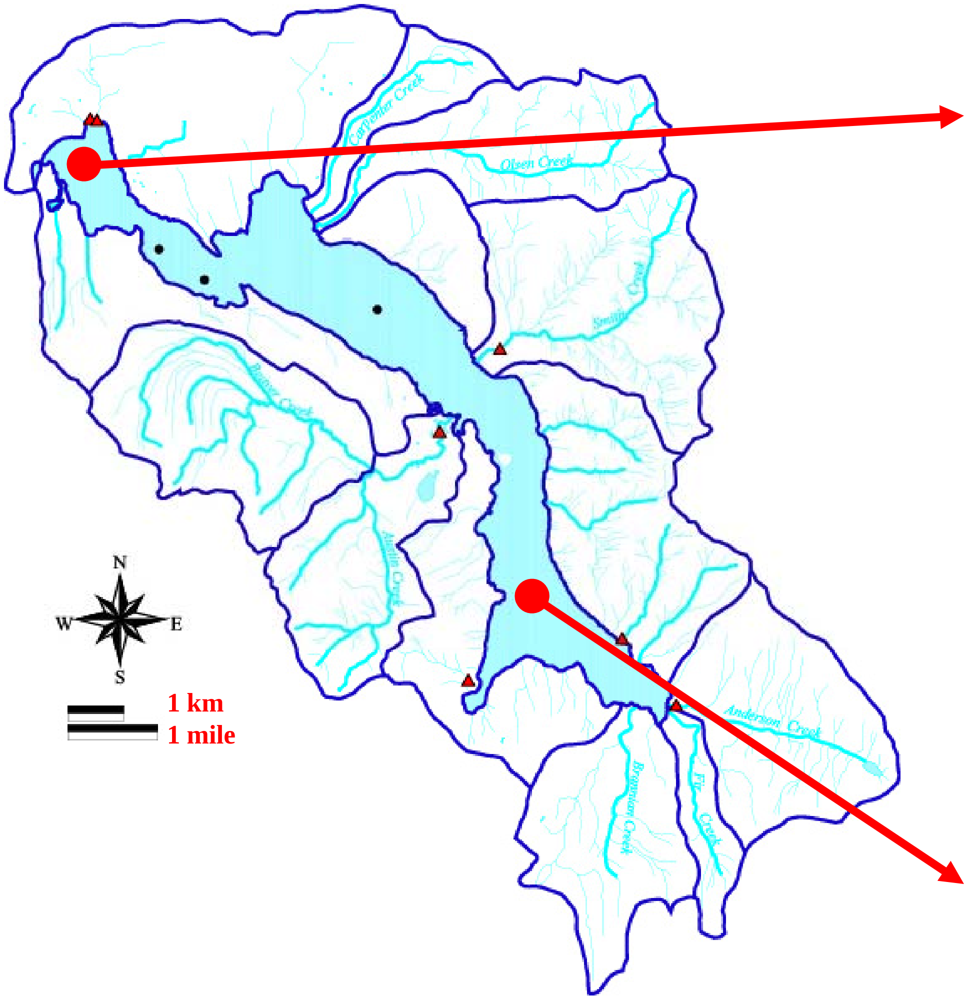
Summer Water Quality in Lake Whatcom

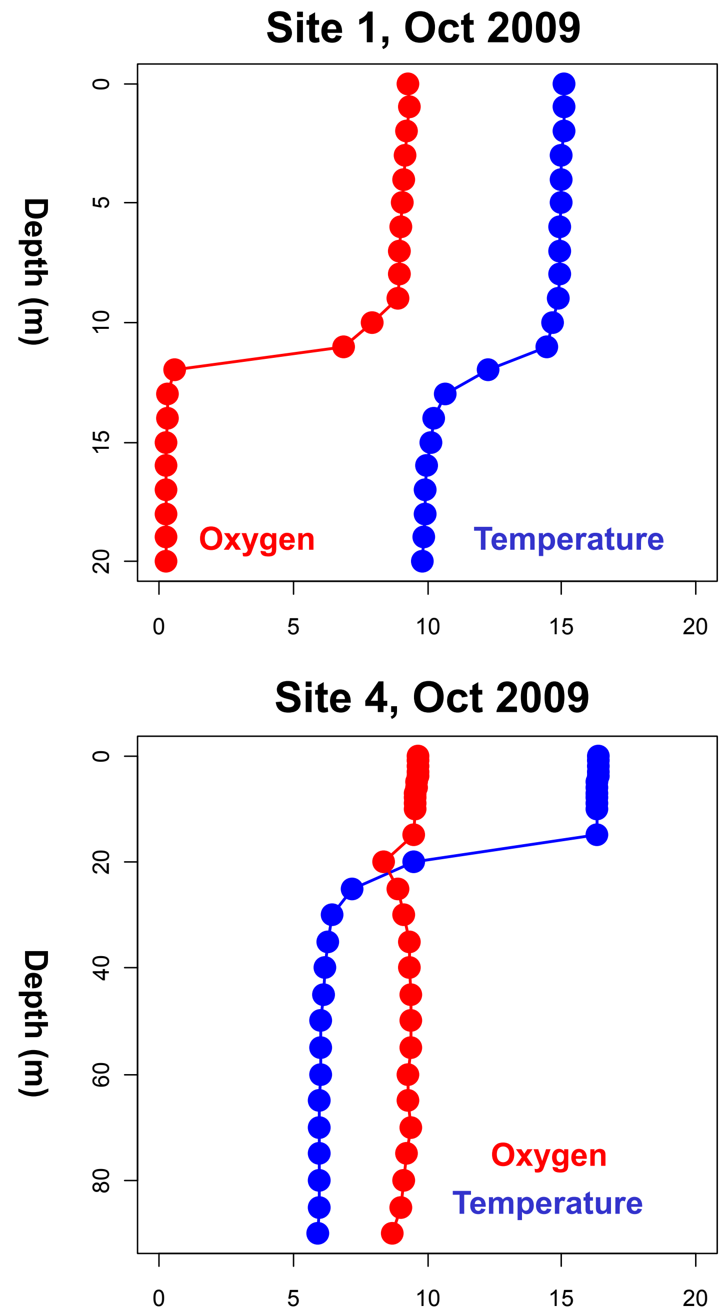
Lake becomes **stratified** into a warm surface layer (**epilimnion**) and cold bottom layer (**hypolimnion**)

Once stratified, wind can't mix the entire water column

In parts of the lake (Sites 1-2), oxygen is depleted in the hypolimnion as bacteria decompose organic matter (dead algae, leaf fragments, etc.)



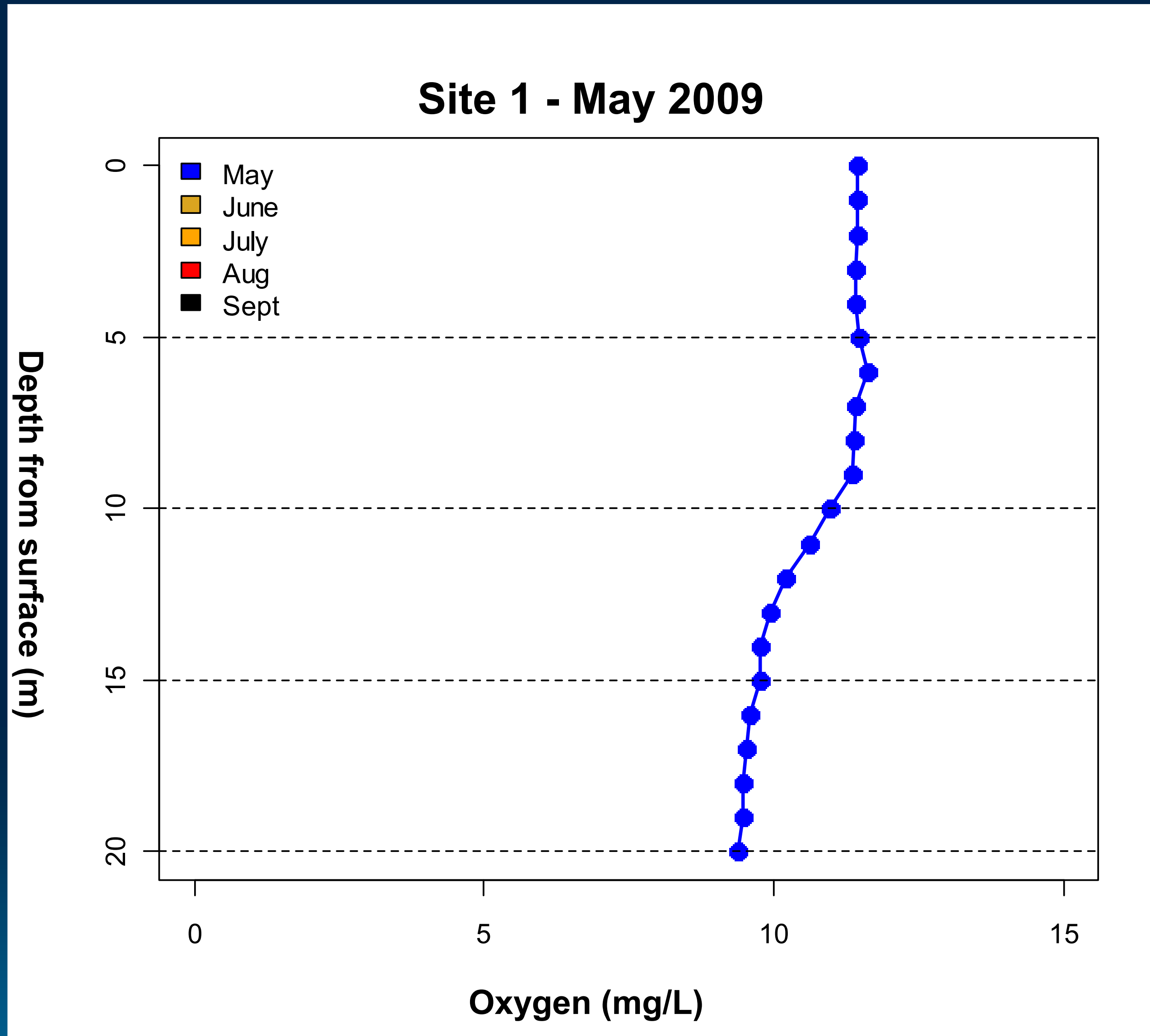




Basins 1 and 2 have different oxygen profiles than basin 3

At Sites 1-2, hypolimnetic oxygen depletion begins when the lake stratifies, and progresses rapidly until there is no more oxygen available in the lower part of the water column

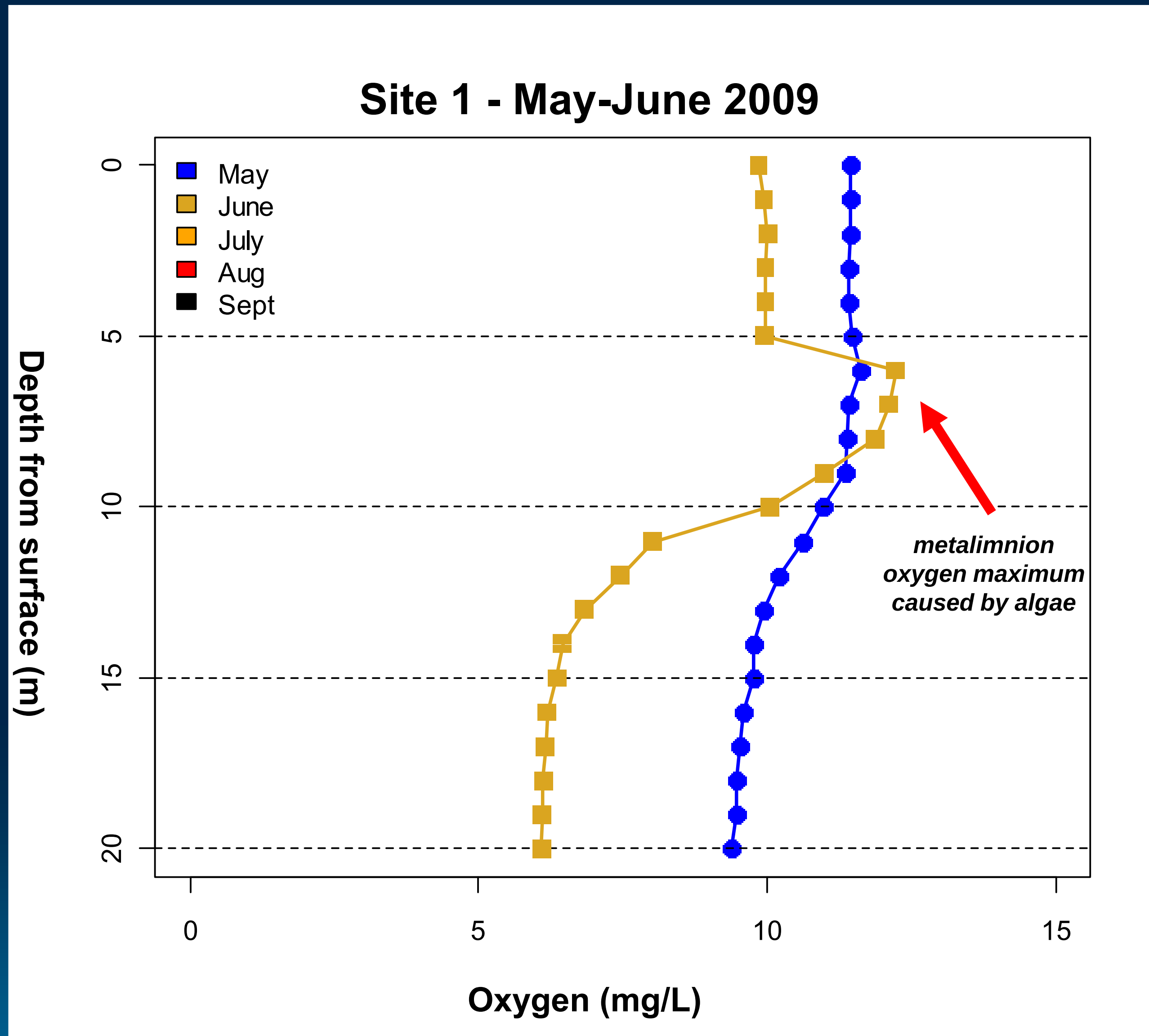
This process may start as early as April, but more often begins in May or early June, depending on weather conditions



By June 2009, a distinct oxygen profile had developed

The bulge between 5-10 meters is a "metalimnetic oxygen maximum" caused by layers of rapidly photo-synthesizing algae

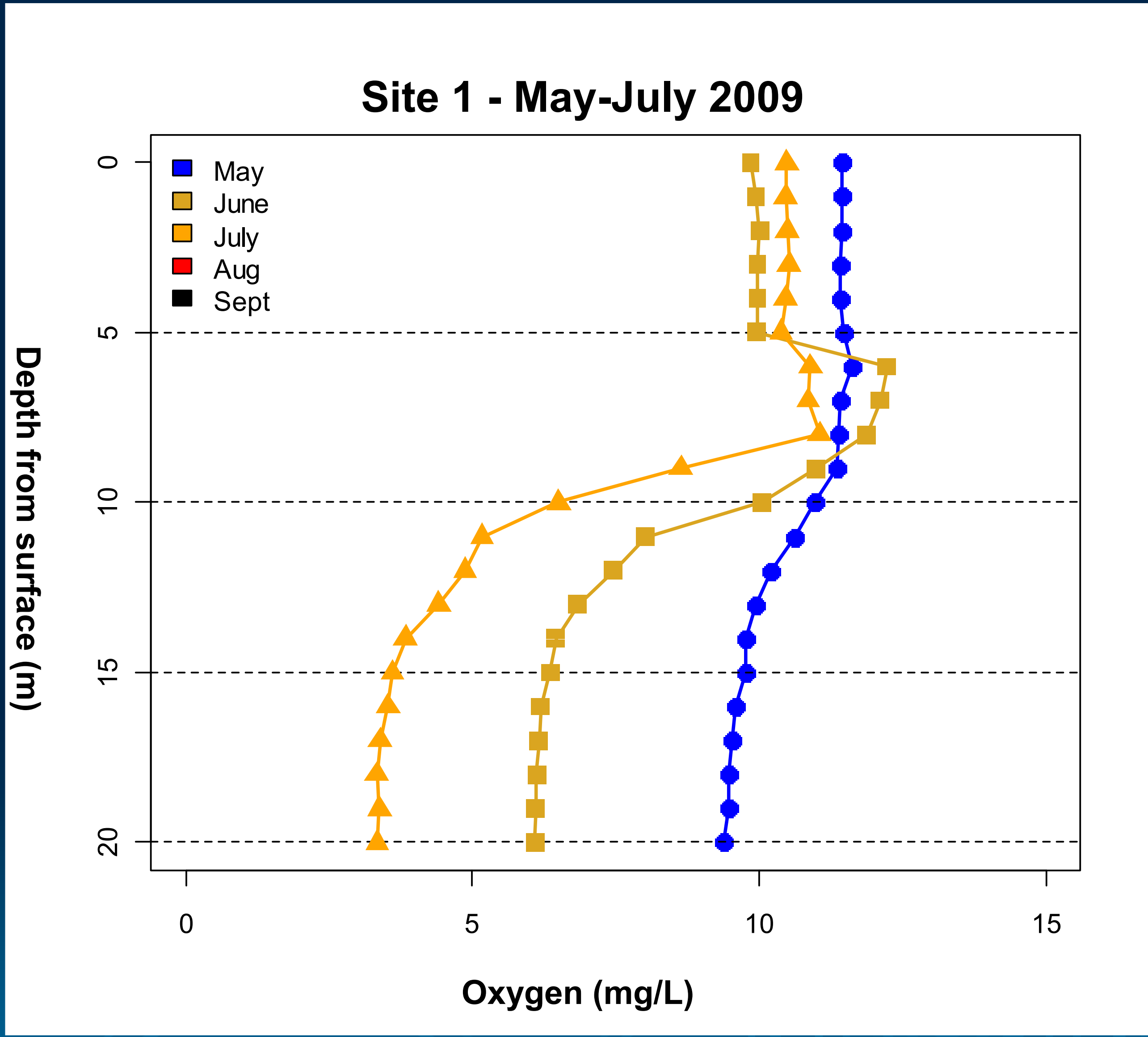
The oxygen bulge is present during the day; at night, there may be an oxygen sag from algae respiration



As the summer progresses, the oxygen depletion in the hypolimnion becomes increasingly evident

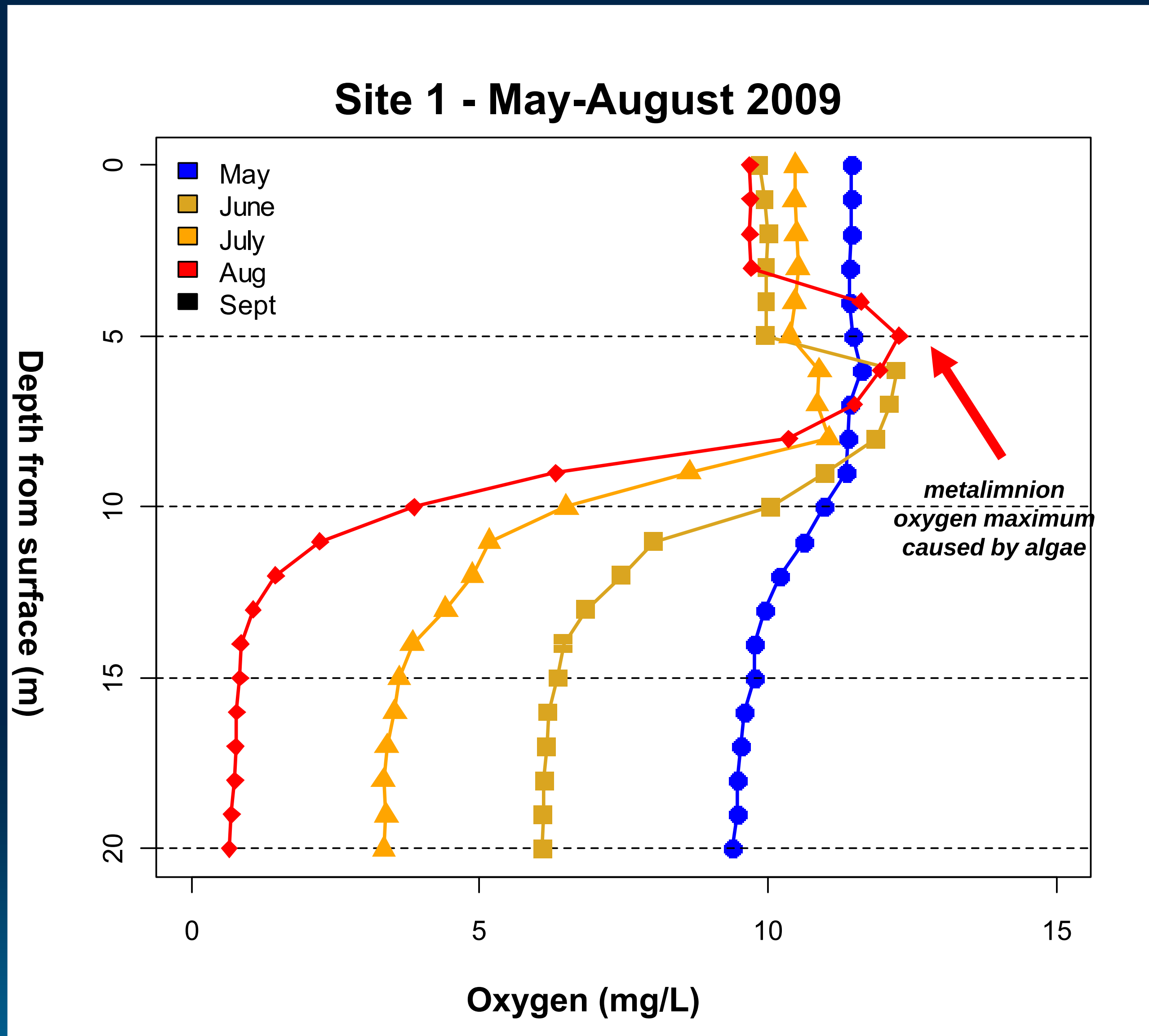
Oxygen levels fall slightly at the surface because the water is warmer

- ➔ warm water holds less dissolved oxygen than cold water



By August 2009, there was almost no oxygen in the hypolimnion

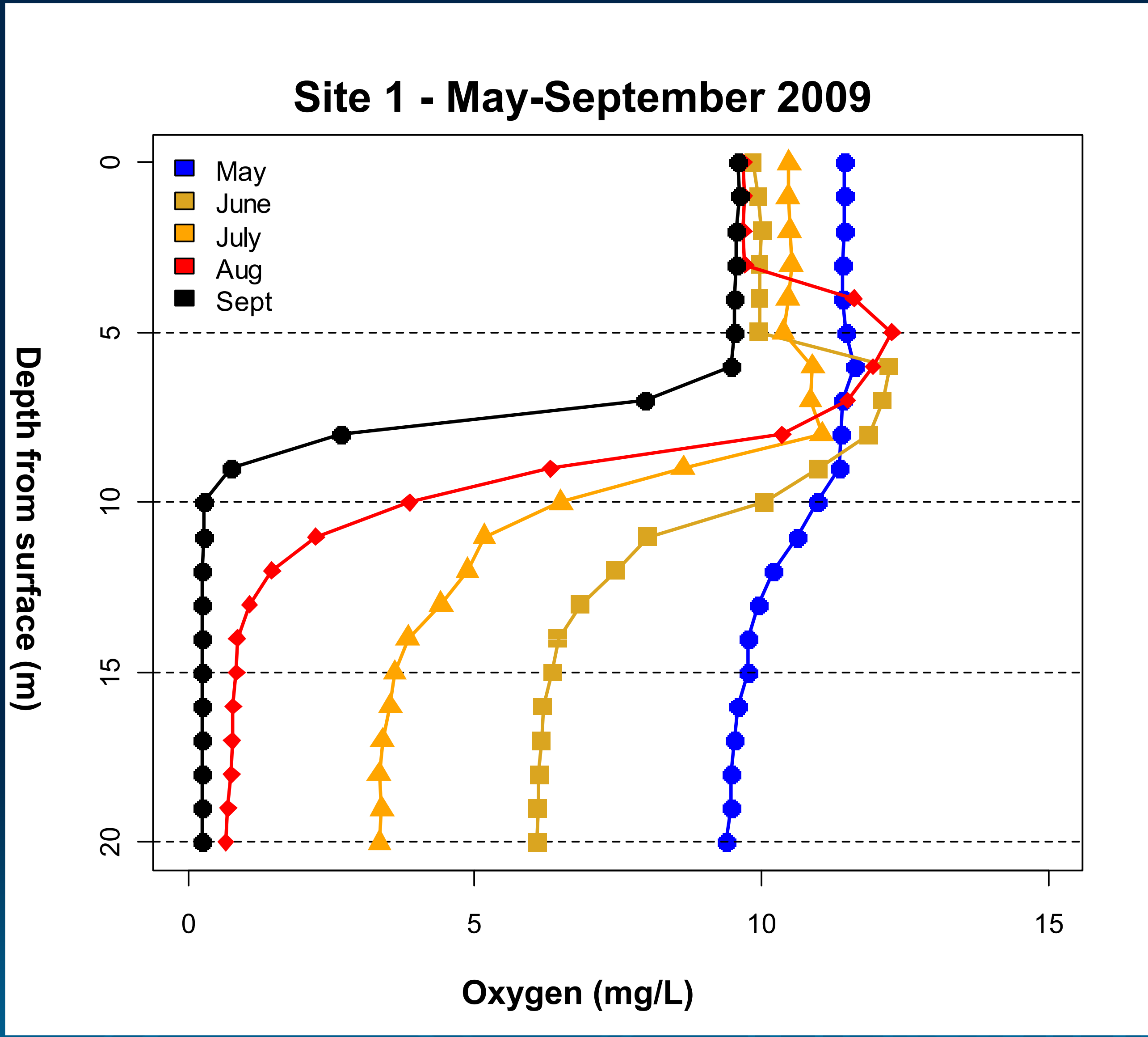
Once oxygen levels fall below ~2 mg/L, the only aquatic organisms that can thrive are anaerobic bacteria ... other species either leave the region (e.g., fish) or go into a resting stage to wait until the lake mixes in the fall

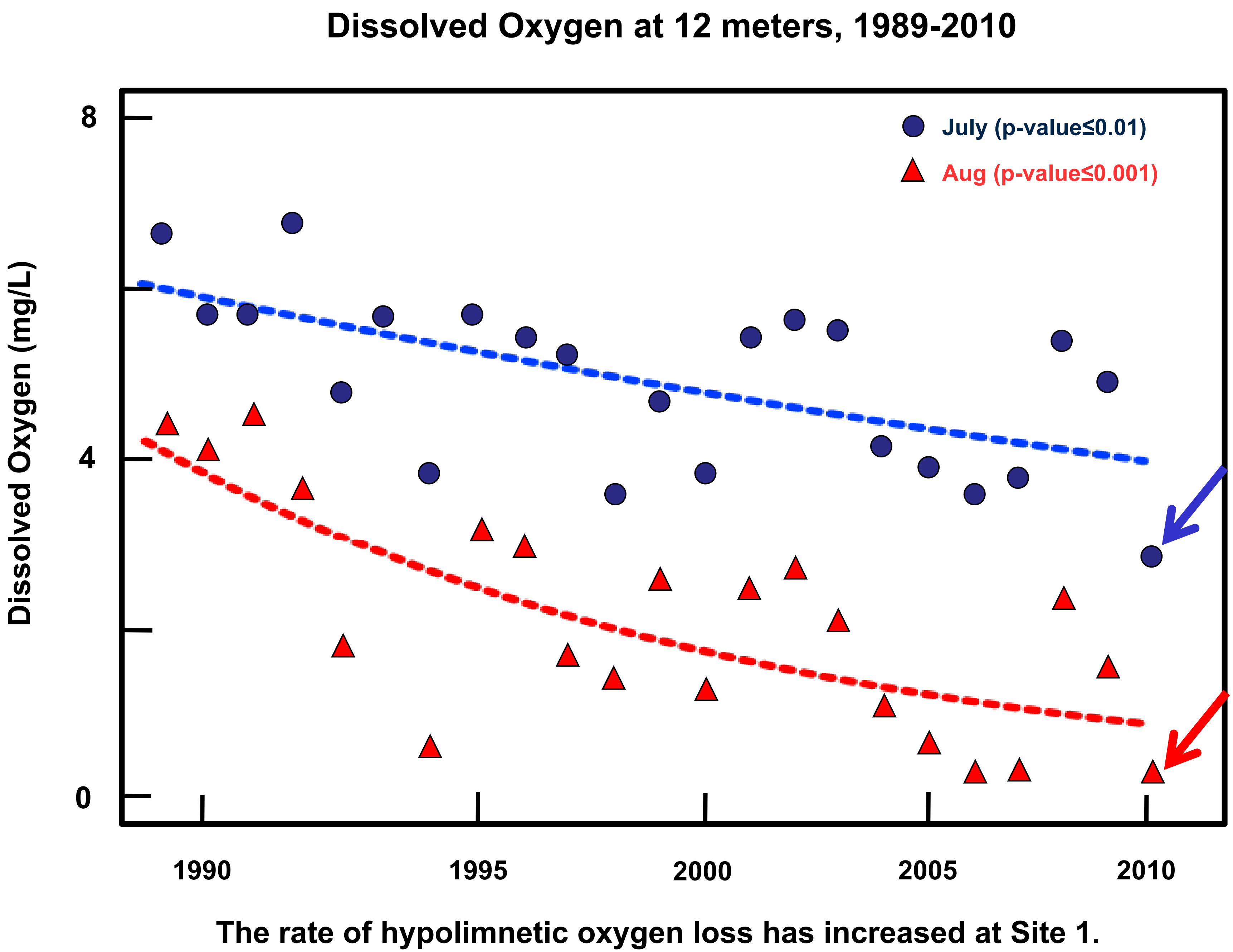


By September 2009, oxygen levels were near zero throughout the hypolimnion at Site 1 (and Site 2)

Oxygen levels occasionally fall below 4 mg/L at Site 3 (north end of basin 3), but are usually >6-8 mg/L at Site 4 (south end of basin 3)

When the lake mixes in the fall, the oxygen levels will be restored




Dissolved Oxygen at 12 meters, 1989-2010
Dissolved Oxygen (mg/L)
8
4
0
1990
1995
2000
2005
2010
July (p-value≤0.01)
Aug (p-value≤0.001)
The rate of hypolimnetic oxygen loss has increased at Site 1.

Reasons for Declining Oxygen Levels

Low oxygen in hypolimnion is caused by bacteria in hypolimnion decomposing organic matter (dead algae, leaf fragments, etc.)

- **Algal growth in the lake is primarily controlled by phosphorus availability**

  ➔If more phosphorus is available, more algae will grow

  ➔Lake receives internal and external phosphorus loading

- **If more algae grow in the lake, there will be more organic matter in the lake (from dead algae)**
- **If more organic matter is present in the lake, bacteria in the hypolimnion will use oxygen faster**

TMDL Report

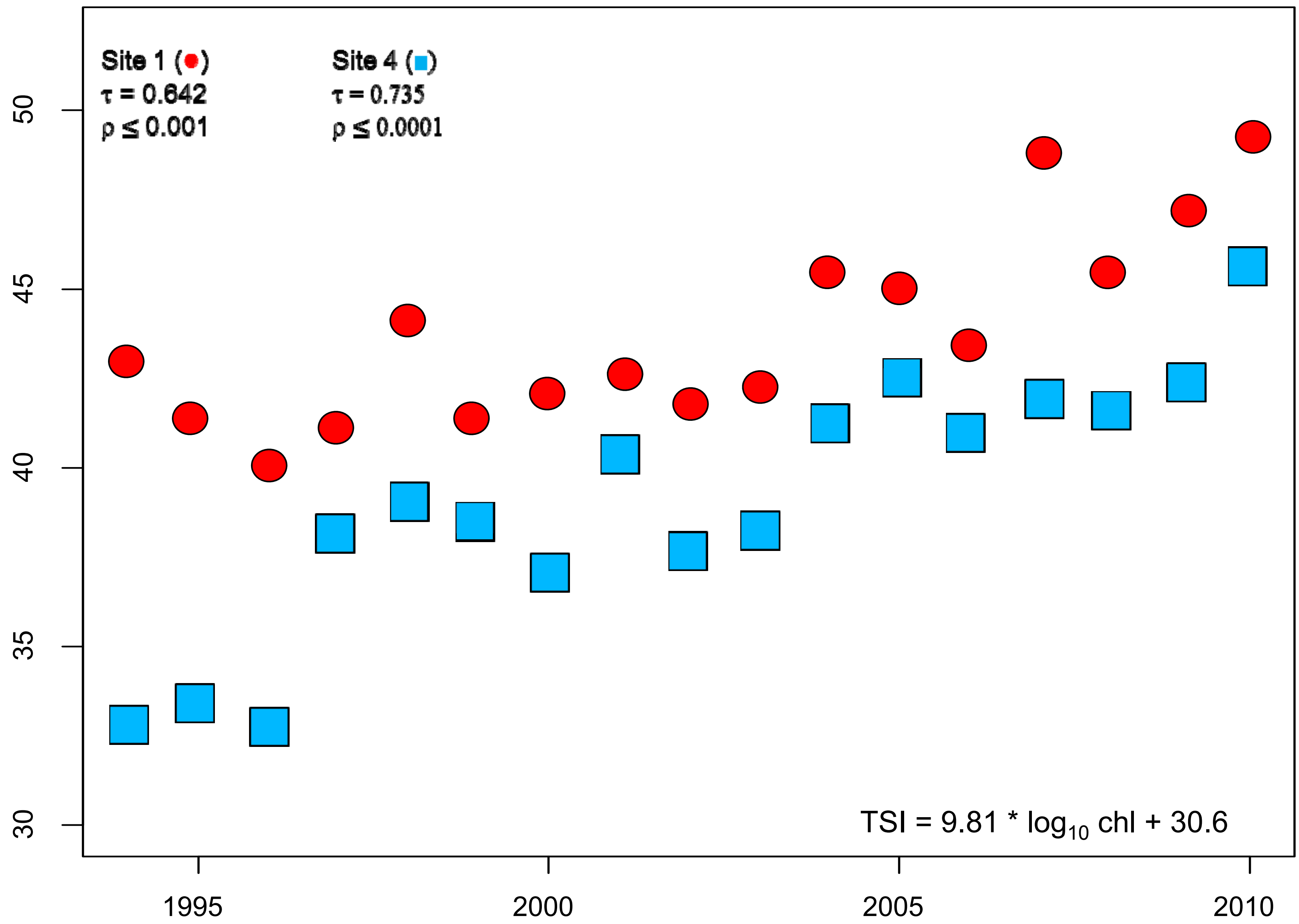
- Lake Whatcom was listed on the 1998 303D list due to declining oxygen levels
- To address the oxygen decline, we need to reduce algal growth by reducing phosphorus
  - Surface runoff in residential areas still contains high concentrations of phosphorus (external P loading)
  - Low hypolimnetic oxygen levels continue to allow phosphorus to move from lake sediments into the overlying water (internal P loading)
- Ecology's TMDL Report (November 2009; No. 08-03-024) proposes a significant reduction in phosphorus entering the lake
  - Controlling external loading will also reduce internal loading by reducing the amount of organic matter in the lake, thus slowing the rate of hypolimnetic oxygen loss

Other Water Quality Trends

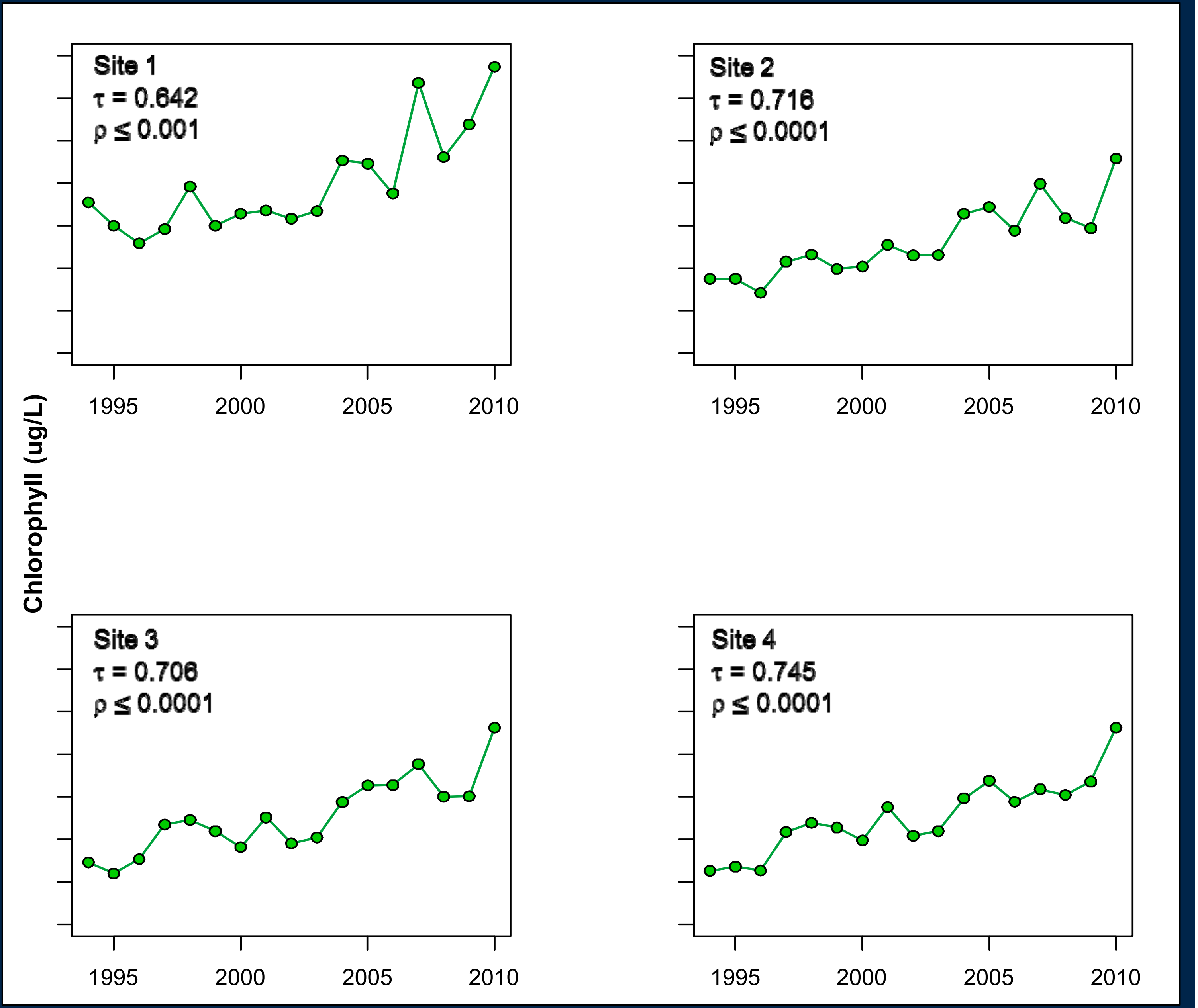
- The long-term water quality data show that the lake's **trophic level** has changed
  - Phosphorus concentrations have increased, but water column phosphorus levels are not the best indicator of lake trophic state
- Algal densities and chlorophyll levels have increased throughout the lake
- Carlson's Trophic State Index is increasing throughout the lake ($TSI = 9.81 * \log_{10} chl + 30.6$)

Unproductive Lakes (Oligotrophic)	Moderately Productive Lakes (Mesotrophic)	Productive Lakes (Eutrophic)
TSI_{chl} <30	TSI_{chl} = 30 - 50	TSI_{chl} >50

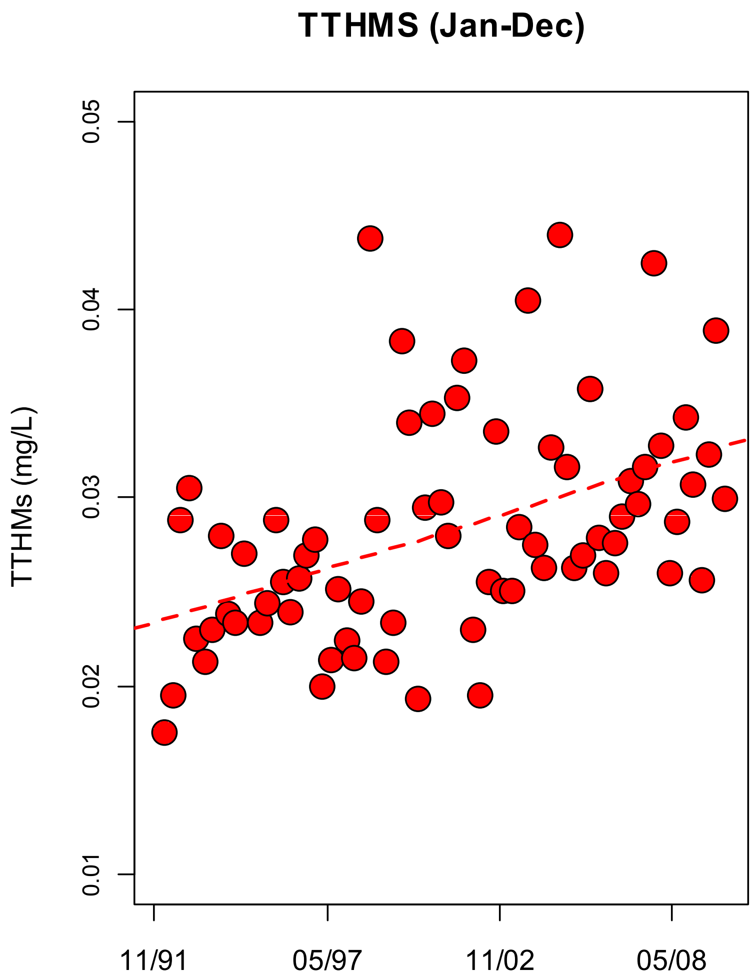
Trophic Index Based on Summer Median Chlorophyll Concentrations

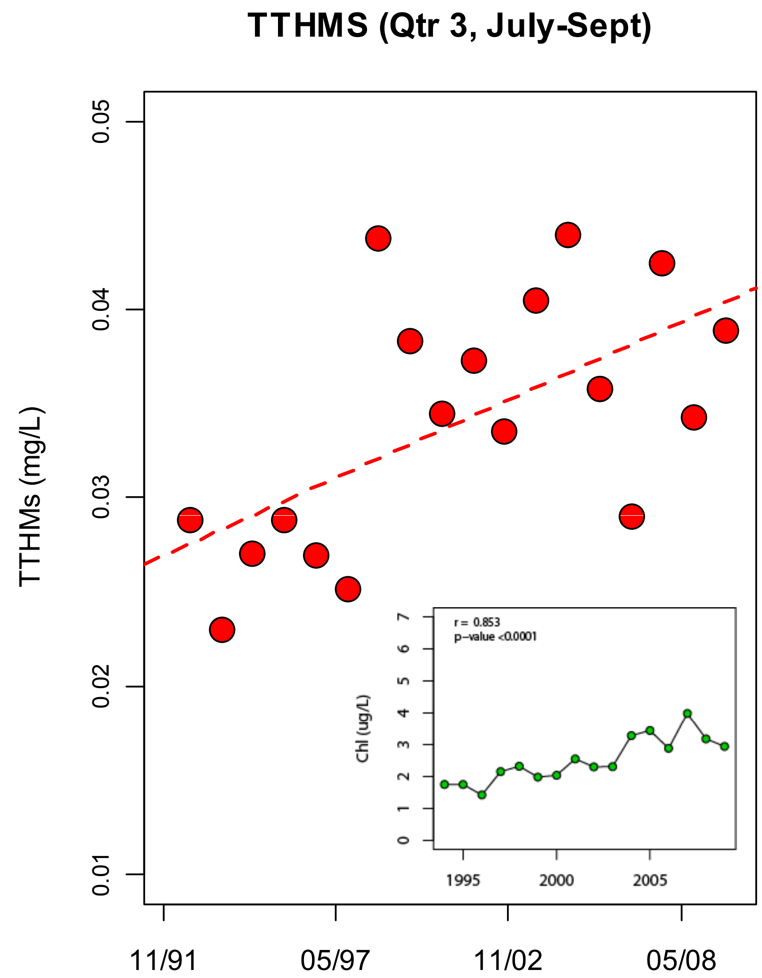


Median summer near-surface chlorophyll levels have increased throughout the lake, especially in basin 3

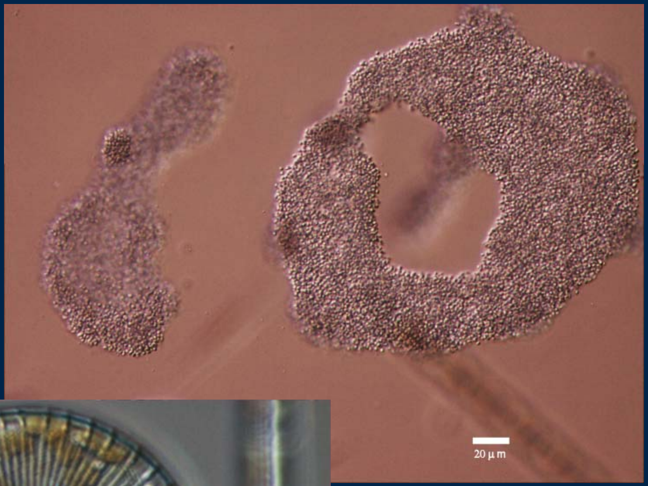


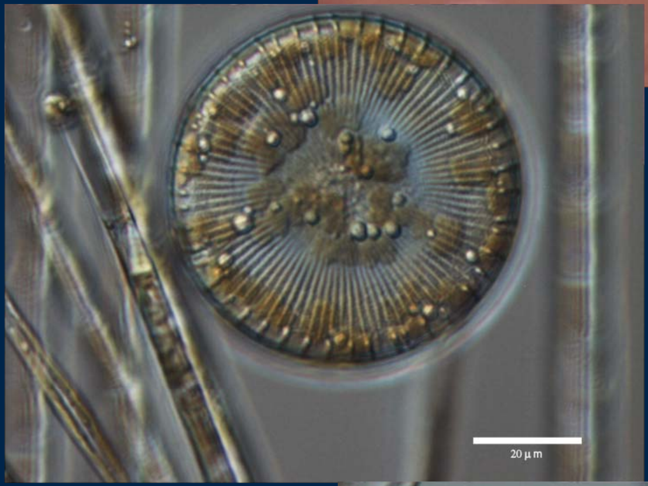
Increasing THMs in Bellingham's Treated Drinking Water

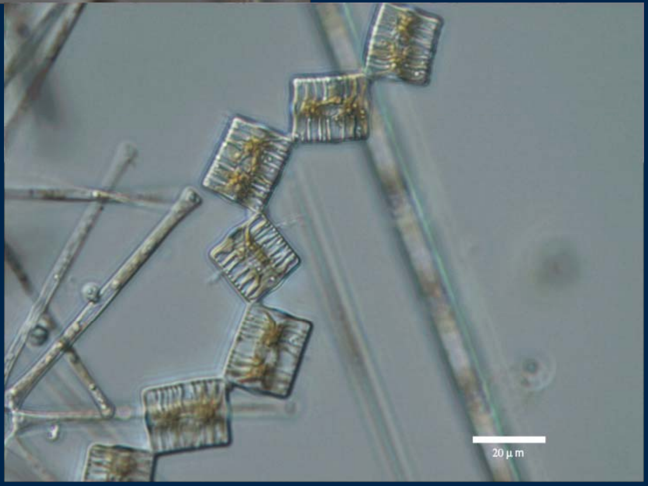




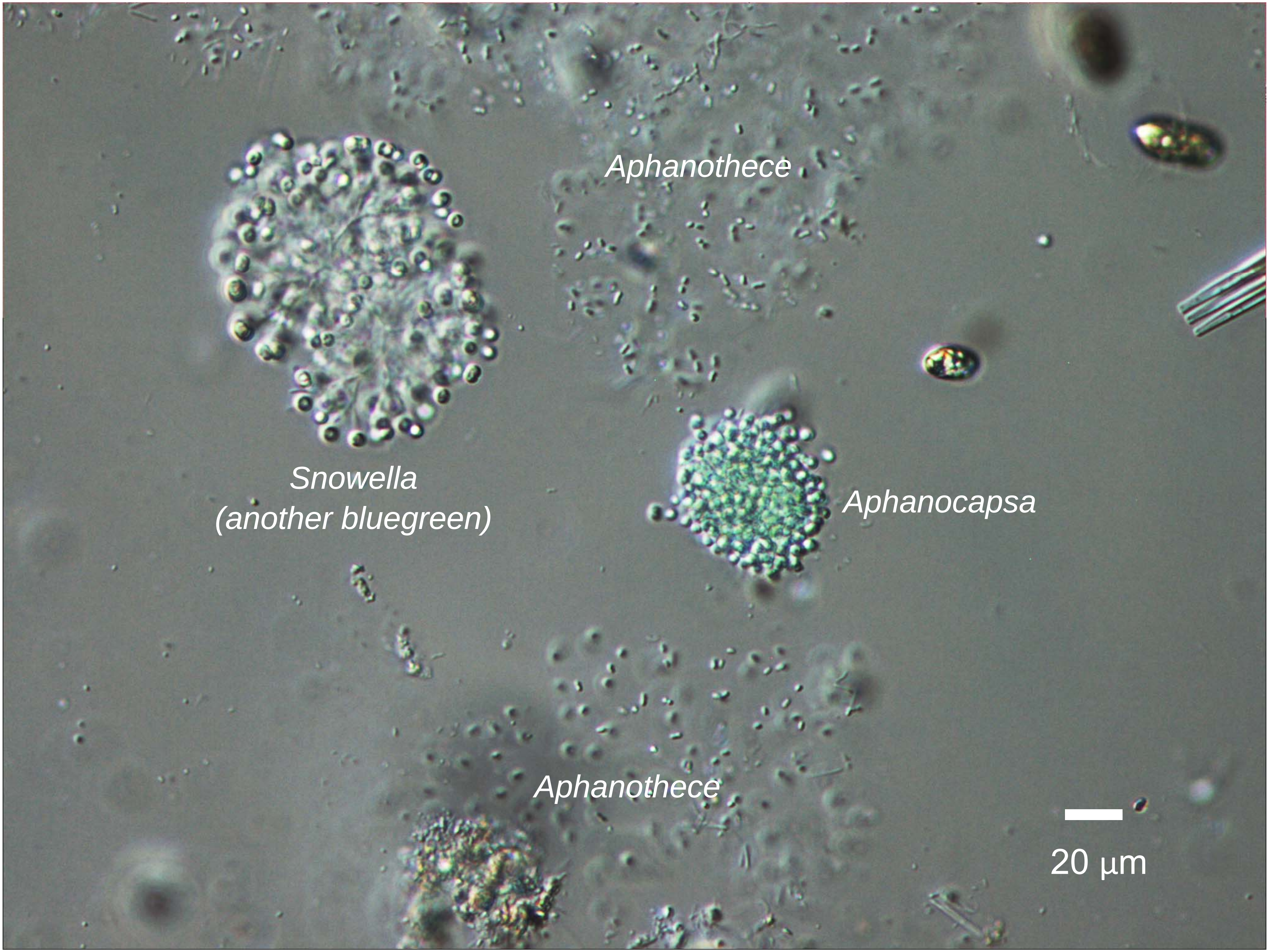
- In 2009, summer algal blooms caused water filtration to slow to the extent that the City imposed mandatory limits on water use
- Cyanobacteria[1] appeared to be the major cause of slow filtration
- IWS is conducting monthly algae counts in basin 2 (Site 2 and the Intake) and raw water gatehouse

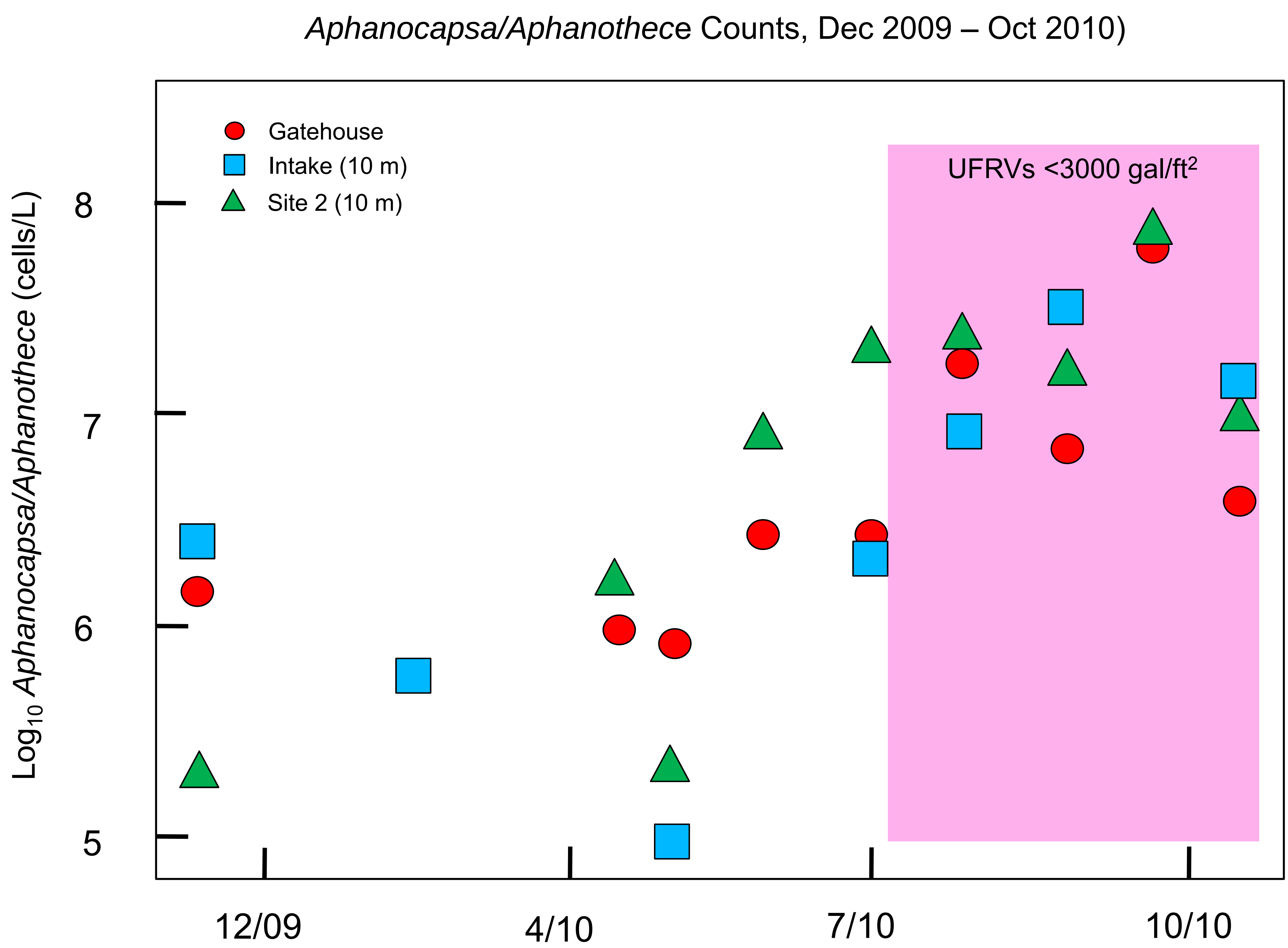


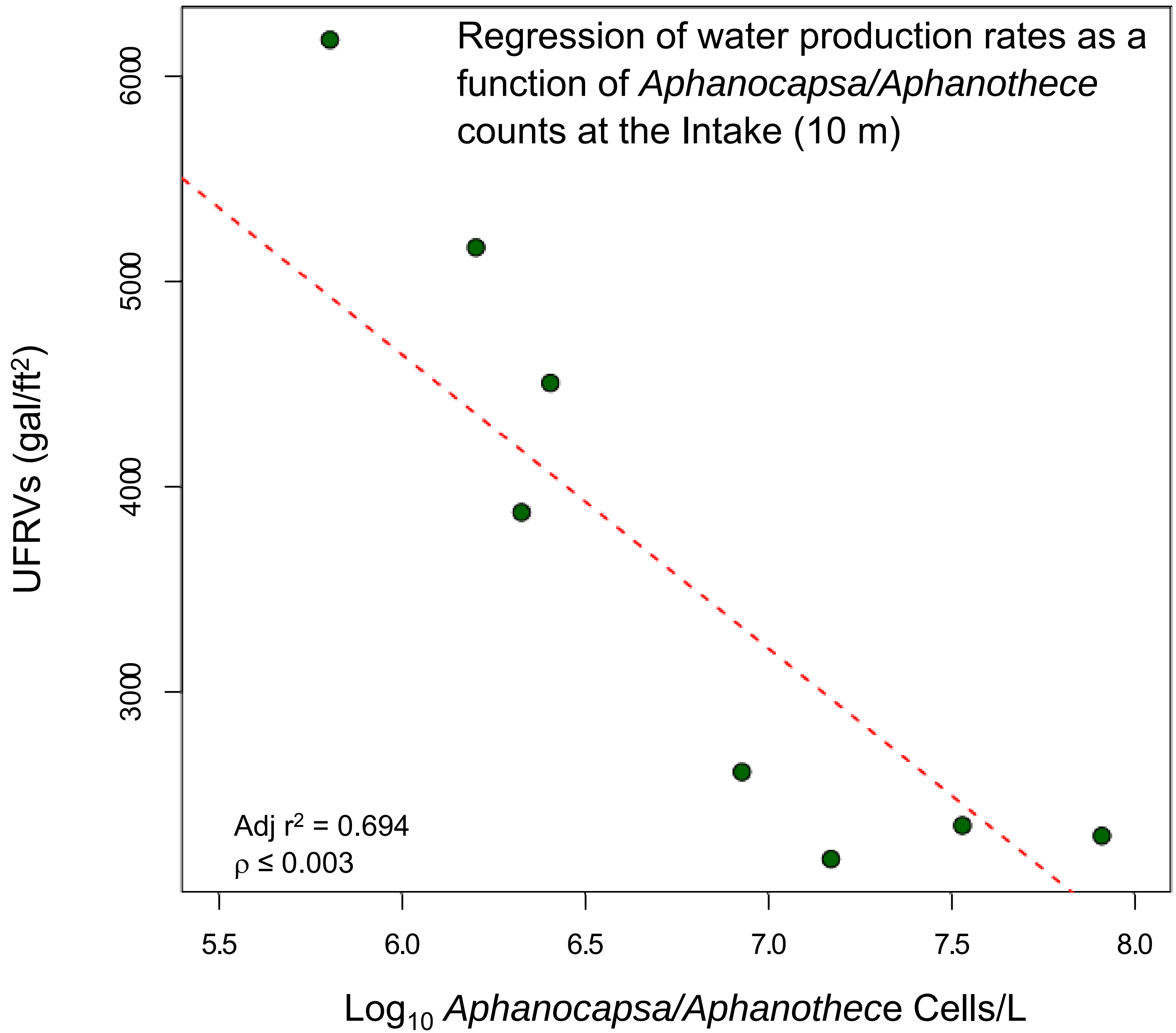




[1]diatoms may also be involved in the filtration problem


Aphanothece
Snowella
(another bluegreen)
Aphanocapsa
Aphanothece
20 µm


Aphanocapsa/Aphanothece Counts, Dec 2009 – Oct 2010)
Gatehouse
Intake (10 m)
Site 2 (10 m)
UFRVs <3000 gal/ft2
Log10 Aphanocapsa/Aphanothece (cells/L)
8
7
6
5
12/09
4/10
7/10
10/10


Regression of water production rates as a function of *Aphanocapsa/Aphanothece* counts at the Intake (10 m)
Adj r^2 = 0.694
$\rho \leq 0.003$
UFRVs (gal/ft^2)
6000
5000
4000
3000
5.5
6.0
6.5
7.0
7.5
8.0
Log$_{10}$ *Aphanocapsa/Aphanothece* Cells/L

Where are we now?

- Lake Whatcom has changed to a higher trophic state
  - ✓ Hypolimnetic oxygen levels declined at Site 1
  - ✓ Phosphorus levels increased throughout the lake
  - ✓ Chlorophyll concentrations and algal counts increased throughout the lake
- High concentrations of phosphorus enter the lake via surface runoff or are released from sediments in low oxygen portions of the hypolimnion
- The City is experiencing water filtration problems due to algal blooms

Summer 2011
(June-November)

IWS will collaborate with the City to help evaluate effectiveness of water filtration treatment options

Gatehouse

continuous:	cyanobacteria fluorescence
	water filtration rates (from City)
	DAF* operation (from City)
	(*dissolved air floatation - used to remove algae)
3x weekly:	algae identification/counts and water quality

Intake Site

2x monthly:	vertical profiles to measure algae and water quality to see if the algae are uniform or stratified in the water column

Thanks!

Mike Hilles

Joan Vandersypen

Marilyn Desmul

Dr. Robert Mitchell

Dr. Geoffrey Matthews

and the undergraduate and graduate students working on the Lake Whatcom Project