Monitoring biogeochemical cycles in the Columbia River Estuary using in situ sensors

Joseph Needoba, Tawnya Peterson, Catherine Corbett

CREW 2014 – May 29, 2014

Partnerships

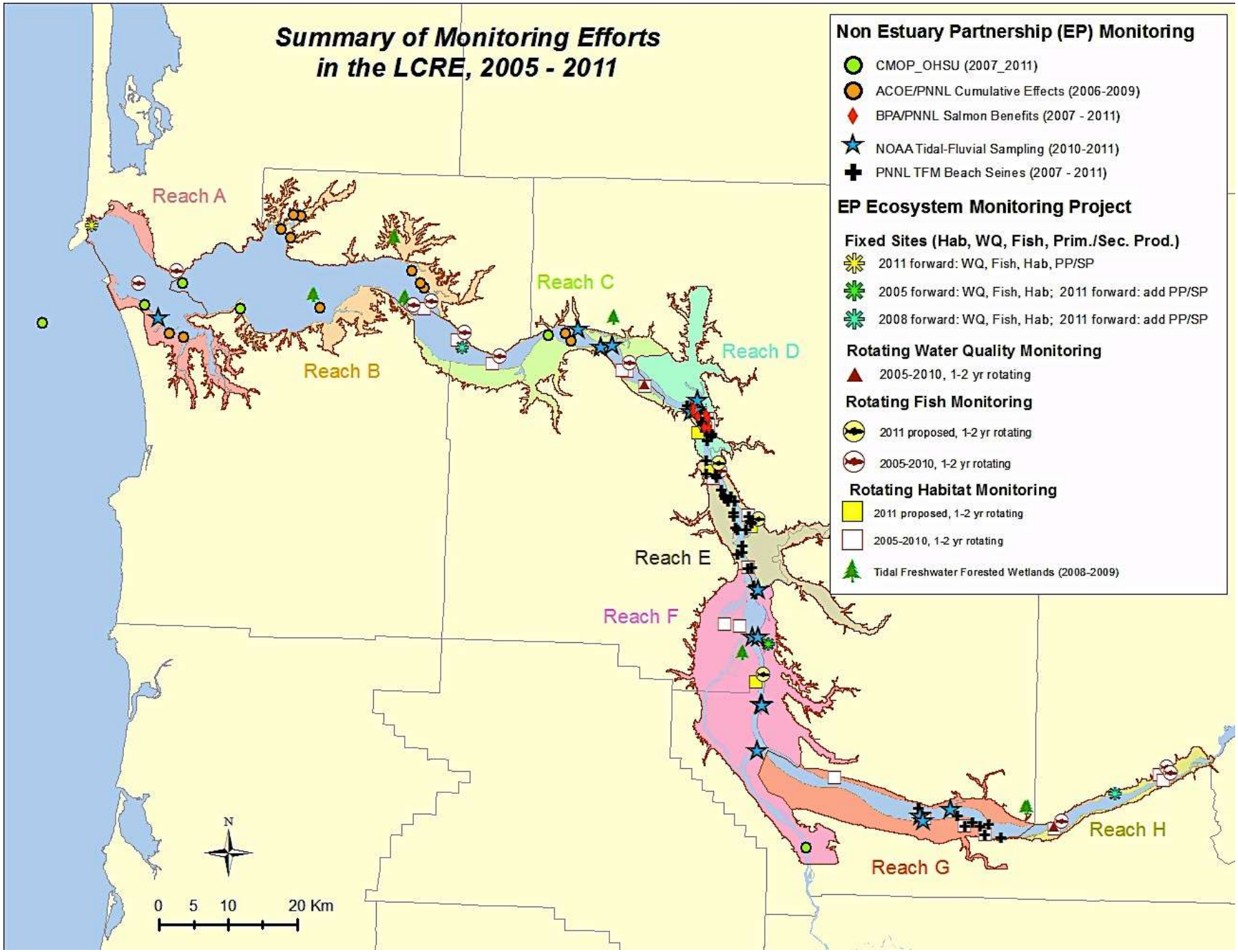
- OHSU Center for Coastal Margin Observation & Prediction
  - Antonio M. Baptista & Field Team
  - Michelle A. Maier, Florian U. Moeller, Estefania Llaneza Garcia
- USGS - Jennifer L. Morace, Whitney Temple
- LCREP - Jina Sagar
- Industry – Andrew Barnard and Corey Koch, SEA-BIRD scientific

CMOP Center for Coastal Margin Observation & Prediction

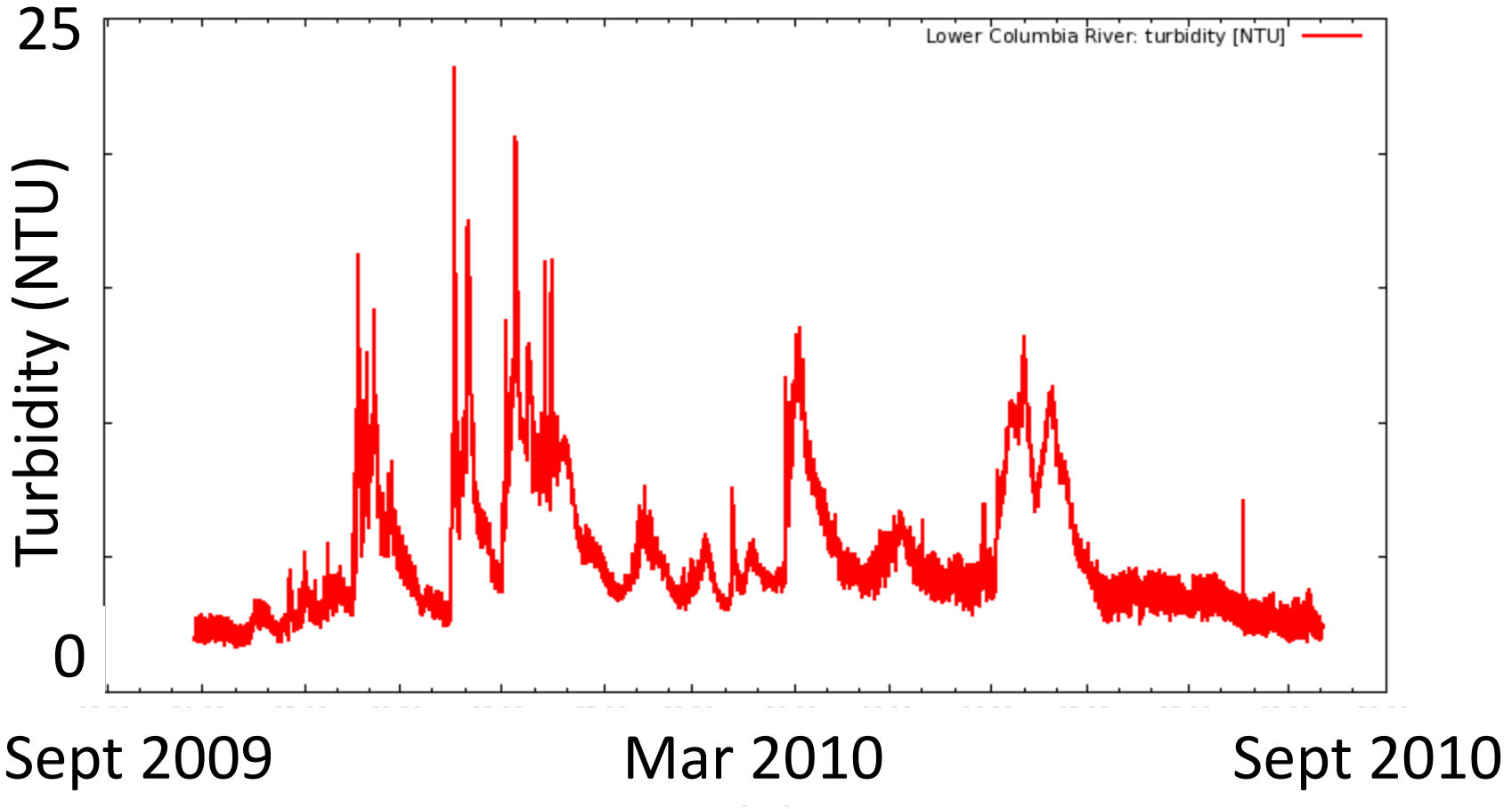
USGS science for a changing world

SEA-BIRD SCIENTIFIC

NSF


Summary of Monitoring Efforts
in the LCRE, 2005 - 2011
Non Estuary Partnership (EP) Monitoring
CMOP_OHSU (2007_2011)
ACOE/PNNL Cumulative Effects (2006-2009)
BPA/PNNL Salmon Benefits (2007 - 2011)
NOAA Tidal-Fluvial Sampling (2010-2011)
PNNL TFM Beach Seines (2007 - 2011)
EP Ecosystem Monitoring Project
Fixed Sites (Hab, WQ, Fish, Prim./Sec. Prod.)
2011 forward: WQ, Fish, Hab, PP/SP
2005 forward: WQ, Fish, Hab; 2011 forward: add PP/SP
2008 forward: WQ, Fish, Hab; 2011 forward: add PP/SP
Rotating Water Quality Monitoring
2005-2010, 1-2 yr rotating
Rotating Fish Monitoring
2011 proposed, 1-2 yr rotating
2005-2010, 1-2 yr rotating
Rotating Habitat Monitoring
2011 proposed, 1-2 yr rotating
2005-2010, 1-2 yr rotating
Tidal Freshwater Forested Wetlands (2008-2009)
Reach A
Reach B
Reach C
Reach D
Reach E
Reach F
Reach G
Reach H
N
0 5 10 20 Km

High resolution data is very informative

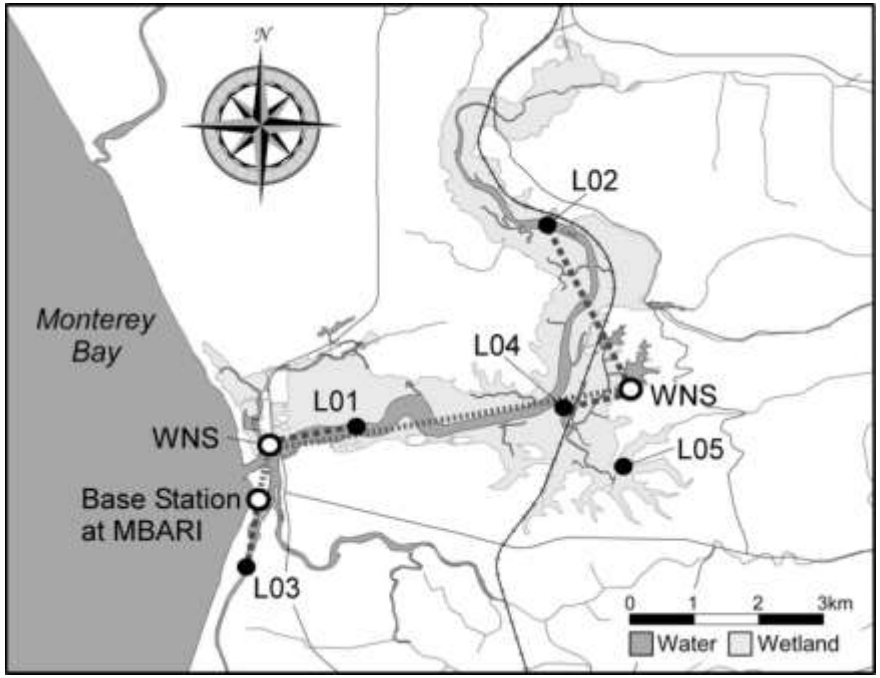


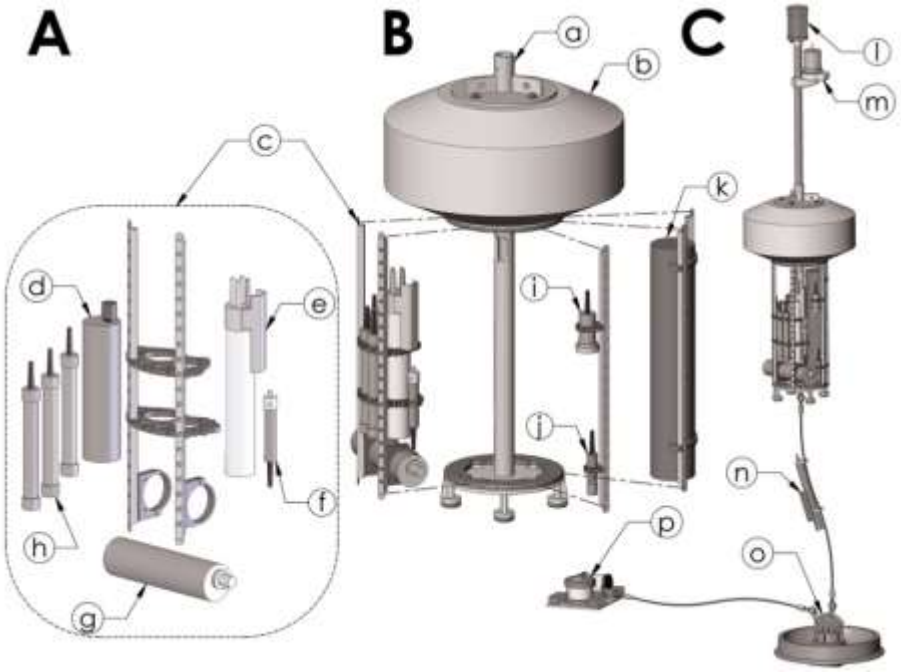
LIMNOLOGY
and
OCEANOGRAPHY: METHODS

Limnol. Oceanogr.: Methods 6, 2008, 263–276

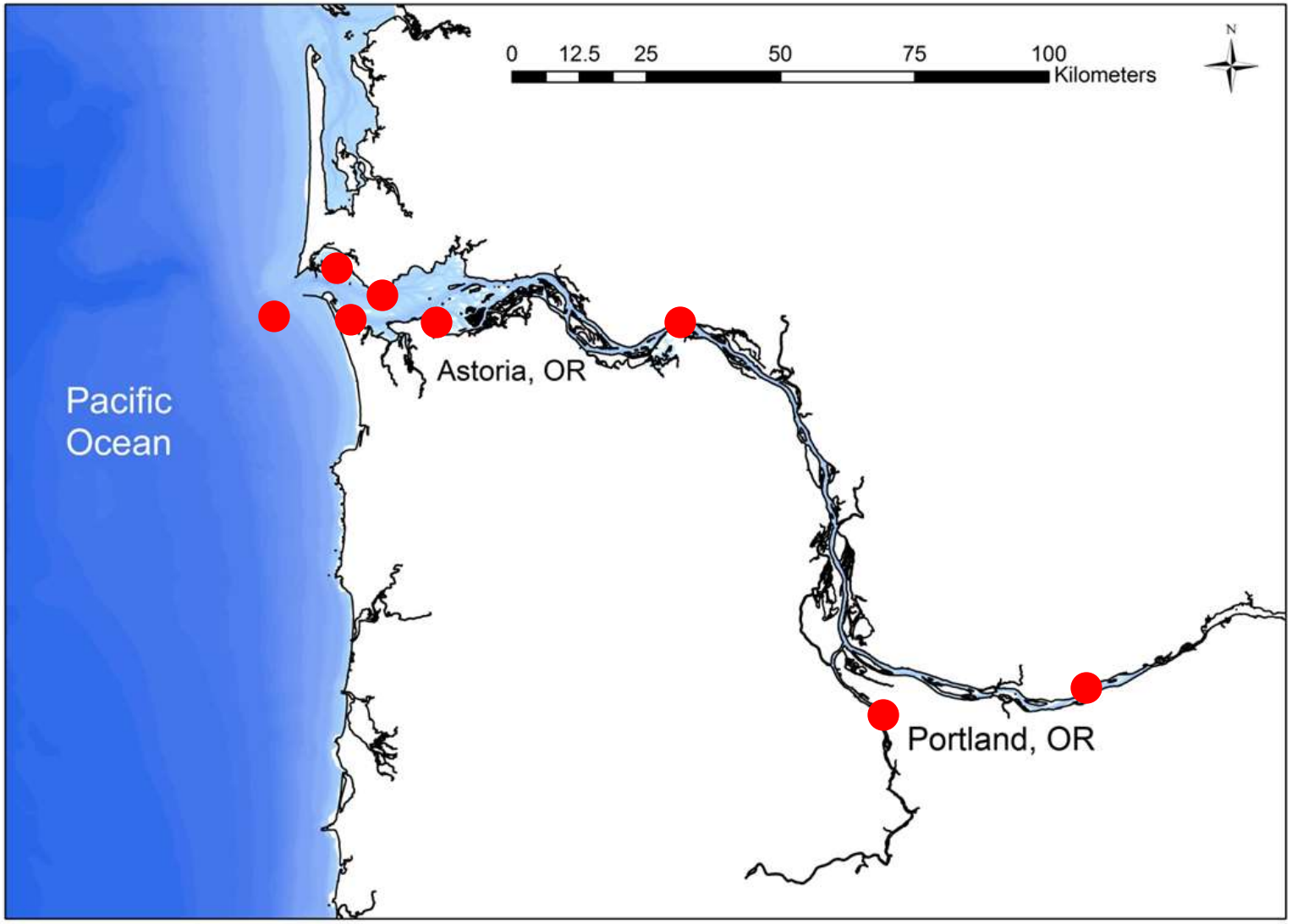
The Land/Ocean Biogeochemical Observatory: A robust networked mooring system for continuously monitoring complex biogeochemical cycles in estuaries

Hans W. Jannasch, Luke J. Coletti, Kenneth S. Johnson, Stephen E. Fitzwater, Joseph A. Needoba, and Joshua N. Plant*
Monterey Bay Aquarium Research Institute (MBARI), 7700 Sandholdt Road, Moss Landing, CA 95039

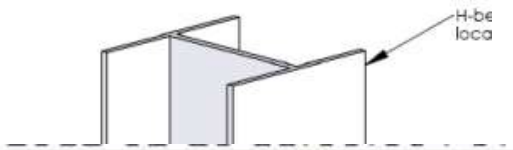




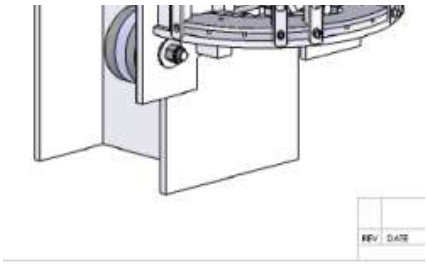
Biogeochemical Platforms



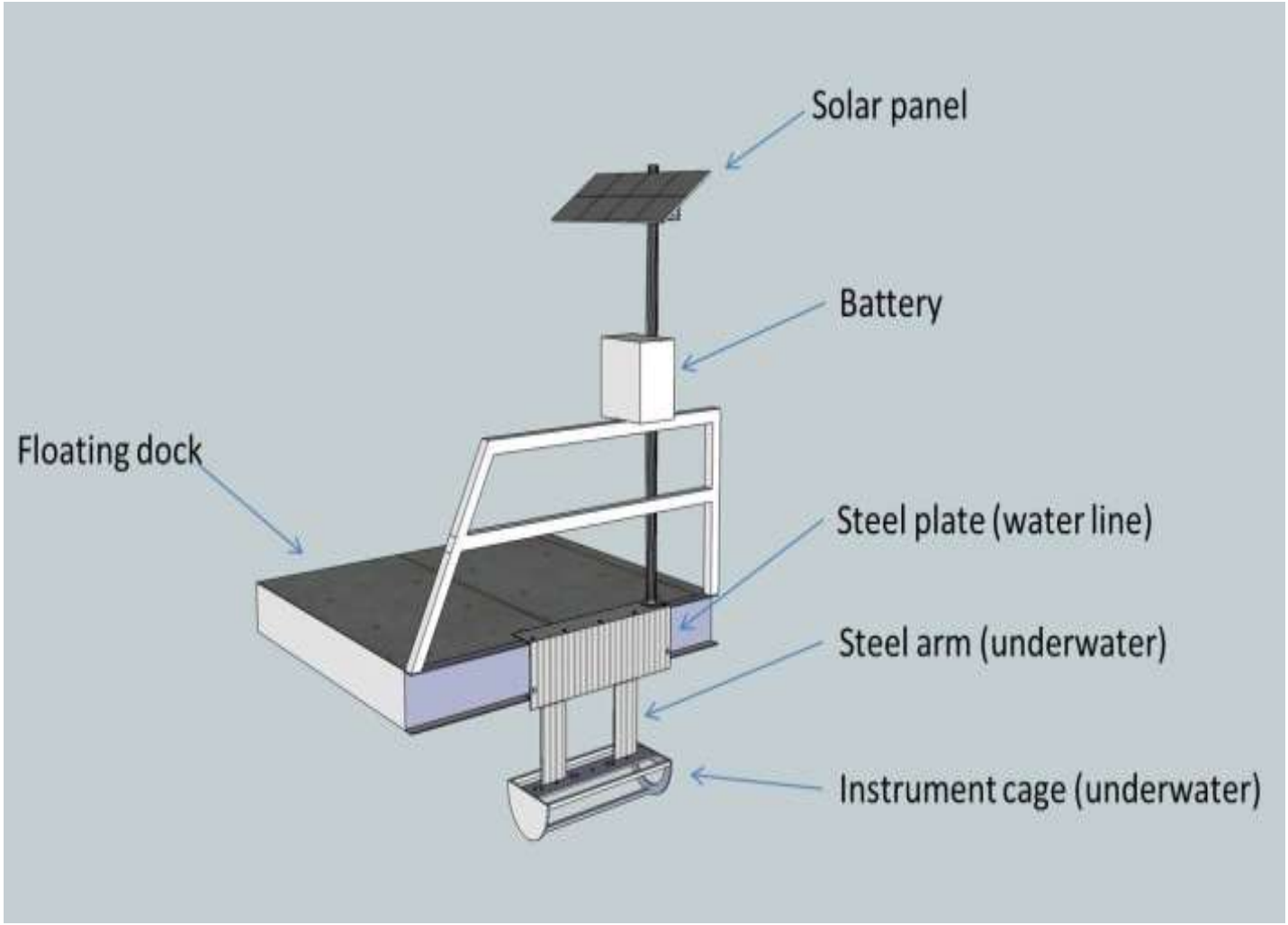
RM-53 Platform Design



CDOM	23.11	QSDE
Chlorophyll	6.68	µg/L
Conductivity	0.0090	S/m
Depth	3.822	m
Dissolved O_2	9.23	ml/l
Nitrate	29.7	µM
O_2 Saturation	8.90	ml/l
O_2 % Saturation	103.7	%
Salinity	0.07	PSU
Temperature	5.10	°C
Turbidity	4.90	NTU
Battery Voltage	12.8	V



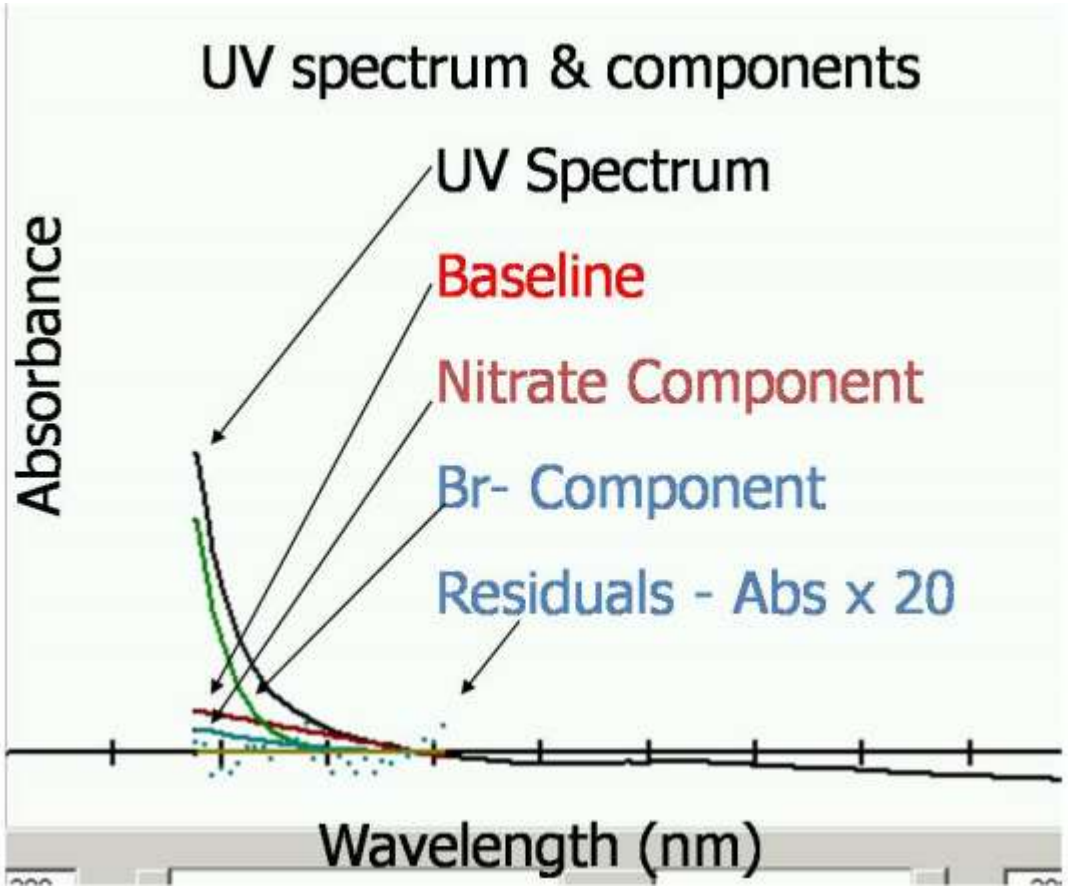
RM-122 Platform Design



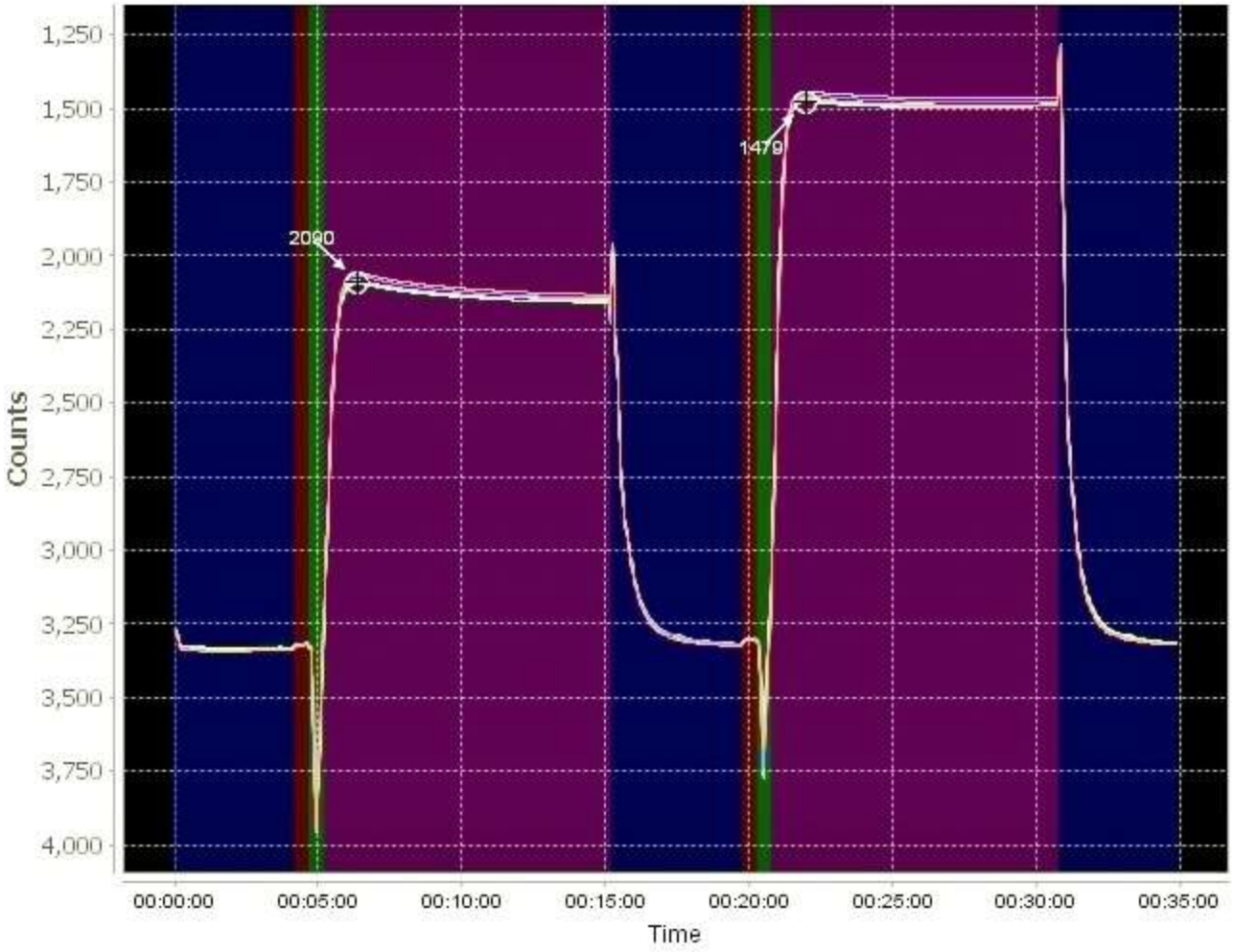
Nitrate Measurement

- ISUS (In Situ Ultraviolet Spectrophotometer)
- Optical sensor for NO_3^-

ISUS sensor with anti-fouling filter

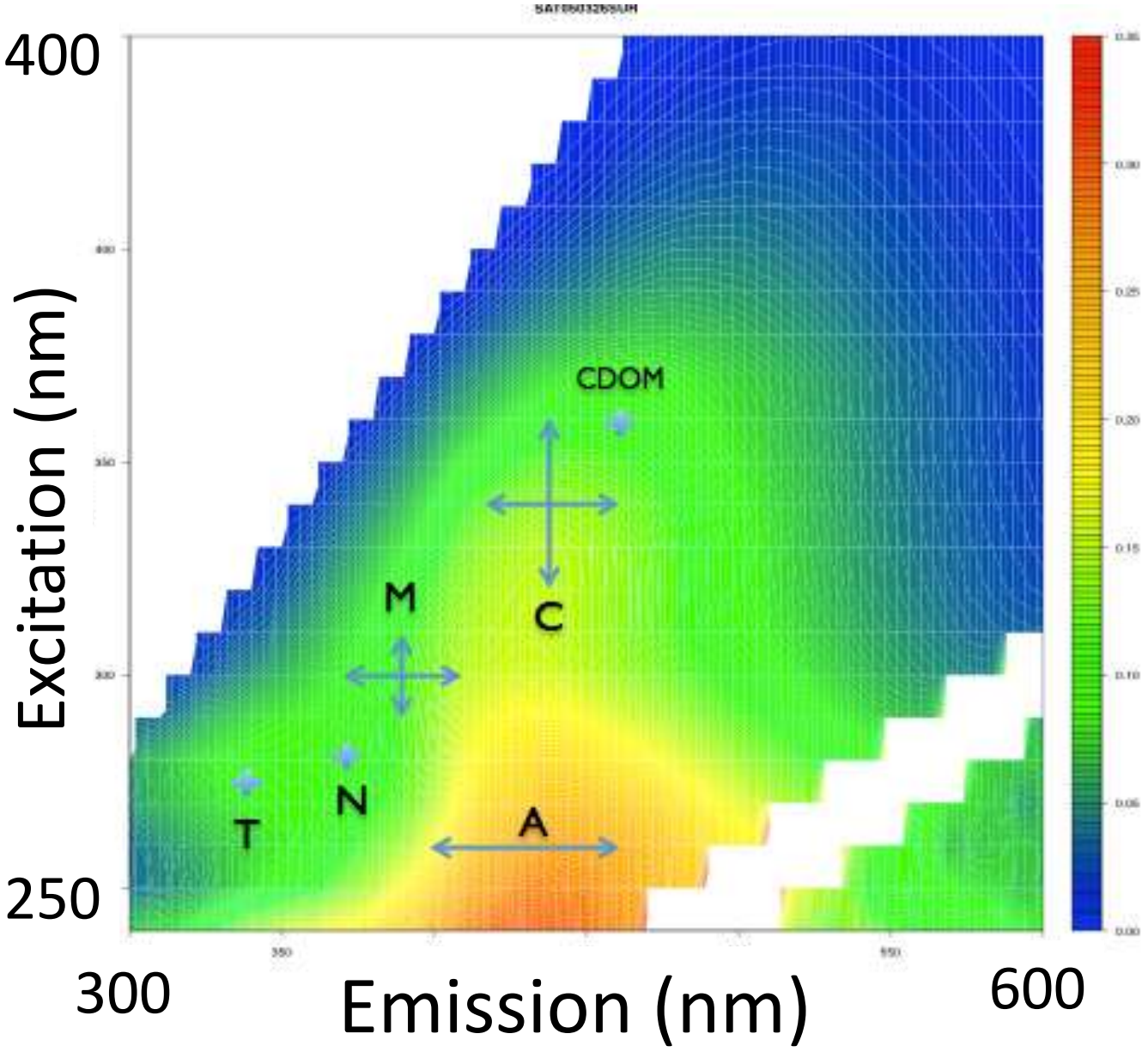


Phosphate Measurement

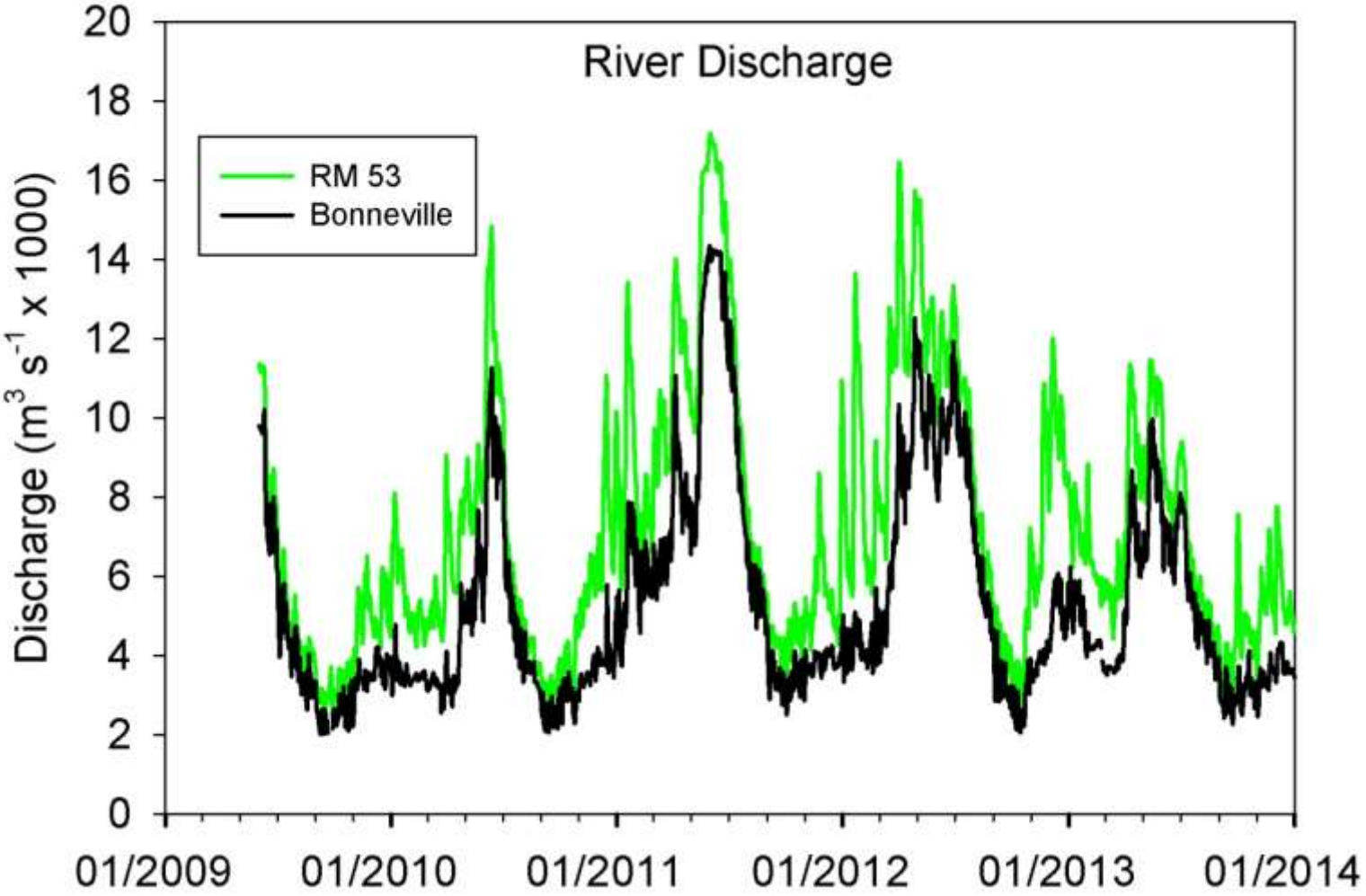


Corey Koch – Sea Bird Scientific

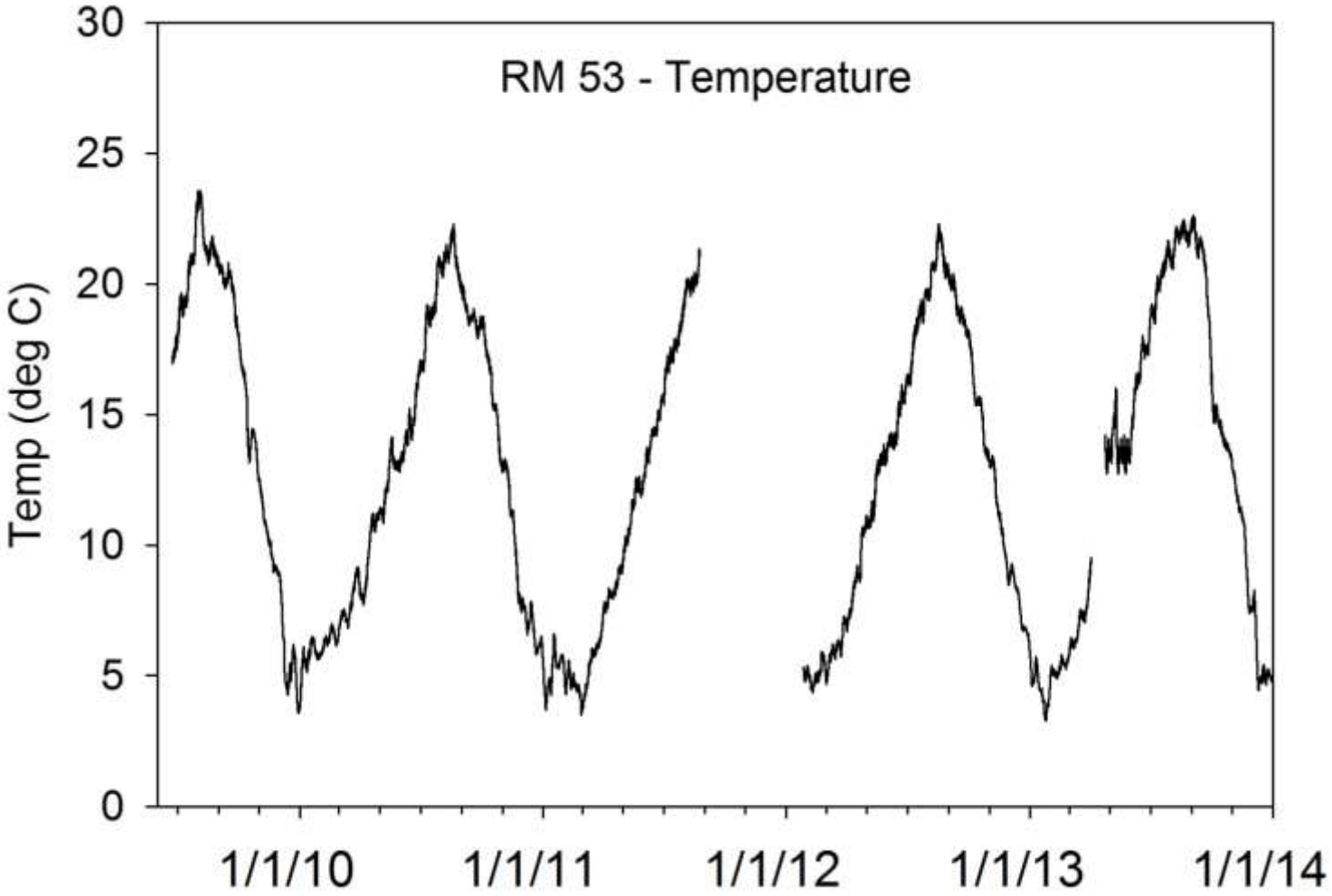
CDOM Measurement



Comparison between stations

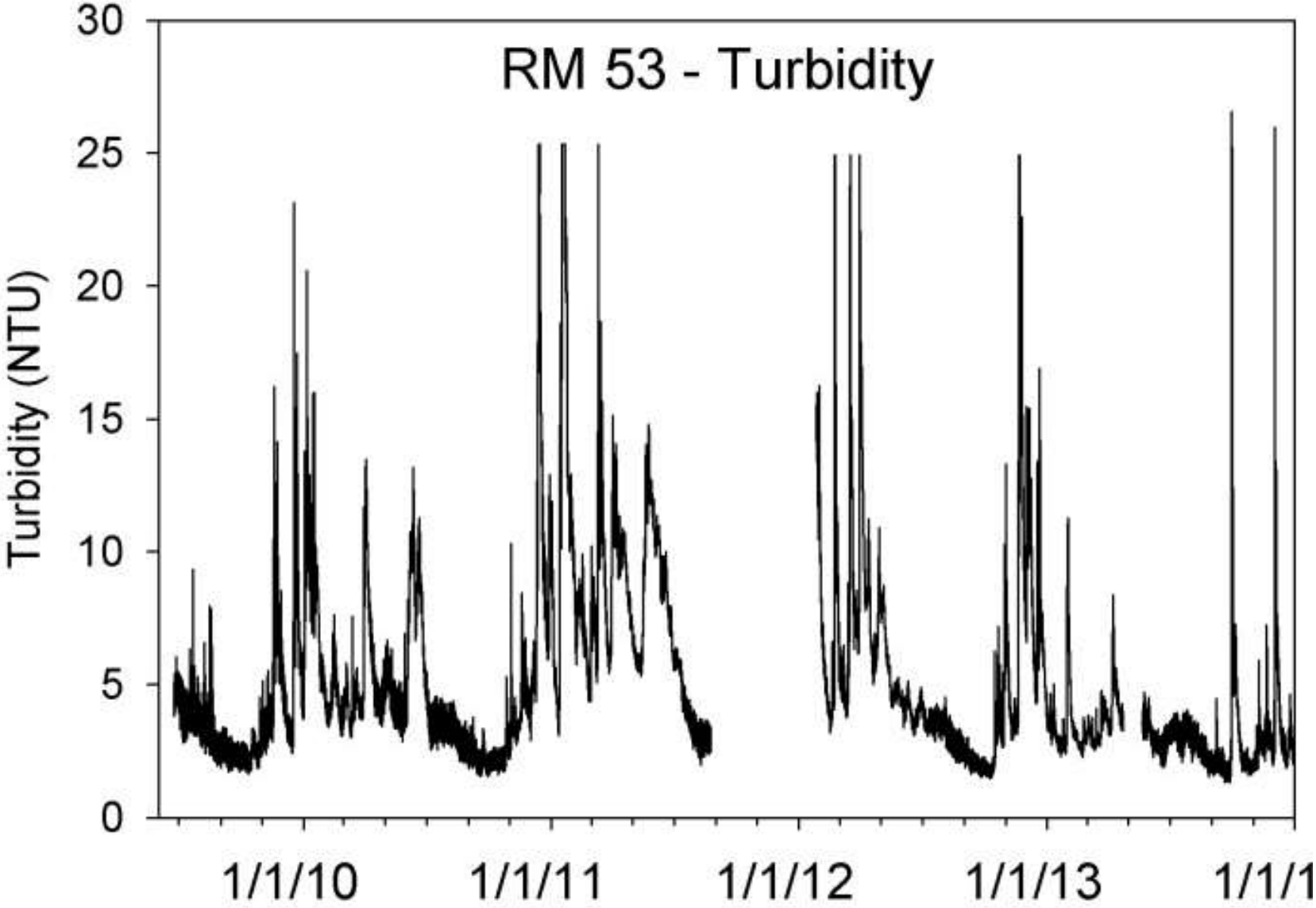


RM 53 Time Series

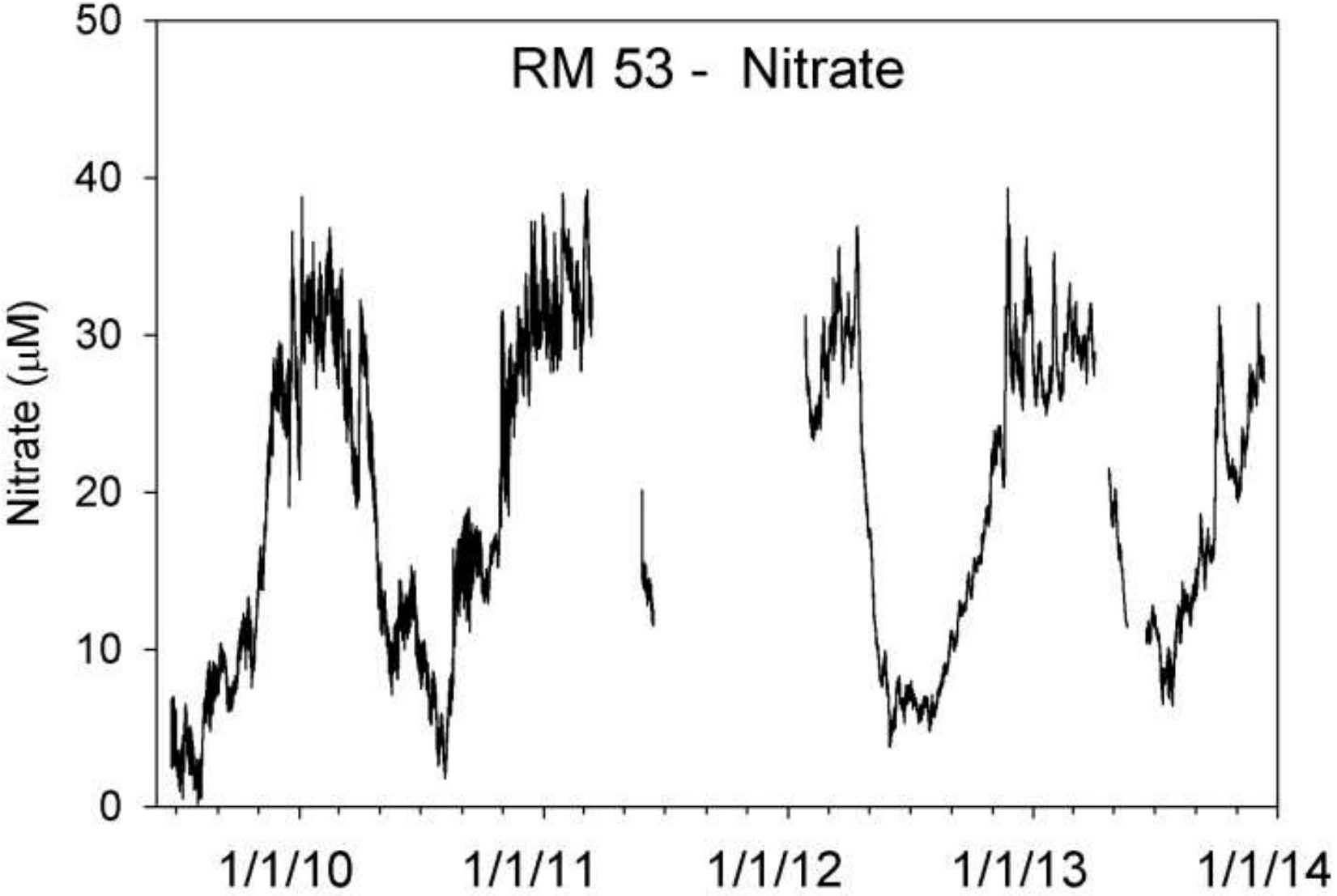


	2009	2010	2012	2013
Range 19-21 °C	70	49	53	67
Above > 21° C	11	2	2	14
Total > 19°C	82	51	55	81

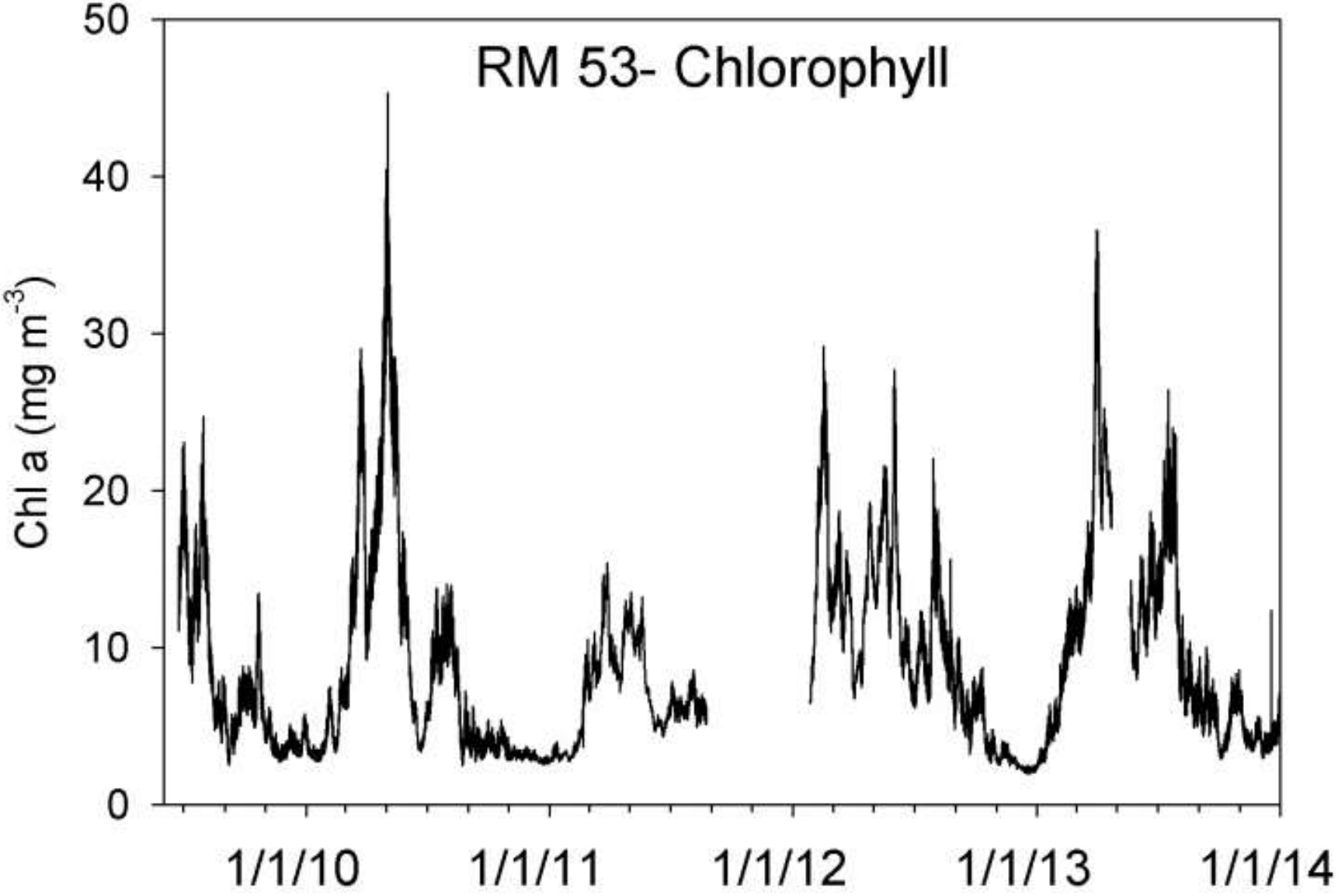
RM 53 Time Series



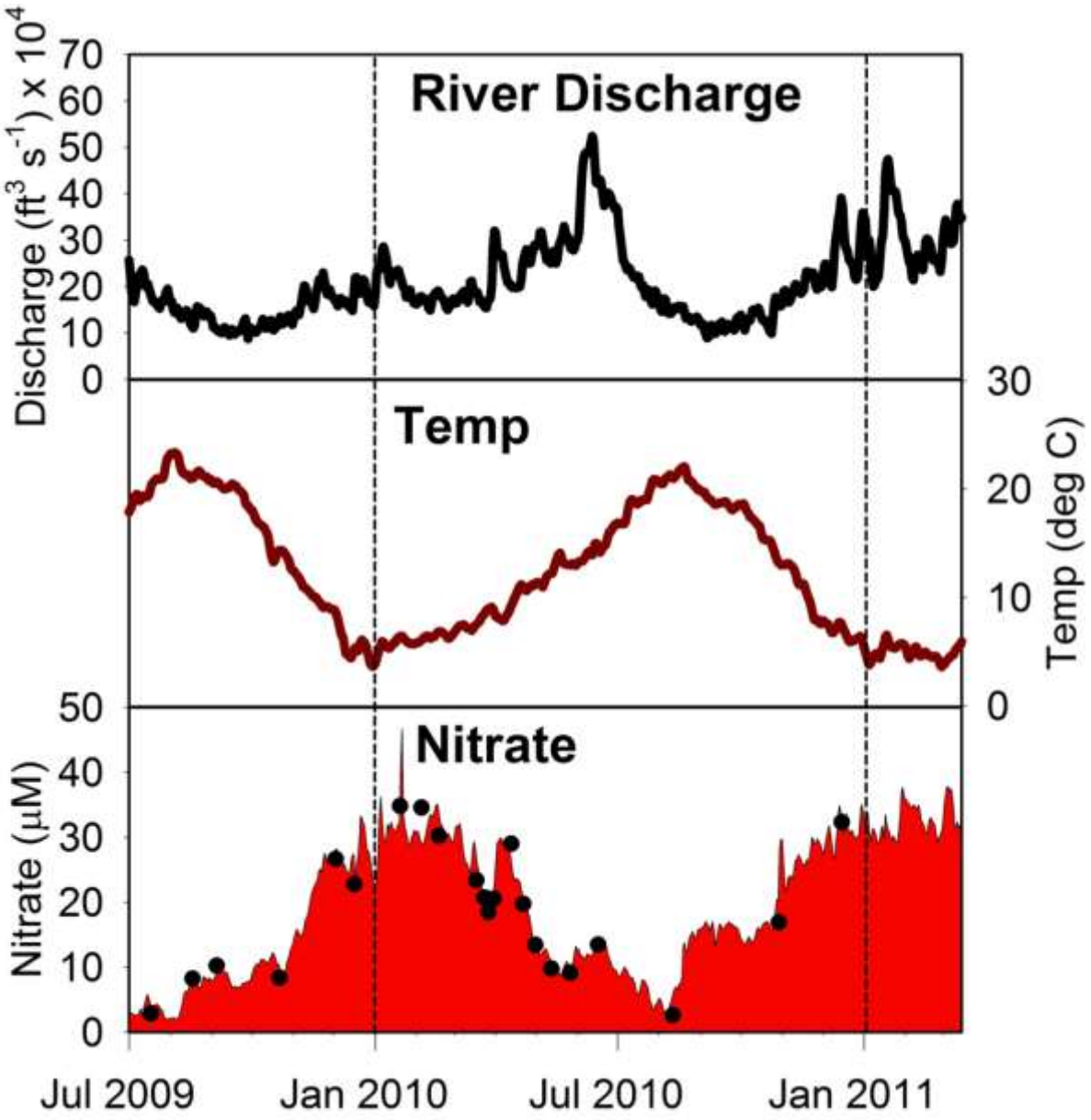
RM 53 Time Series



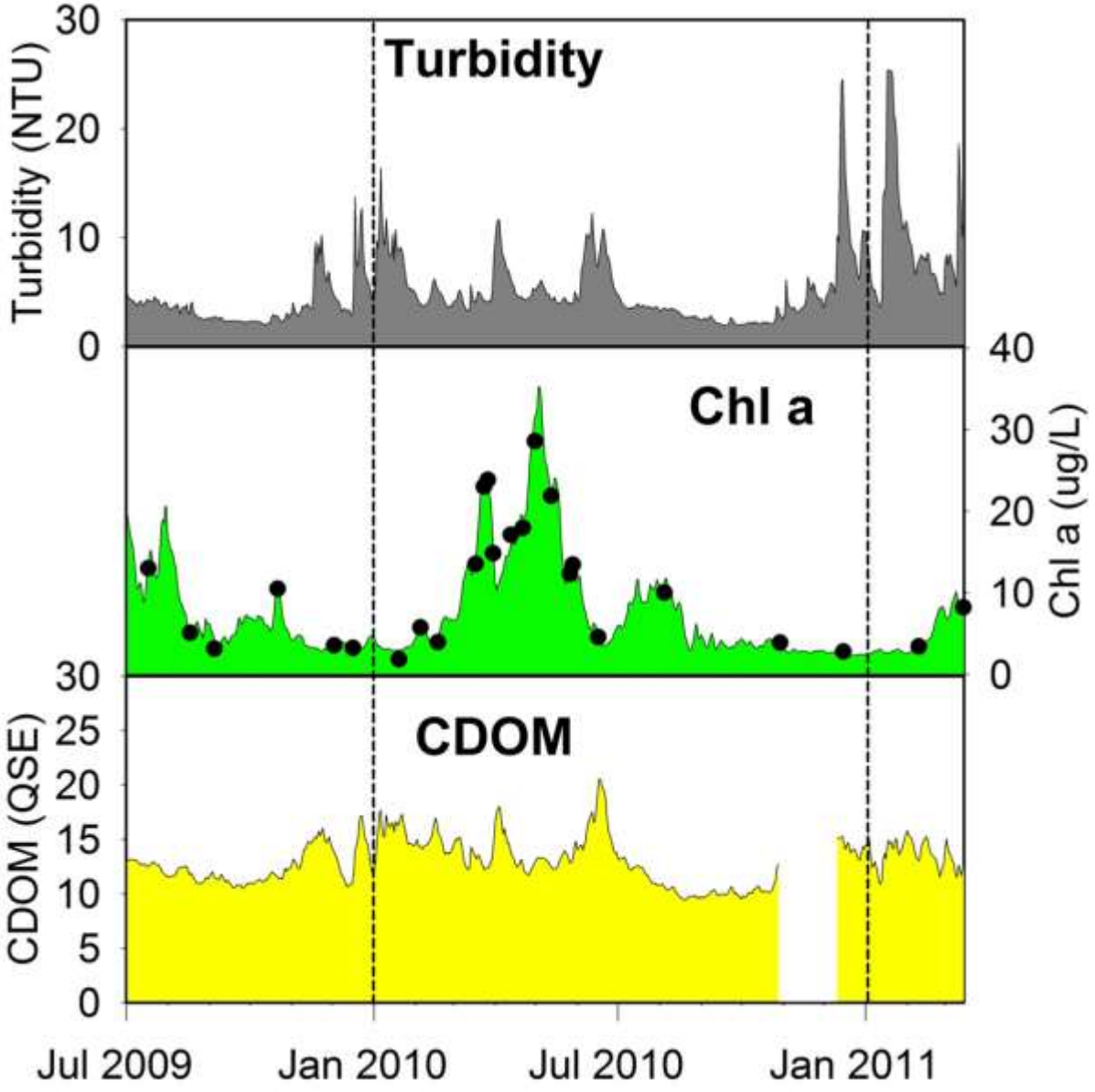
RM 53 Time Series



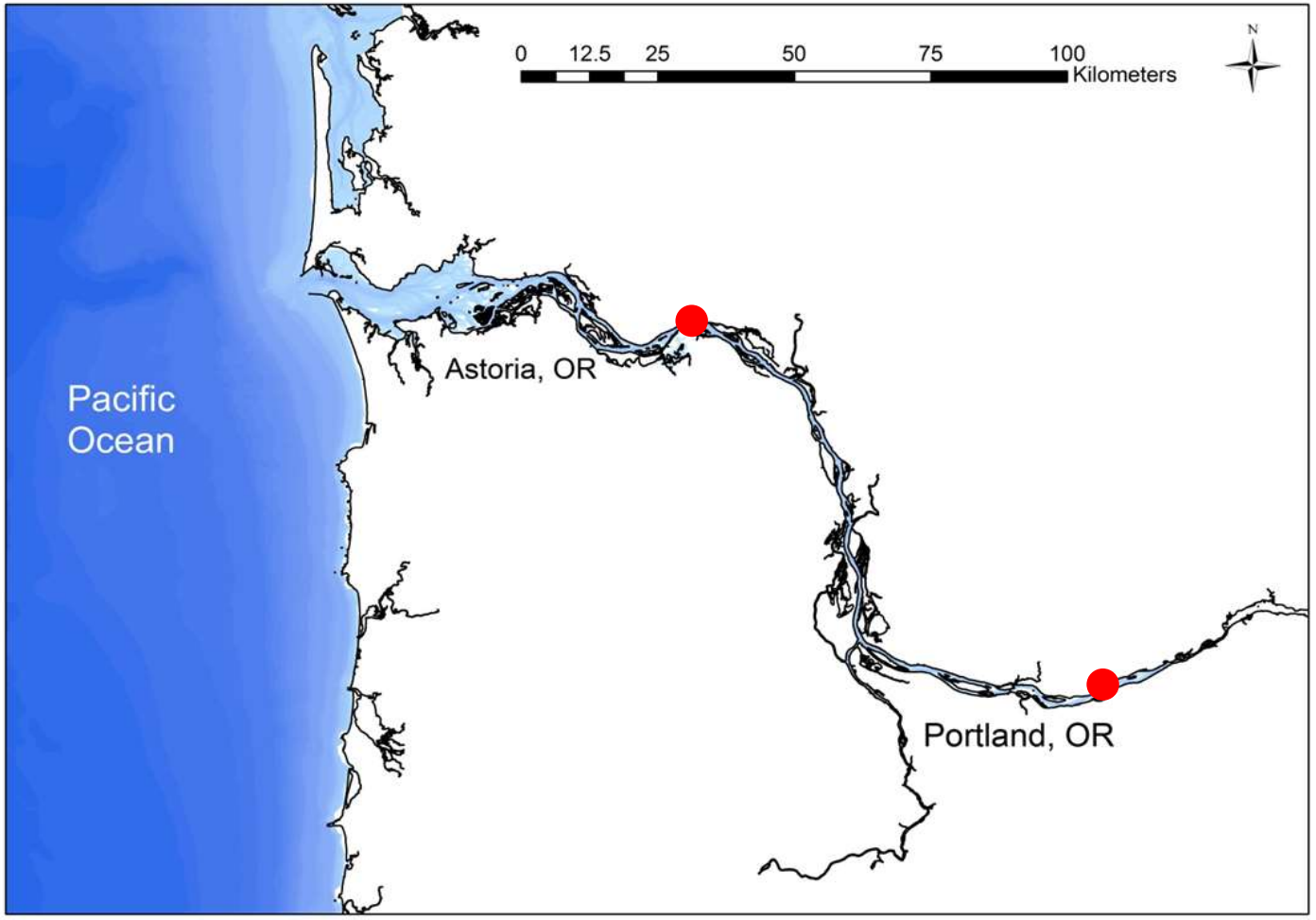
Biogeochemical data from RM-53



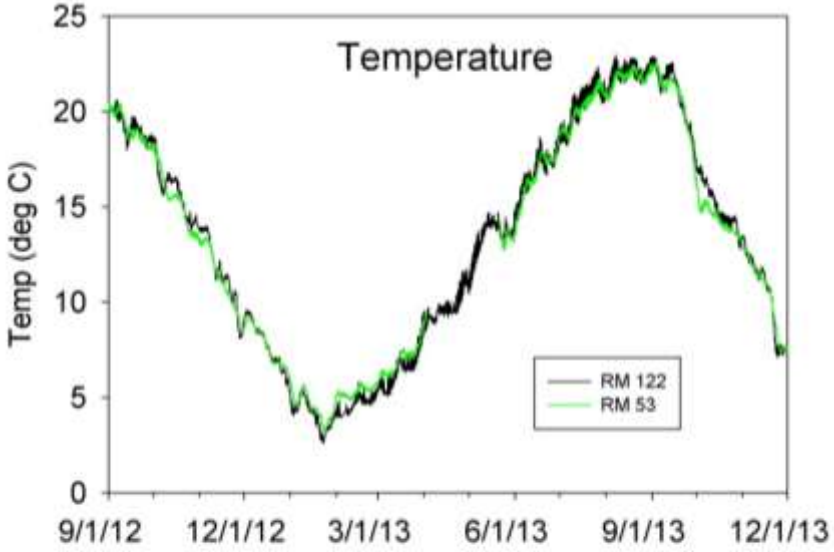
Biogeochemical data from RM-53

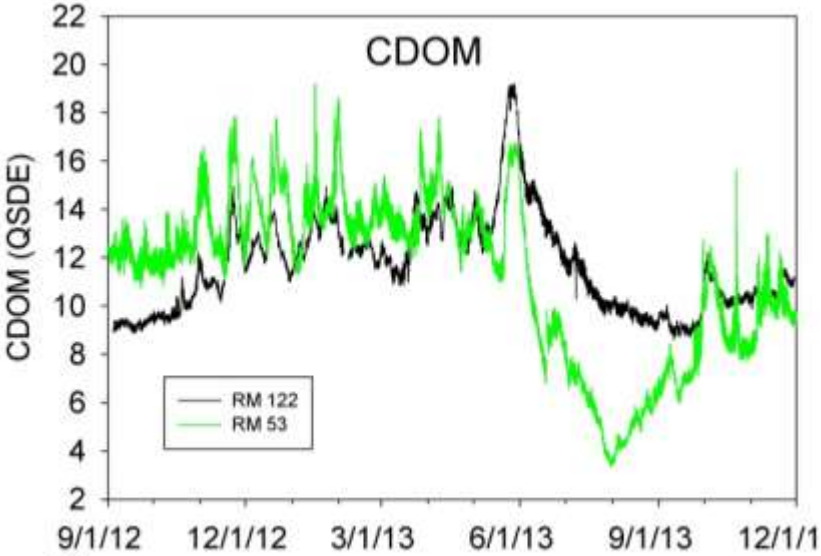


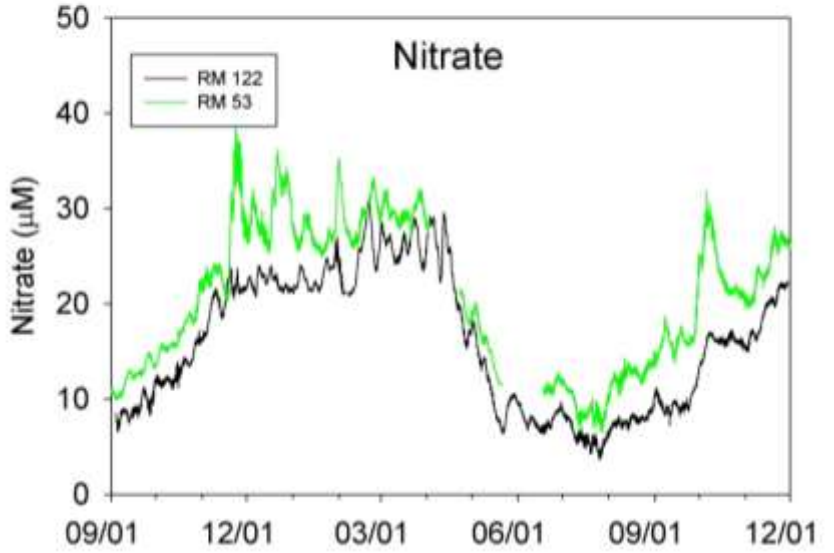
What is the role of the Willamette River and other tributaries to Columbia River water quality?

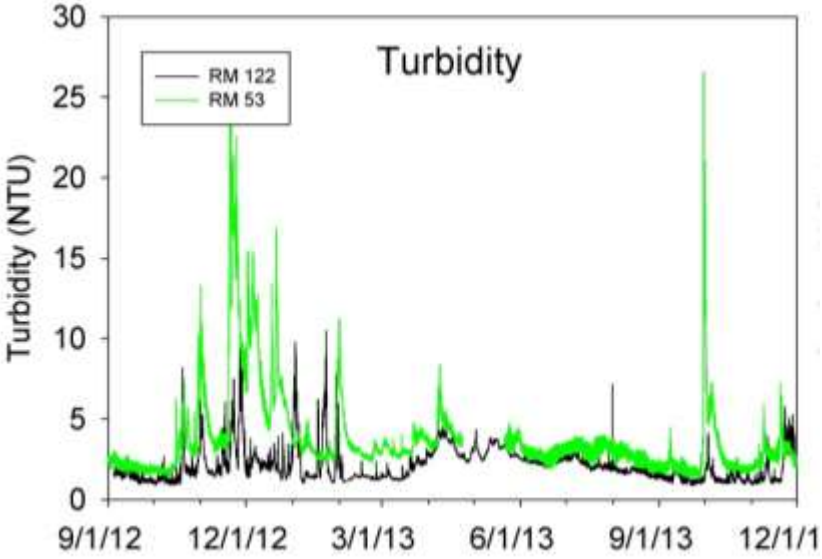


Evidence for downstream runoff

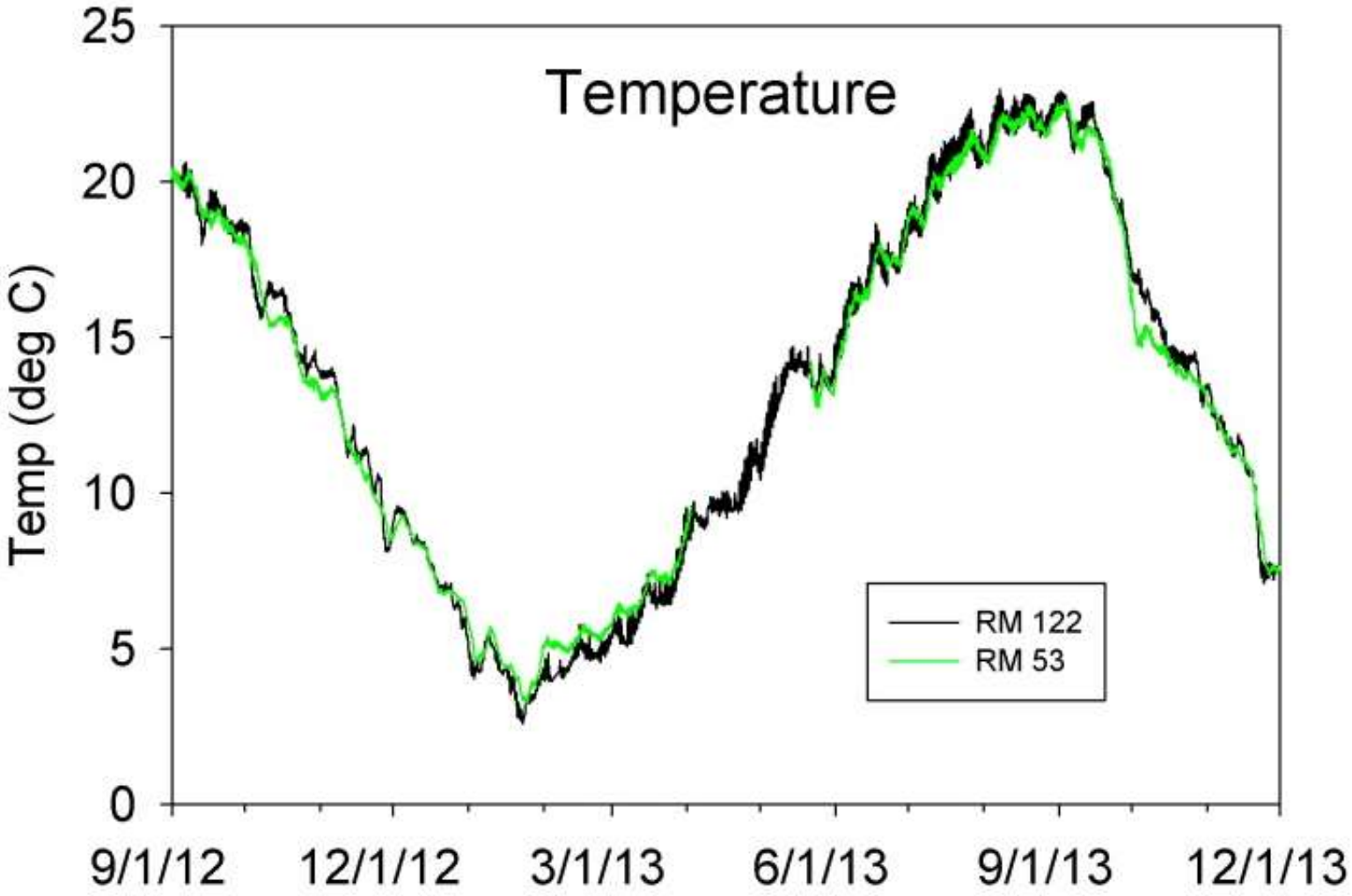




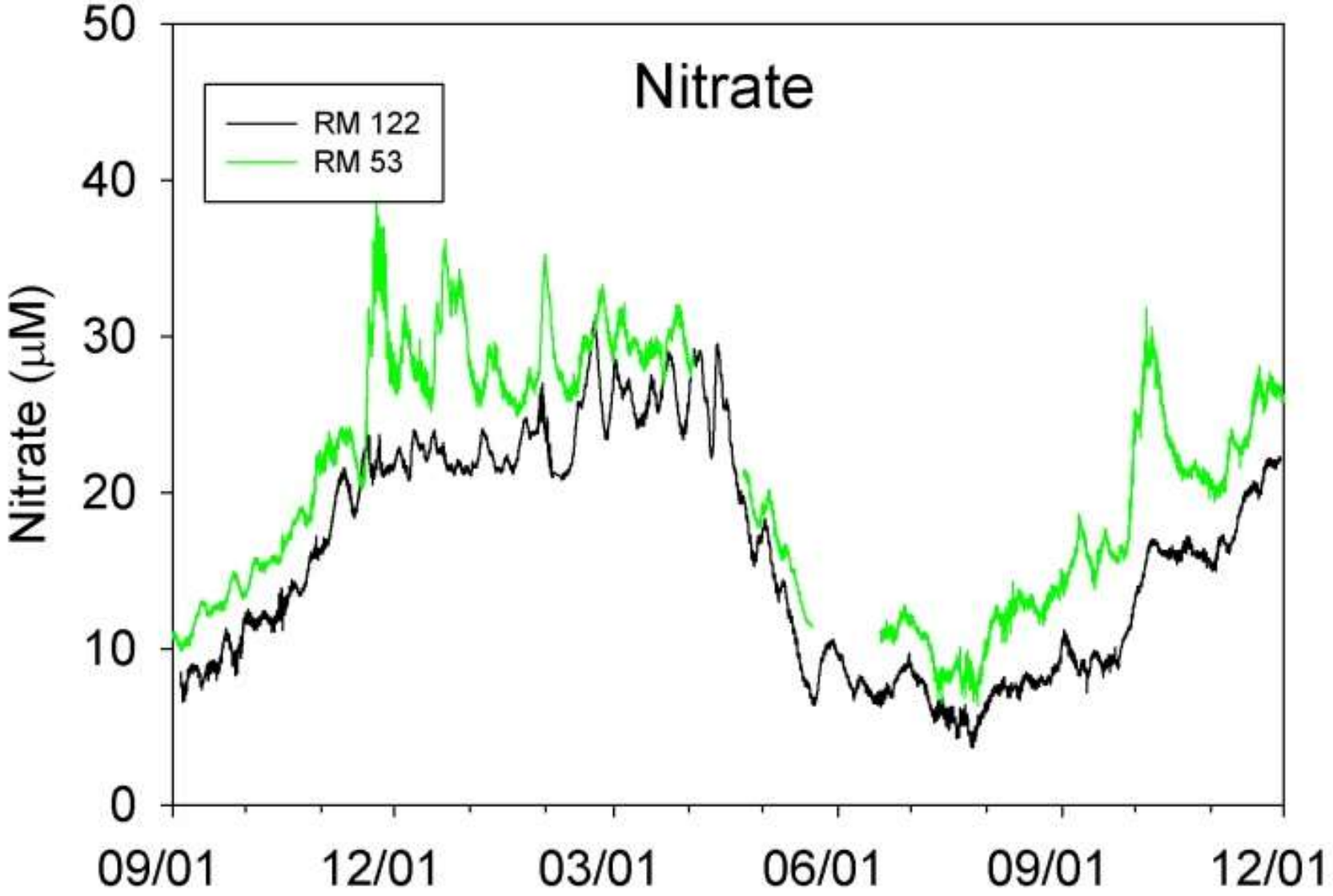




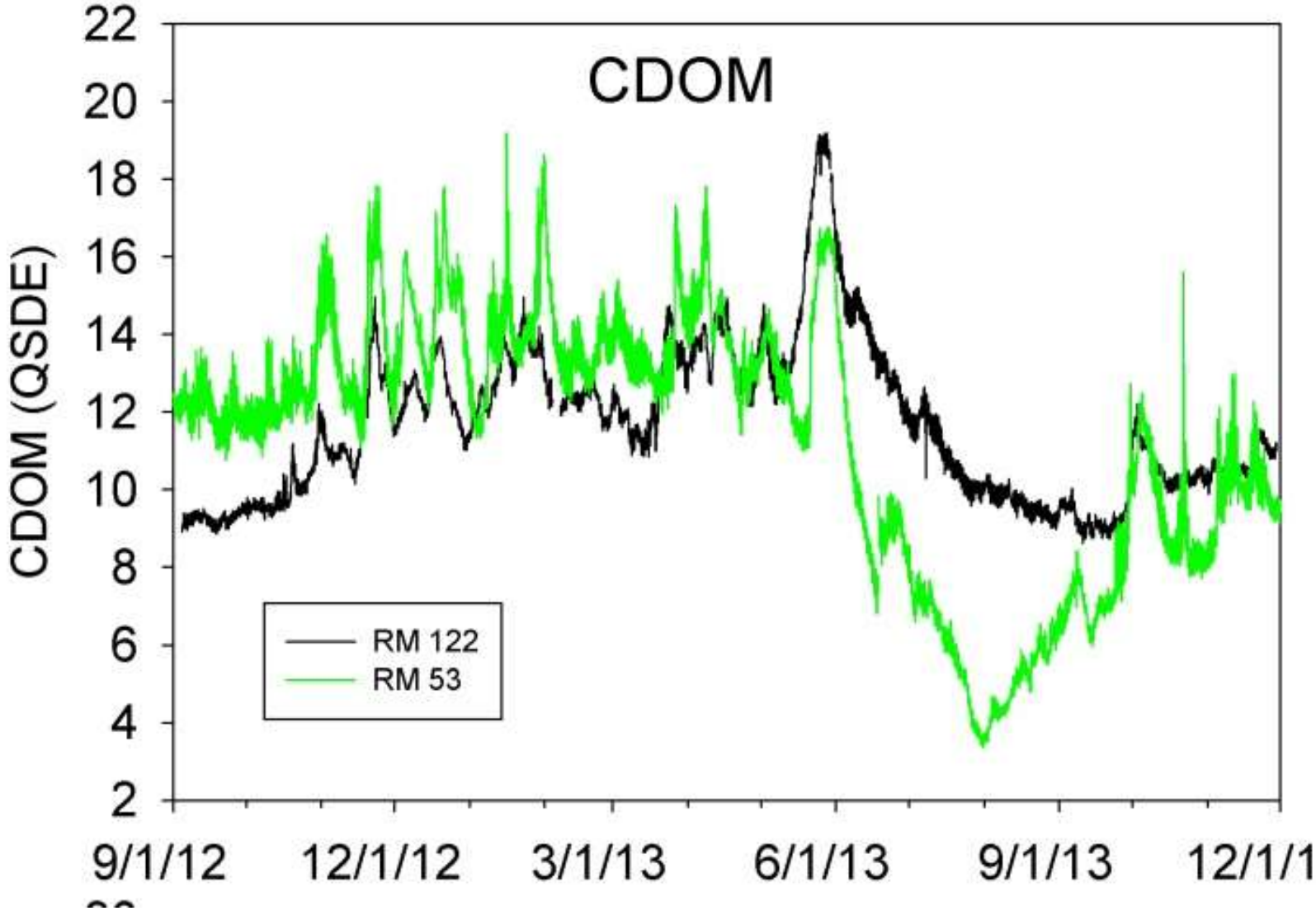
Comparison between stations



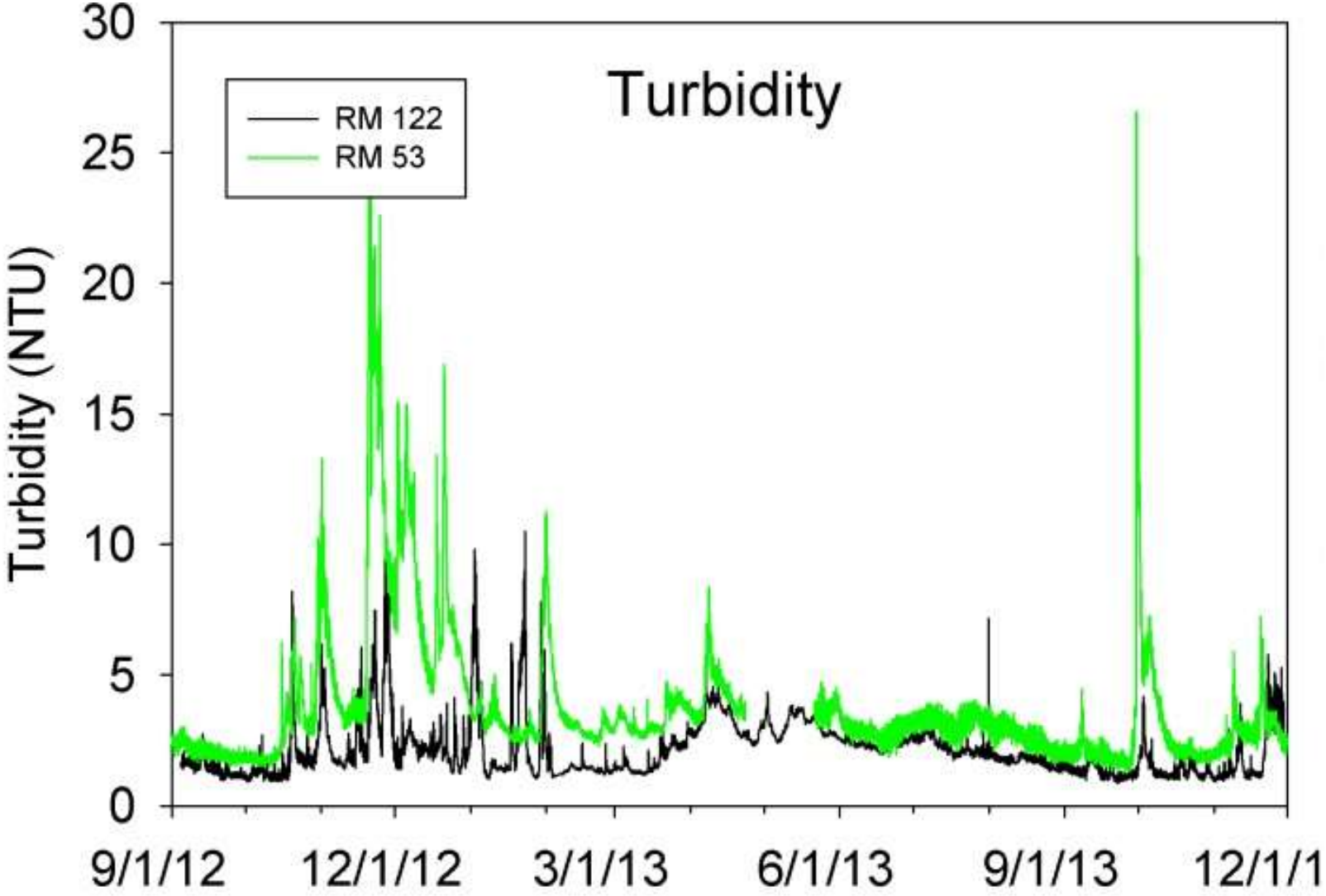
Comparison between stations



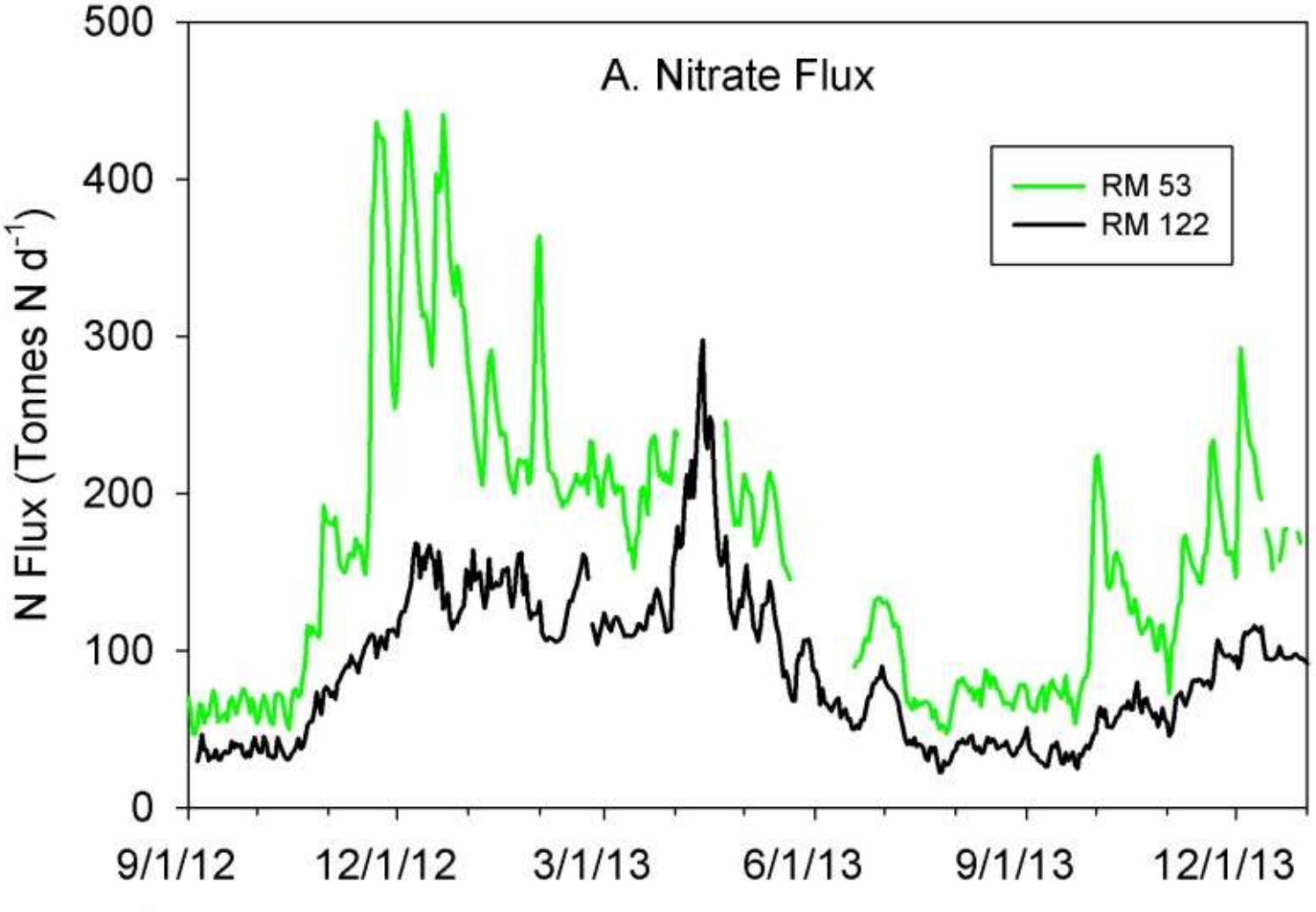
Comparison between stations



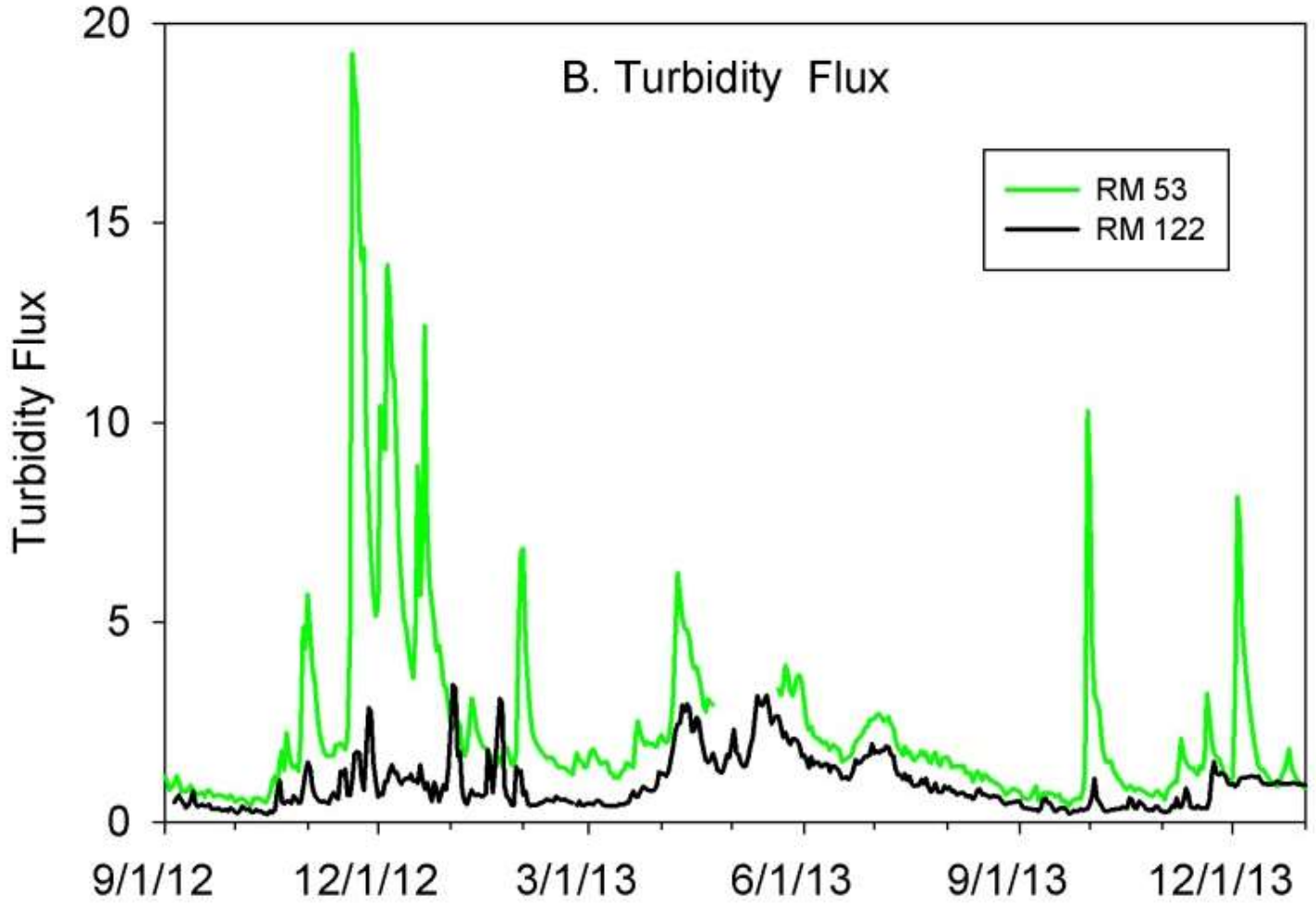
Comparison between stations



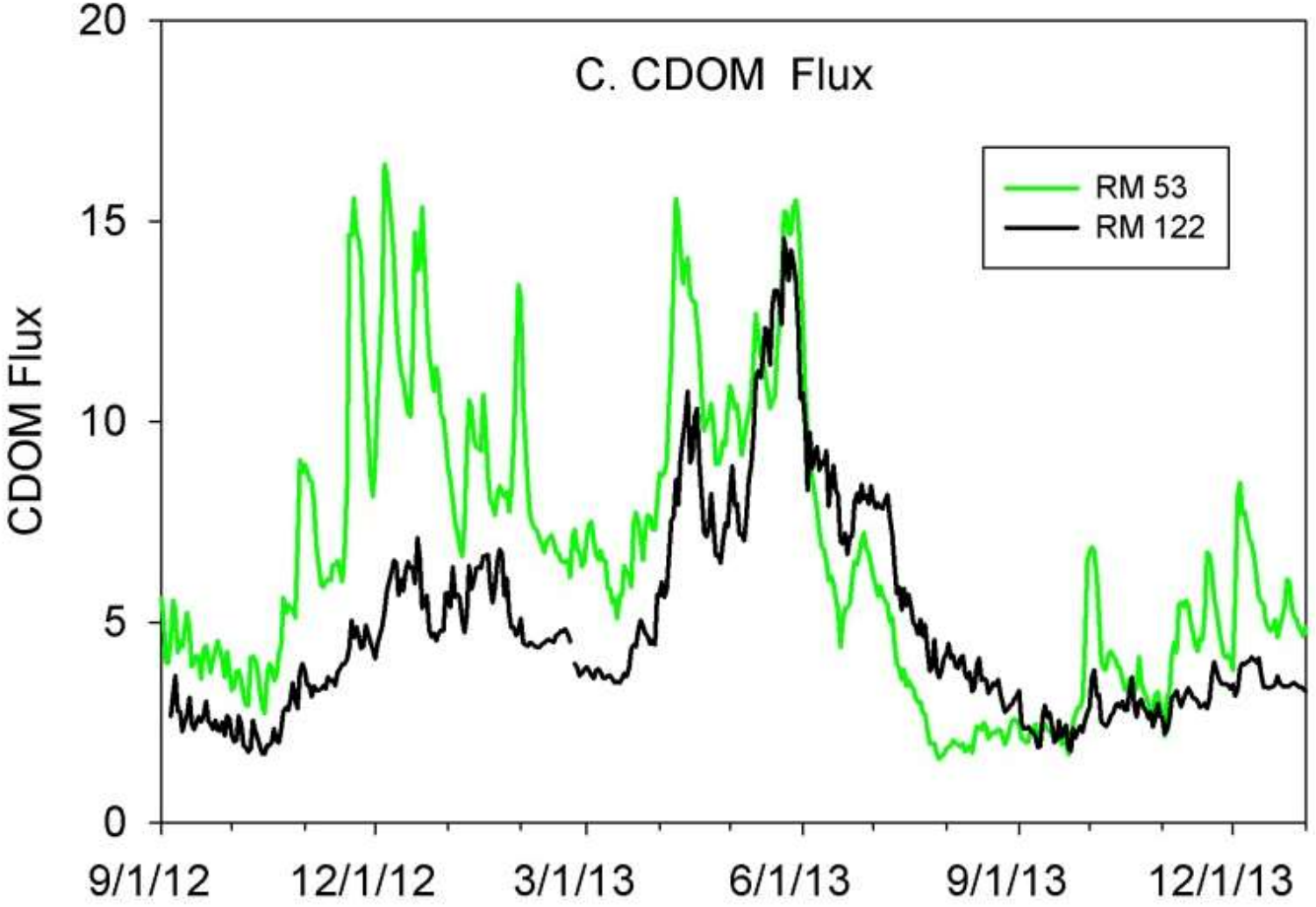
Comparison between stations



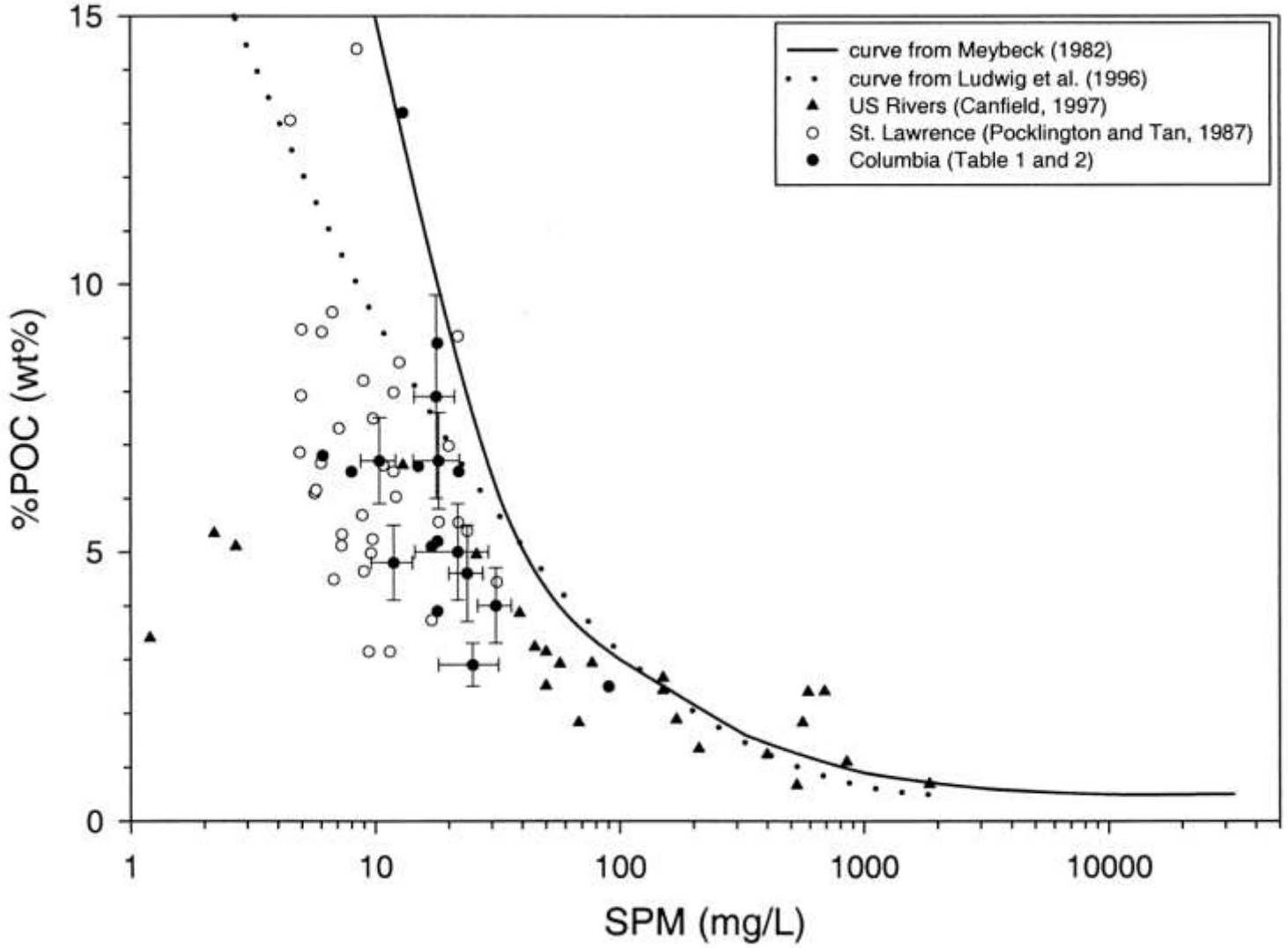
Comparison between stations



Comparison between stations

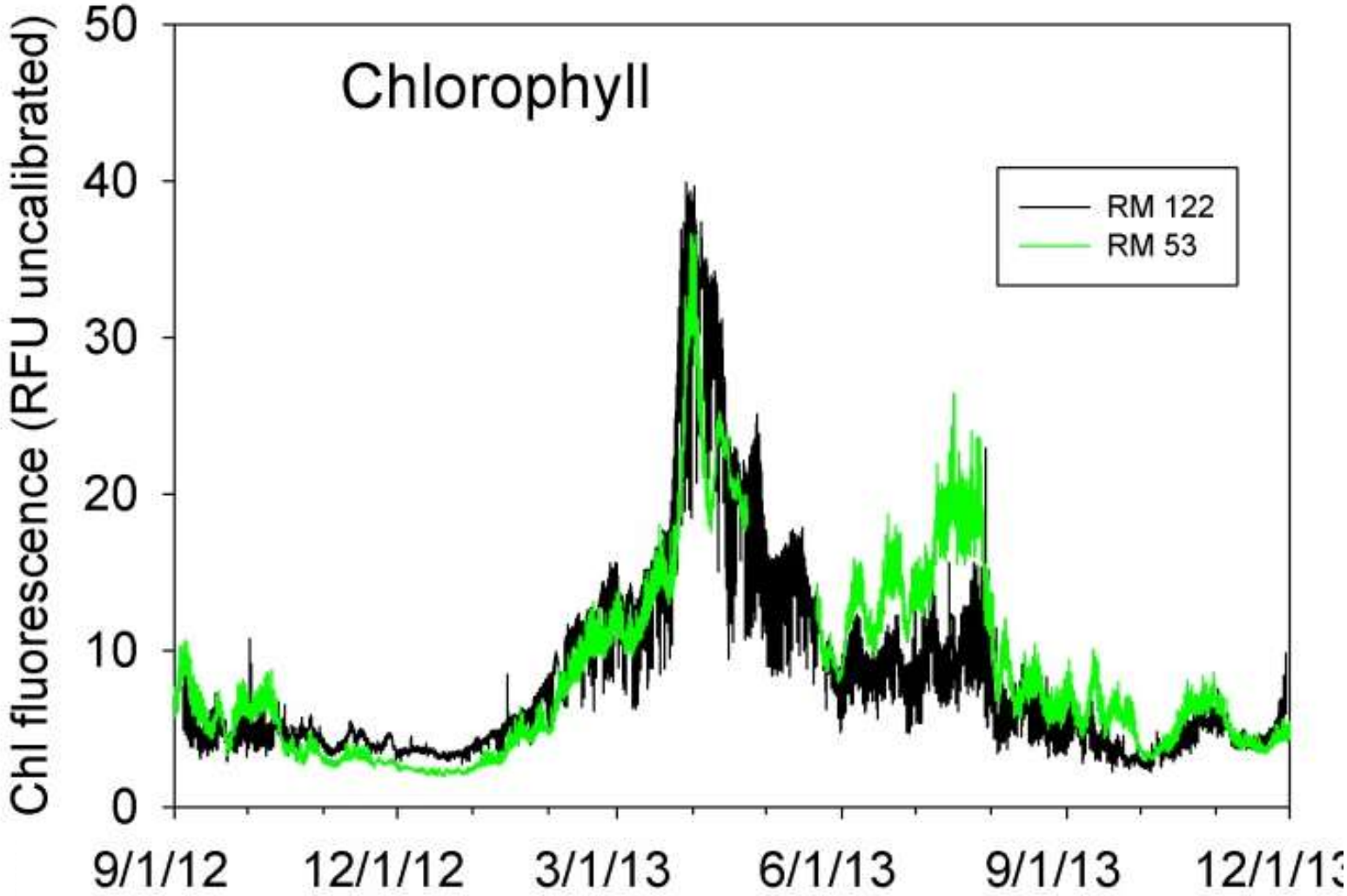


‘Greening’ of the Columbia River

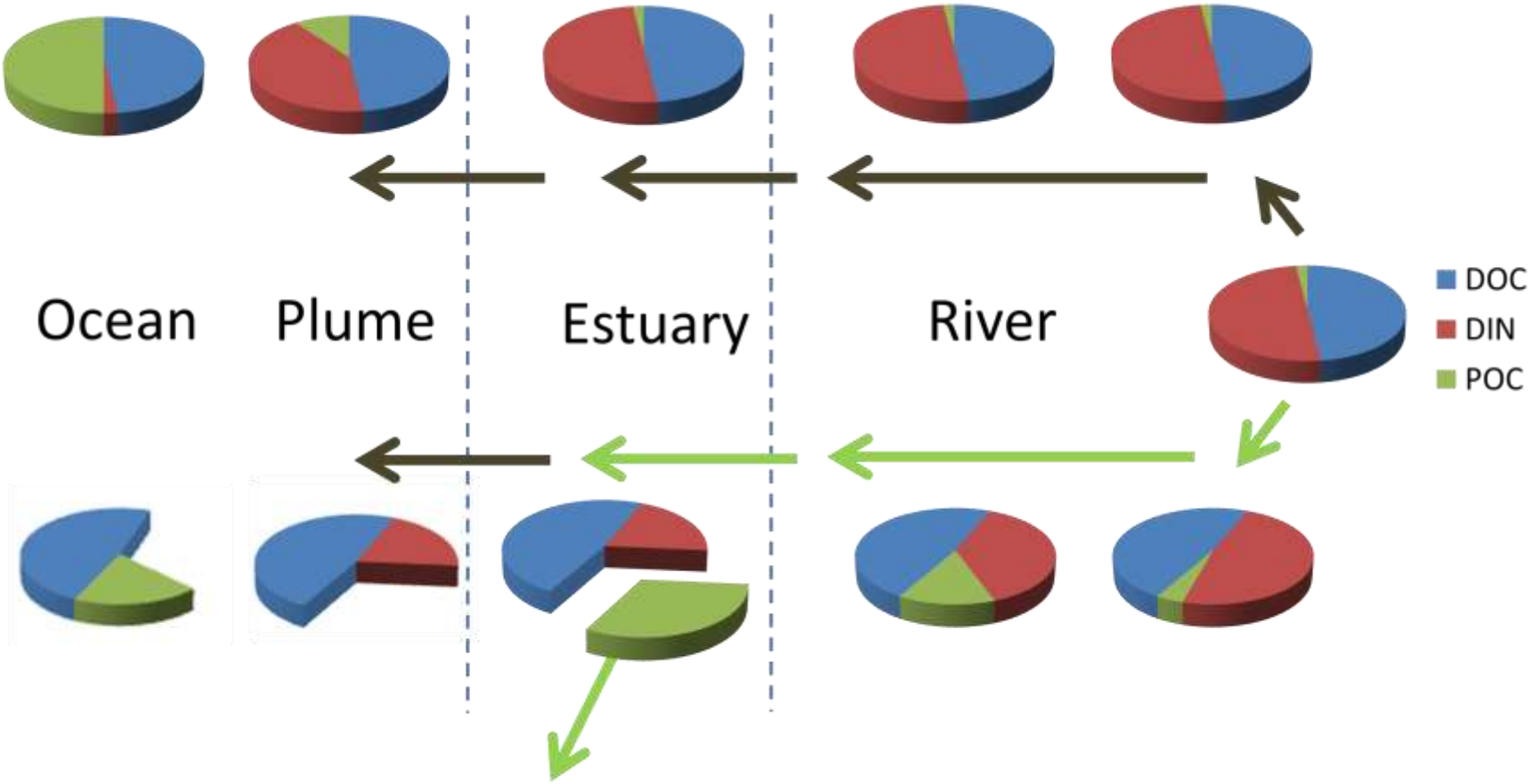


Sullivan et al 2001

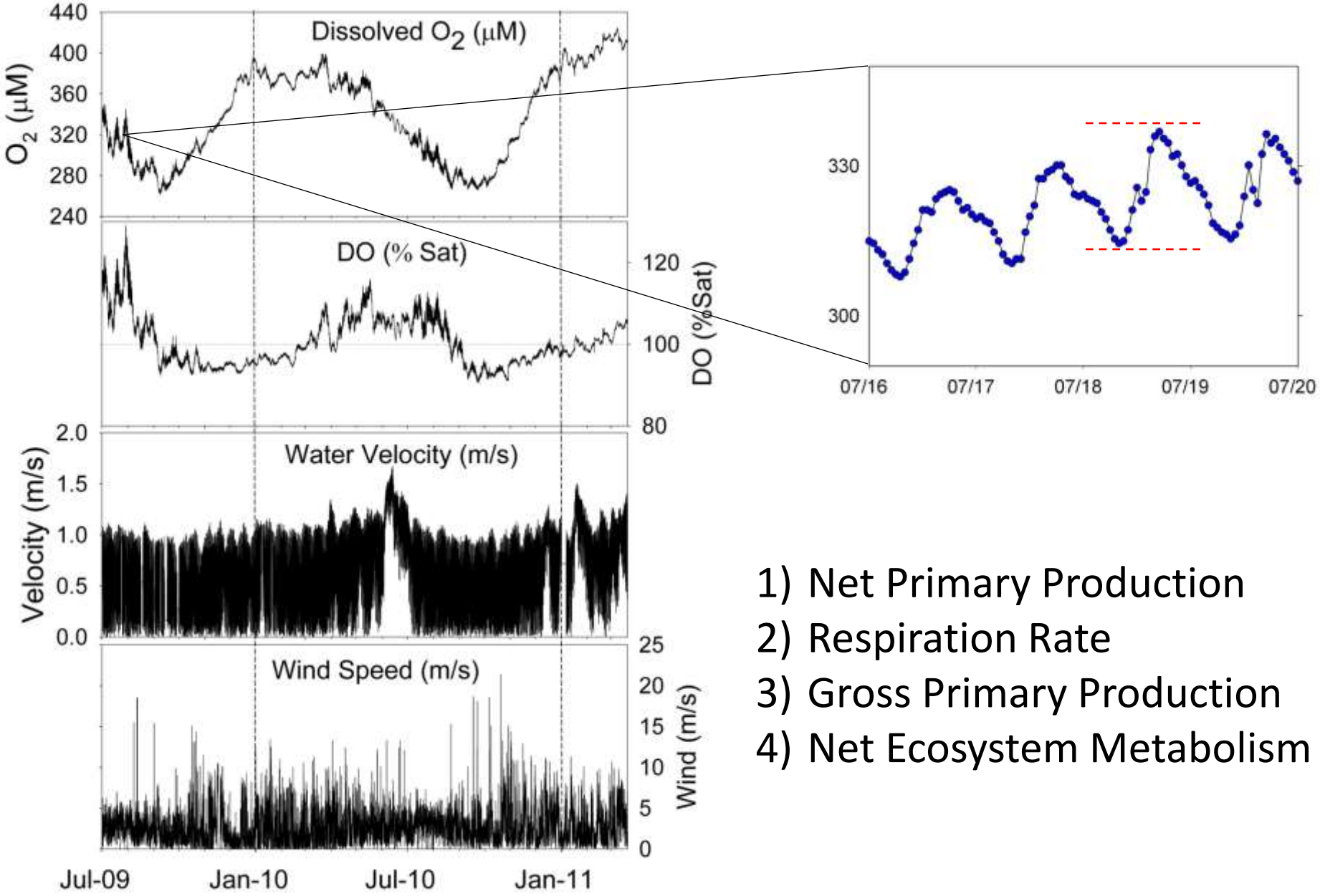
Phytoplankton bloom throughout the Lower Columbia River



Implications of a Green vs Brown River



Using dissolved O_2 to calculate metabolic rates



1) Net Primary Production
2) Respiration Rate
3) Gross Primary Production
4) Net Ecosystem Metabolism

Calculating oxygen flux

1) Biological Oxygen Change per hour:

$$BDO_t = (DO_t - DO_{t-1}) * h - F_{O2}$$

2) Oxygen Flux by air-water diffusion:

$$F_{O2} = -vO_2 \times (O_{2\,meas} - O_{2\,sat})$$

3) Piston velocity estimates:

$$k_{flow} = U\left(\frac{\nu}{D}\right)^{-\frac{1}{2}}\left(\frac{Uh}{\nu}\right)^{-\frac{1}{2}} = \sqrt{\frac{UD}{h}}$$

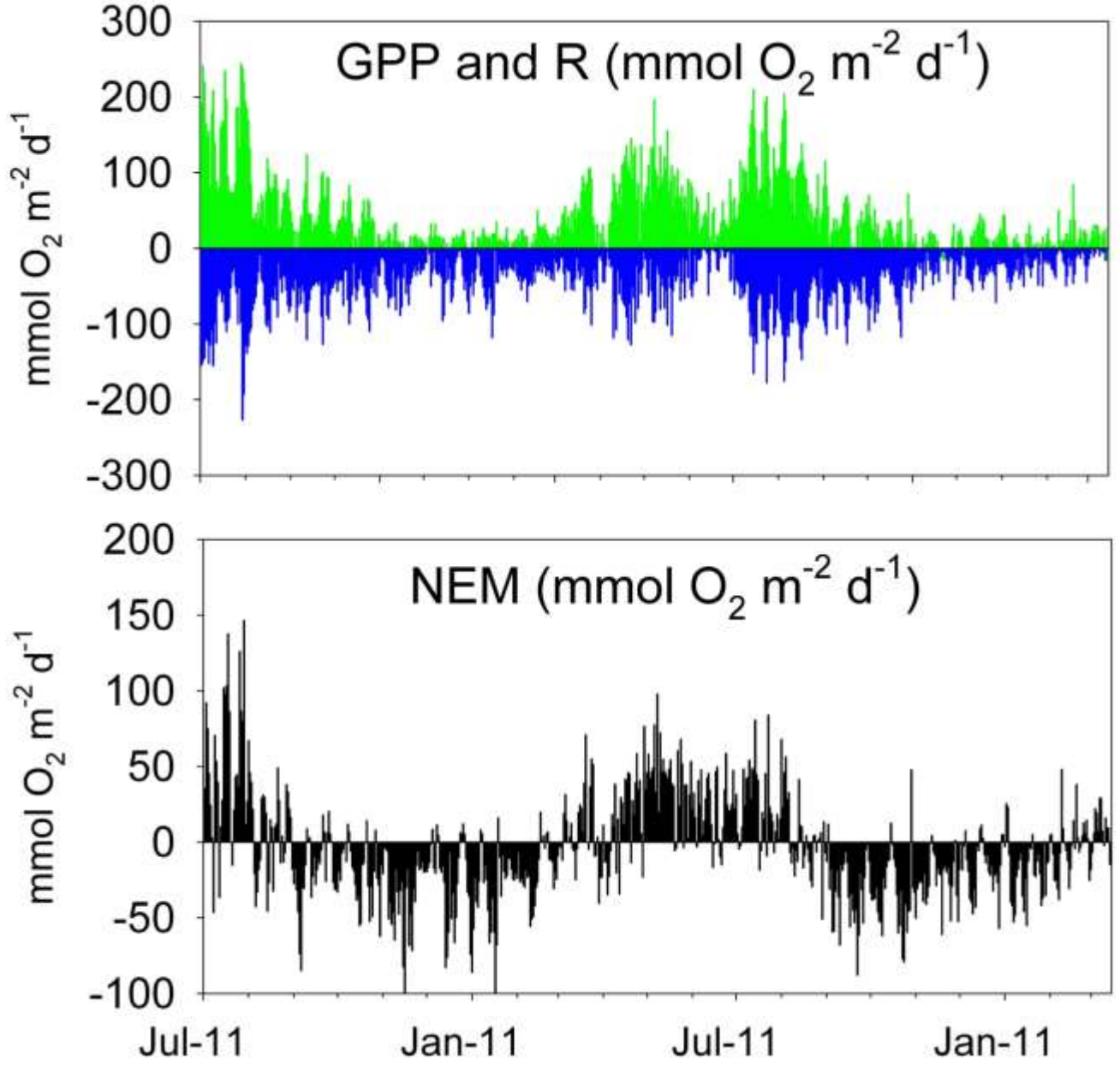
O'Connor DJ and WE Dobbins (1958)

$$k_{wind} = 0.31 \times u_{10}^2\left(\frac{Sc}{660}\right)^{-0.5}$$

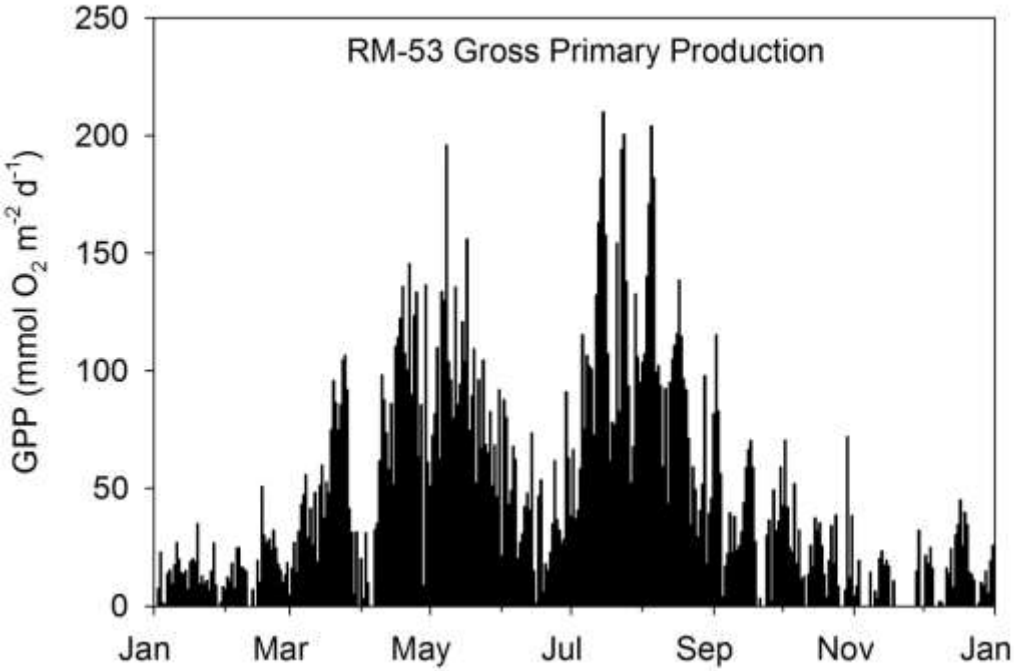
Wanninkhof R. (1992)

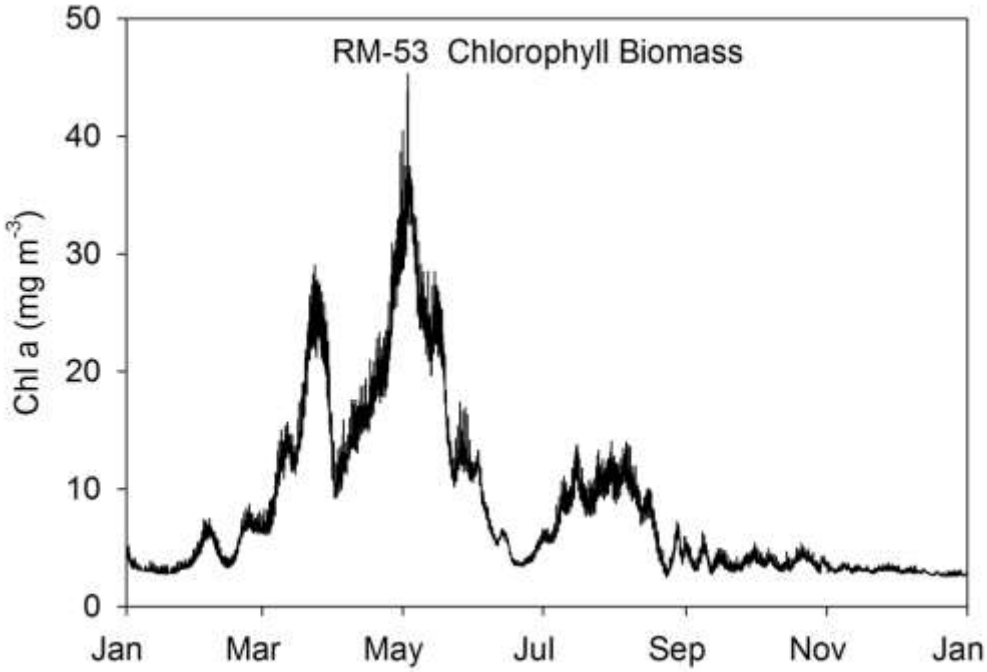
Needoba et al 2012

Net Ecosystem Metabolism of Columbia River



Evidence for grazing and food web implications





Lower River: Seasonal Impacts of Net Metabolism

DOC (μmol L^{-1})

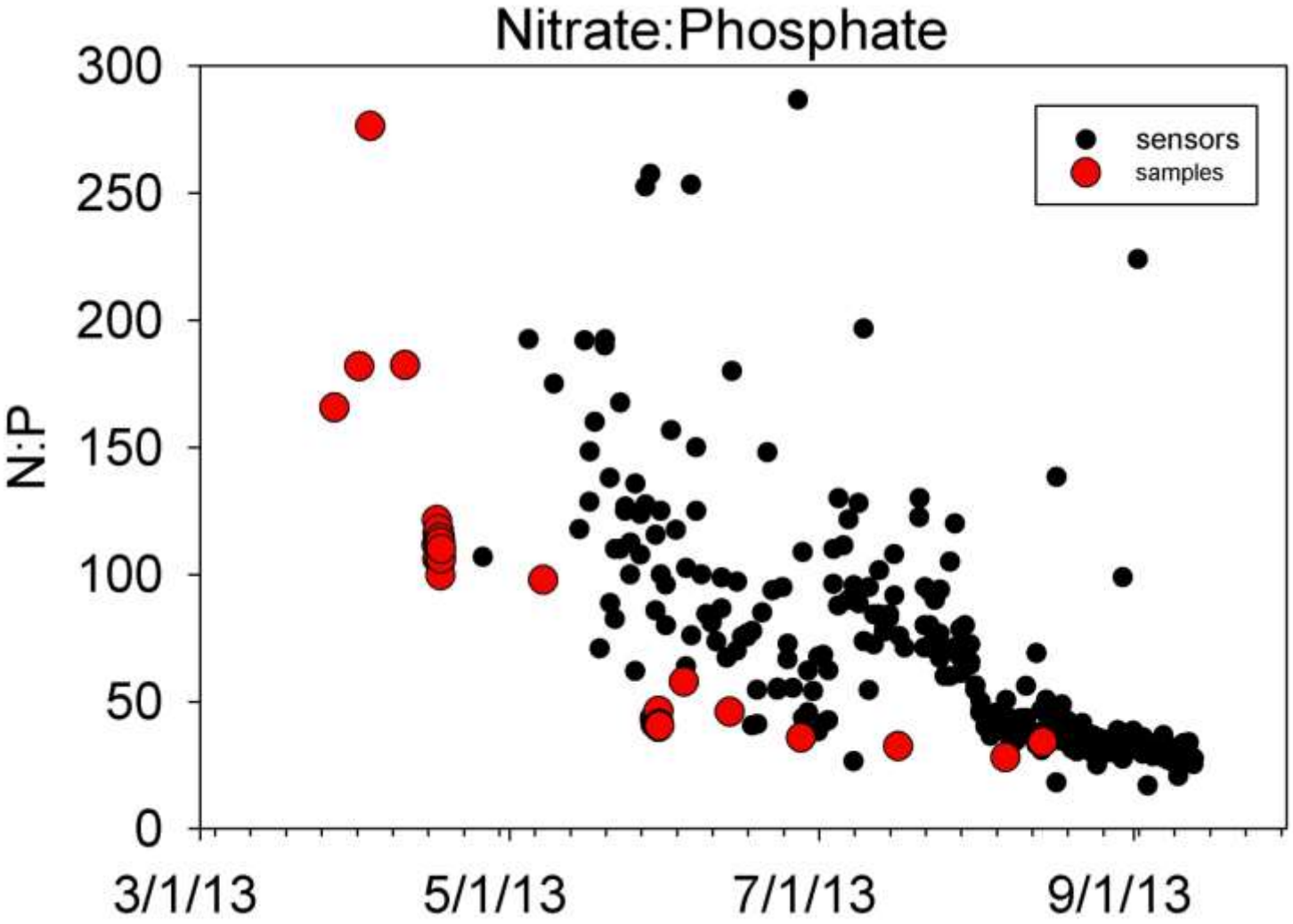
	Bonneville Dam	Salt water estuary	% Change
Winter	113	108	-4
Spring	129	133	3
Summer	189	191	1
Fall	138	133	-4

Nitrate (μmol L^{-1})

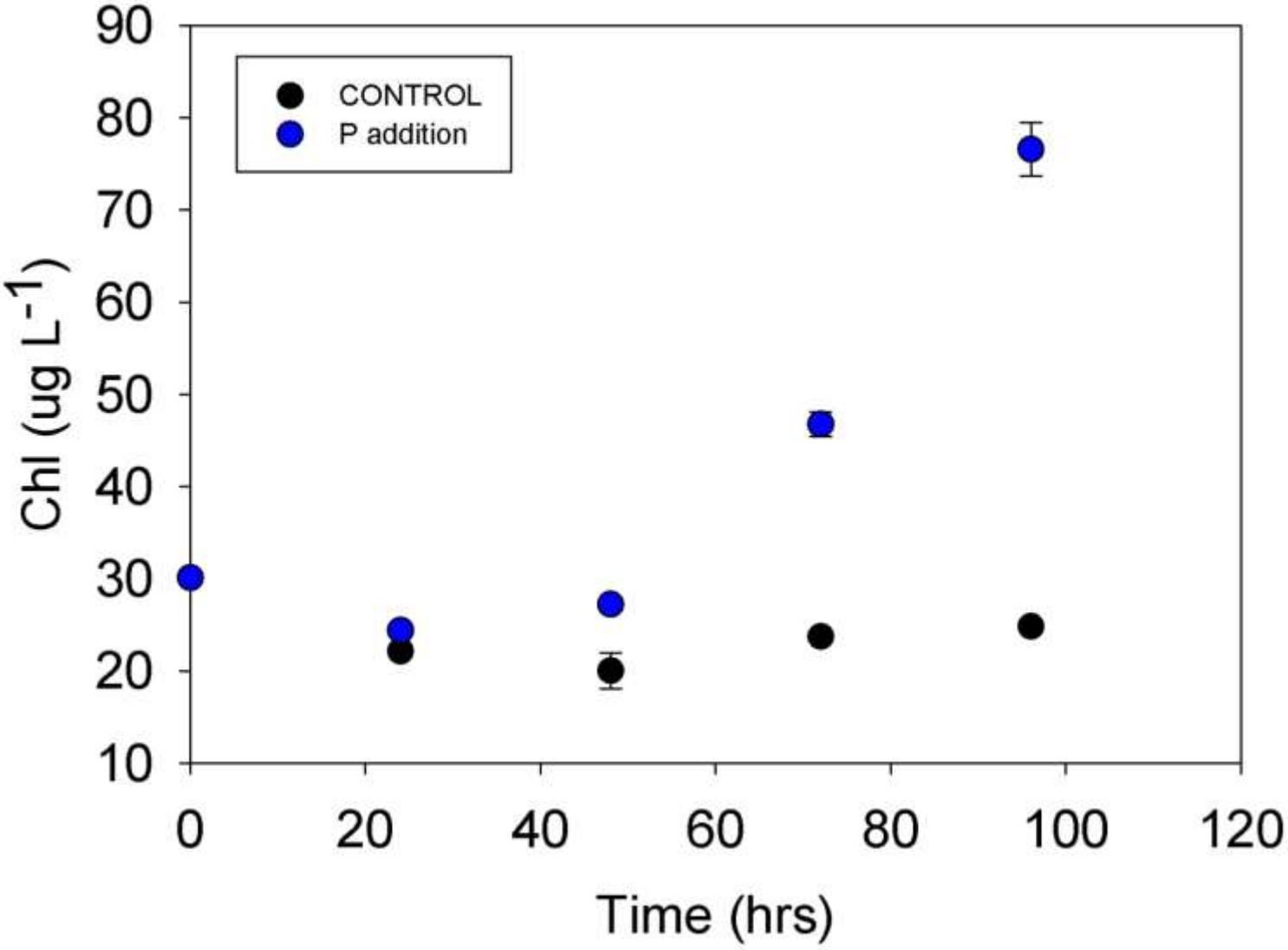
	Bonneville Dam	Salt water estuary	% Change
Winter	30	32	5
Spring	17	15	-11
Summer	7	6	-15
Fall	22	23	7

POC (μmol L^{-1})

	Bonneville Dam	Salt water estuary	% Change
Winter	20	15	-25
Spring	45	53	19
Summer	18	23	26
Fall	18	13	-29


Nitrate:Phosphate
N:P
300
250
200
150
100
50
0
3/1/13
5/1/13
7/1/13
9/1/13
sensors
samples

Phytoplankton are usually phosphorus limited



Summary

- What is the role of the Willamette River and other tributaries to Columbia River water quality?
  - Winter fluxes of nitrate, turbidity and dissolved organic carbon are dominated by episodic storm events that are not evident in the mainstem river above the Willamette confluence

Summary

- How does ‘greening’ alter river fluxes and organic carbon production?
  - Chlorophyll levels are high throughout the lower Columbia River and can reach bloom conditions during spring
  - Organic carbon is consumed during winter and produced during summer – with important implications for salt water estuary organic matter supply
  - Biomass vs oxygen production suggests that grazing introduces phytoplankton carbon into the Columbia River foodweb

Where to get the data?

- Email me: needobaj@ohsu.edu
- Raw data: www.columbia.loboviz.com
- CMOP website: www.stccmop.org

Modern Day Columbia River

Endangered Species

- Salmon

Hydropower management

- Columbia River Treaty

Land use, irrigation, agriculture

- Increased water demand and decreased water quality

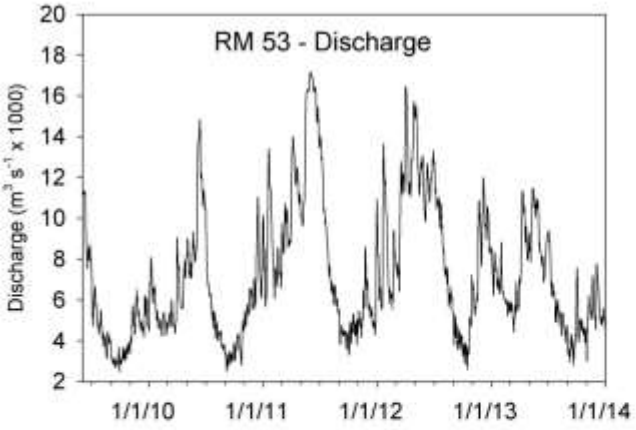
Emerging contaminants

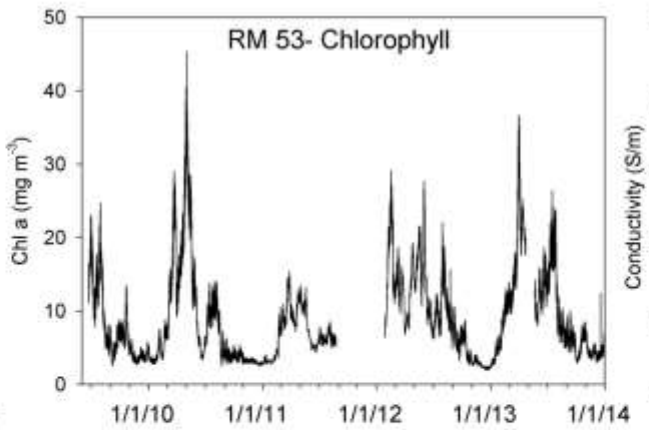
- Personal care products, flame retardants

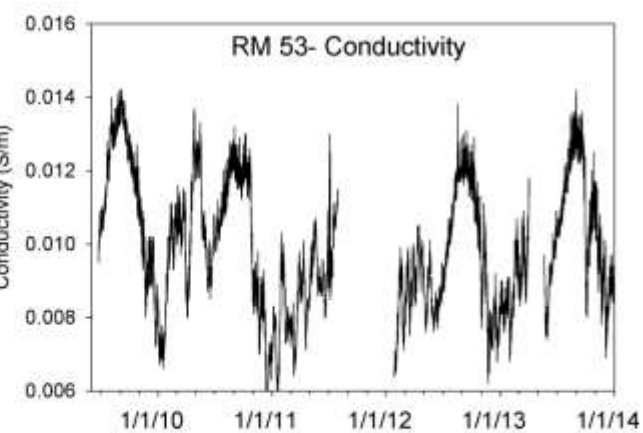
Changing ocean conditions

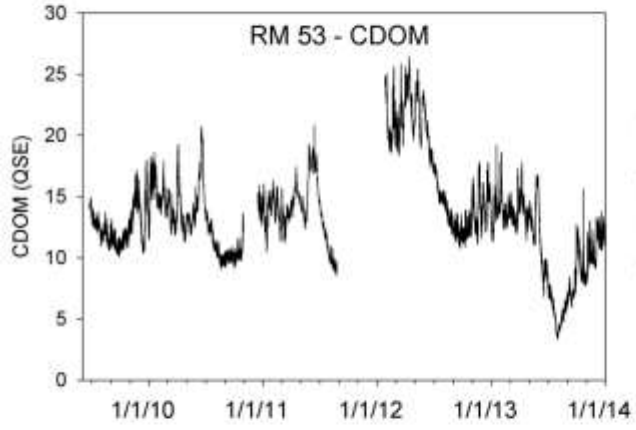
- Hypoxia and Ocean Acidification

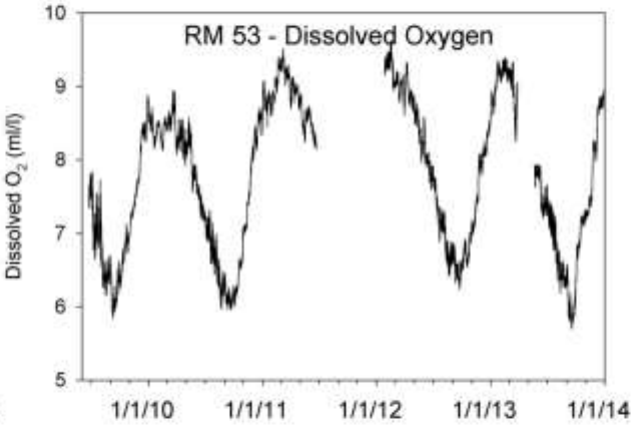
http://en.wikipedia.org/wiki/File:Columbiarivermap.png

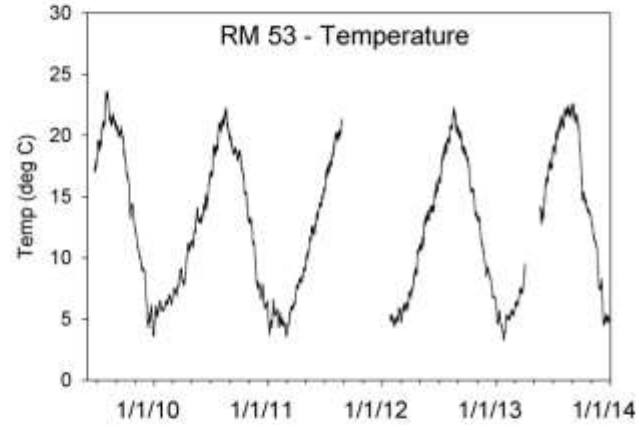

RM 53 - Discharge
Discharge ($m^3 s^{-1}$ x 1000)
20
18
16
14
12
10
8
6
4
2
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

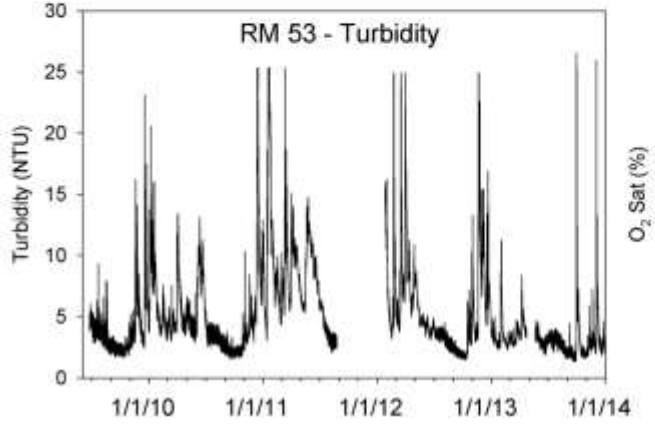

RM 53- Chlorophyll
Chl a (mg m^{-3})
50
40
30
20
10
0
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

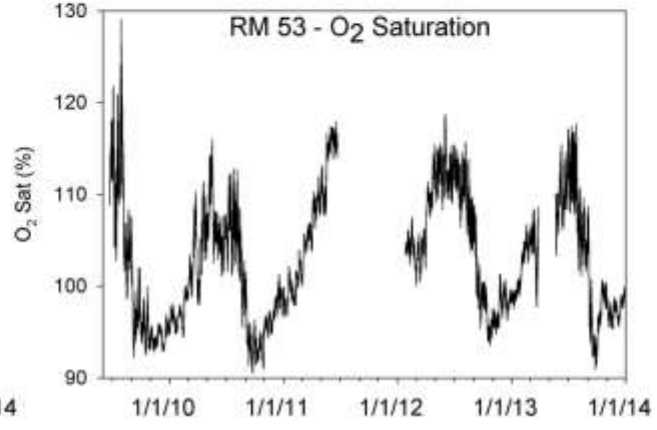

RM 53- Conductivity
Conductivity (S/m)
0.016
0.014
0.012
0.010
0.008
0.006
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

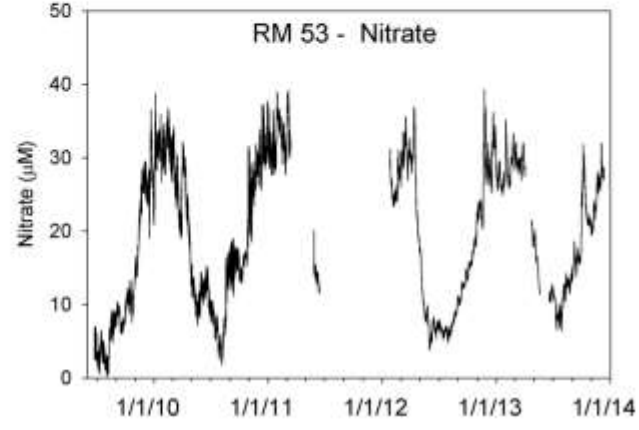

RM 53 - CDOM
CDOM (QSE)
30
25
20
15
10
5
0
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

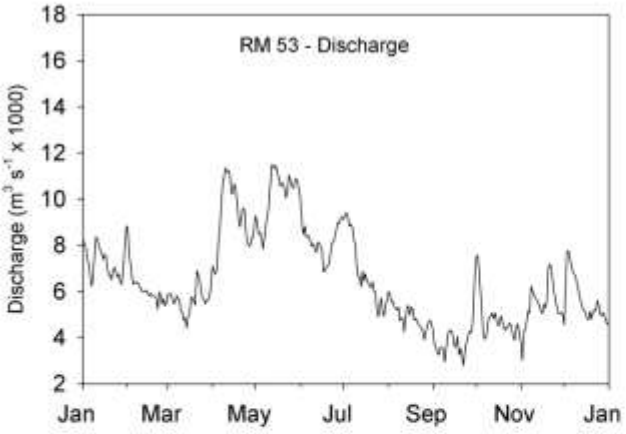

RM 53 - Dissolved Oxygen
Dissolved O_2 (ml/l)
10
9
8
7
6
5
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

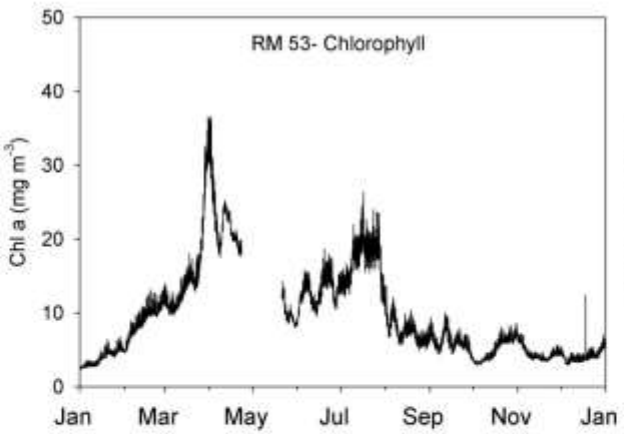

RM 53 - Temperature
Temp (deg C)
30
25
20
15
10
5
0
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

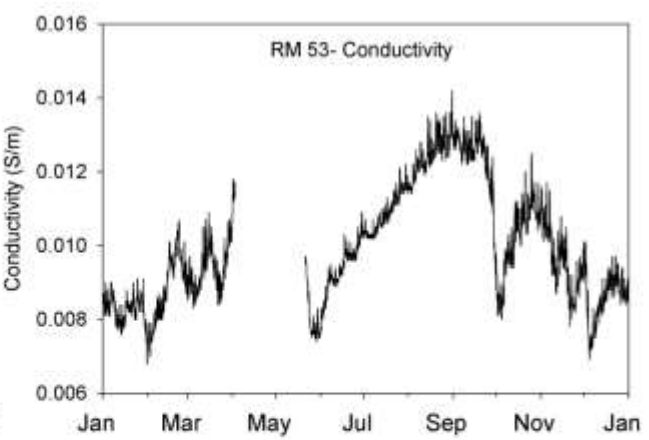

RM 53 - Turbidity
Turbidity (NTU)
30
25
20
15
10
5
0
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

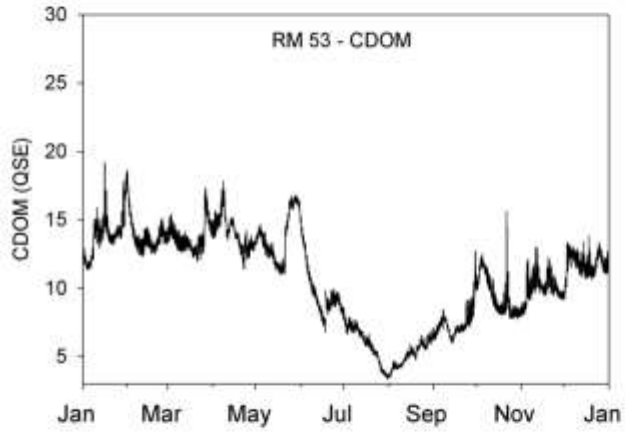

RM 53 - O_2 Saturation
O_2 Sat (%)
130
120
110
100
90
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

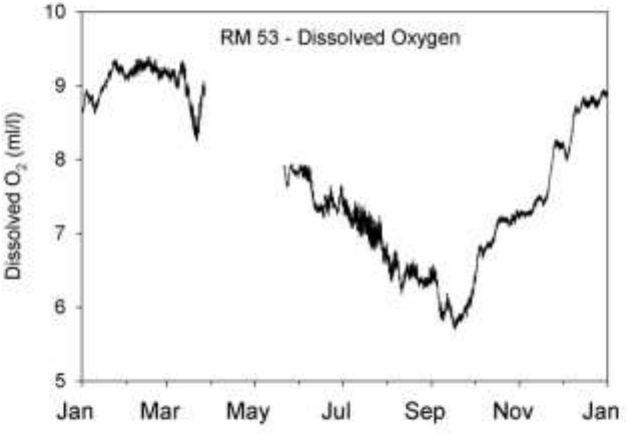

RM 53 - Nitrate
Nitrate (µM)
50
40
30
20
10
0
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14

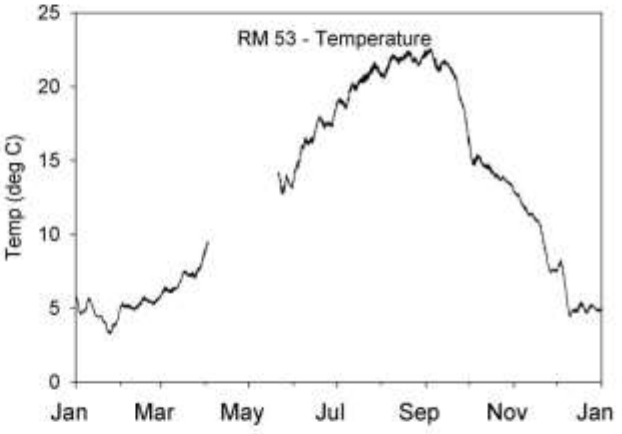

RM 53 - Discharge
Discharge (m3 s-1 x 1000)
18
16
14
12
10
8
6
4
2
Jan
Mar
May
Jul
Sep
Nov
Jan

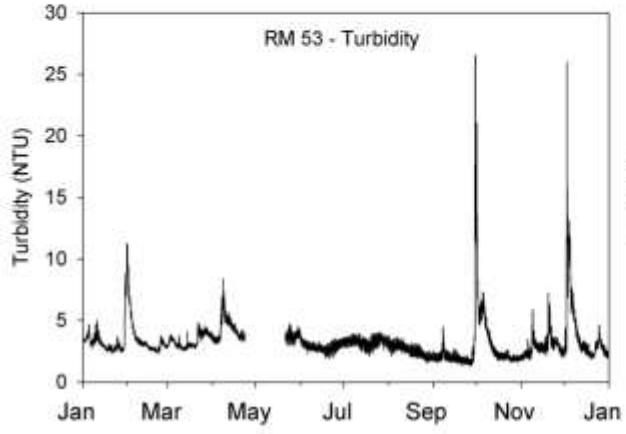

RM 53- Chlorophyll
Chl a (mg m-3)
50
40
30
20
10
0
Jan
Mar
May
Jul
Sep
Nov
Jan

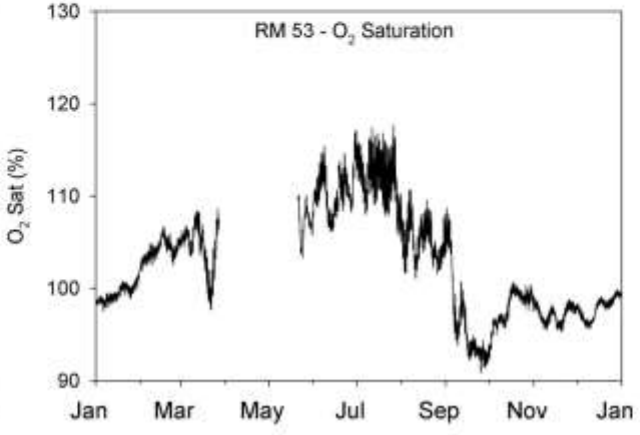

RM 53- Conductivity
Conductivity (S/m)
0.016
0.014
0.012
0.010
0.008
0.006
Jan
Mar
May
Jul
Sep
Nov
Jan

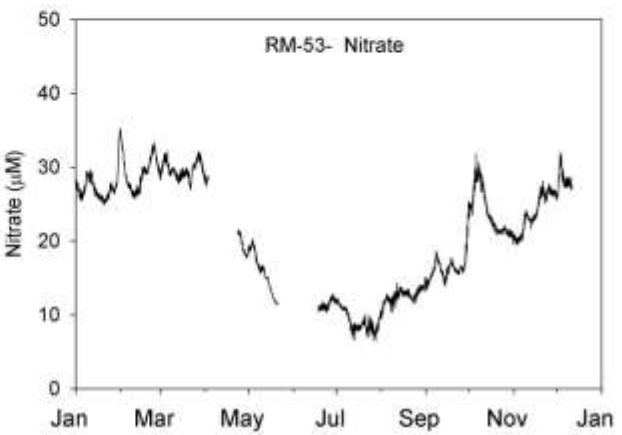

RM 53 - CDOM
CDOM (QSE)
30
25
20
15
10
5
Jan
Mar
May
Jul
Sep
Nov
Jan

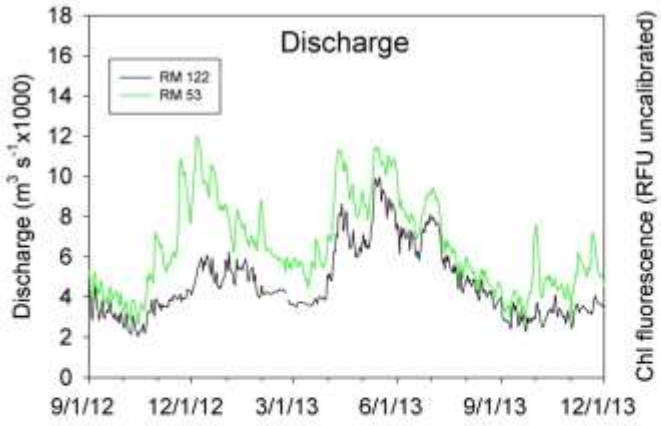

RM 53 - Dissolved Oxygen
Dissolved O2 (ml/l)
10
9
8
7
6
5
Jan
Mar
May
Jul
Sep
Nov
Jan

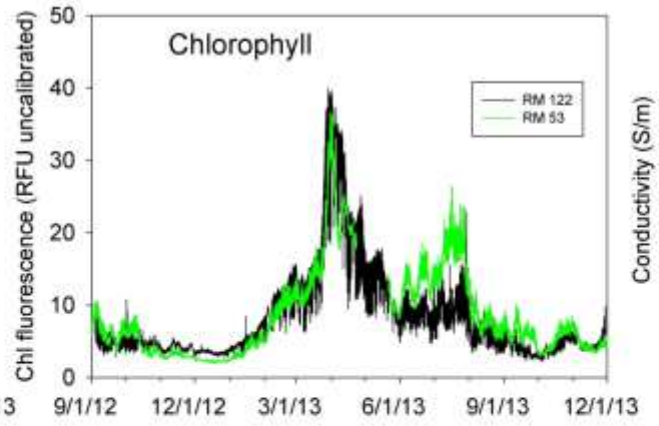

RM 53 - Temperature
Temp (deg C)
25
20
15
10
5
0
Jan
Mar
May
Jul
Sep
Nov
Jan

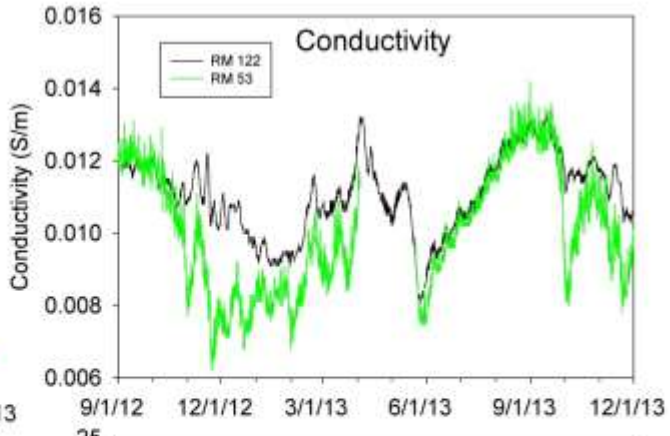

RM 53 - Turbidity
Turbidity (NTU)
30
25
20
15
10
5
0
Jan
Mar
May
Jul
Sep
Nov
Jan

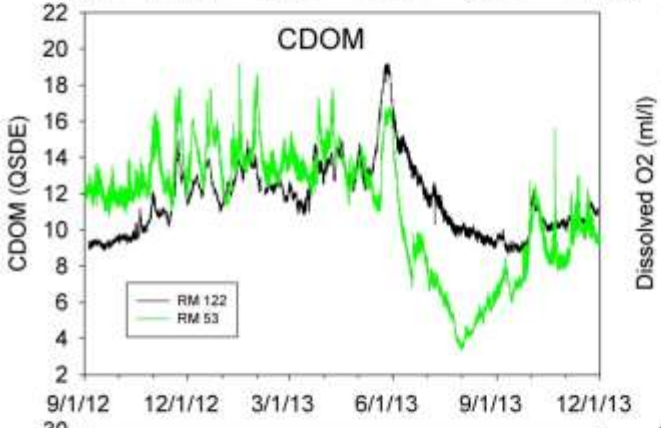

RM 53 - O2 Saturation
O2 Sat (%)
130
120
110
100
90
Jan
Mar
May
Jul
Sep
Nov
Jan


RM-53- Nitrate
Nitrate (µM)
50
40
30
20
10
0
Jan
Mar
May
Jul
Sep
Nov
Jan

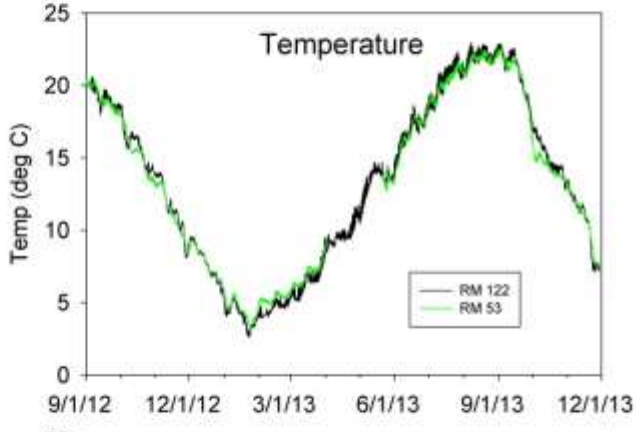

Discharge
Discharge (m3 s-1x1000)
RM 122
RM 53
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

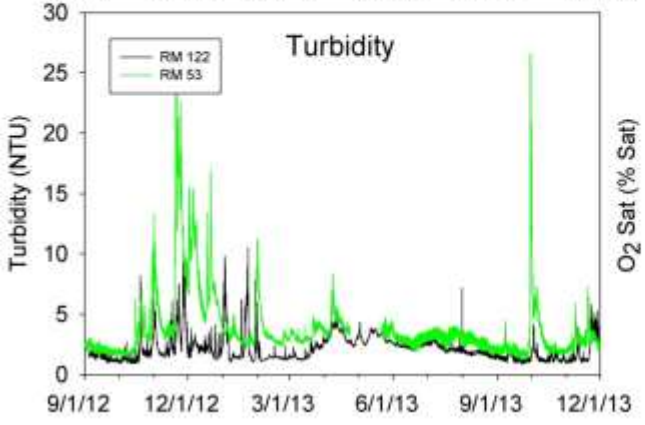

Chlorophyll
Chl fluorescence (RFU uncalibrated)
RM 122
RM 53
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

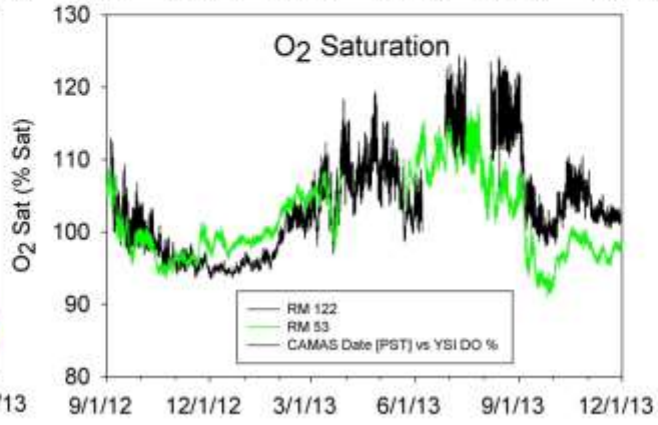

Conductivity
Conductivity (S/m)
RM 122
RM 53
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

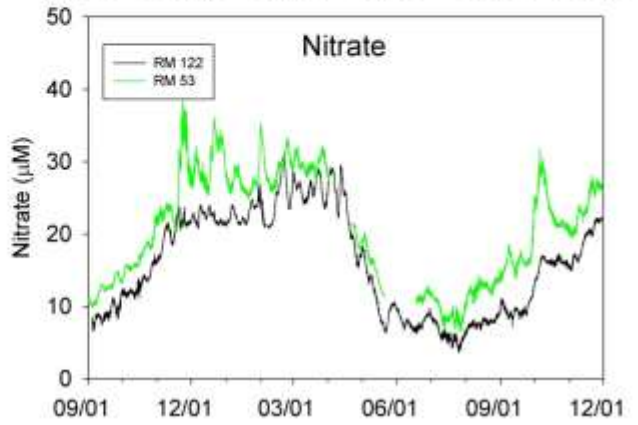

CDOM
CDOM (QSDE)
RM 122
RM 53
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

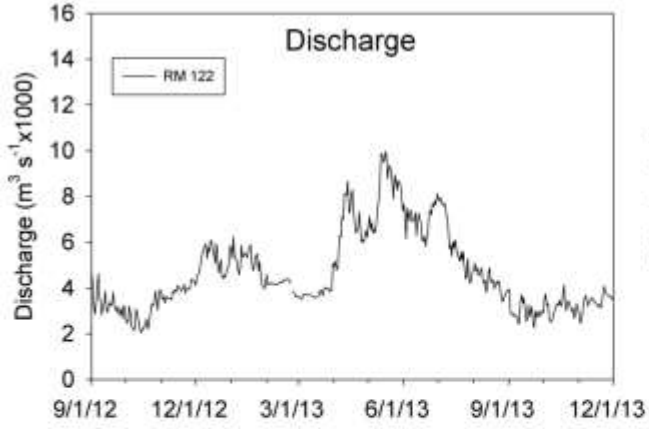

Dissolved Oxygen
Dissolved O2 (ml/l)
RM 122
RM 53
CAMAS Date [PST] vs YSI DO
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

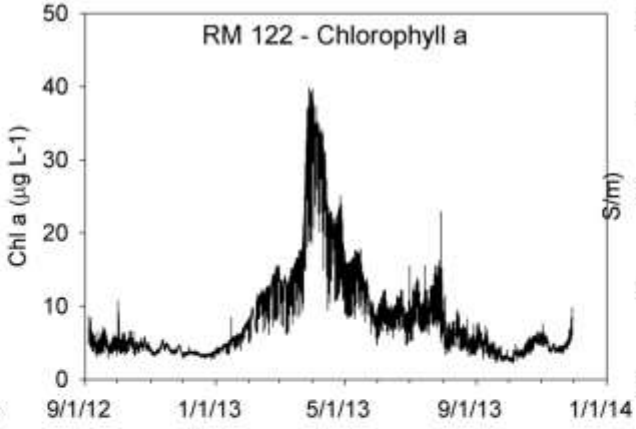

Temperature
Temp (deg C)
RM 122
RM 53
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

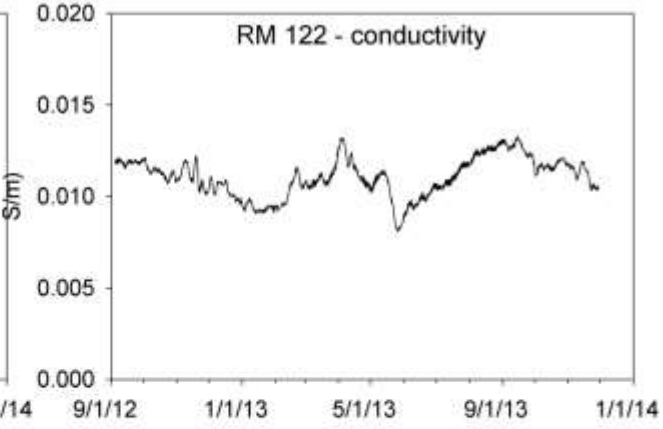

Turbidity
Turbidity (NTU)
RM 122
RM 53
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

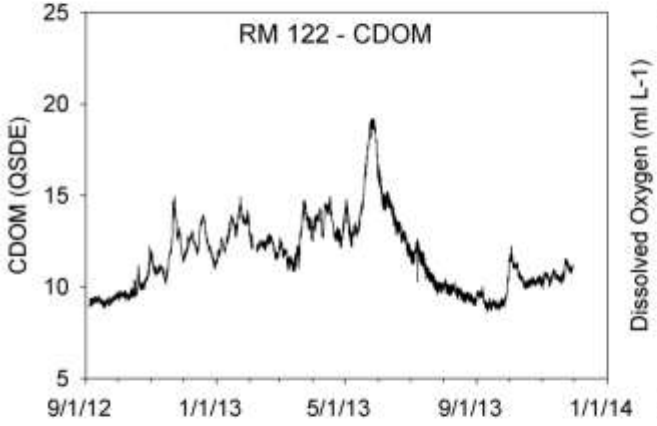

O2 Saturation
O2 Sat (% Sat)
RM 122
RM 53
CAMAS Date [PST] vs YSI DO %
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

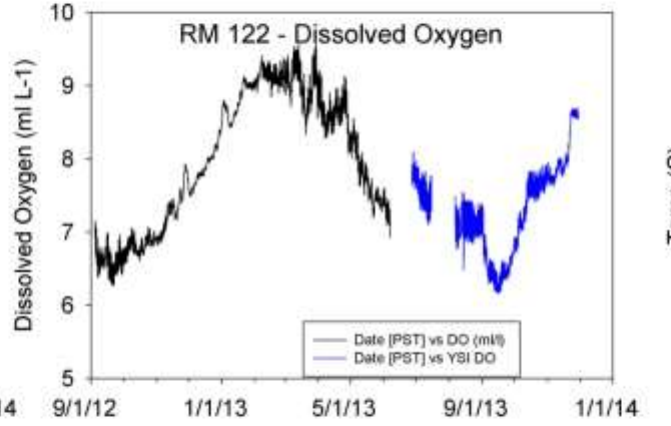

Nitrate
Nitrate (µM)
RM 122
RM 53
09/01
12/01
03/01
06/01
09/01
12/01

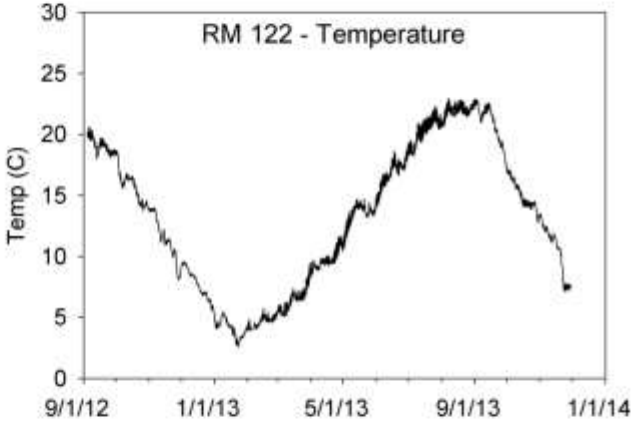

Discharge
RM 122
Discharge (m3 s-1x1000)
16
14
12
10
8
6
4
2
0
9/1/12
12/1/12
3/1/13
6/1/13
9/1/13
12/1/13

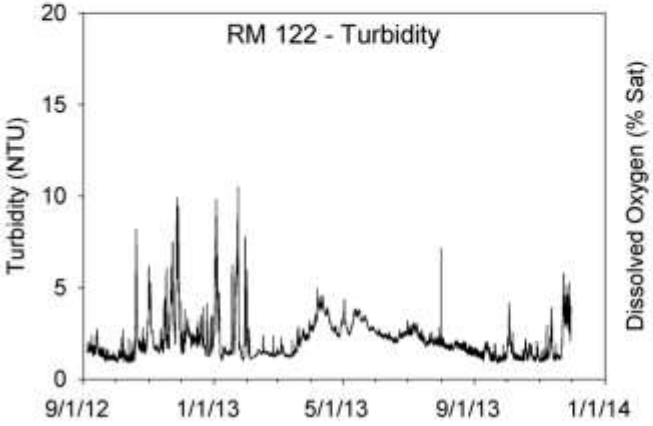

RM 122 - Chlorophyll a
Chl a (µg L-1)
50
40
30
20
10
0
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14

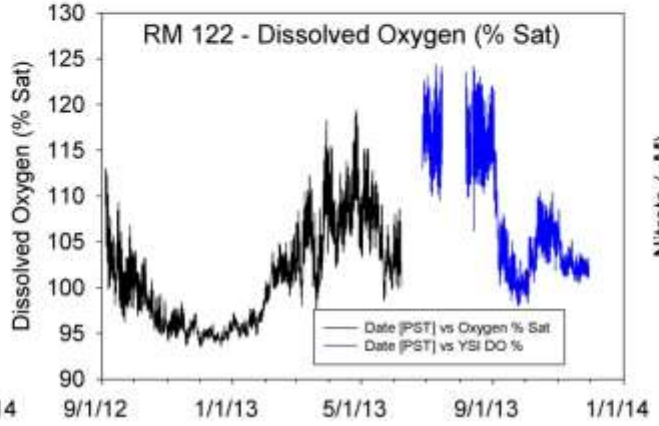

RM 122 - conductivity
S/m)
0.020
0.015
0.010
0.005
0.000
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14

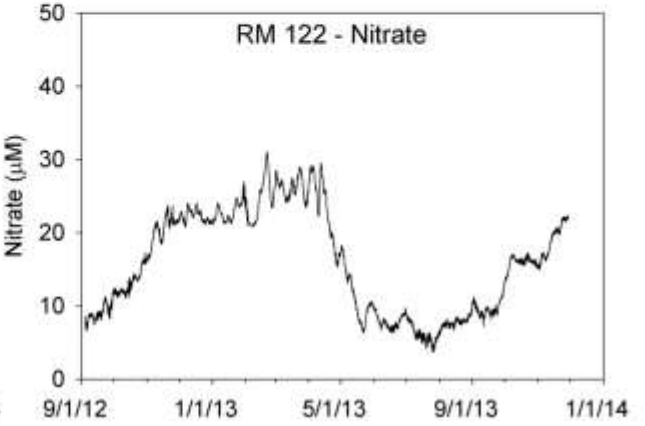

RM 122 - CDOM
CDOM (QSDE)
25
20
15
10
5
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14


RM 122 - Dissolved Oxygen
Dissolved Oxygen (ml L-1)
10
9
8
7
6
5
Date [PST] vs DO (ml/l)
Date [PST] vs YSI DO
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14

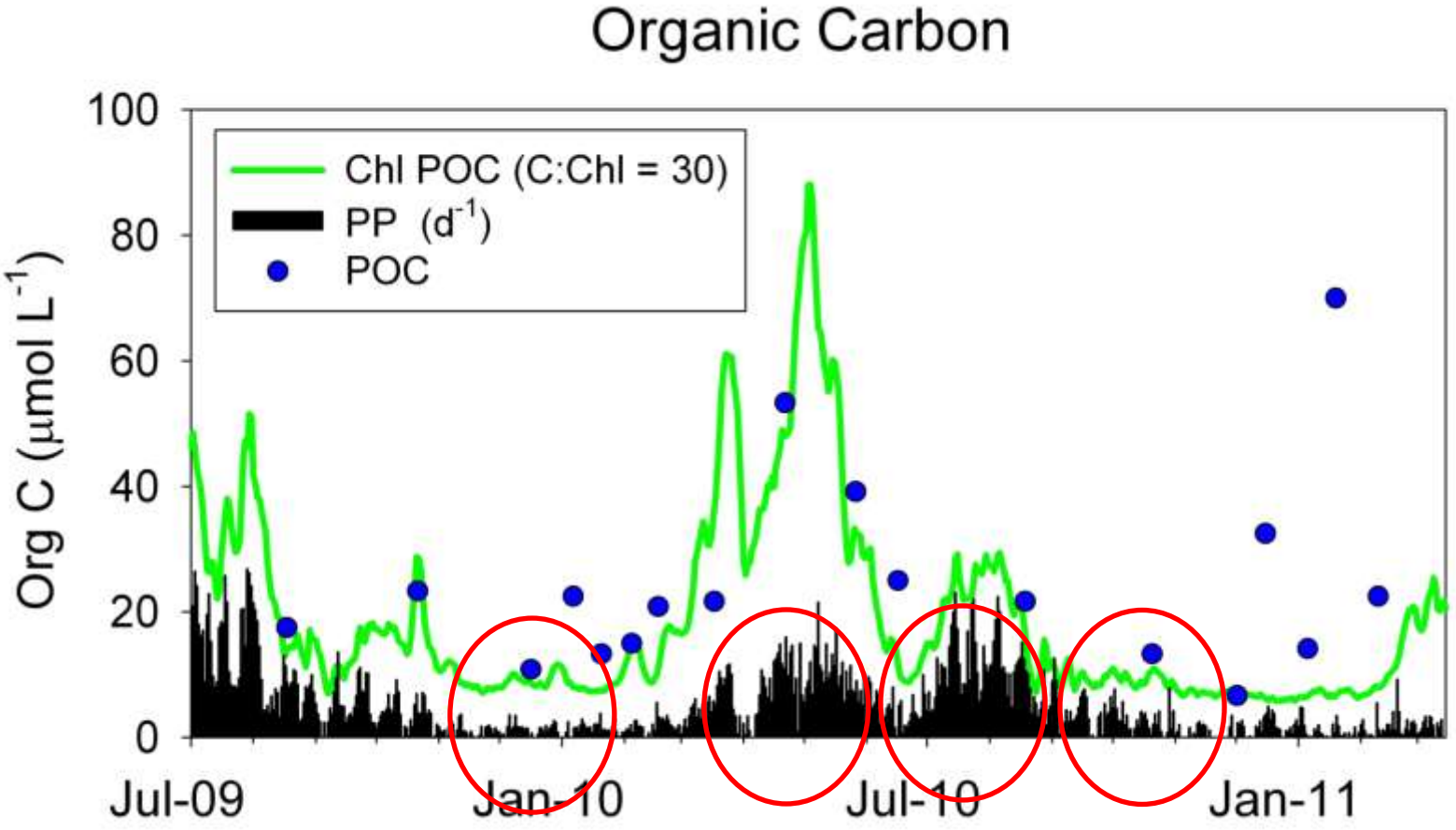

RM 122 - Temperature
Temp (C)
30
25
20
15
10
5
0
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14


RM 122 - Turbidity
Turbidity (NTU)
20
15
10
5
0
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14


RM 122 - Dissolved Oxygen (% Sat)
Dissolved Oxygen (% Sat)
130
125
120
115
110
105
100
95
90
Date [PST] vs Oxygen % Sat
Date [PST] vs YSI DO %
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14


RM 122 - Nitrate
Nitrate (µM)
50
40
30
20
10
0
9/1/12
1/1/13
5/1/13
9/1/13
1/1/14

Organic Carbon: Comparison of estimates



Quality control and Maintenance Trips

RM-53	RM-122
9/5/2012	9/5/2012
12/4/2012	12/10/2012
1/8/2013	1/16/2013
2/12/2013	2/7/2013
3/26/2013	3/27/2013
4/23/2013	4/17/2013
5/21/2013	5/29/2013
6/18/2013	6/27/2013
8/20/2013	7/15/2013
12/4/2013	8/6/2013
	8/14/2013
	9/3/2013
	12/15/2013