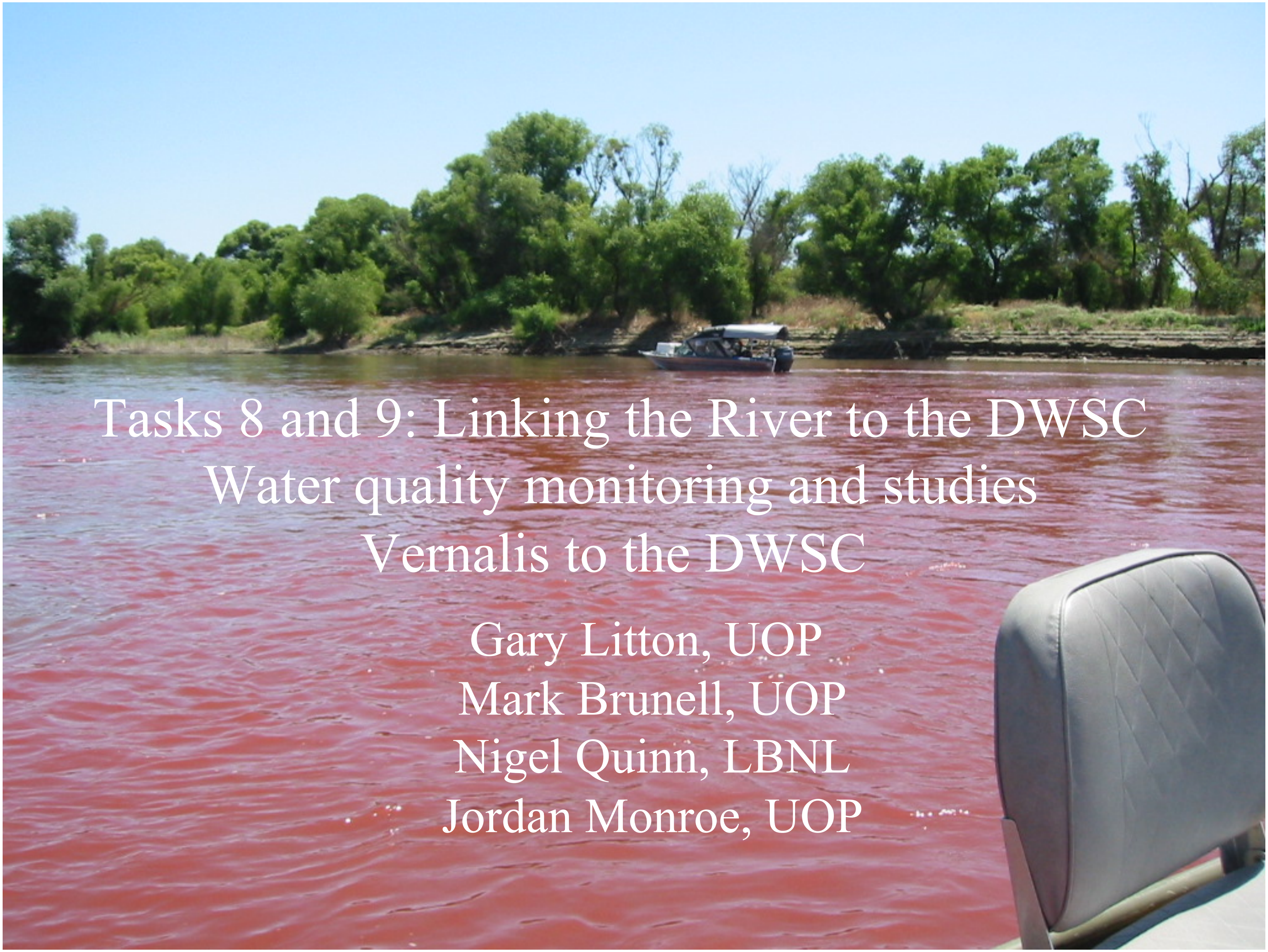
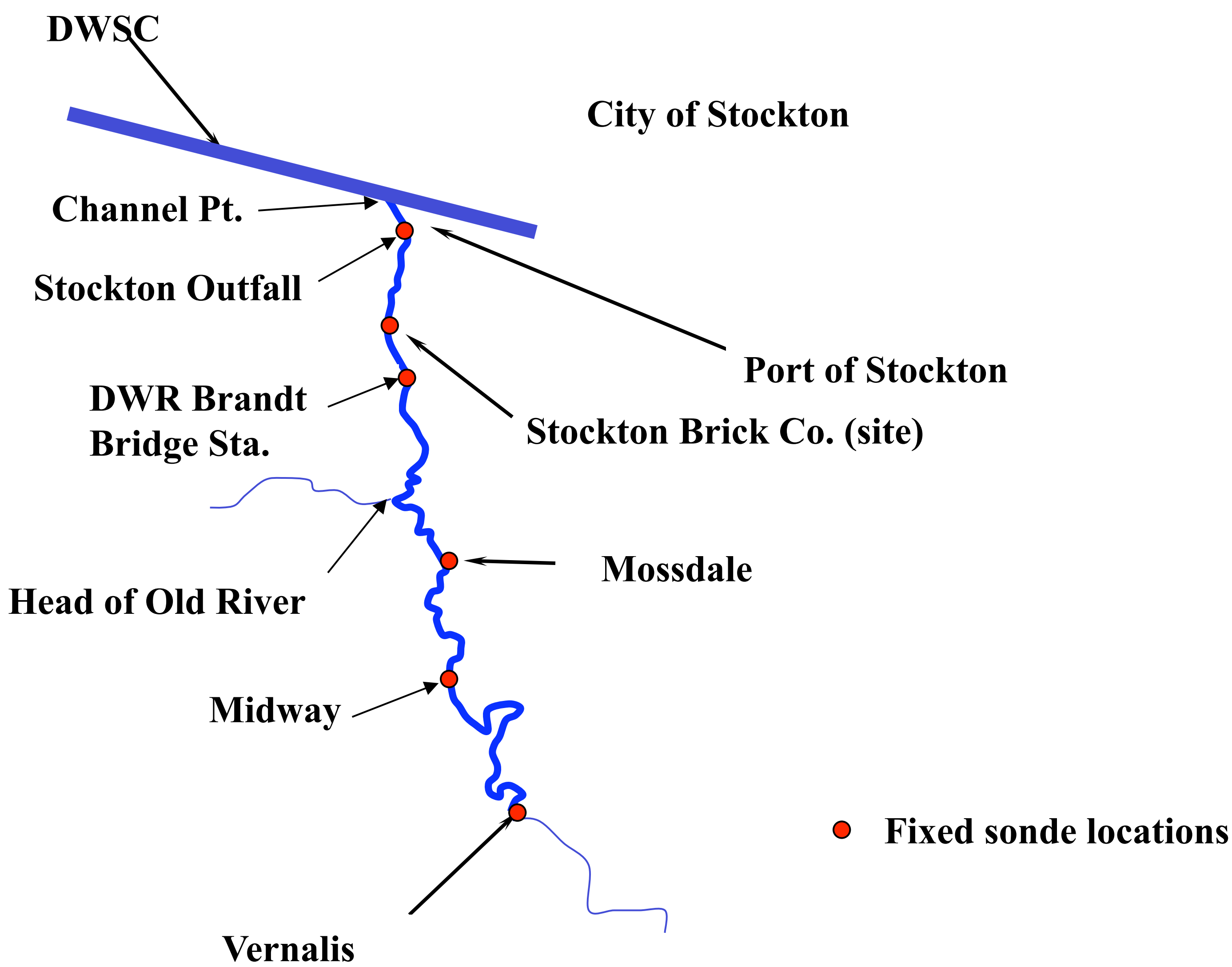


Tasks 8 and 9: Linking the River to the DWSC Water quality monitoring and studies Vernalis to the DWSC

Gary Litton, UOP
Mark Brunell, UOP
Nigel Quinn, LBNL
Jordan Monroe, UOP

San Joaquin River Task 8 & 9 Study Reach



Motivation

- Water quality model prediction is 3x the measured chl *a* concentration at Channel Point using Mossdale input.[1]
- Model DO is approximately 2 mg/L less than observations at Channel Point.[1]
- Contradictory data for algal growth and decay between Vernalis and the DWSC.[2,3,4]
- Significant loss of algal biomass below Vernalis [1,3]

[1]Jones & Stokes, 2002. *Evaluation of Stockton Deep Water Ship Channel Model Simulations of 2001 Conditions: Loading Estimates and Model Sensitivity,* Prepared for the CALFED Bay-Delta Program 2001 Grant 01-N61, Sacramento, CA

[2]Jones & Stokes, 1998. *Potential solutions for achieving the San Joaquin River dissolved oxygen objectives*. Prepared for the City of Stockton Department of Municipal Utilities, Sacramento, CA.

[3]Lehman, P., 2001. *The Contribution of Algal Biomass to Oxygen Demand in the San Joaquin River Deep Water Channel*, Final Draft Report, San Joaquin River Dissolved Oxygen TMDL Steering Committee, Department of Water Resources, Central District, Sacramento, CA.

[4]Foe, C., M. Gowdy, and M. McCarthy, 2002. Draft Strawman Allocation of Responsibility Report, California Regional Water Quality Control Board, Central Valley Region, January, Sacramento, CA.

Objectives

- Determine the mechanisms influencing algal growth and decay from Vernalis to the DWSC.
- Quantify oxygen demands entering the DWSC
- Provide a comprehensive data set for water quality model calibration upstream of the DWSC

Approach Overview

- Deploy continuous monitoring sondes at fixed locations for extended periods (≈1 wk to several months in 2007).
- Track a parcel of water using a tracer to measure changes in chlorophyll, pheophytin, BOD, and ammonia from Vernalis to the DWSC.
- Longitudinal profiles were performed from Mossdale to the DWSC during the extreme low net flow periods observed in 2007.
- Assess grazing component by enumerating zooplankton and benthic macroinvertebrates.
- Augment field work with laboratory assessment of BOD kinetics.
- Assess algal productivity with field light/dark bottle experiments.
- Develop a simple numerical model to assess light effects and zooplankton grazing on algae populations.

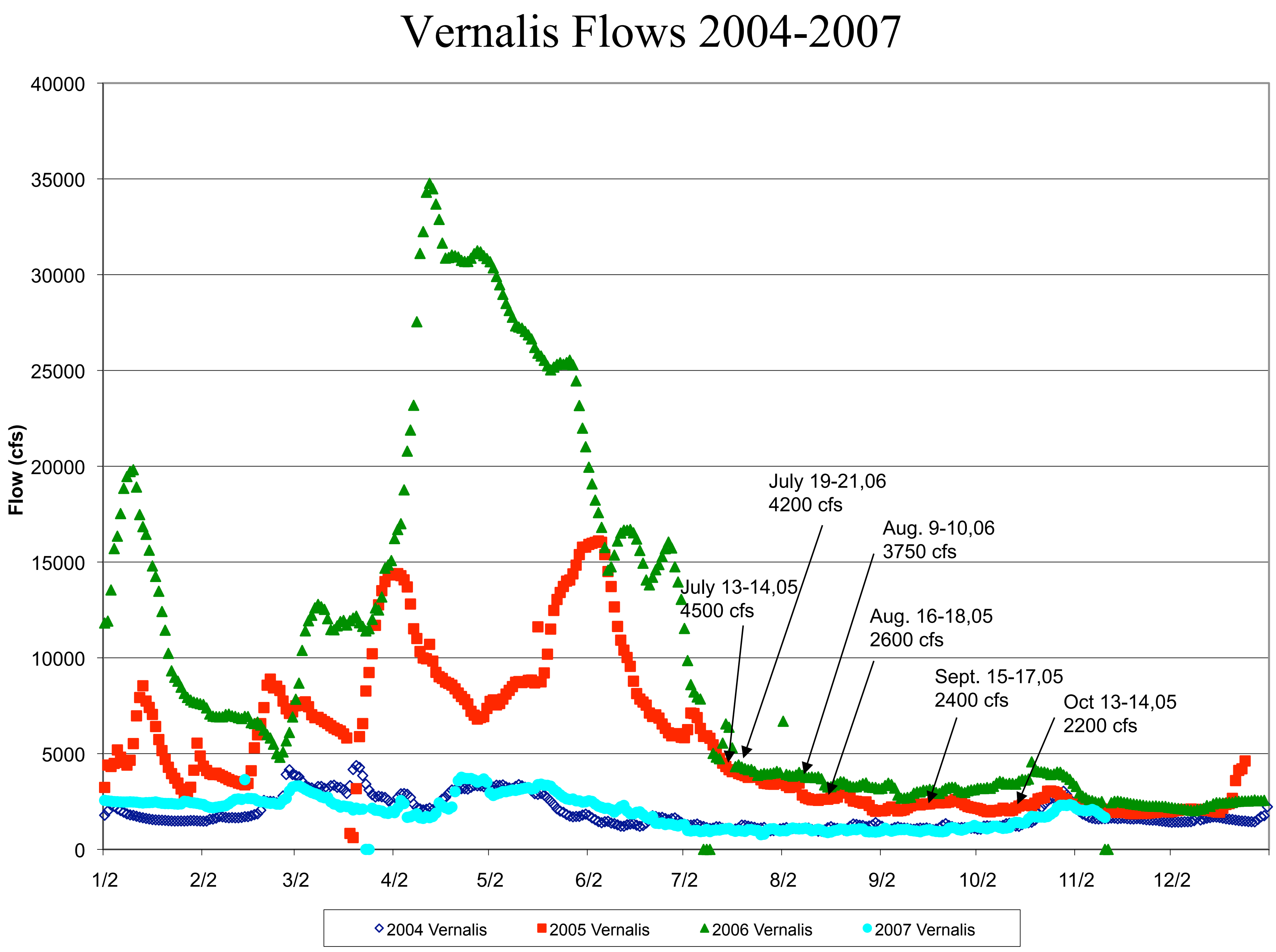

YAMAHA

Water Quality Parameters

- Field measurements:
  - Fixed sondes: temp, pH, DO, EC, chl a, ph a, turbidity, river stage
  - Dye tracking: rhodamine WT, water depth, location
  - Light/dark bottles & light intensity profiles
  - Zooplankton grazing microcosms experiments

- Laboratory measurements:
  - chl a, ph a, BOD, CBOD, VSS, TSS, alkalinity, nitrogen and phosphorous species

- Biological examination:
  - Phytoplankton
  - Zooplankton
  - macroinvertebrates


Vernalis Flows 2004-2007
Flow (cfs)
40000
35000
30000
25000
20000
15000
10000
5000
0
1/2
2/2
3/2
4/2
5/2
6/2
7/2
8/2
9/2
10/2
11/2
12/2
July 19-21,06
4200 cfs
Aug. 9-10,06
3750 cfs
July 13-14,05
4500 cfs
Aug. 16-18,05
2600 cfs
Sept. 15-17,05
2400 cfs
Oct 13-14,05
2200 cfs
2004 Vernalis
2005 Vernalis
2006 Vernalis
2007 Vernalis

Biological Examination: Methods

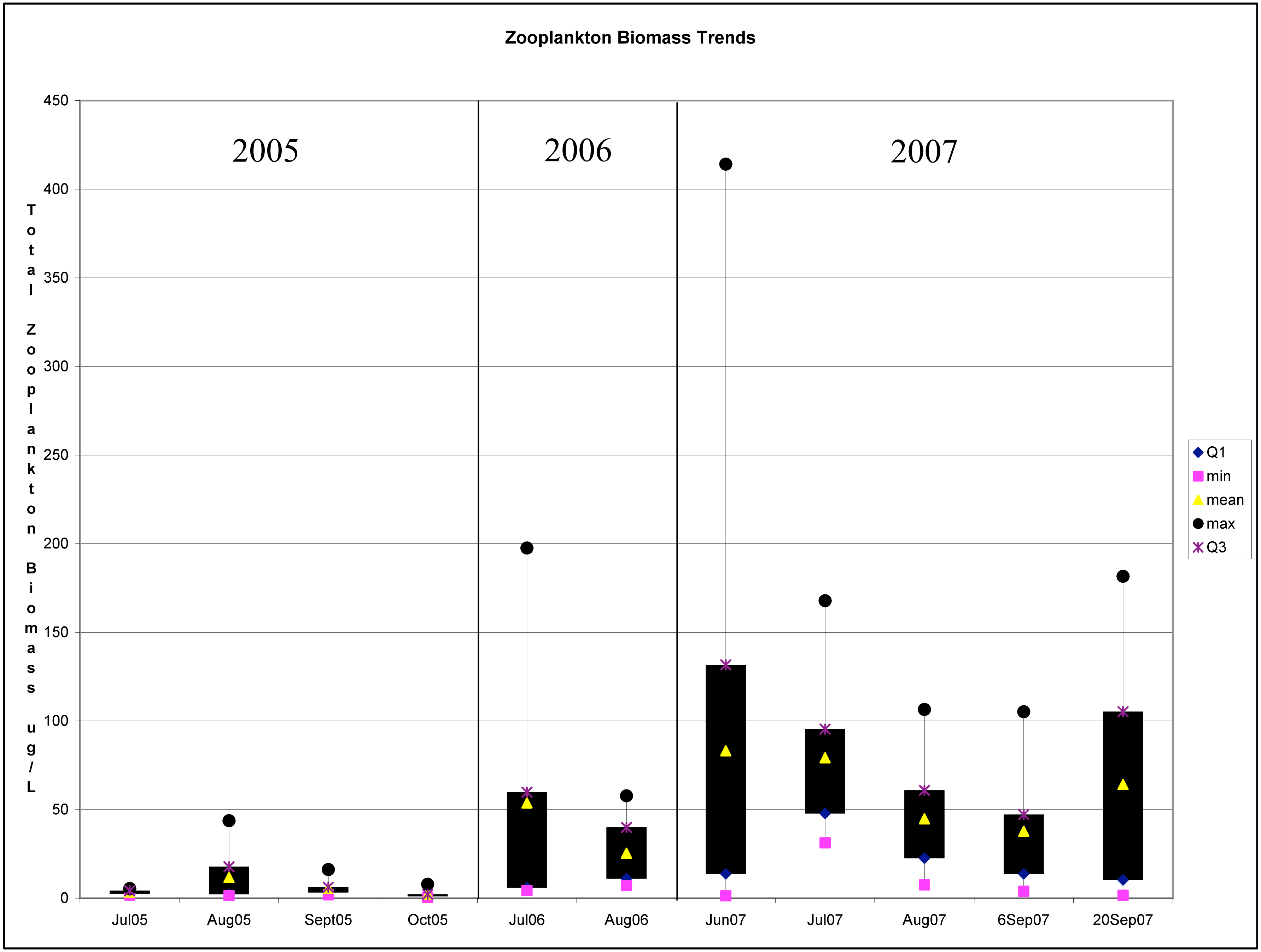
- Samples coincided with water quality measurements
- Zooplankton: Schindler-Patalas Trap with 63um net, 30L sampled at specific depth, samples fixed in formalin
  - Volume-adjusted samples were subsampled and settled in Standard Utermöhl Chambers and organisms were viewed and measured with an inverted microscope
  - For each sample, at least 200 organisms (rotifers and copepod nauplii) were counted, and for each species up to 20 individuals were measured for body length per sample, then body lengths converted to dry weight biomass (μg/L) using literature conversions.
- Algae: whole water sample (500mL) fixed in Lugol's solution.
- Benthos: Ponar dredge and hand digging used to locate bivalves, specimens preserved, did not coincide with other sampling events.

Grazing Results: Species

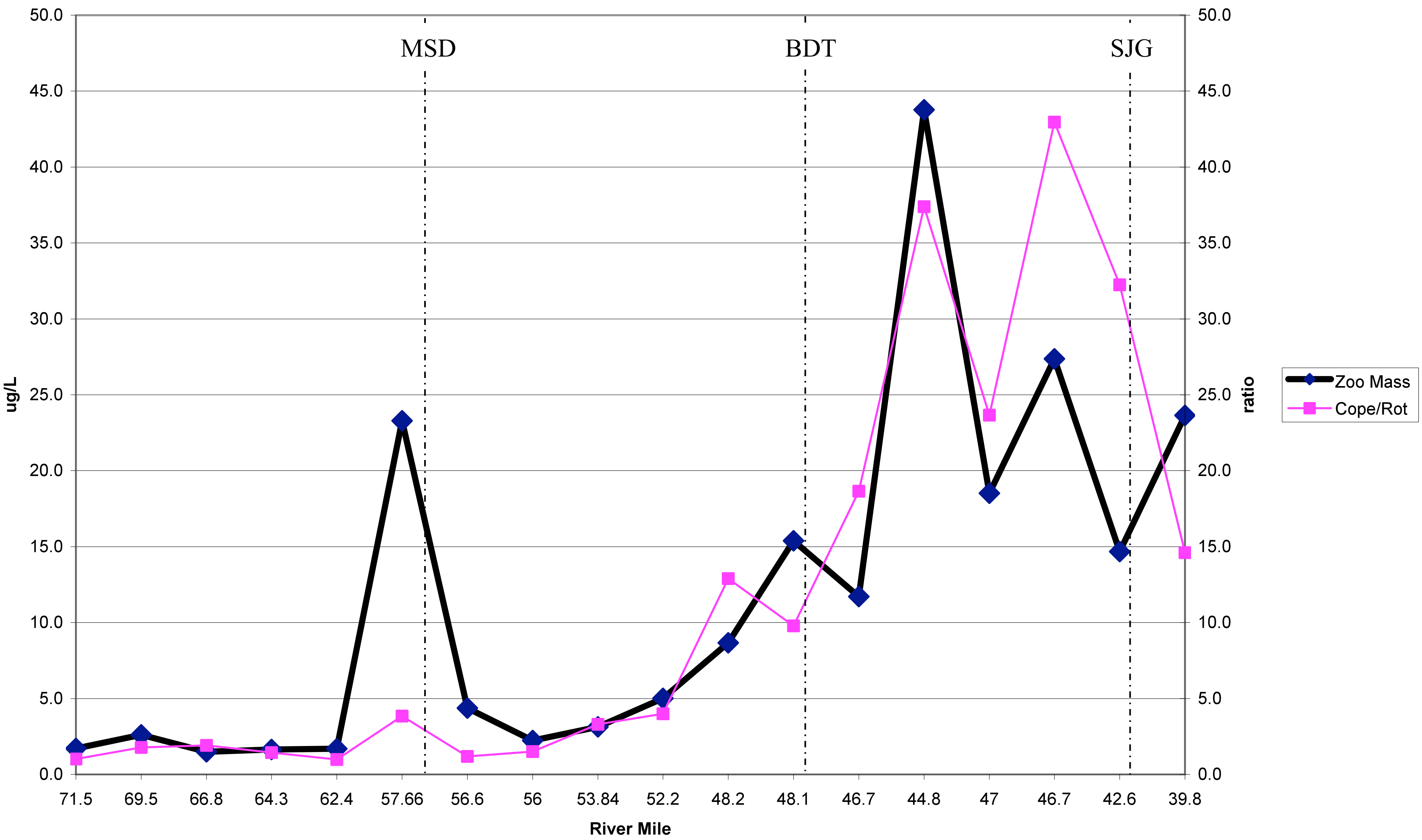
- Over the study periods, 52 species of zooplankton were identified, consisting of Rotifers, Copepods, and Cladocerans.
  - Rotifers: 42 species; major species were *Brachionus calyciflorus, B. budapestinensis, Polyarthra remata, Asplancha priodonta*, and *Brachionus angularis*.
  - Copepods: 4 species; *Pseudodiaptomus forbesii*, *Microcyclops rubellus*, *Eurytemora affinis*, one harpacticoid species. Nauplii had highest biomass over entire study.
  - Cladocera: 7 species; most abundant were *Bosmina longirostris, Ceriodaphnia lacustris, Daphnia parvula*

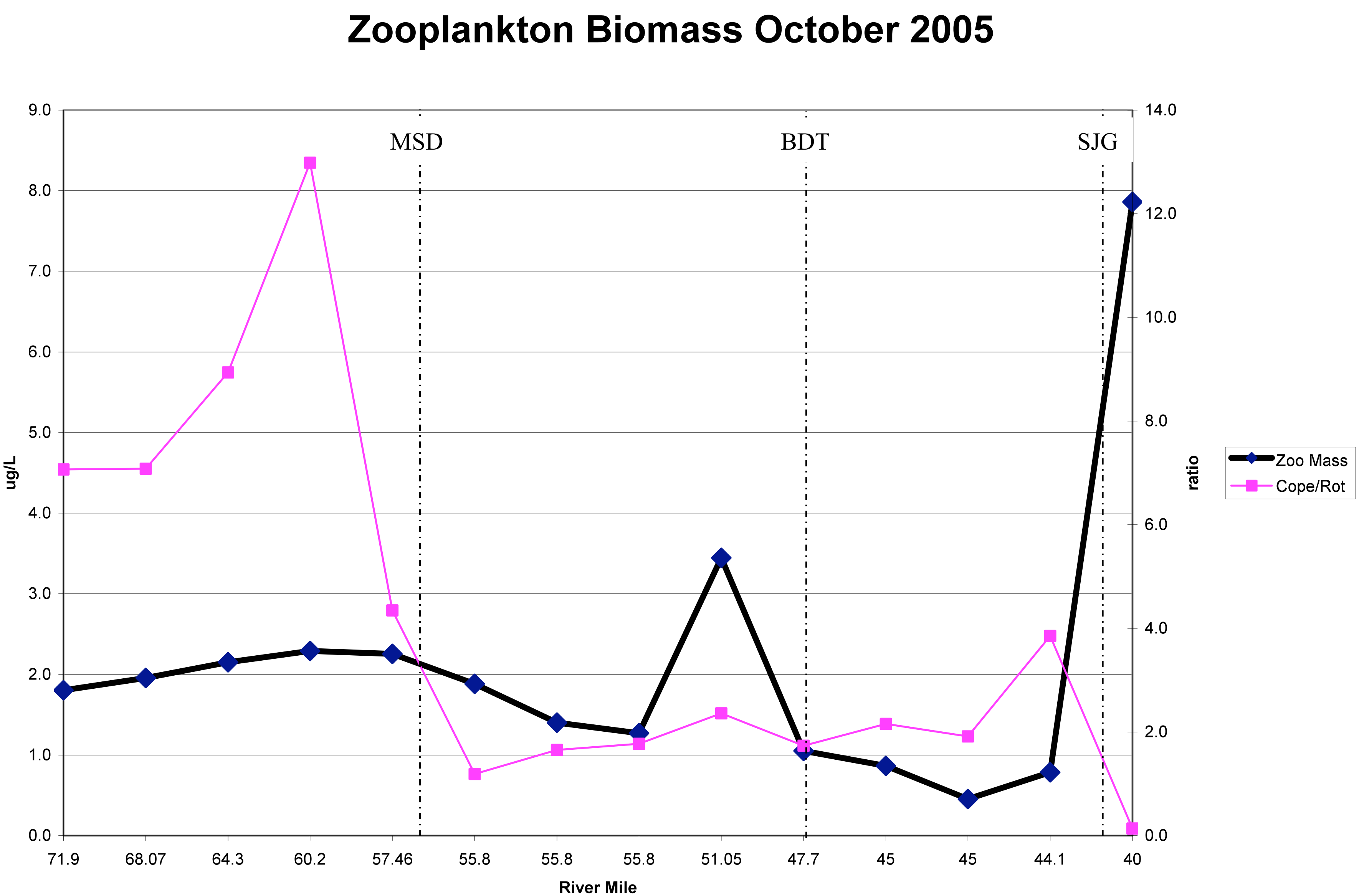
Grazing Results: Trends

- Species over time
  - Total biomass per period generally decreased as season progressed.
  - At sites with large zooplankton biomass, copepods almost always comprise the majority of the biomass.
- Variation in site biomass:
  - Sites ranged widely in total biomass.
  - Range: 0.5 – 414.1 μg/L
  - In most periods, total biomass increases downstream, with peaks usually occurring between the Head of Old River and the DWSC, and are generally associated with copepods and night.
  - During the low flow period of 2007, peaks were centered between river mile 52 and 44, with peaks occurring at river mile 48 (near BDT) most often.
  - Also during the low flow period, peaks shift with tidal flow, that is, move upstream during flood tide and downstream during ebb tide.

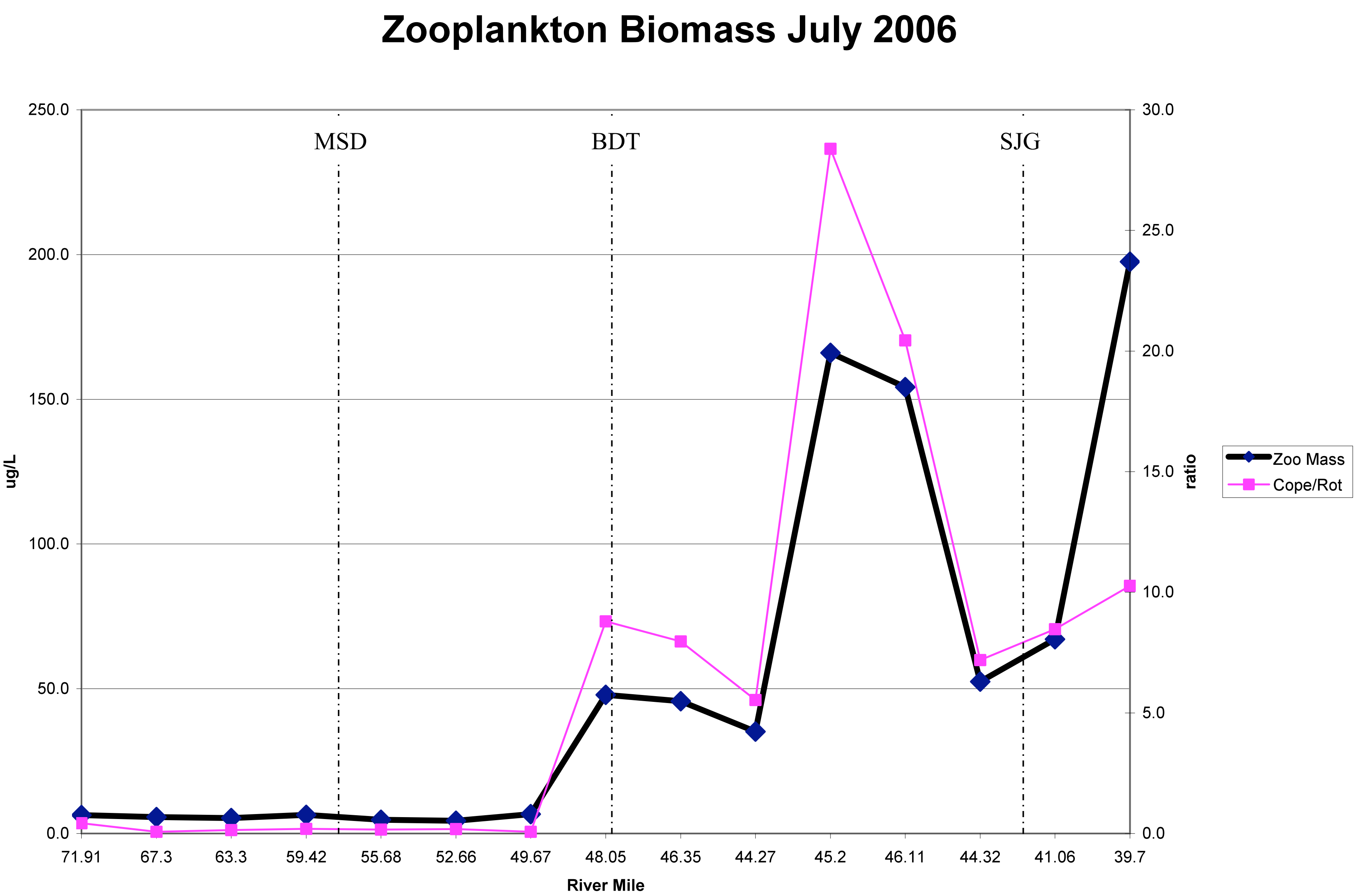

Zooplankton Biomass Trends
Total Zooplankton Biomass ug/L
450
400
350
300
250
200
150
100
50
0
2005
2006
2007
Jul05
Aug05
Sept05
Oct05
Jul06
Aug06
Jun07
Jul07
Aug07
6Sep07
20Sep07
Q1
min
mean
max
Q3

Zooplankton Biomass August 2005



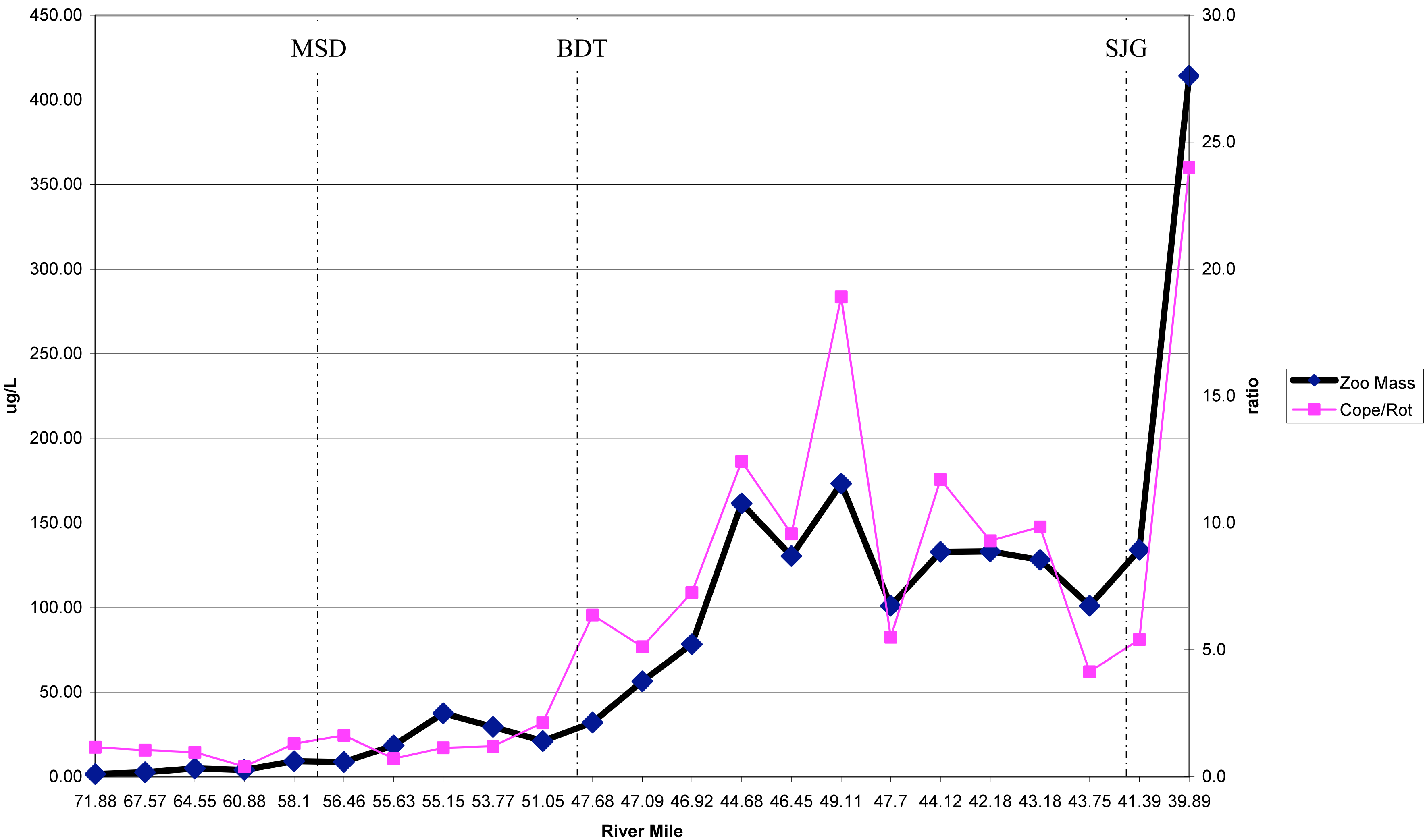


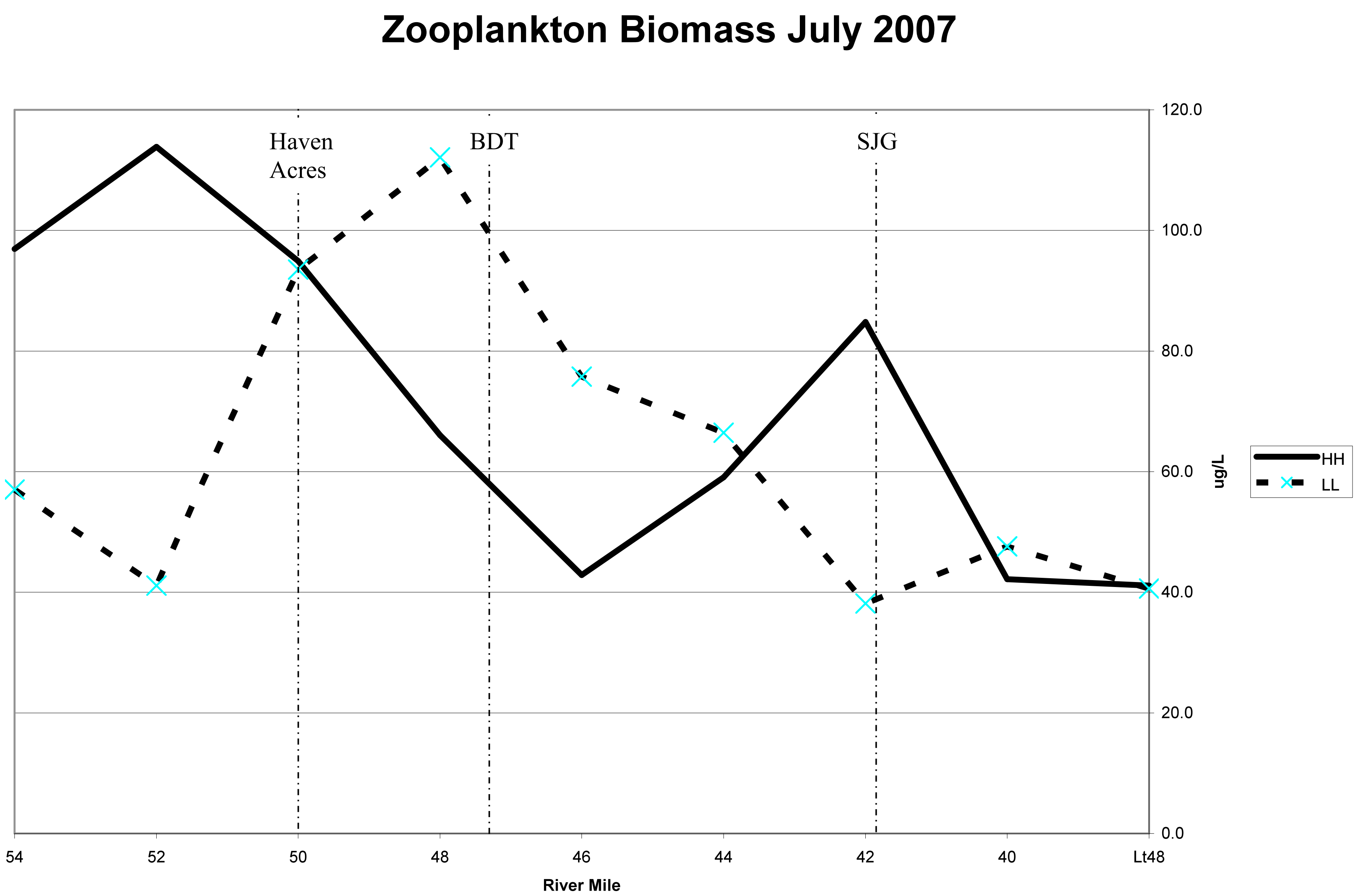
Zooplankton Biomass October 2005
ug/L
ratio
River Mile
MSD
BDT
SJG
Zoo Mass
Cope/Rot
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
71.9
68.07
64.3
60.2
57.46
55.8
55.8
55.8
51.05
47.7
45
45
44.1
40



Zooplankton Biomass July 2006
250.0
200.0
150.0
100.0
50.0
0.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ug/L
ratio
MSD
BDT
SJG
71.91
67.3
63.3
59.42
55.68
52.66
49.67
48.05
46.35
44.27
45.2
46.11
44.32
41.06
39.7
River Mile
Zoo Mass
Cope/Rot

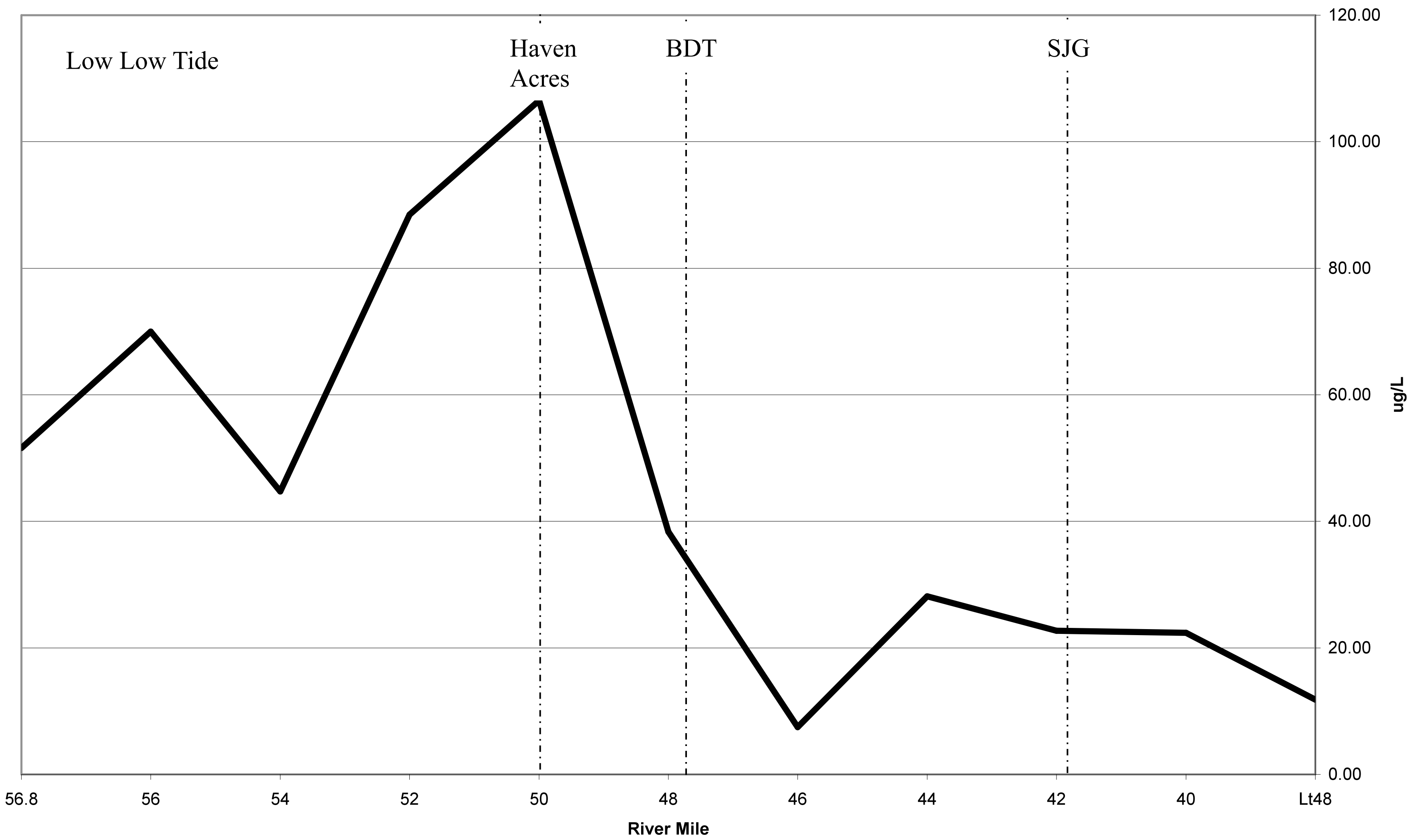
Zooplankton Biomass June 2007



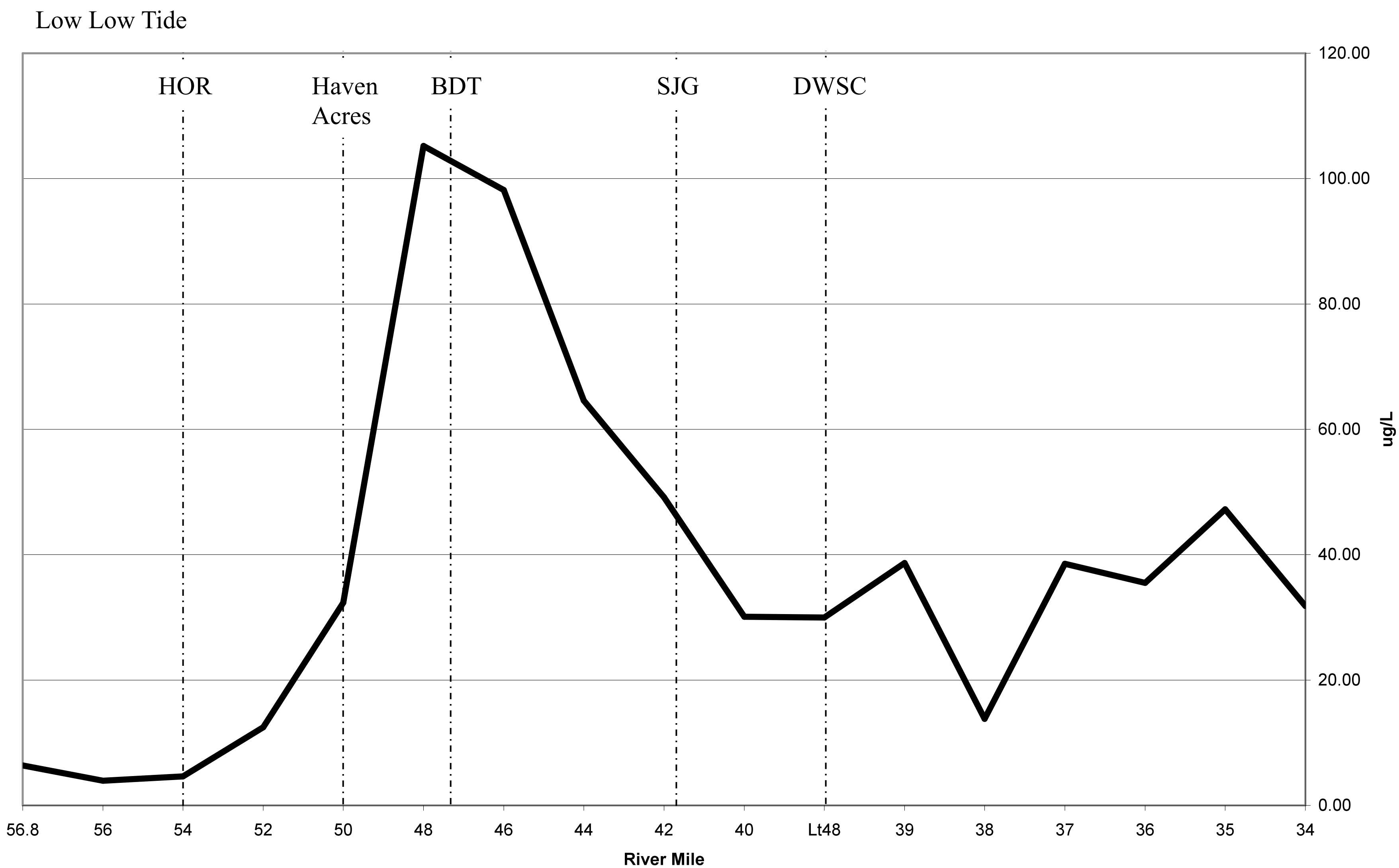


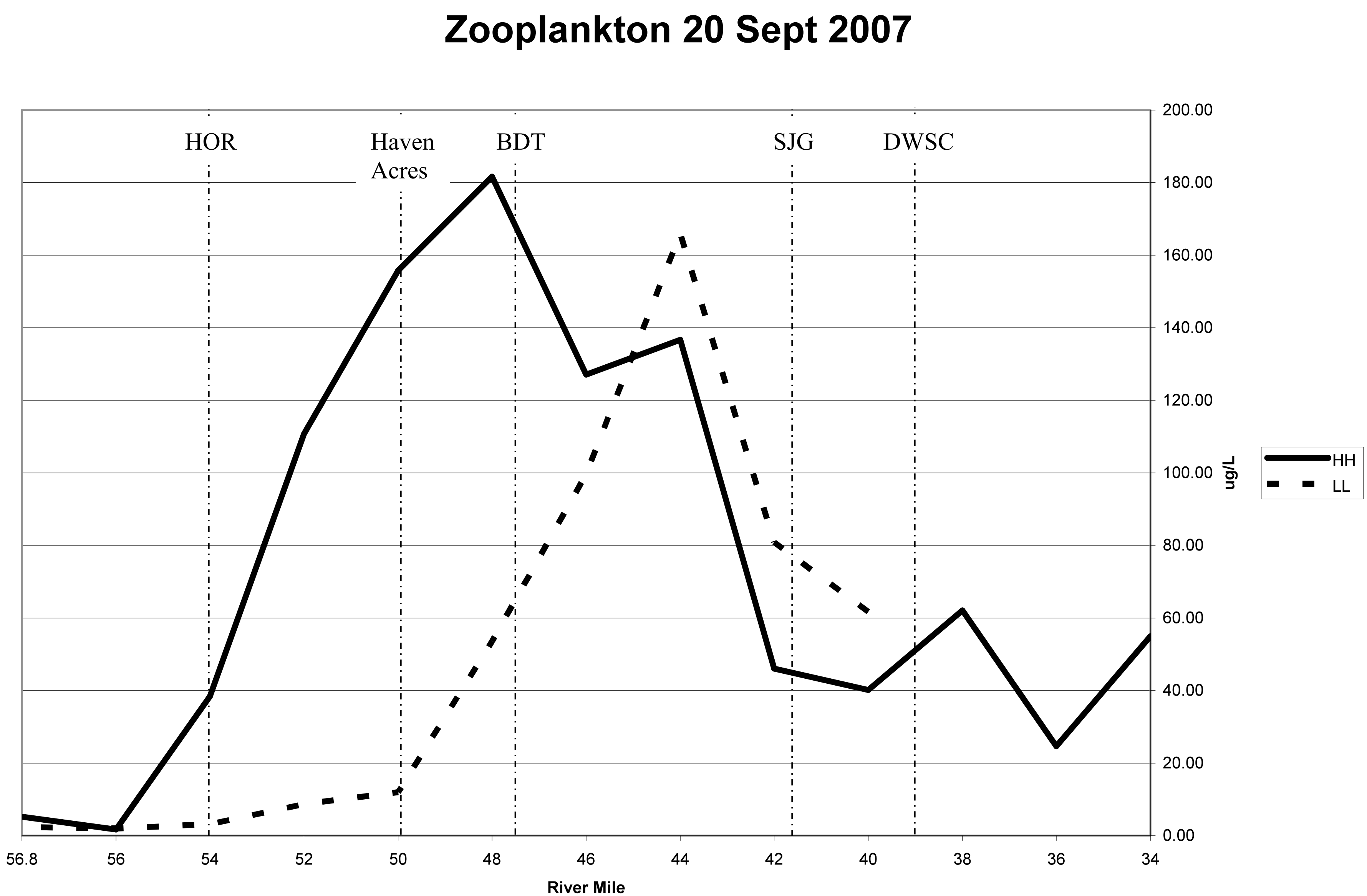
Zooplankton Biomass July 2007
Haven Acres
BDT
SJG
120.0
100.0
80.0
60.0
40.0
20.0
0.0
ug/L
HH
LL
54
52
50
48
46
44
42
40
Lt48
River Mile

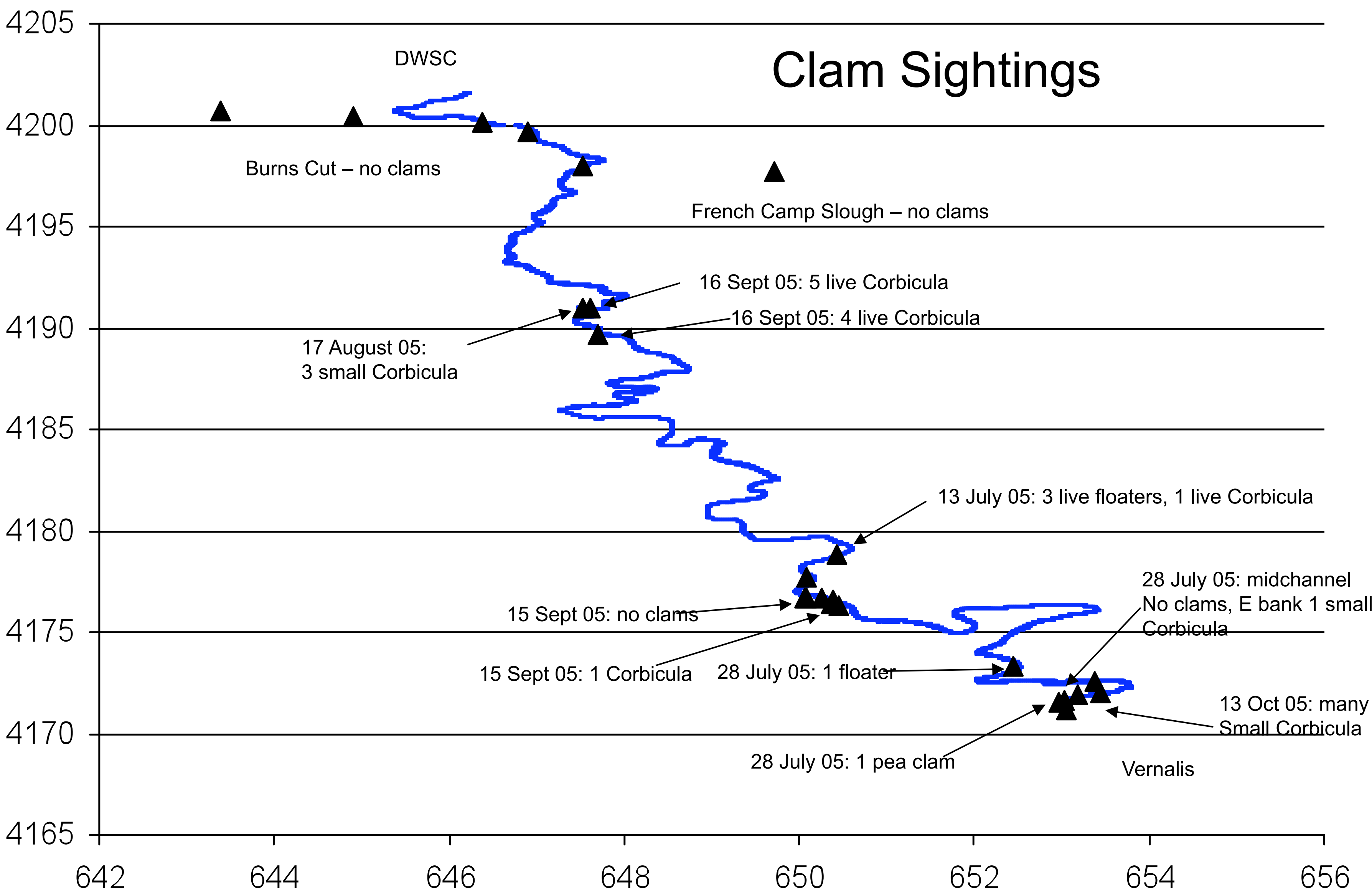
Zooplankton Biomass August 2007



Zooplankton 6 Sept 2007

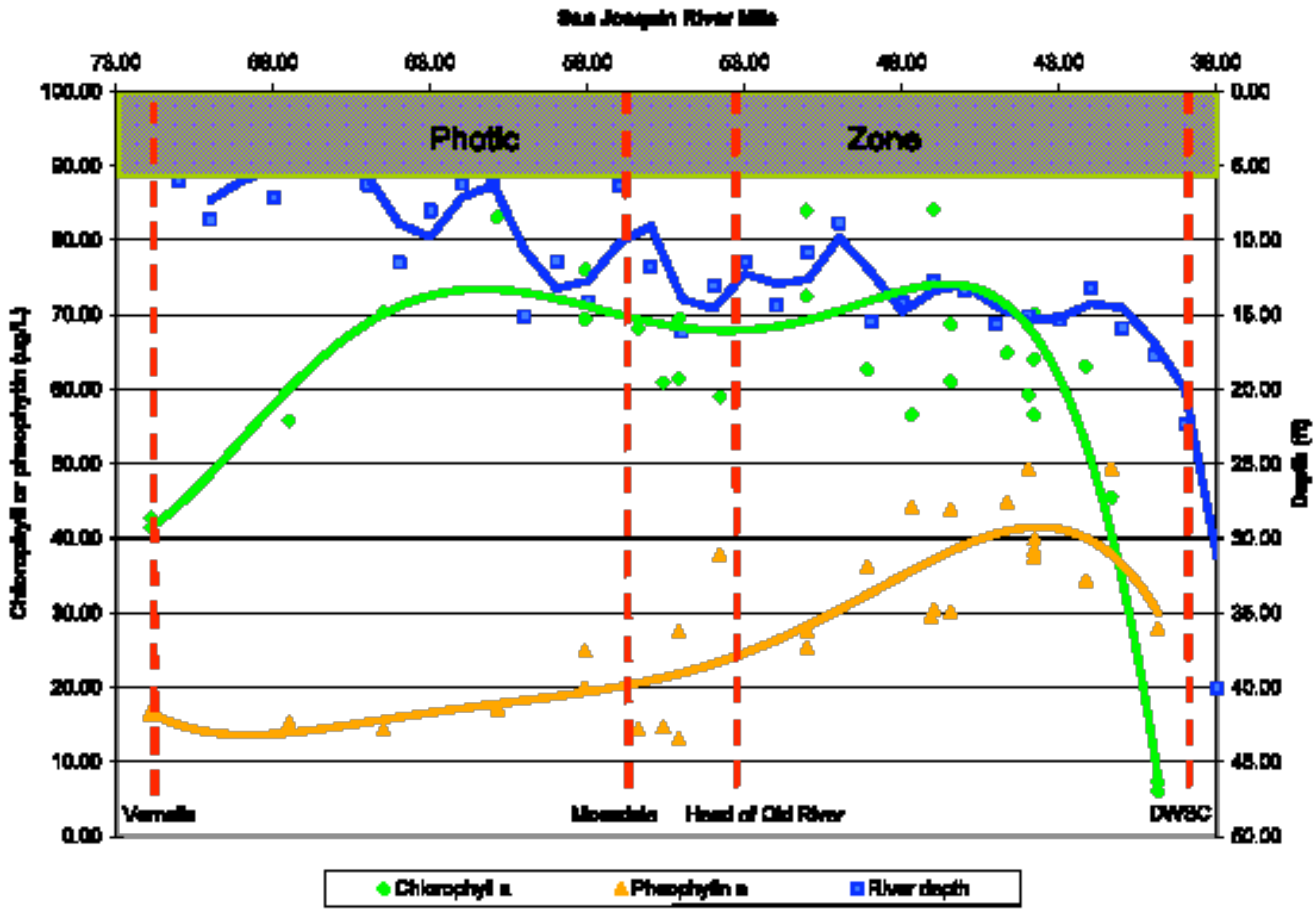



Zooplankton 20 Sept 2007
HOR
Haven Acres
BDT
SJG
DWSC
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
ug/L
HH
LL
56.8
56
54
52
50
48
46
44
42
40
38
36
34
River Mile


Clam Sightings
DWSC
Burns Cut – no clams
French Camp Slough – no clams
16 Sept 05: 5 live Corbicula
16 Sept 05: 4 live Corbicula
17 August 05:
3 small Corbicula
13 July 05: 3 live floaters, 1 live Corbicula
28 July 05: midchannel
No clams, E bank 1 small
Corbicula
15 Sept 05: no clams
15 Sept 05: 1 Corbicula
28 July 05: 1 floater
13 Oct 05: many
Small Corbicula
28 July 05: 1 pea clam
Vernalis
4205
4200
4195
4190
4185
4180
4175
4170
4165
642
644
646
648
650
652
654
656

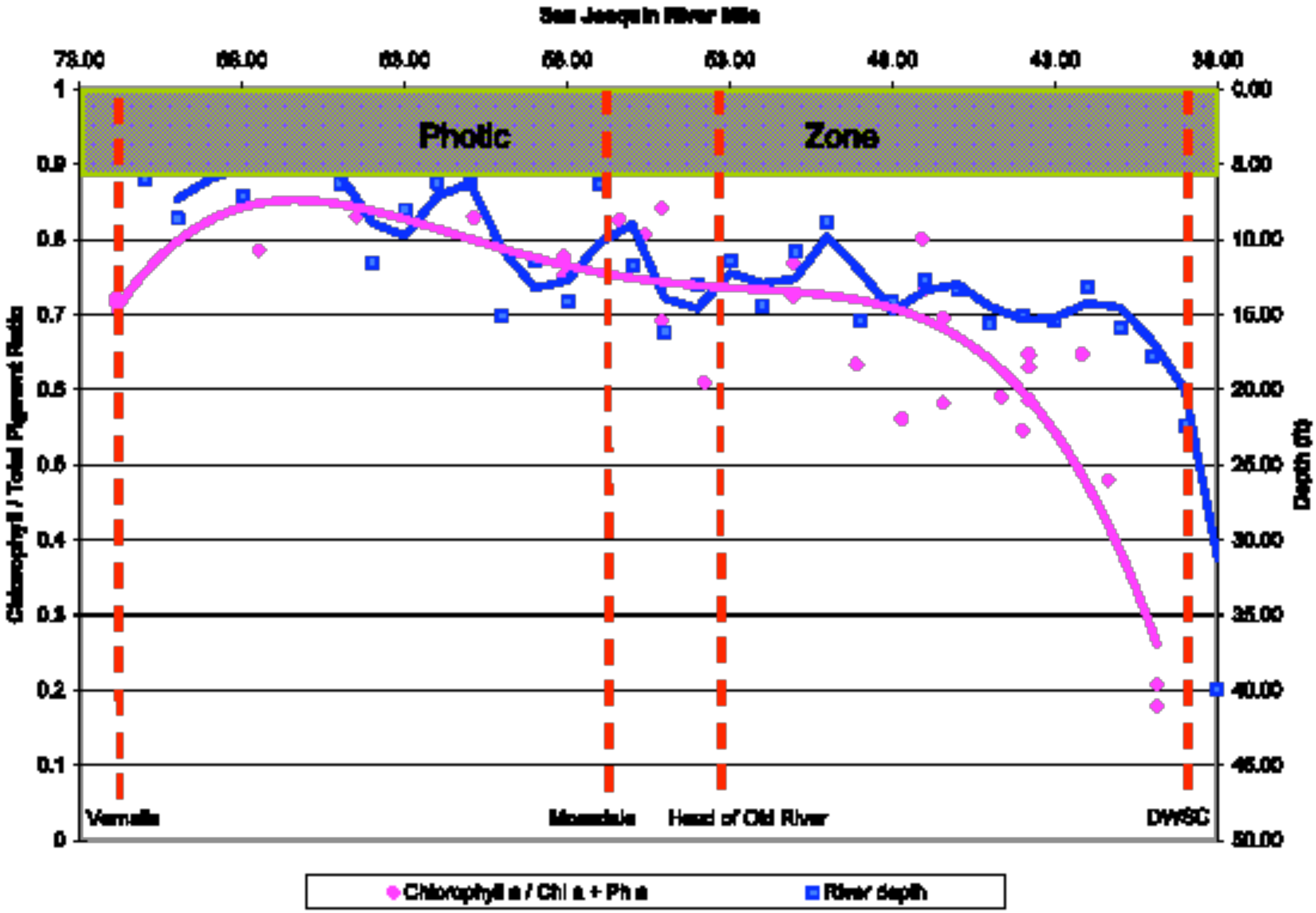
Algae Pigment and River Depth

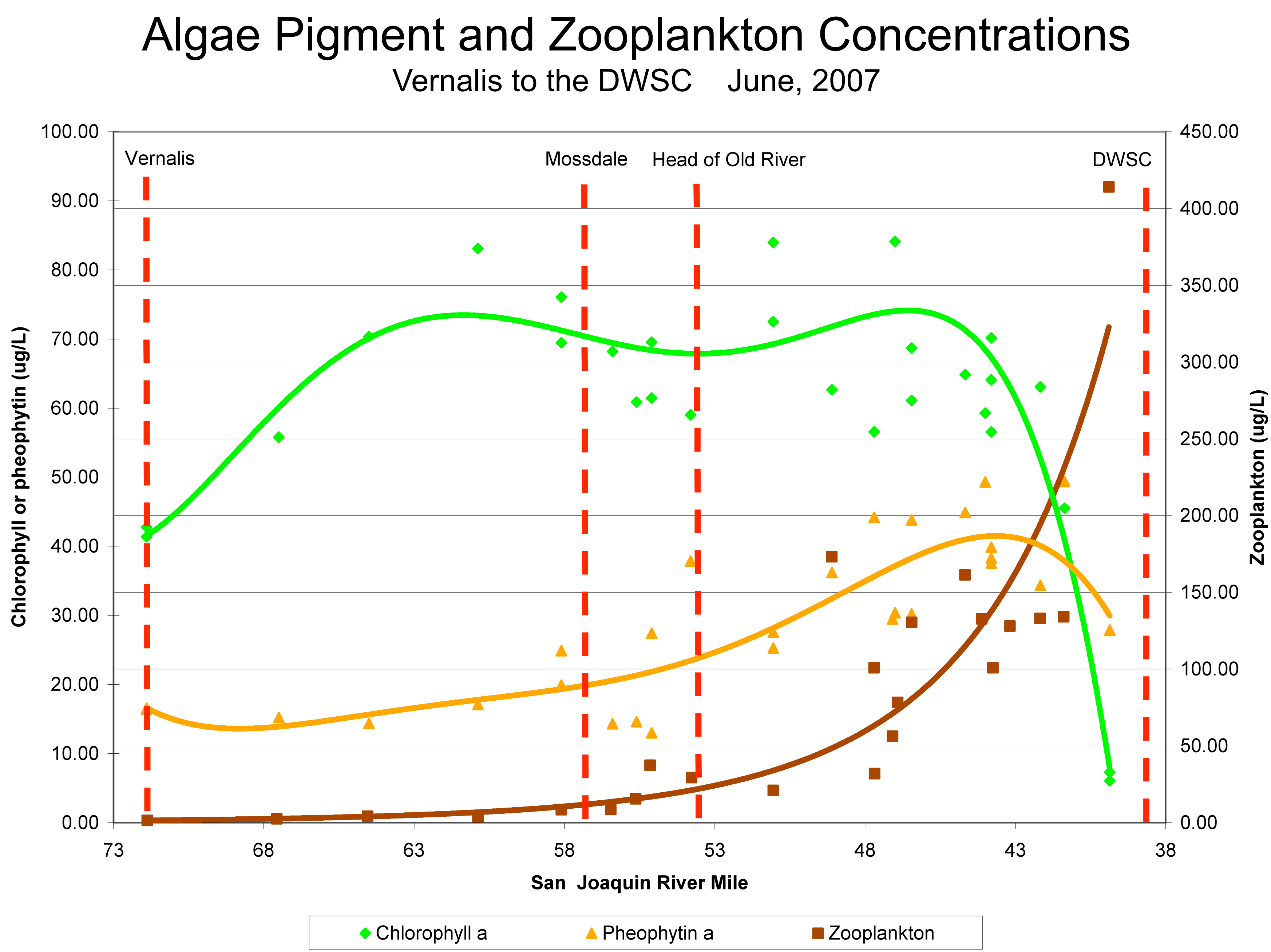
Vernalis to the DWSC   June, 2007



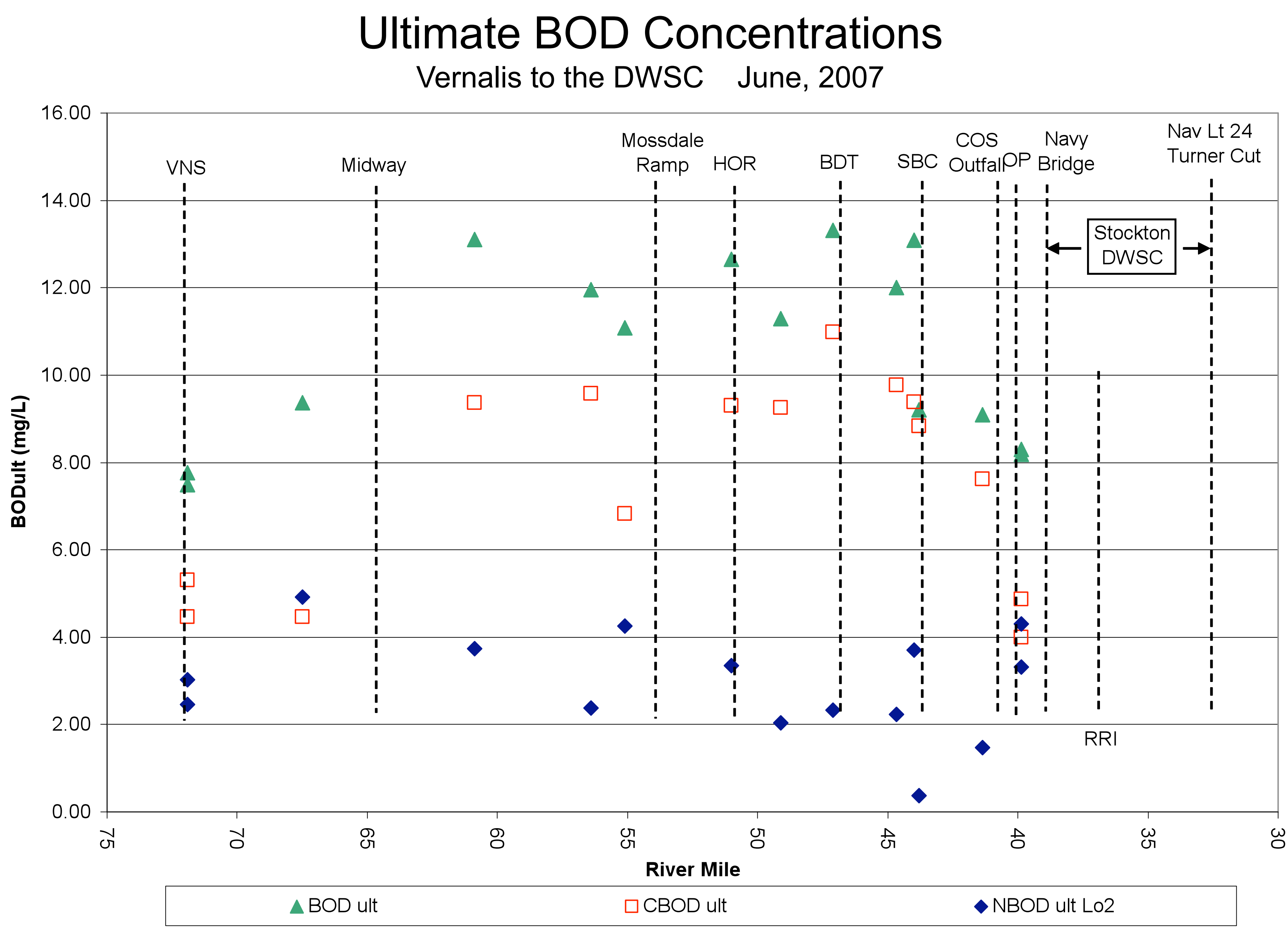
Algae Pigment Ratio and River Depth

Vernalis to the DWSC June, 2007

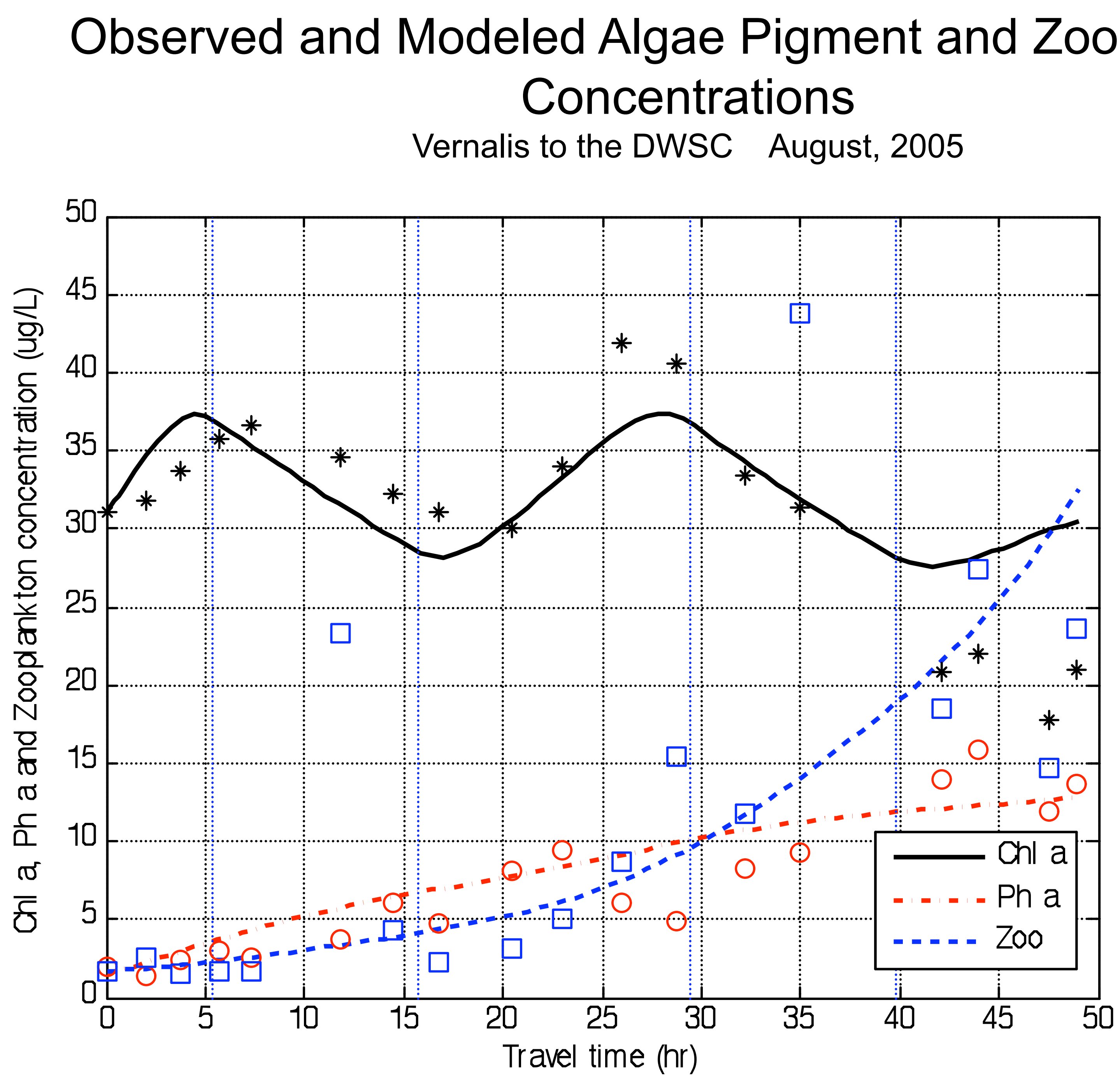


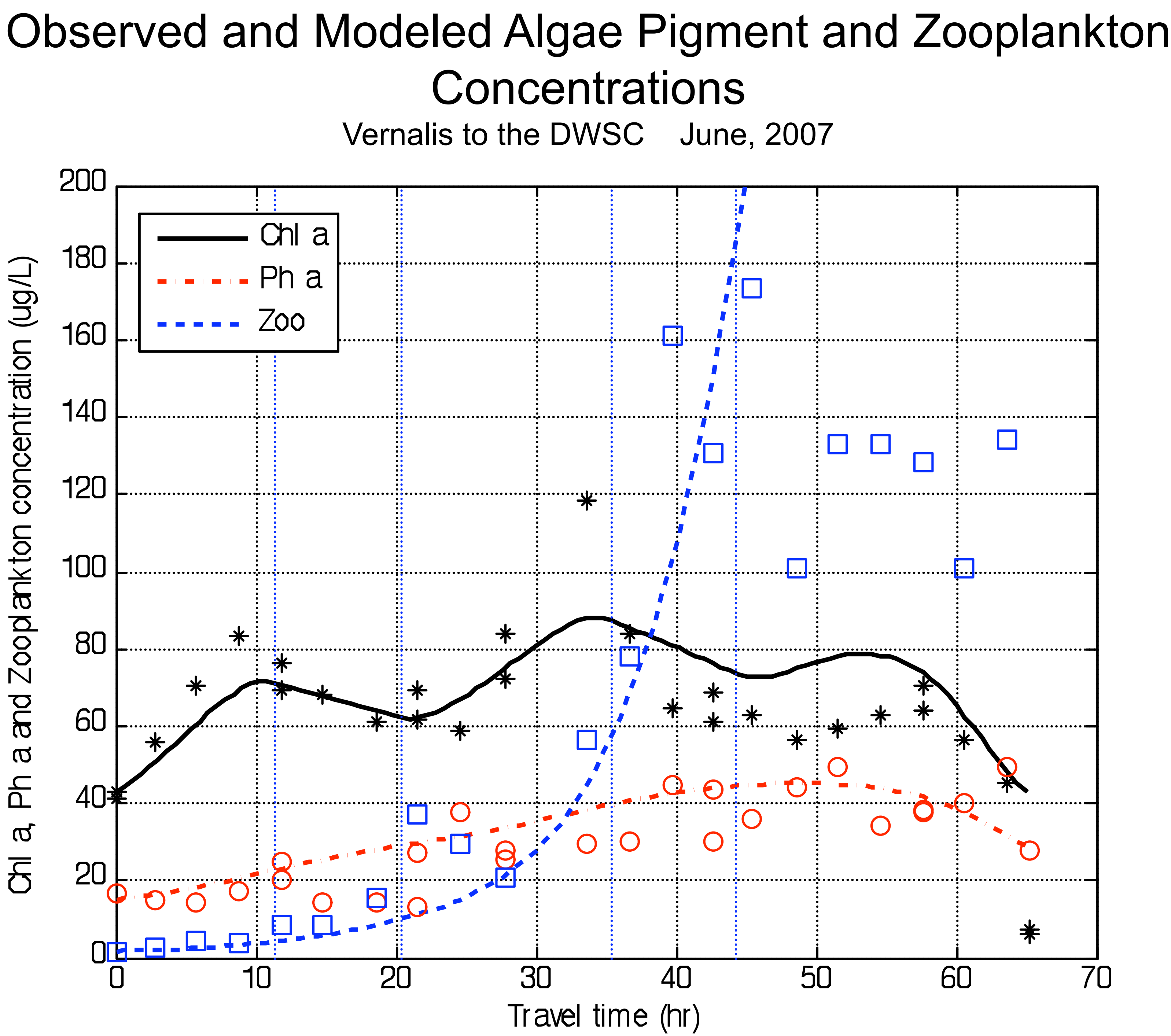


Algae Pigment and Zooplankton Concentrations
Vernalis to the DWSC June, 2007
Vernalis
Mossdale
Head of Old River
DWSC
Chlorophyll or pheophytin (ug/L)
Zooplankton (ug/L)
San Joaquin River Mile
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
73
68
63
58
53
48
43
38
Chlorophyll a
Pheophytin a
Zooplankton

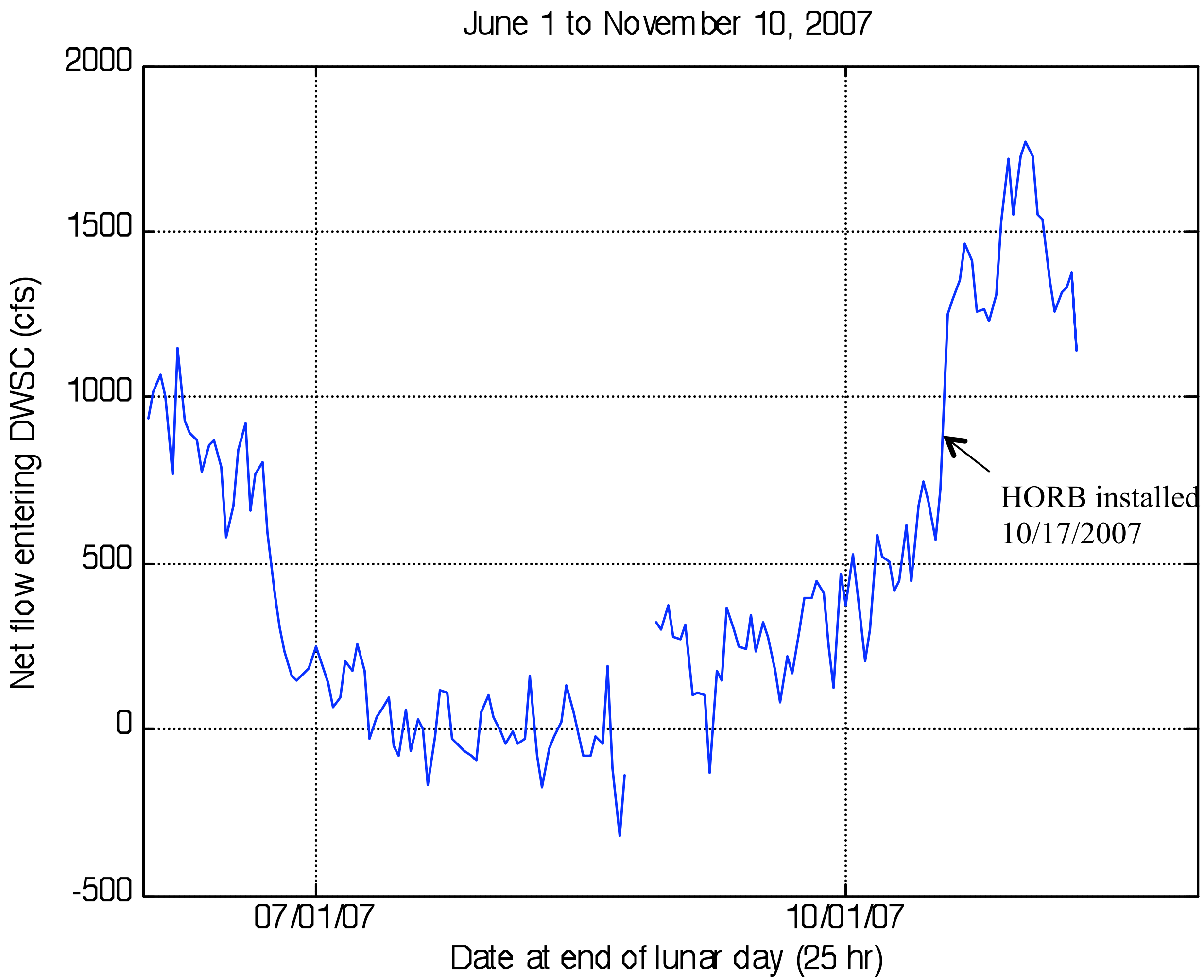


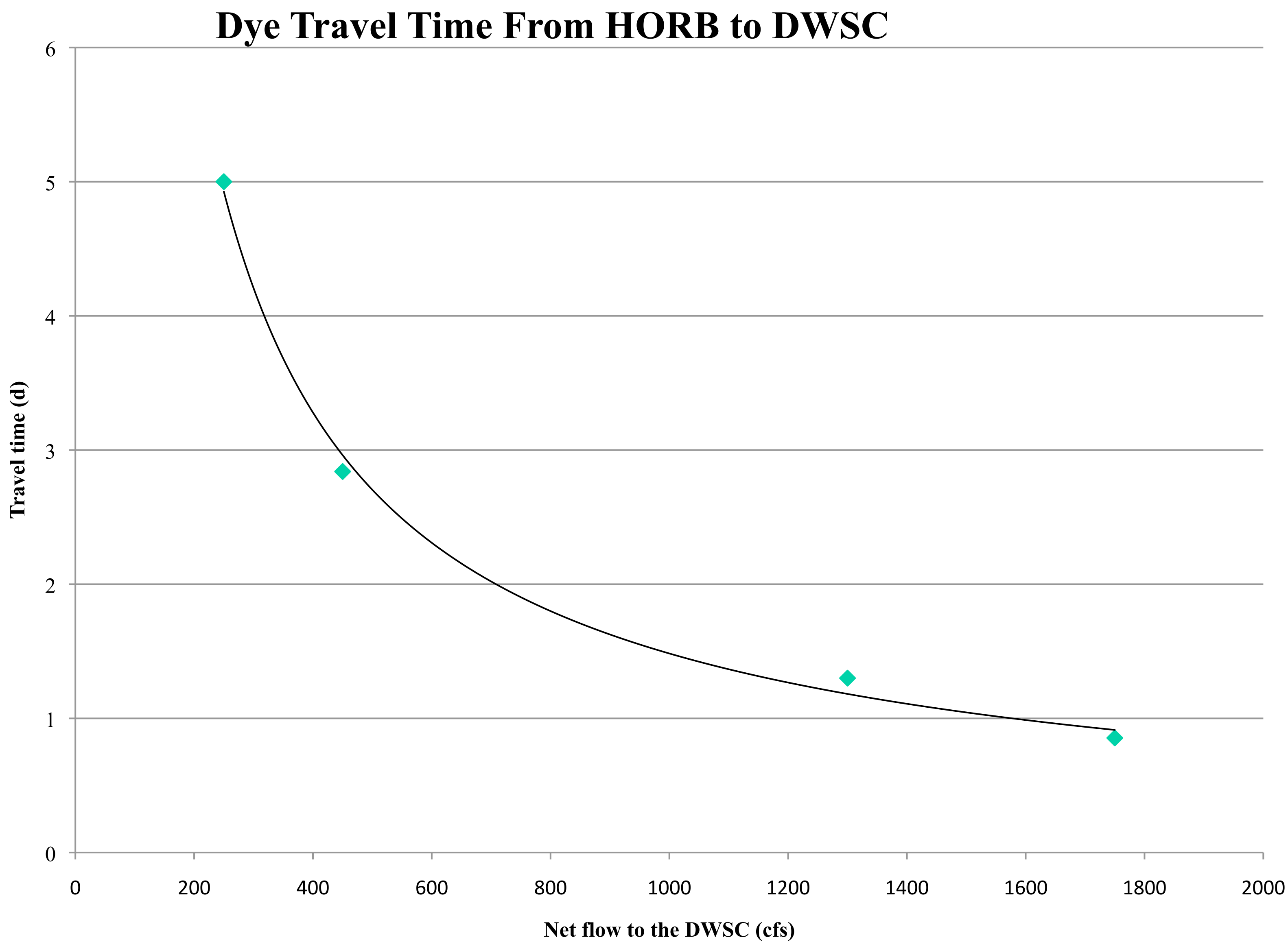
Ultimate BOD Concentrations
Vernalis to the DWSC June, 2007
BODult (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
VNS
Midway
Mossdale Ramp
HOR
BDT
SBC
COS Outfall
OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
75
70
65
60
55
50
45
40
35
30
River Mile
BOD ult
CBOD ult
NBOD ult Lo2


Observed and Modeled Algae Pigment and Zooplankton Concentrations
Vernalis to the DWSC August, 2005
Chl a, Ph a and Zooplankton concentration (ug/L)
0
5
10
15
20
25
30
35
40
45
50
Travel time (hr)
Chl a
Ph a
Zoo

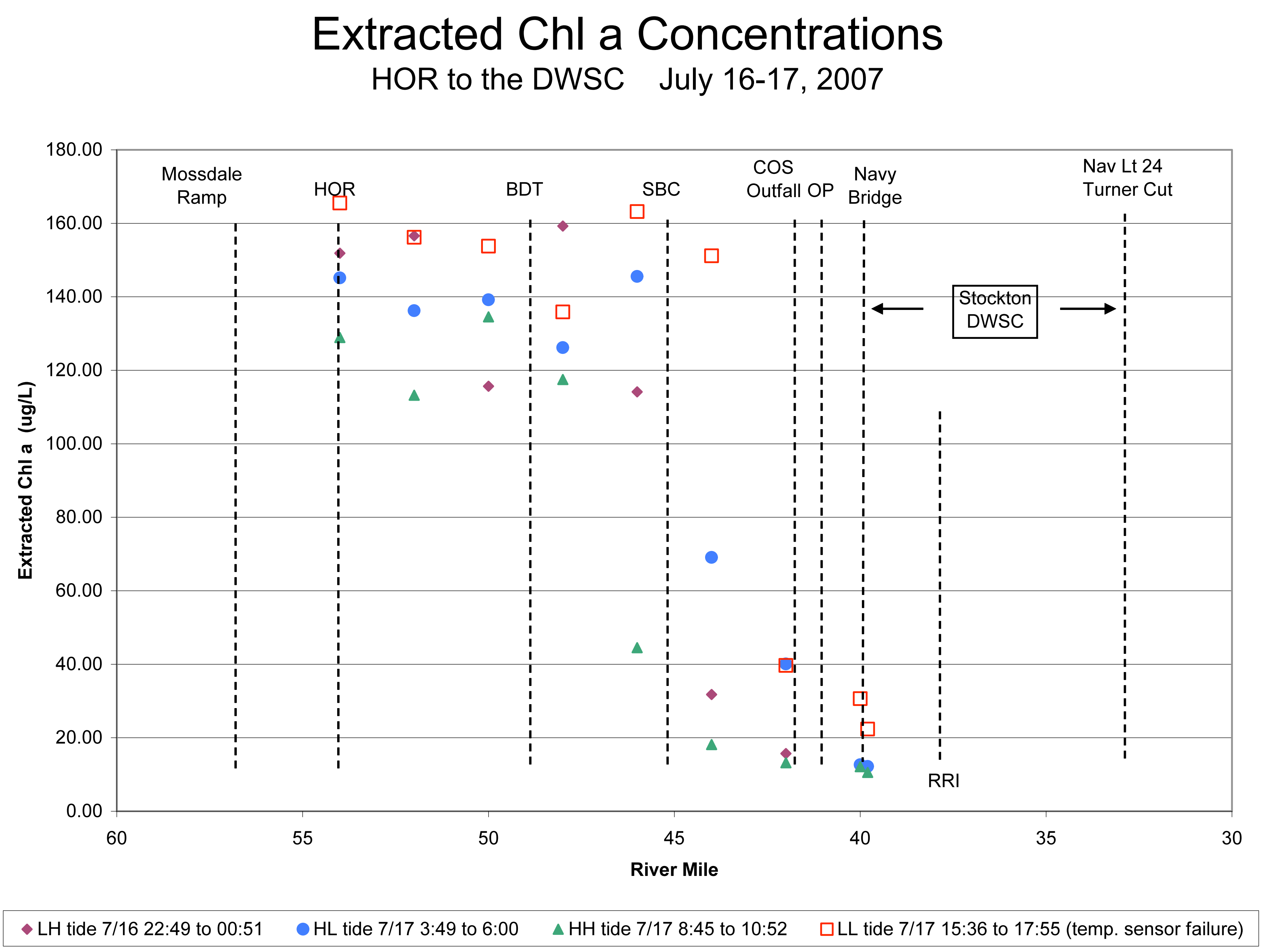

Observed and Modeled Algae Pigment and Zooplankton Concentrations
Vernalis to the DWSC June, 2007
Chl a
Ph a
Zoo
Chl a, Ph a and Zooplankton concentration (ug/L)
Travel time (hr)
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50
60
70

Net Flow Entering the DWSC June-November, 2007



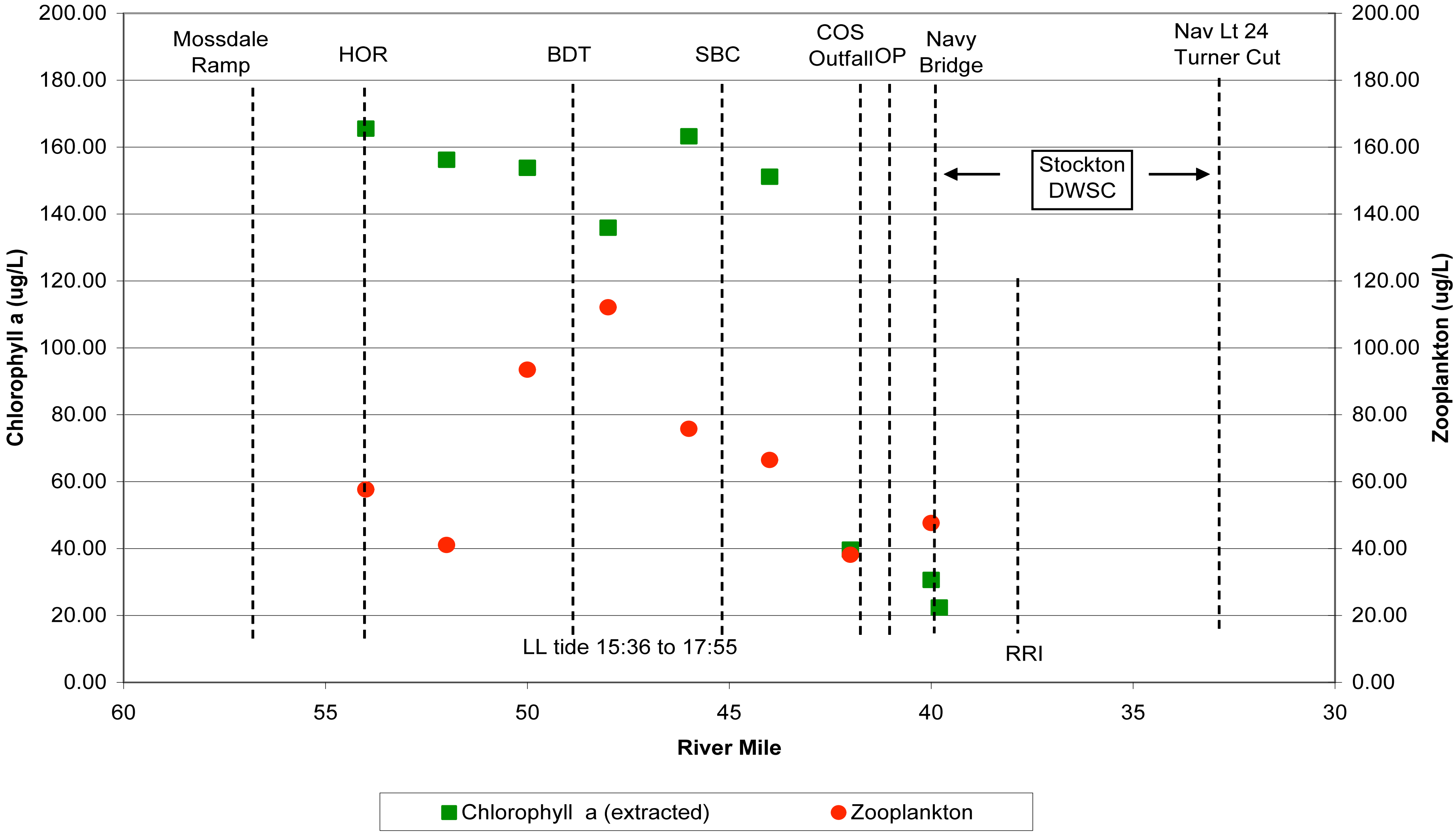


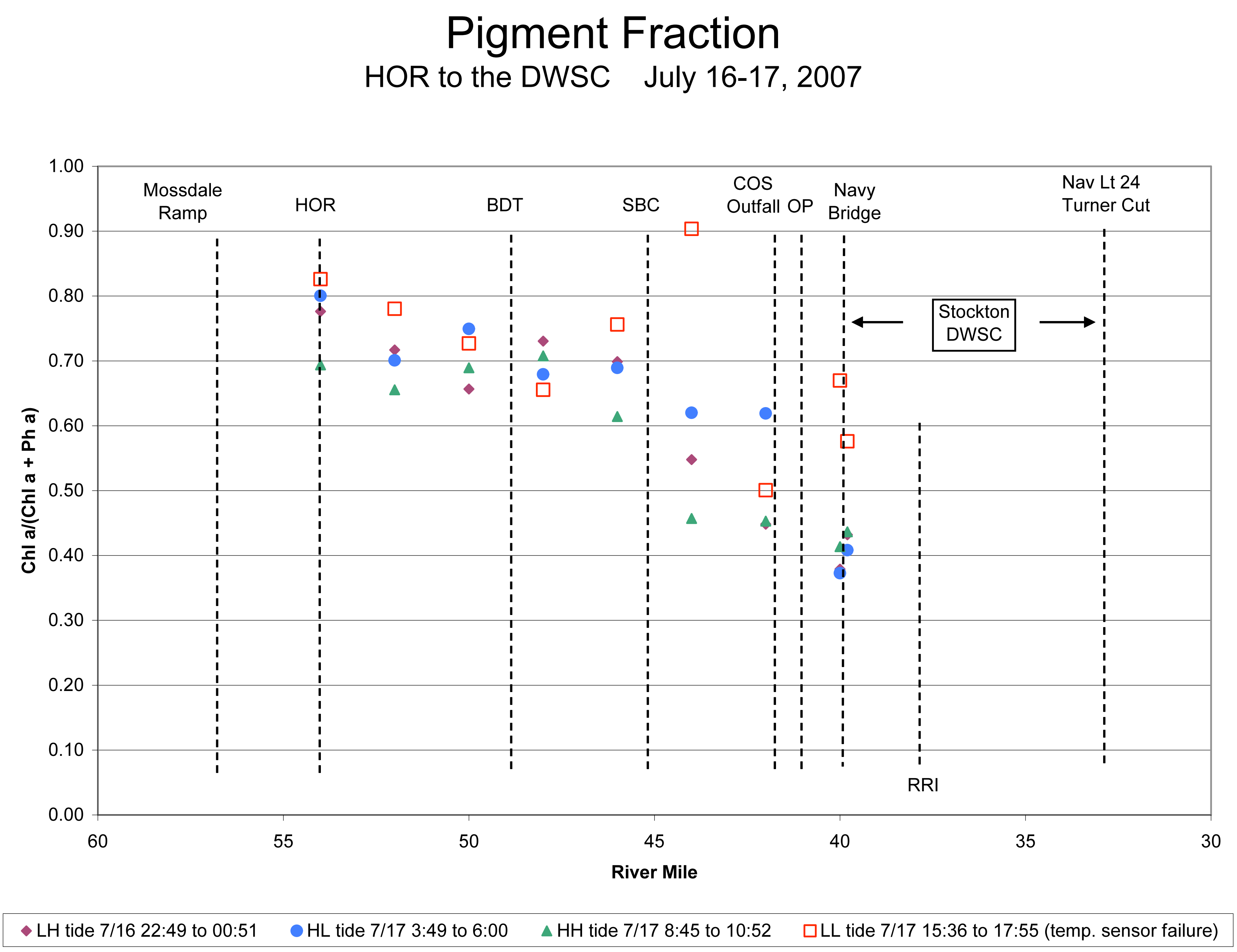
Dye Travel Time From HORB to DWSC
Travel time (d)
Net flow to the DWSC (cfs)
0
1
2
3
4
5
6
0
200
400
600
800
1000
1200
1400
1600
1800
2000

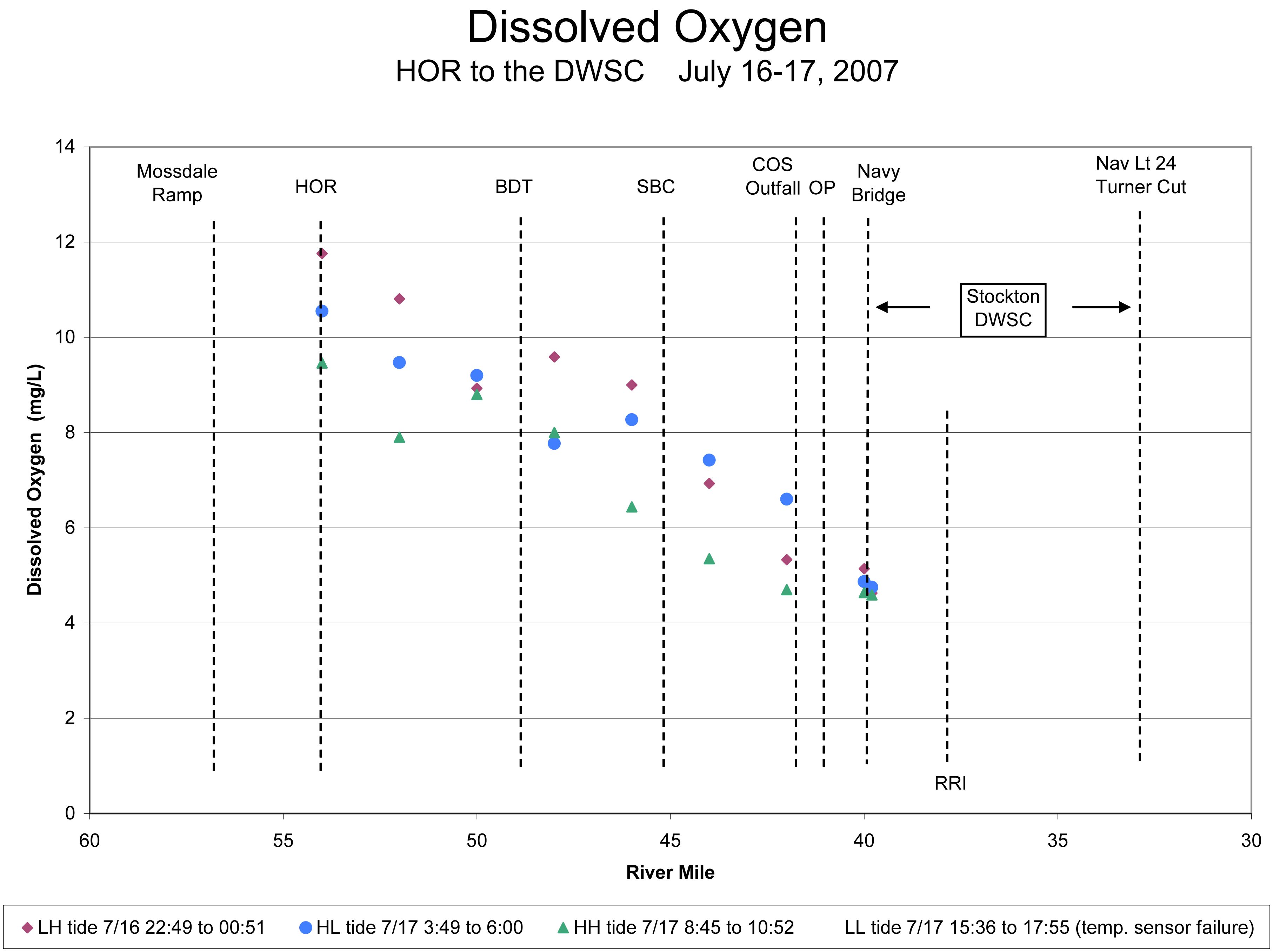

Extracted Chl a Concentrations
HOR to the DWSC July 16-17, 2007
Extracted Chl a (ug/L)
River Mile
Mossdale Ramp
HOR
BDT
SBC
COS Outfall OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
60
55
50
45
40
35
30
LH tide 7/16 22:49 to 00:51
HL tide 7/17 3:49 to 6:00
HH tide 7/17 8:45 to 10:52
LL tide 7/17 15:36 to 17:55 (temp. sensor failure)

Extracted Chl a and Zooplankton Concentrations

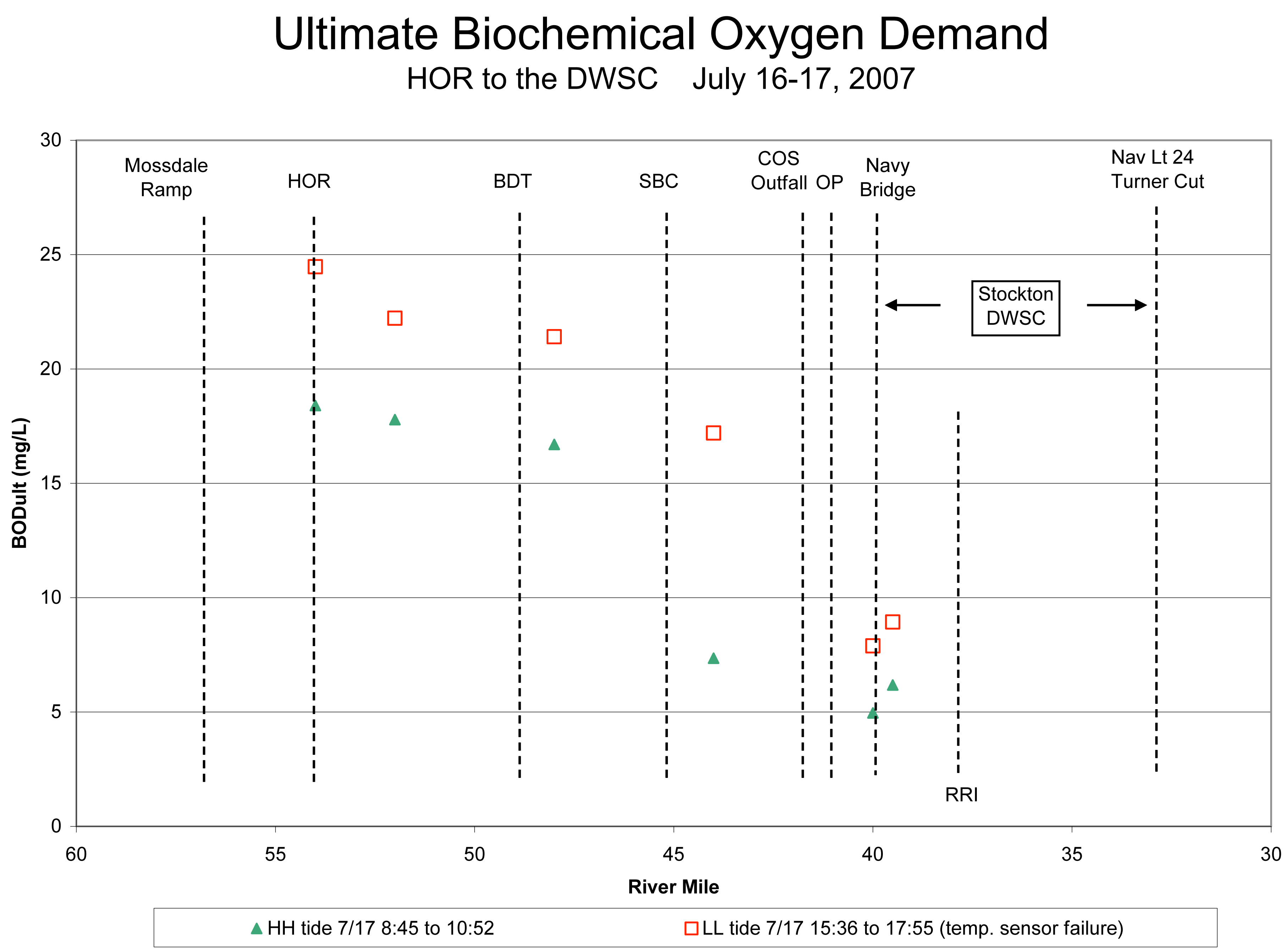
HOR to the DWSC July 16-17, 2007



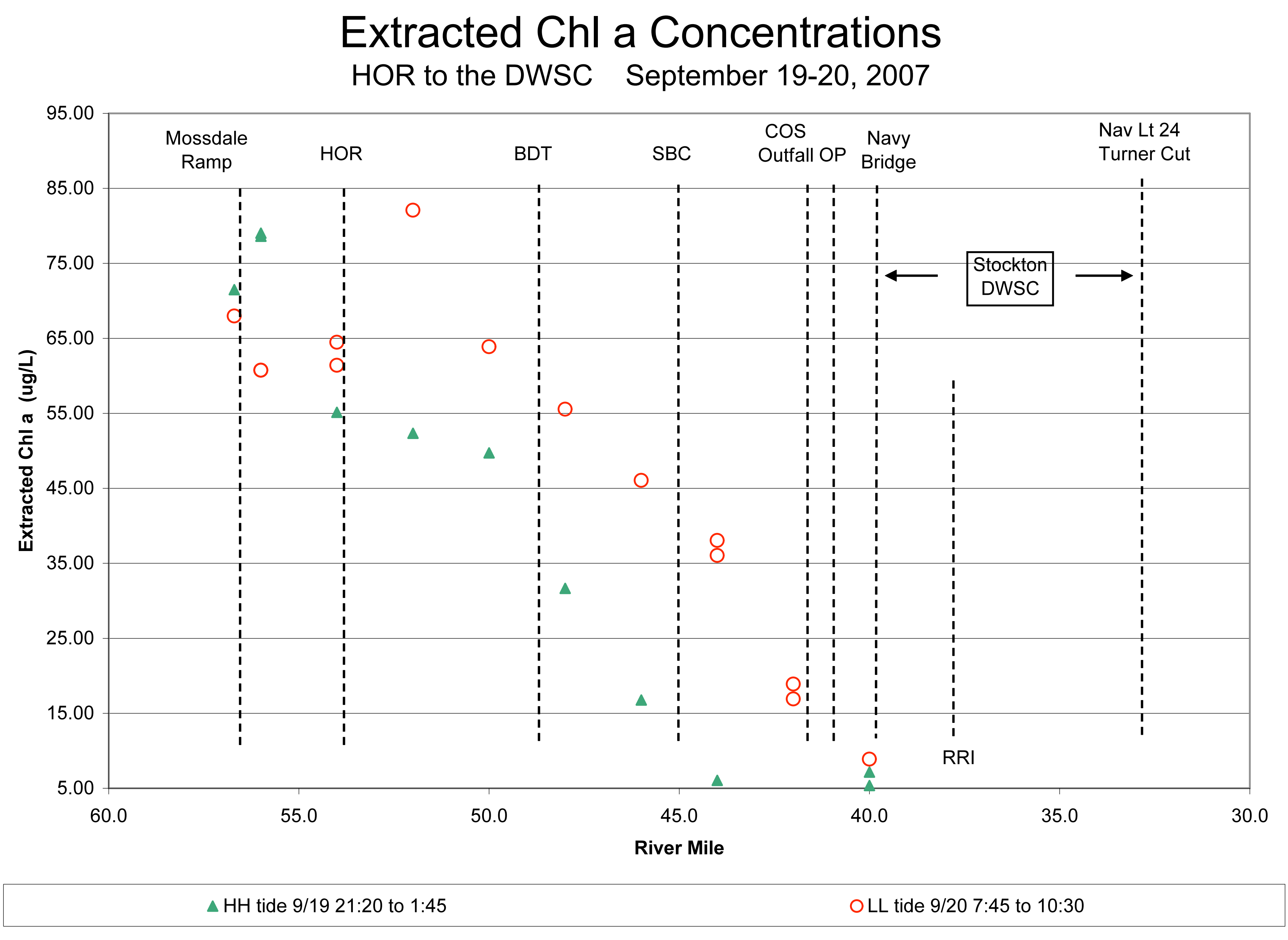

Pigment Fraction
HOR to the DWSC July 16-17, 2007
Chl a/(Chl a + Ph a)
River Mile
Mossdale Ramp
HOR
BDT
SBC
COS Outfall
OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
60
55
50
45
40
35
30
LH tide 7/16 22:49 to 00:51
HL tide 7/17 3:49 to 6:00
HH tide 7/17 8:45 to 10:52
LL tide 7/17 15:36 to 17:55 (temp. sensor failure)



Dissolved Oxygen
HOR to the DWSC July 16-17, 2007
Mossdale Ramp
HOR
BDT
SBC
COS Outfall
OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
14
60
55
50
45
40
35
30
River Mile
LH tide 7/16 22:49 to 00:51
HL tide 7/17 3:49 to 6:00
HH tide 7/17 8:45 to 10:52
LL tide 7/17 15:36 to 17:55 (temp. sensor failure)



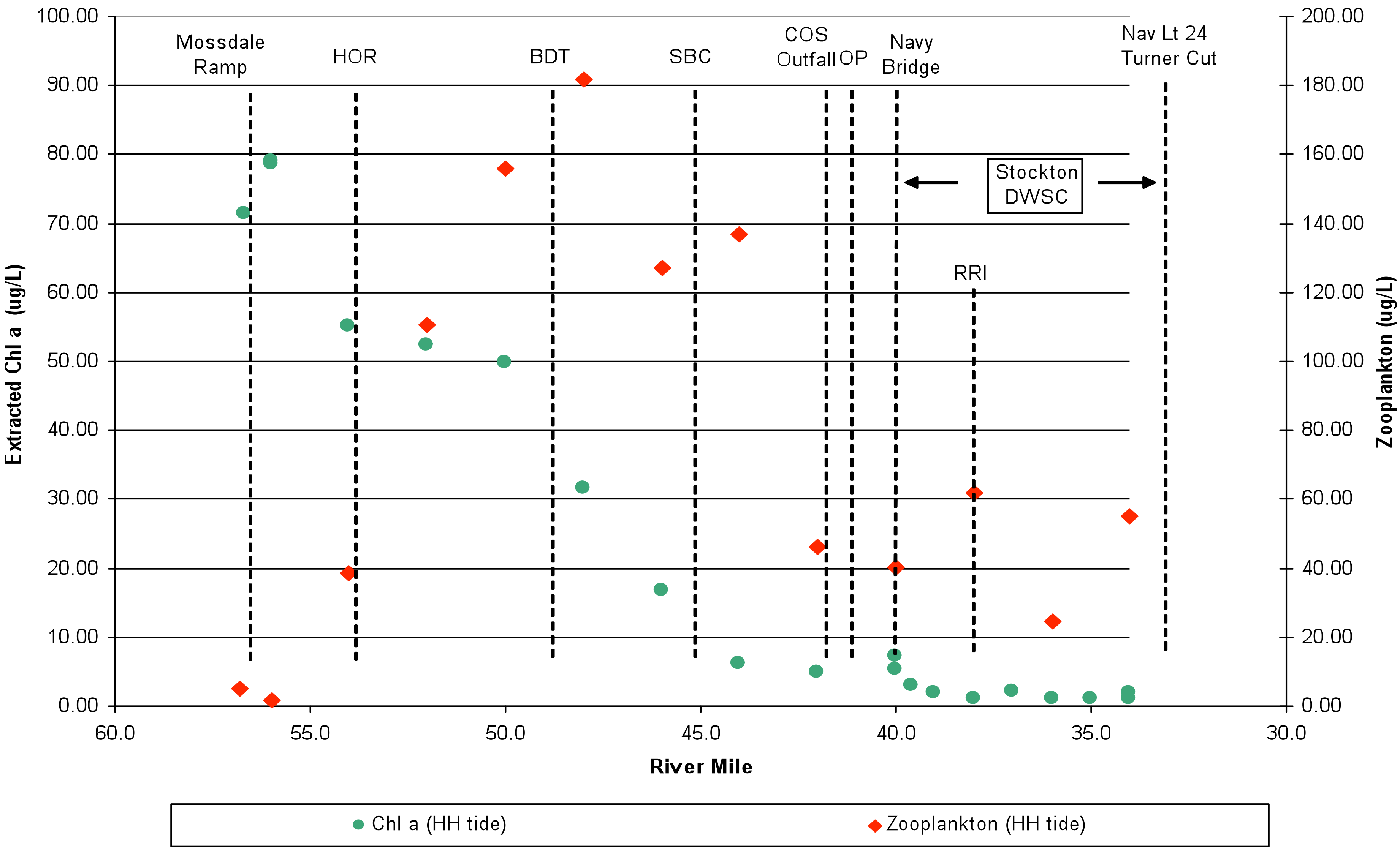
Ultimate Biochemical Oxygen Demand
HOR to the DWSC July 16-17, 2007
Mossdale Ramp
HOR
BDT
SBC
COS Outfall
OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
BODult (mg/L)
River Mile
0
5
10
15
20
25
30
60
55
50
45
40
35
30
HH tide 7/17 8:45 to 10:52
LL tide 7/17 15:36 to 17:55 (temp. sensor failure)

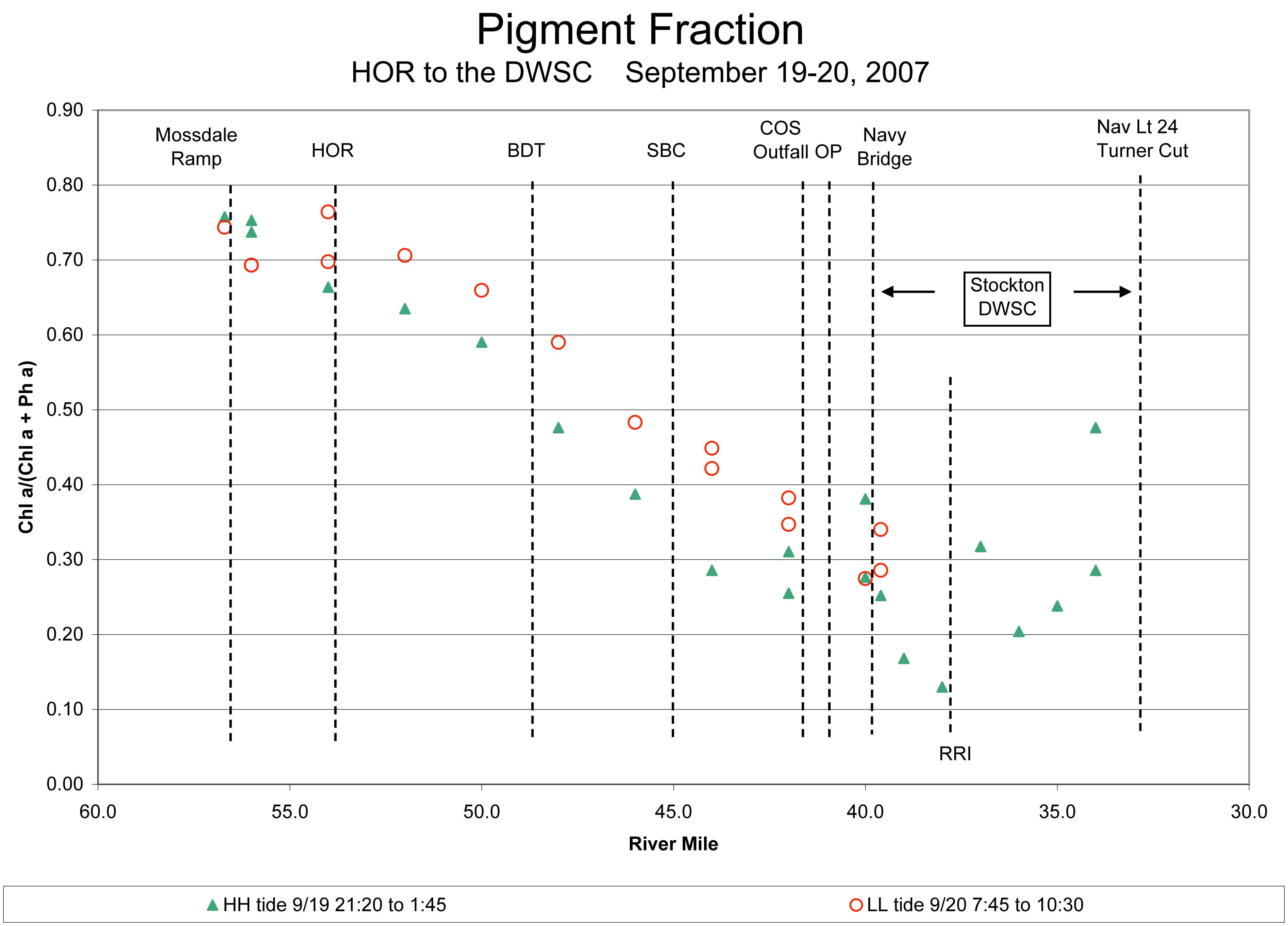


Extracted Chl a Concentrations
HOR to the DWSC September 19-20, 2007
Extracted Chl a (ug/L)
95.00
85.00
75.00
65.00
55.00
45.00
35.00
25.00
15.00
5.00
Mossdale Ramp
HOR
BDT
SBC
COS Outfall OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
60.0
55.0
50.0
45.0
40.0
35.0
30.0
River Mile
HH tide 9/19 21:20 to 1:45
LL tide 9/20 7:45 to 10:30

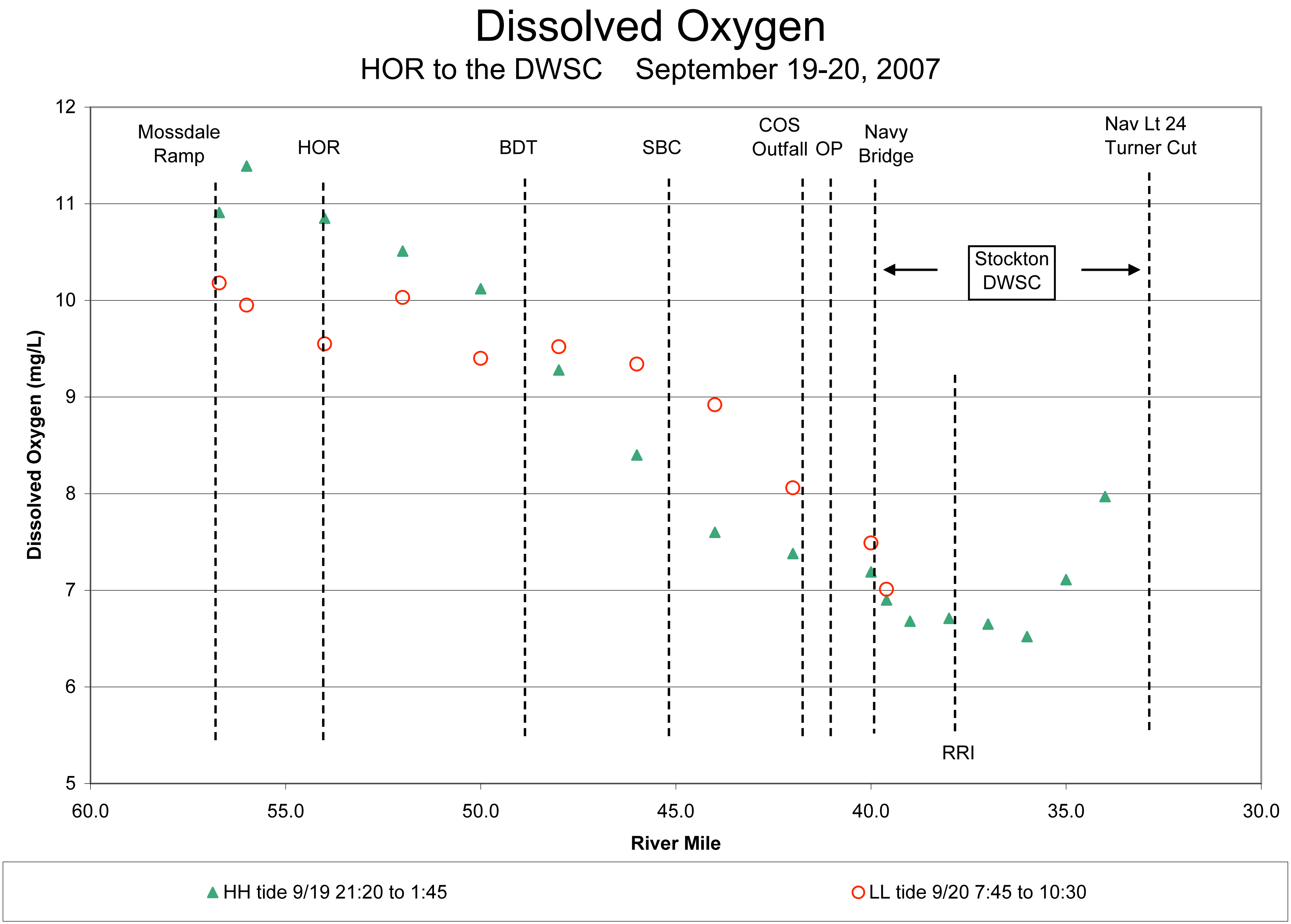
Extracted Chl a and Zooplankton Concentrations

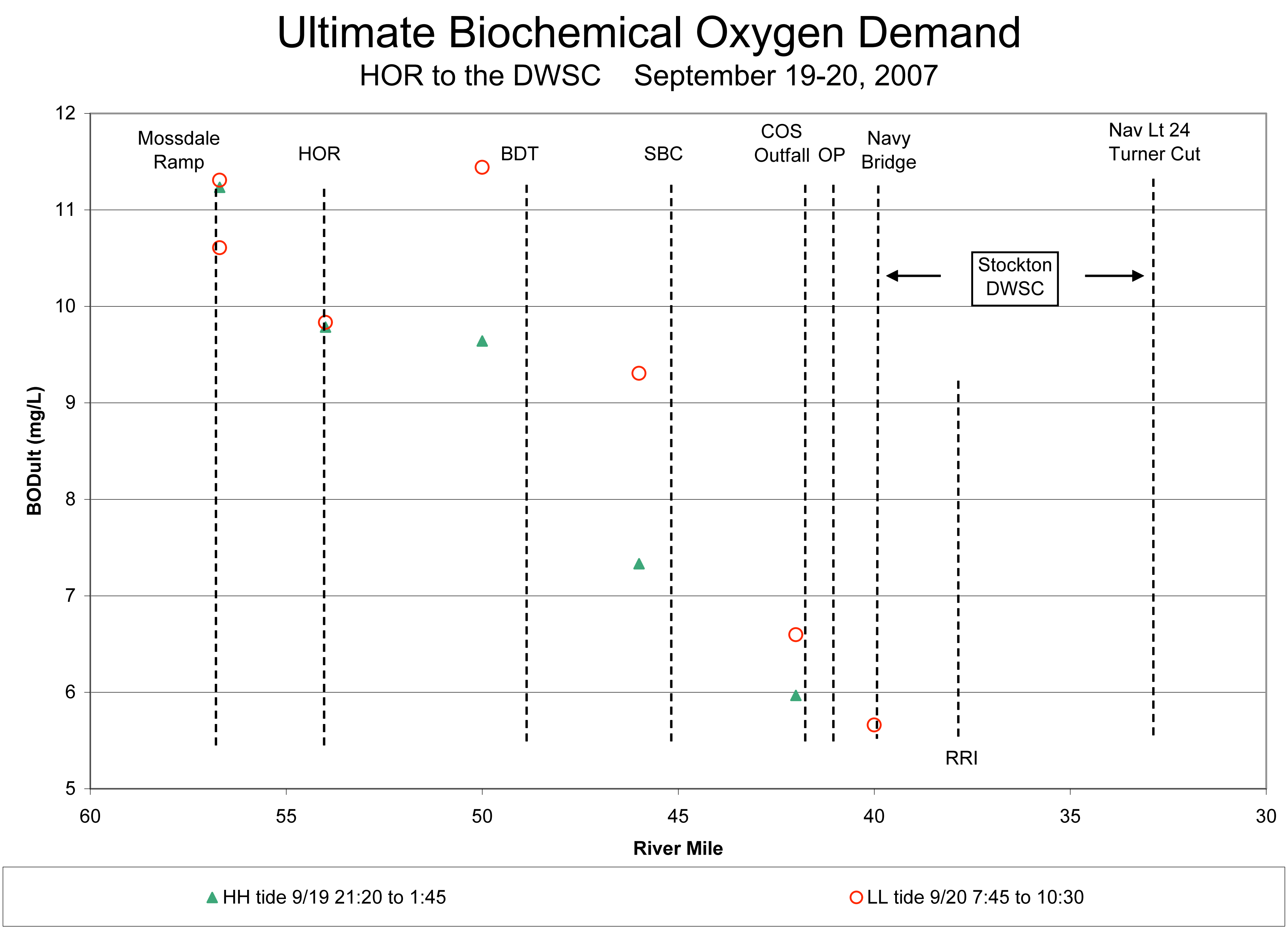
HOR to the DWSC   September 19-20, 2007

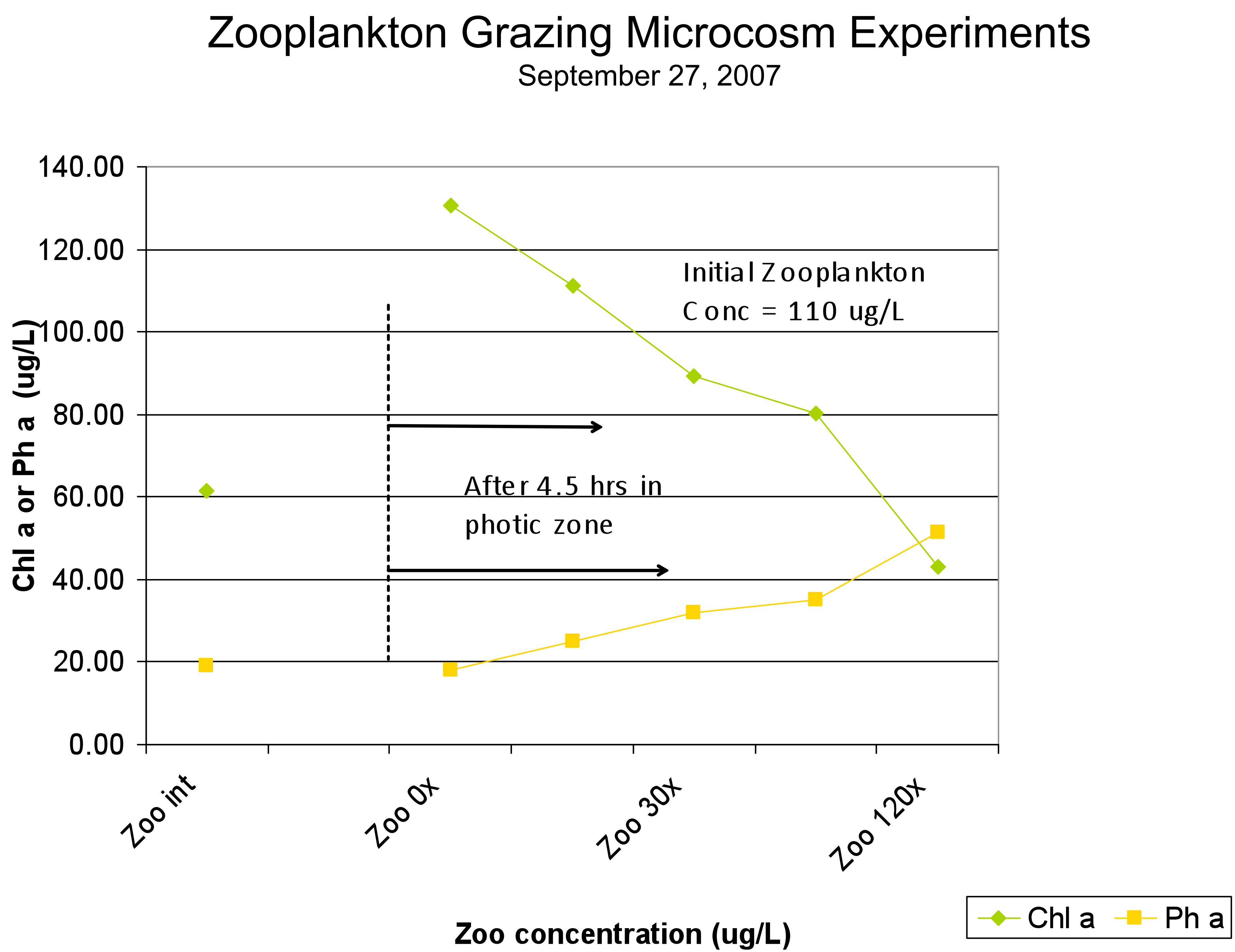




Pigment Fraction
HOR to the DWSC September 19-20, 2007
Chl a/(Chl a + Ph a)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Mossdale Ramp
HOR
BDT
SBC
COS Outfall OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
60.0
55.0
50.0
45.0
40.0
35.0
30.0
River Mile
HH tide 9/19 21:20 to 1:45
LL tide 9/20 7:45 to 10:30


Dissolved Oxygen
HOR to the DWSC September 19-20, 2007
Dissolved Oxygen (mg/L)
River Mile
Mossdale Ramp
HOR
BDT
SBC
COS Outfall
OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
12
11
10
9
8
7
6
5
60.0
55.0
50.0
45.0
40.0
35.0
30.0
HH tide 9/19 21:20 to 1:45
LL tide 9/20 7:45 to 10:30

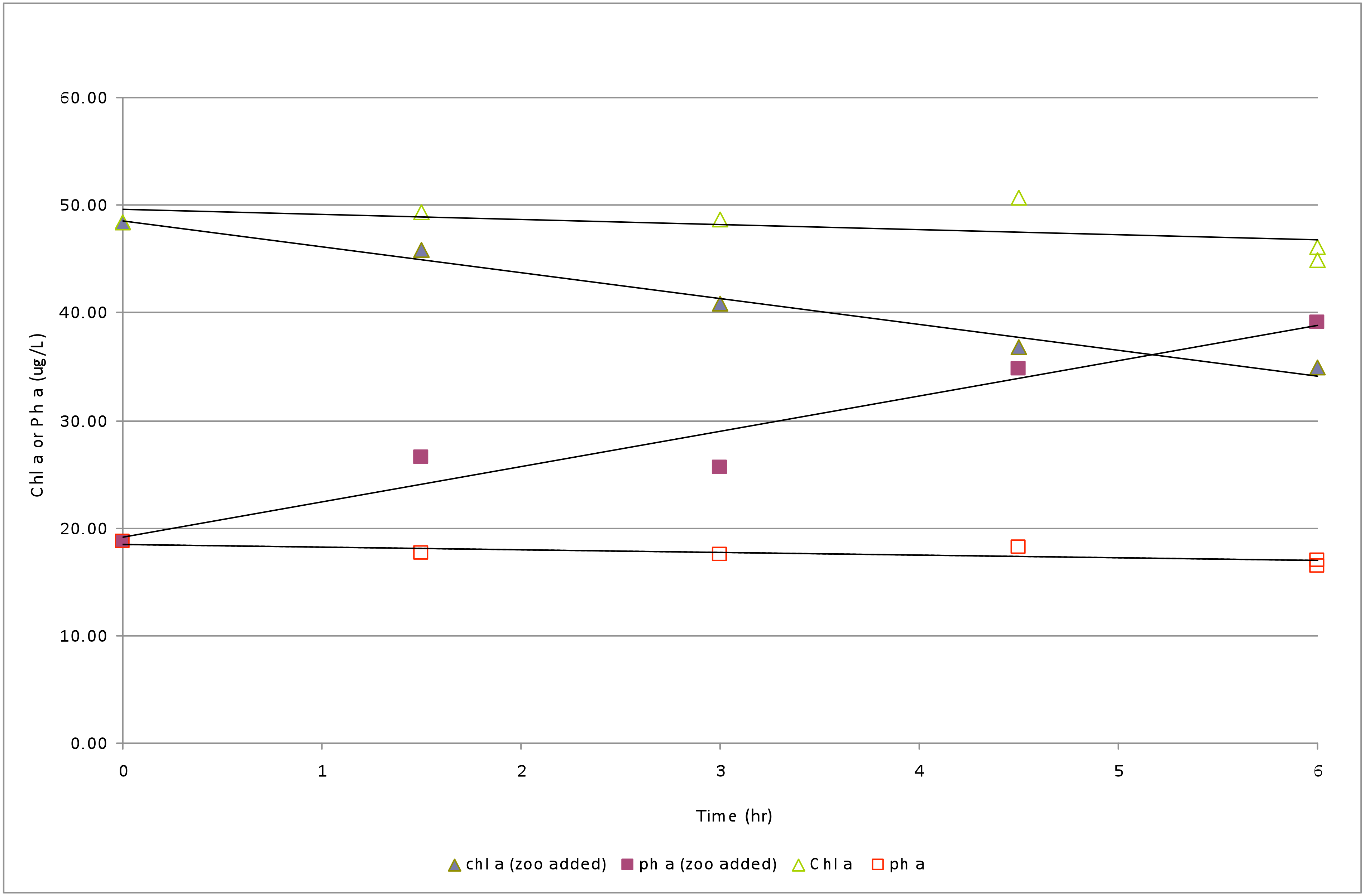

Ultimate Biochemical Oxygen Demand
HOR to the DWSC September 19-20, 2007
BODult (mg/L)
River Mile
Mossdale Ramp
HOR
BDT
SBC
COS Outfall
OP
Navy Bridge
Nav Lt 24 Turner Cut
Stockton DWSC
RRI
12
11
10
9
8
7
6
5
60
55
50
45
40
35
30
HH tide 9/19 21:20 to 1:45
LL tide 9/20 7:45 to 10:30



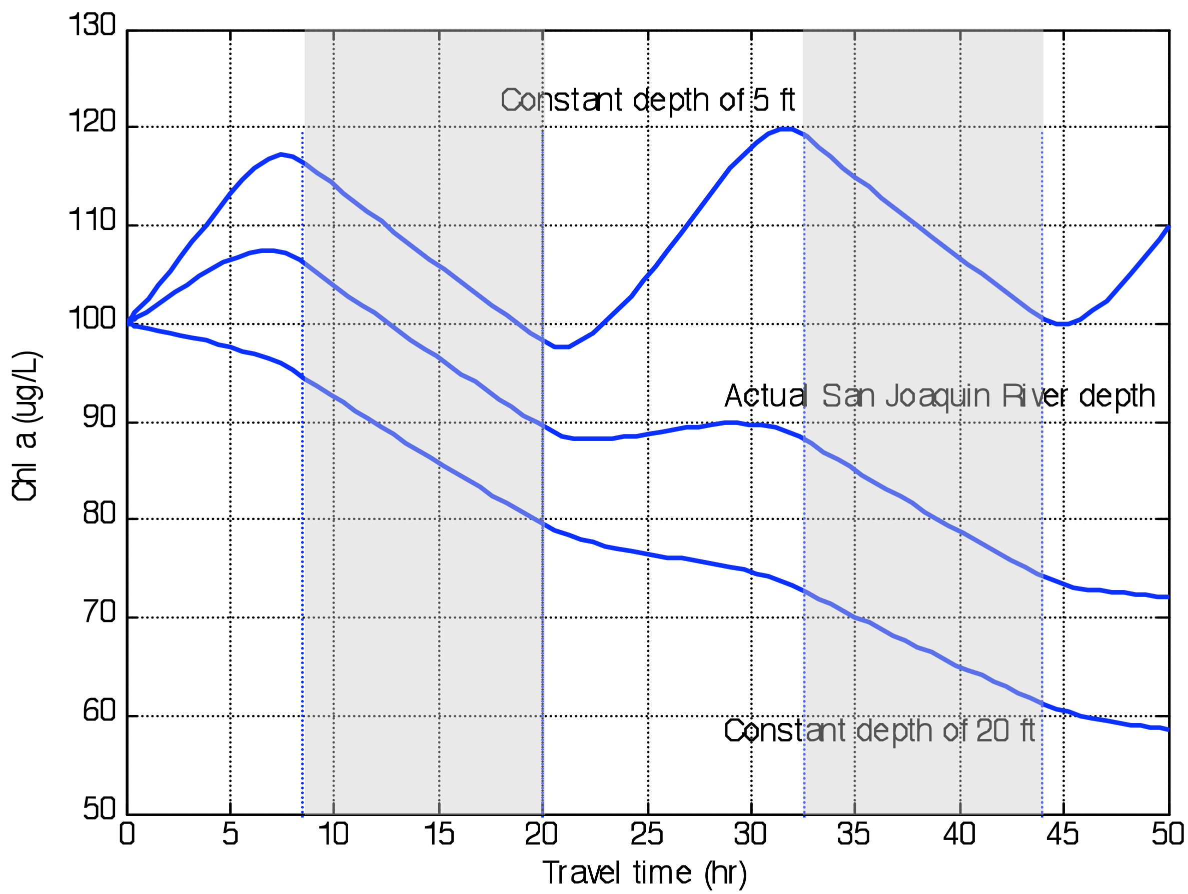
Zooplankton Grazing Microcosm Experiments
September 27, 2007
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Chl a or Ph a (ug/L)
Initial Zooplankton
Conc = 110 ug/L
After 4.5 hrs in
photic zone
Zoo int
Zoo 0x
Zoo 30x
Zoo 120x
Zoo concentration (ug/L)
Chl a
Ph a

Zooplankton Grazing Microcosm Experiments

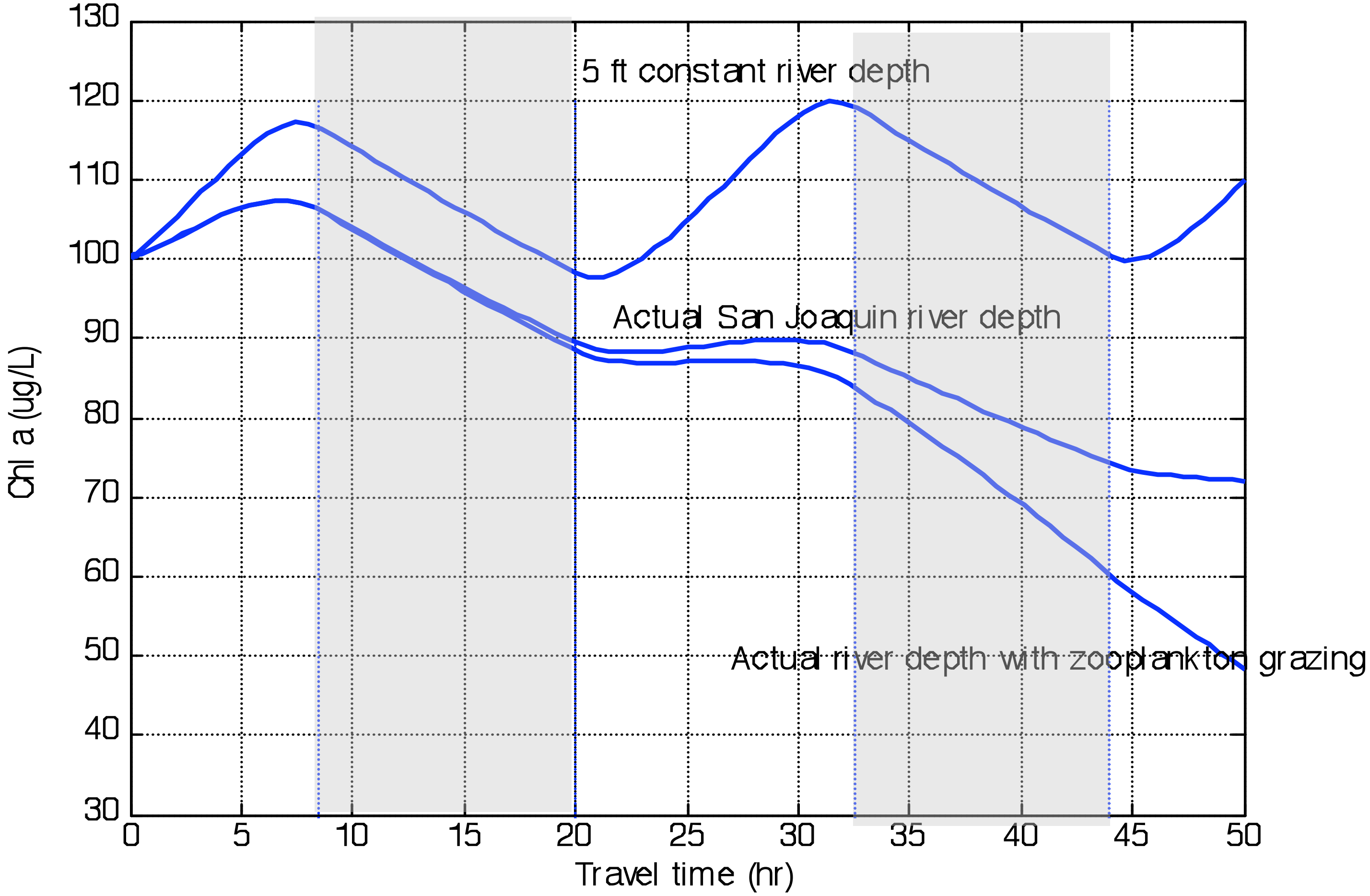
October 3, 2007



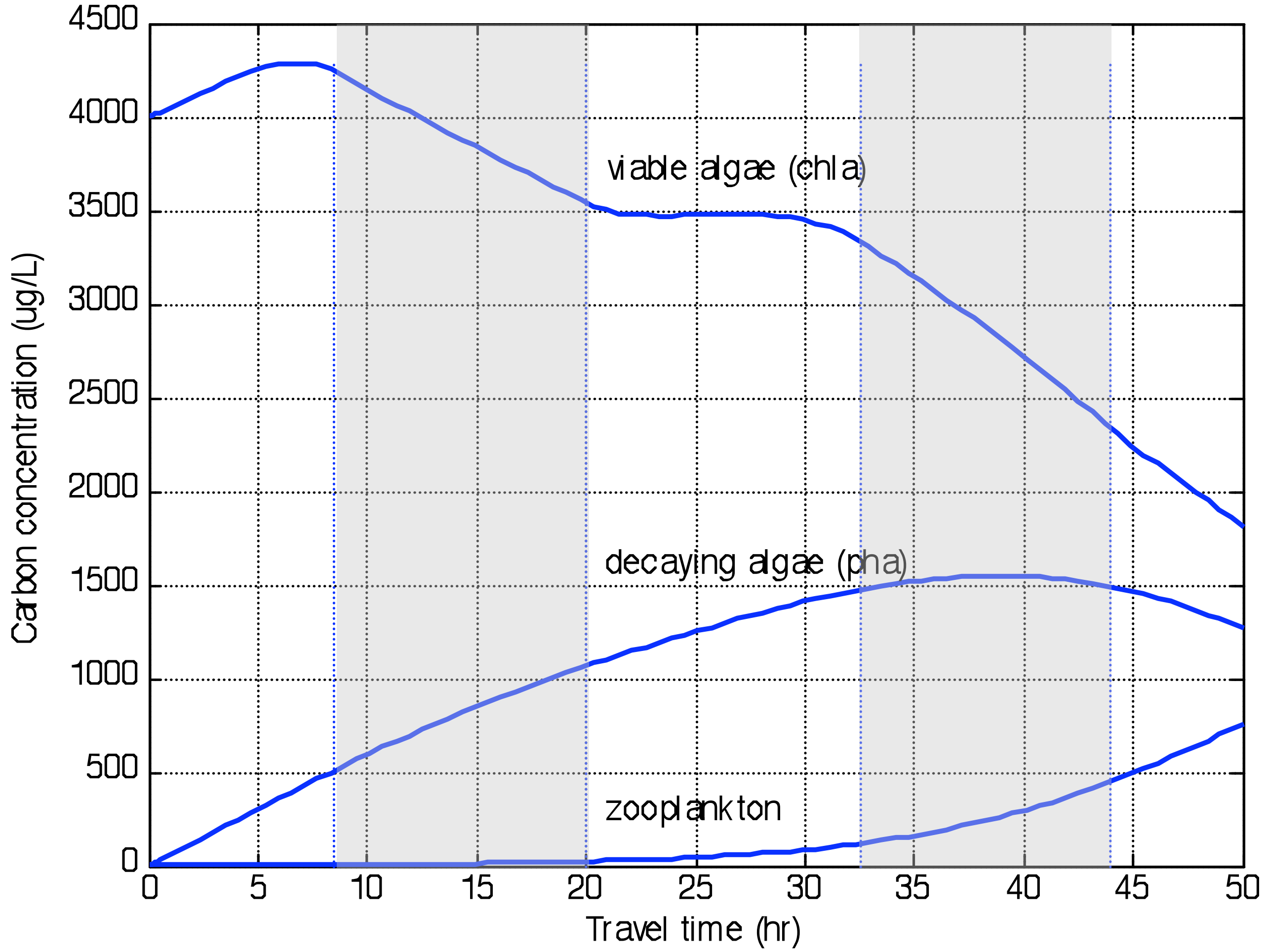
Simulated influence of river depth on chlorophyll *a* from Vernalis to the DWSC for flow conditions of September, 2005. Dye was released at 9:45 AM and tracked for the next 50 hours to the DWSC. The river depth was fixed at 5 feet and 20 feet for two of these simulations, the third line was calculated with the actual measured San Joaquin river depth in this reach. Parameters used in the simulations are presented in Table 3. Night is delineated with the shaded regions.



• Chl a simulation: Vernalis to the DWSC



- Simulations of the carbon concentrations associated with viable algae, decaying algae, and zooplankton for water flowing from Vernalis to the DWSC in 50 hours.



Conclusions

- Observations for 2005 and 2006 are atypical due to high flows, but data analyses indicate that grazing and light limitation effects are significant in explaining the fate of algae below Mossdale.

- For 2007, under conditions of near zero net flow, the zooplankton maximum shifts upstream in response to available food resources yielding a steep decline in chlorophyll a. Under the low flow conditions observed this season, residence time increases dramatically which can amplify the effects of grazing pressure and light limitation. However, tidal dispersion dominates advective transport at low net flows, leading to greater mixing of the DWSC water with algae-rich river water. This dilution effect may be an additional factor in the decline of phytoplankton below the Head of Old River.

- A diagnostic model was developed to evaluate the effects of light limitation associated with increased depth below Mossdale and zooplankton grazing. Model simulations are consistent with the transformation and degradation of algal pigments.