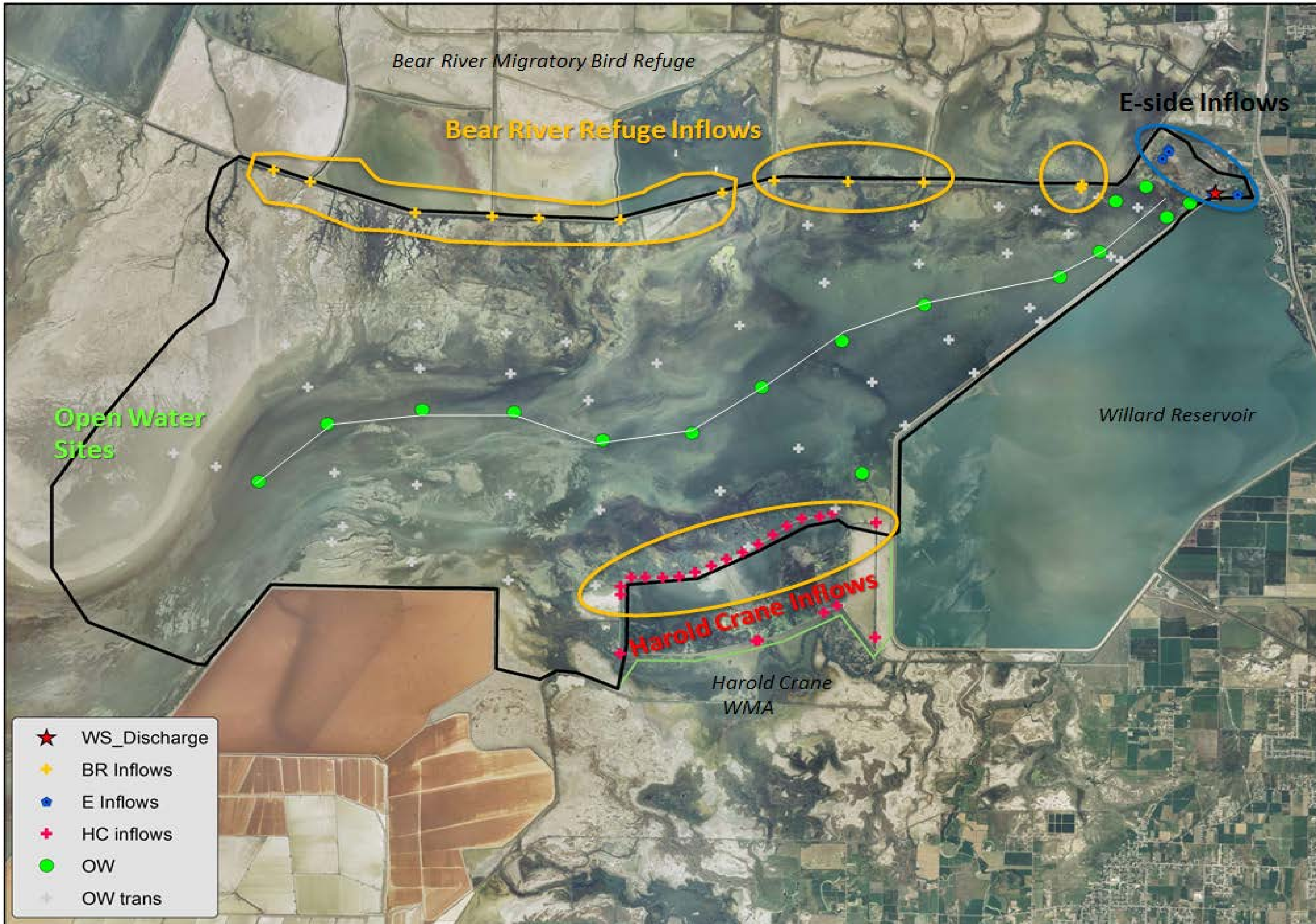
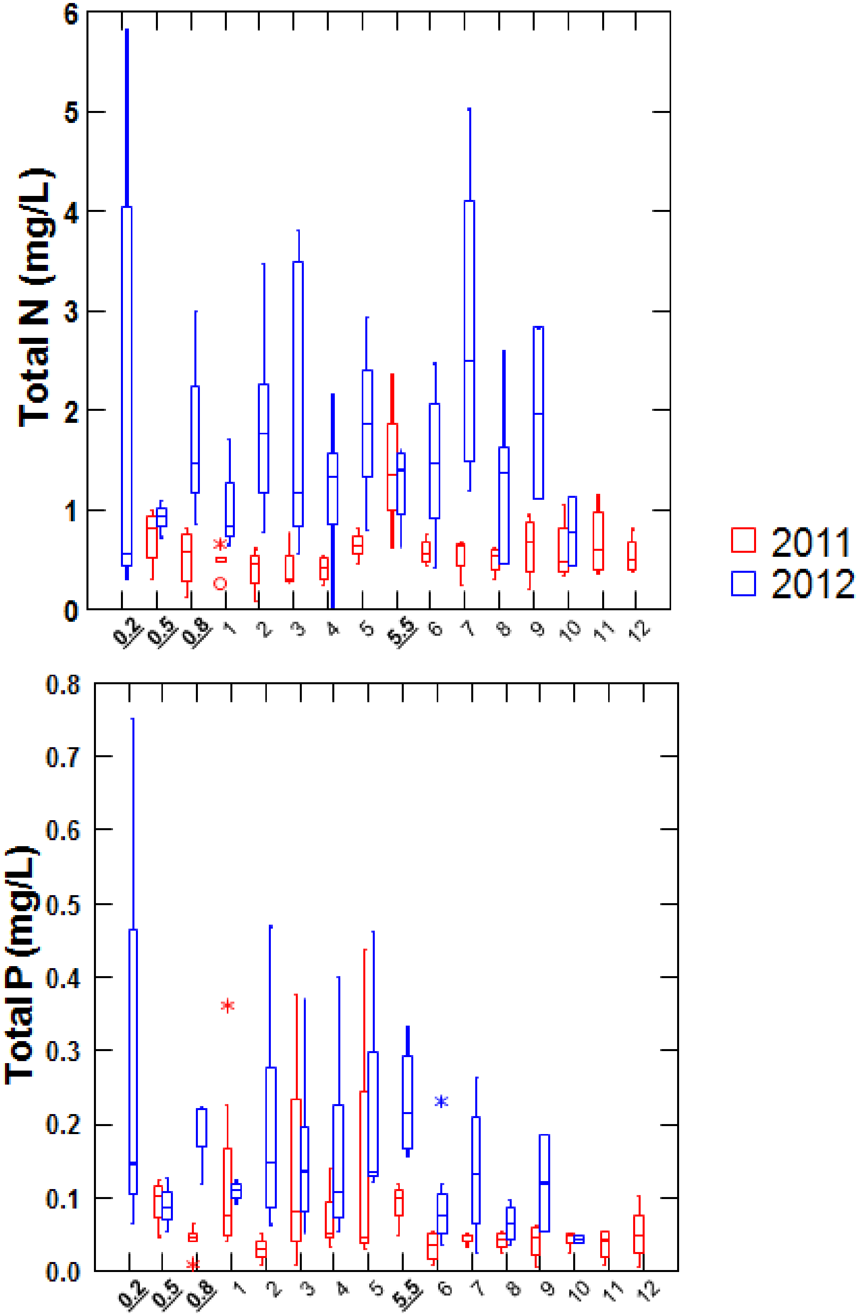
Willard Spur: Nutrients and Ecosystem Processes

Biogeochemical Patterns and Processes



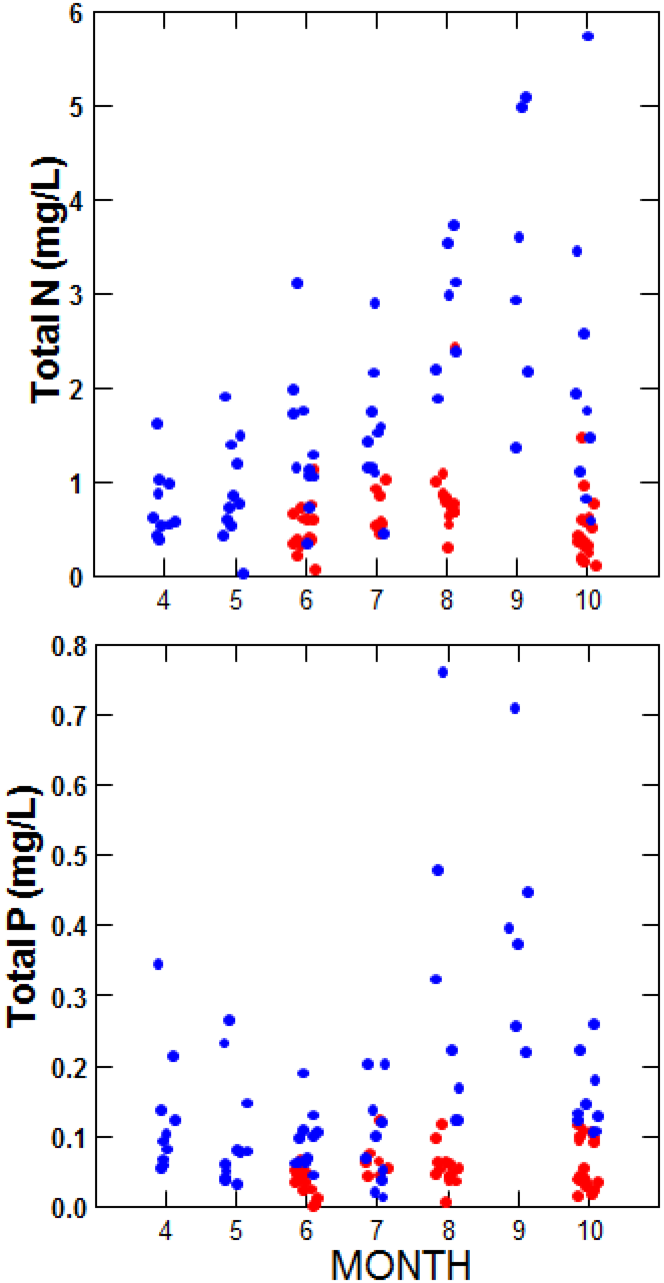
Water Column Nutrient Pools



Total Nutrient Pools

- Total N (TKN + NO3) concentrations greater in 2012 vs. 2011 -- Across Open Water sites
- Total P concentrations *occasionally* greater in 2012 vs 2011 -- Particularly sites near Inflows
- **Western-most sites had lowest TN and TP concentrations**

Water Column Nutrient Pools



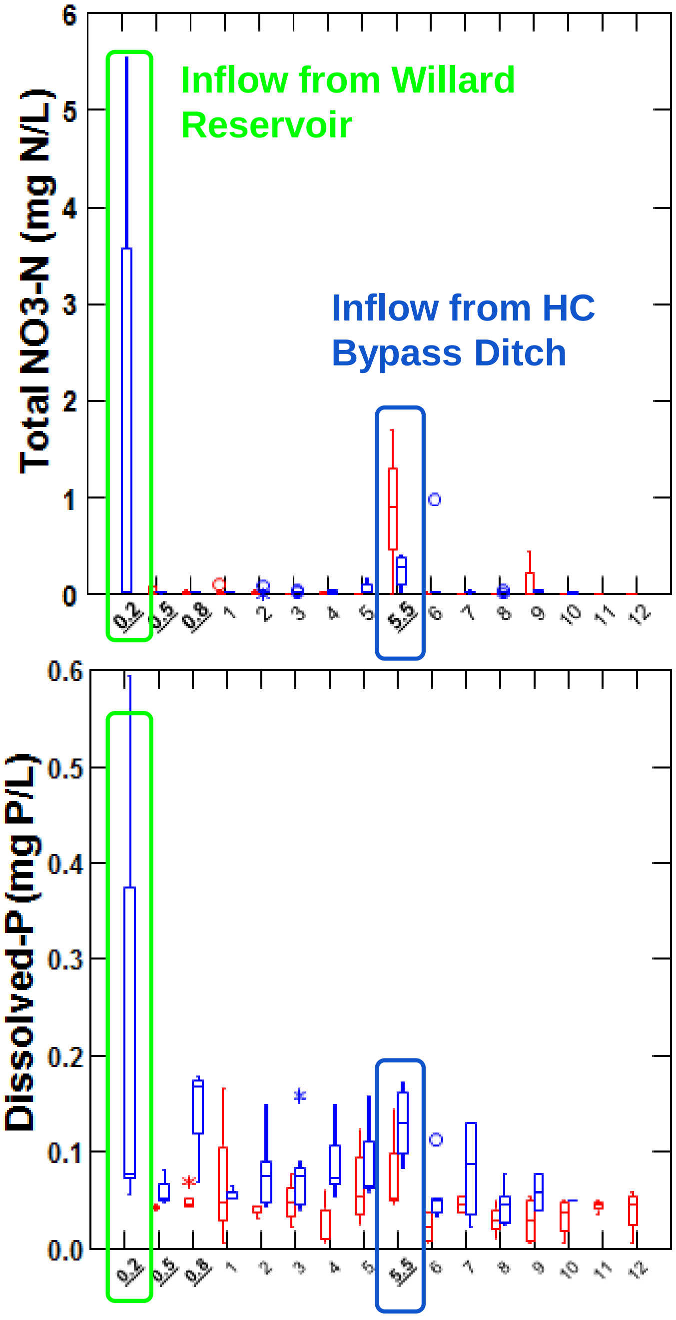
TN

- Increased over time in 2012, not 2011
  - o Flushing?
- Highest TN concentrations in late summer
- 90%ile:
  - o 2011 = 0.88 mg N/L
  - o 2012 = 3.18 mg N/L

TP

- Increased over time in 2012, not 2011
- 90%ile:
  - o 2011 = 0.098 mg P/L
  - o 2012 = 0.333 mg P/L

3. Water Column Dissolved Nutrient Pools



- Inorganic N and P pools are generally low
  - o Except for sites near inflows

- Given the seasonal increases in TN and TP, this suggests that:
  - o Inorganic nutrient cycling is tight (ie that available nutrients are rapidly taken up)
  - o ***Nutrient fluxes from inflows are rapidly assimilated within the Open Water sites***

Pelagic Nutrient Limitation

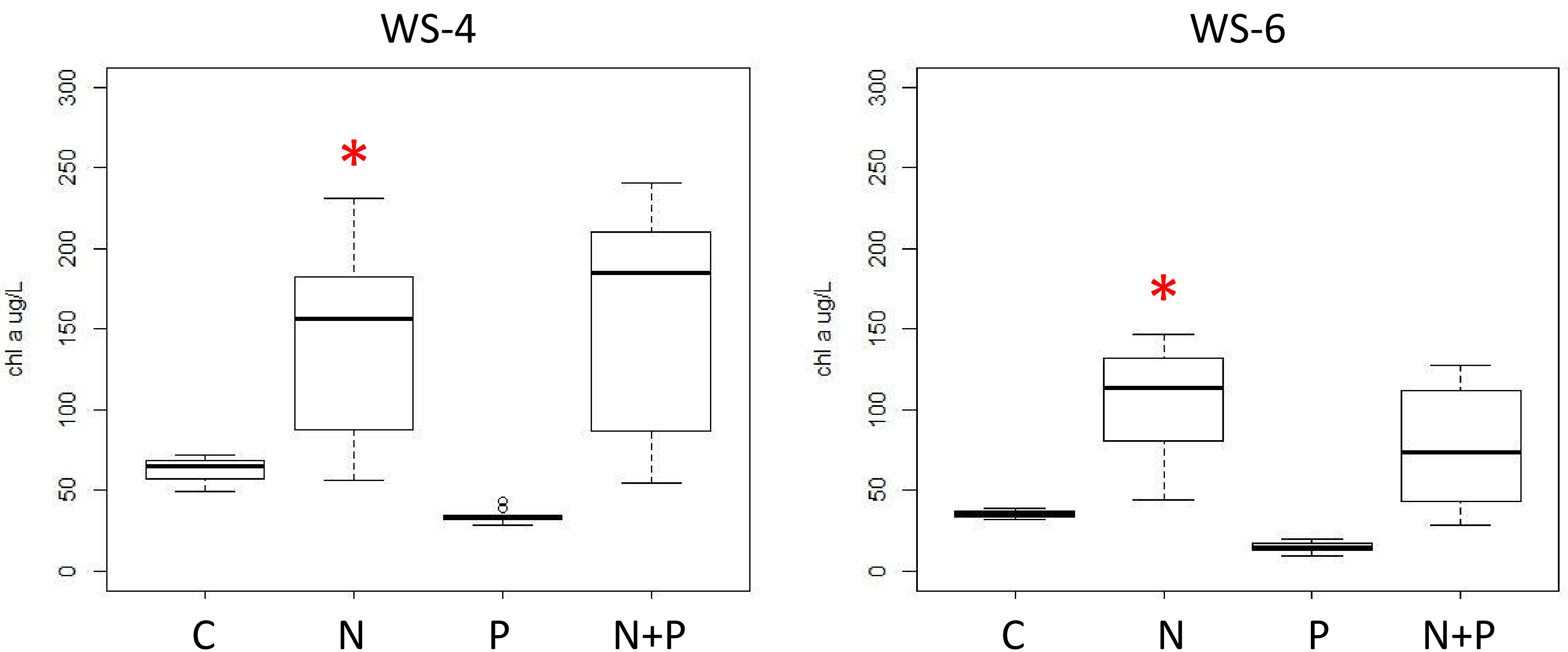
Treatments:

Control

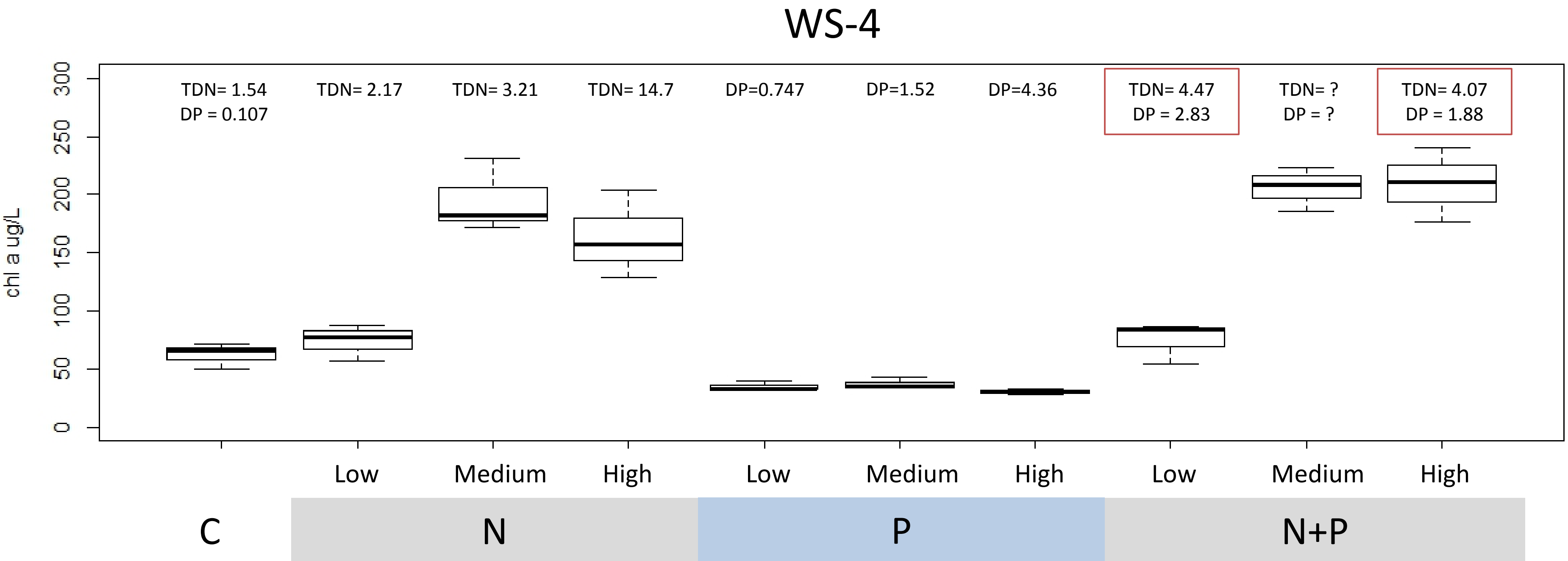
Nitrogen → Low / Medium / High

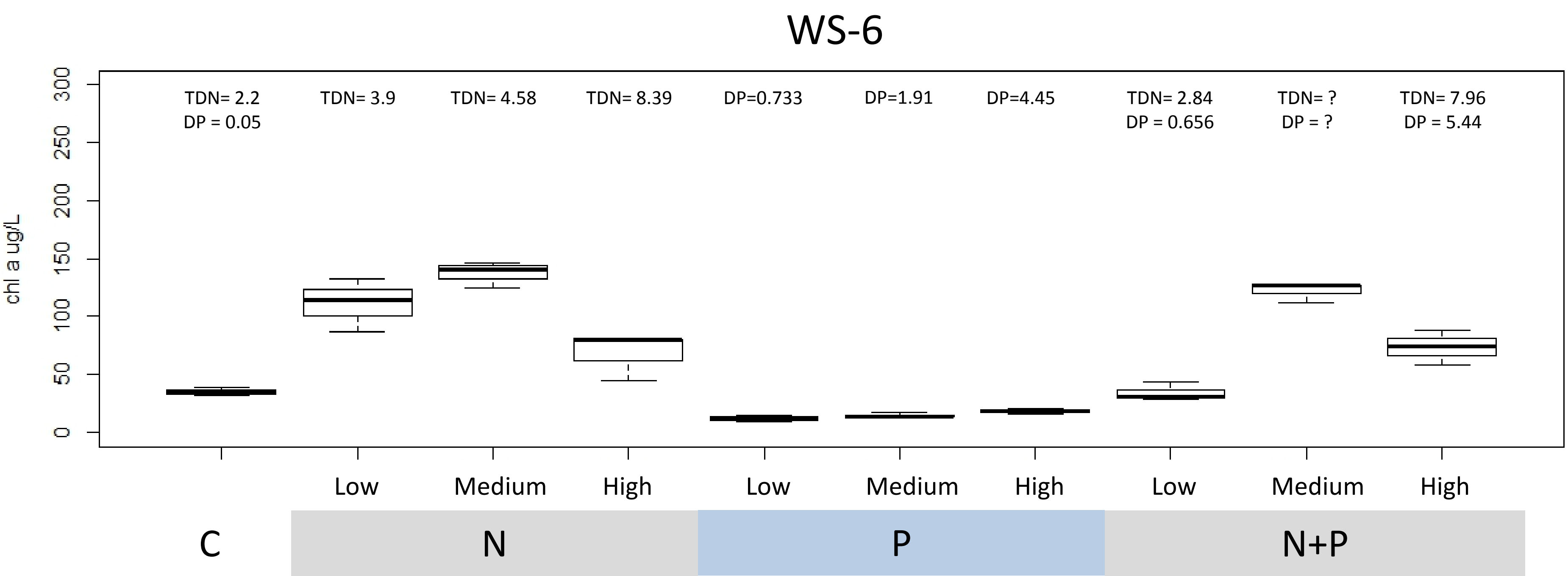
Phosphorus → Low / Medium / High

N + P → Low / Medium / High


WS-4
WS-6
chl a ug/L
0
50
100
150
200
250
300
C
N
P
N+P
*

Chl a n=3, for all plots





Metabolism: The Carbon Story

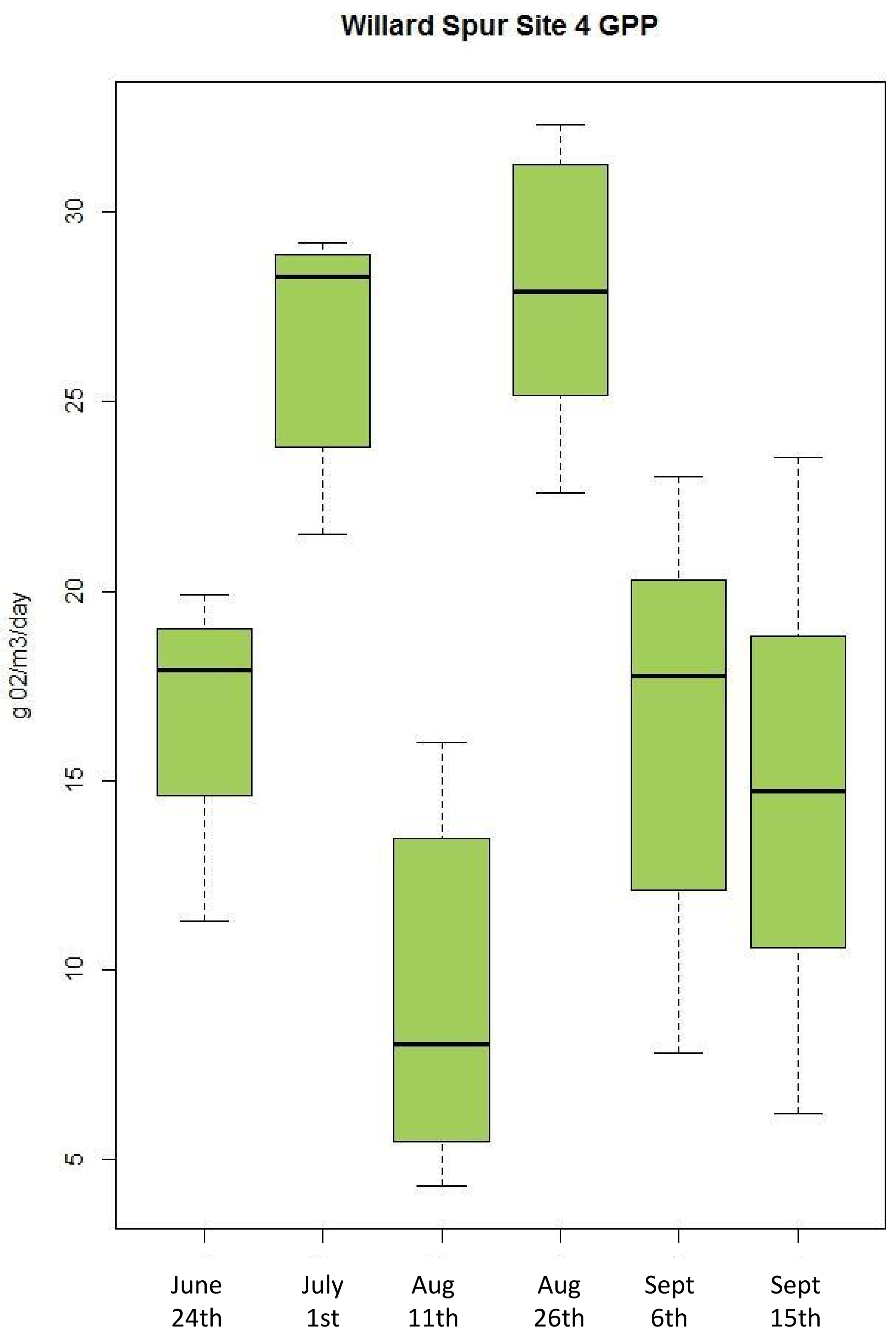
Scale experimental processing rates to the Willard Spur ecosystem

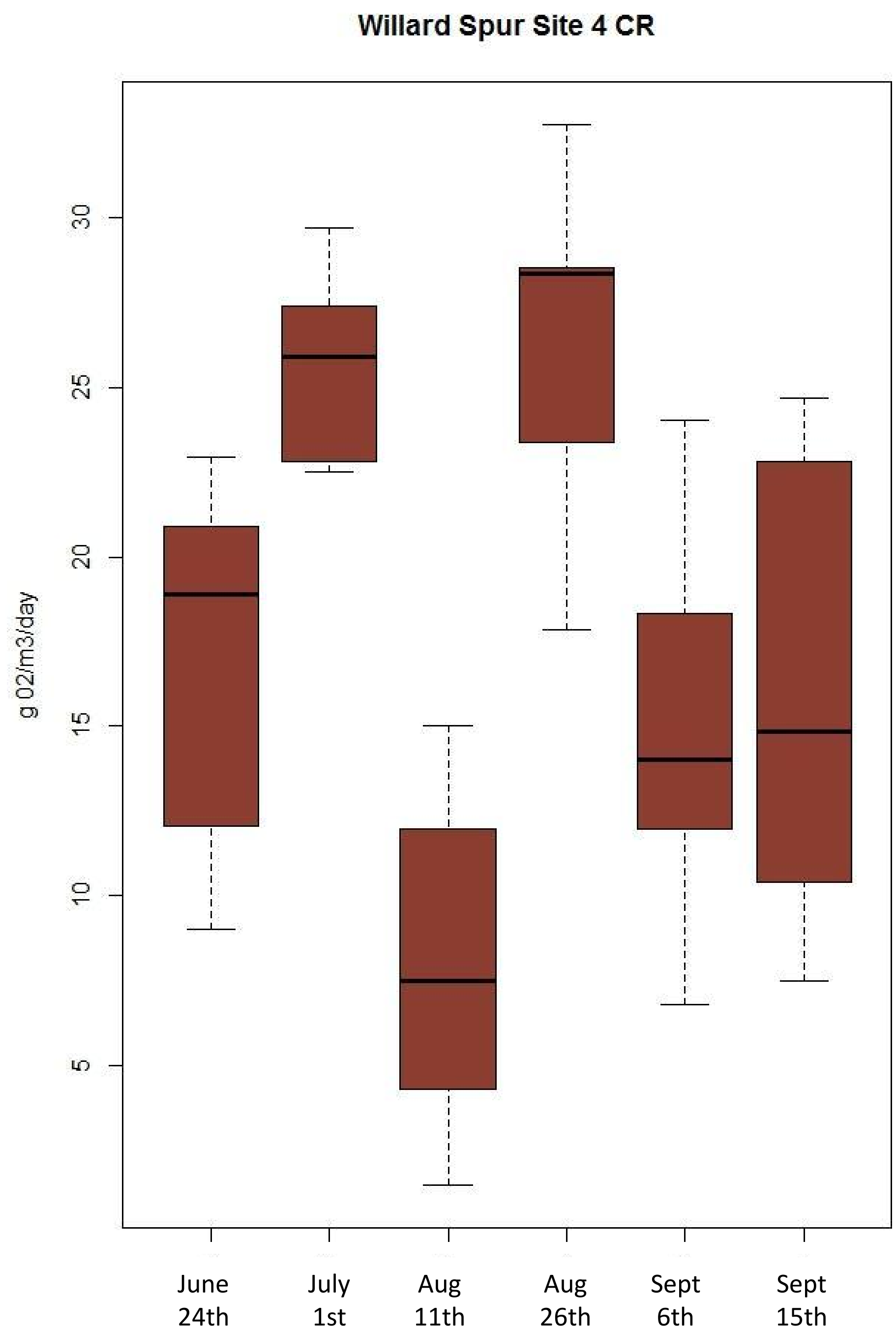
Primary Production

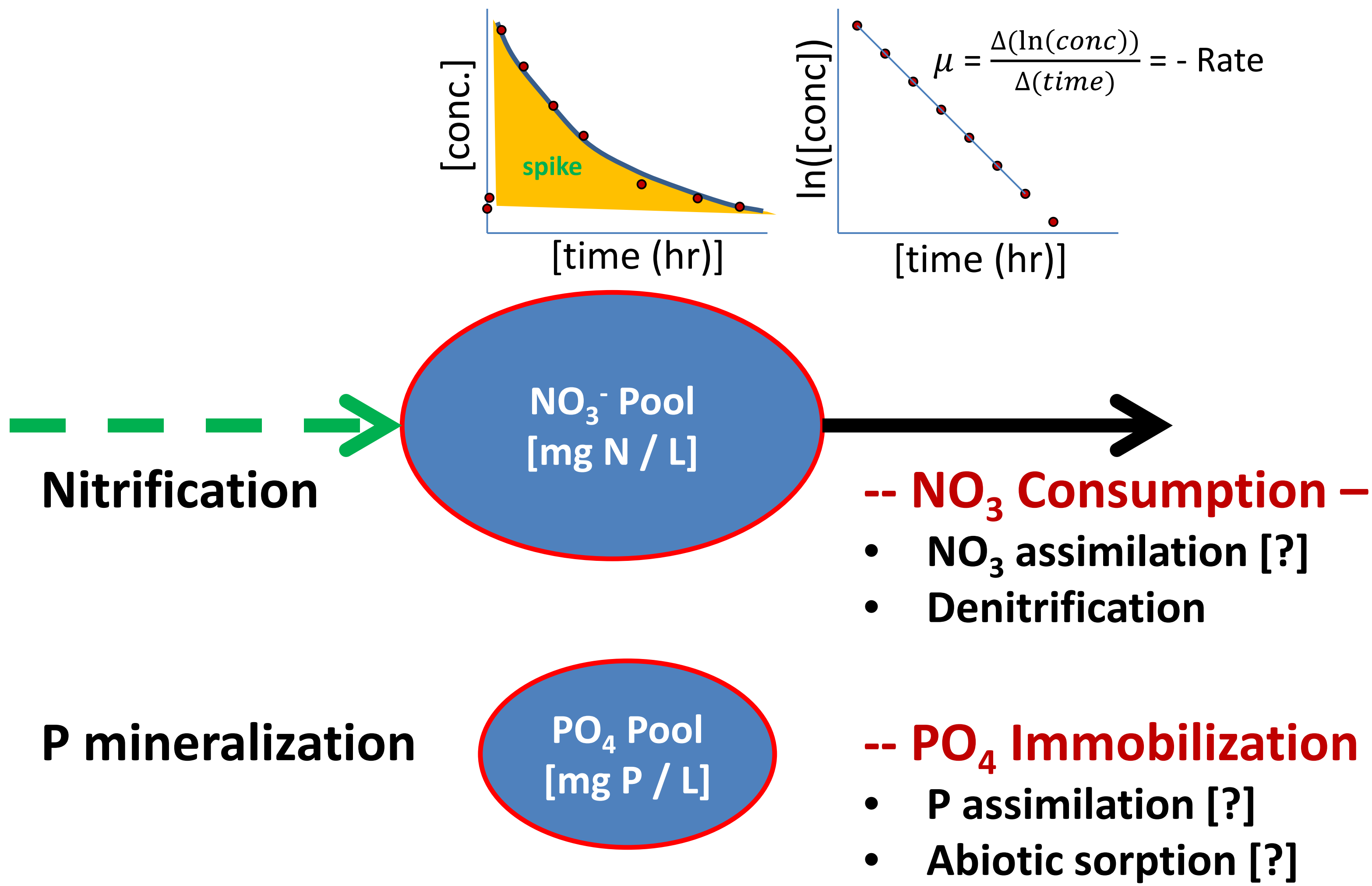
- Links rates of C production to measures of O_2 production
- Daytime O_2 = GPP + reaeration
- Potential to provide linkages between discrete measurements
- Rates dictated by daytime conditions (production requires photosynthesis)
- May be particularly important in dynamic ecosystems

Respiration

- Oxygen consumption by all organisms during daytime and nightime
- Rates obtained from differences between daytime and nighttime (no autotrophic O_2 production) DO concentration


Willard Spur Site 4 GPP
g 02/m3/day
30
25
20
15
10
5
June 24th
July 1st
Aug 11th
Aug 26th
Sept 6th
Sept 15th

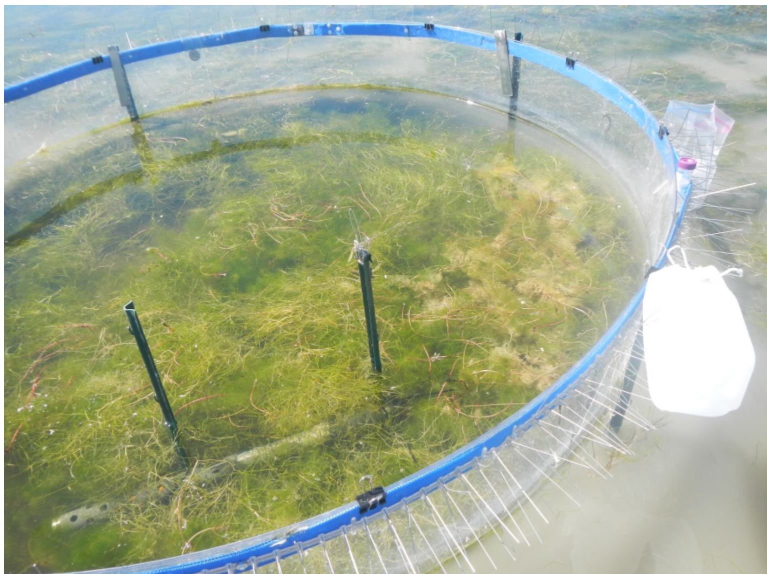

Willard Spur Site 4 CR
g 02/m3/day
30
25
20
15
10
5
June 24th
July 1st
Aug 11th
Aug 26th
Sept 6th
Sept 15th

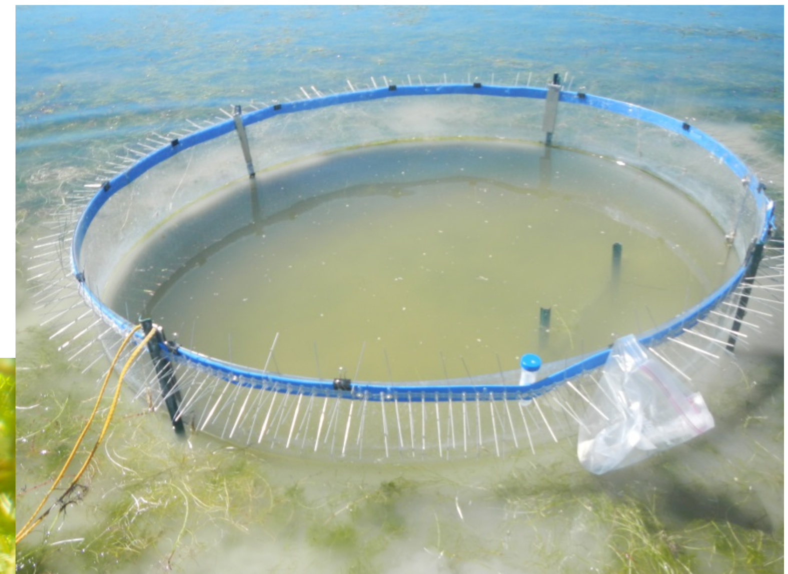


These type of measurements can give us a sense of the magnitude of the kinetics, but *they do not tell us about the fate* of the “removed” or “assimilated” nutrient

Trip #1 – June 2013

- Installed six (6) 2-m diameter mesocosms 5 days prior to experiment
- Removed SAV from three mesocosms
- Added 0.08 mg NO3-N / L and 0.08 mg PO4-P / L to each mesocosm
- Collected 50 mL of filtered water over 6 hours (15 min x 8, 30 min x 8)





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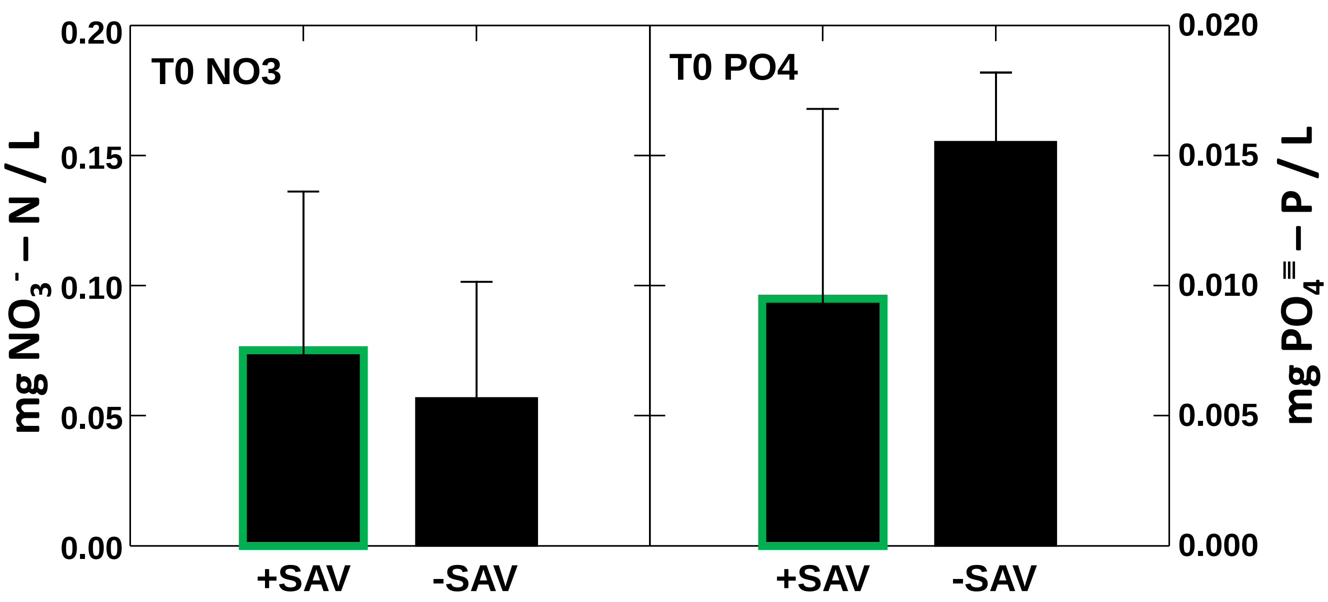
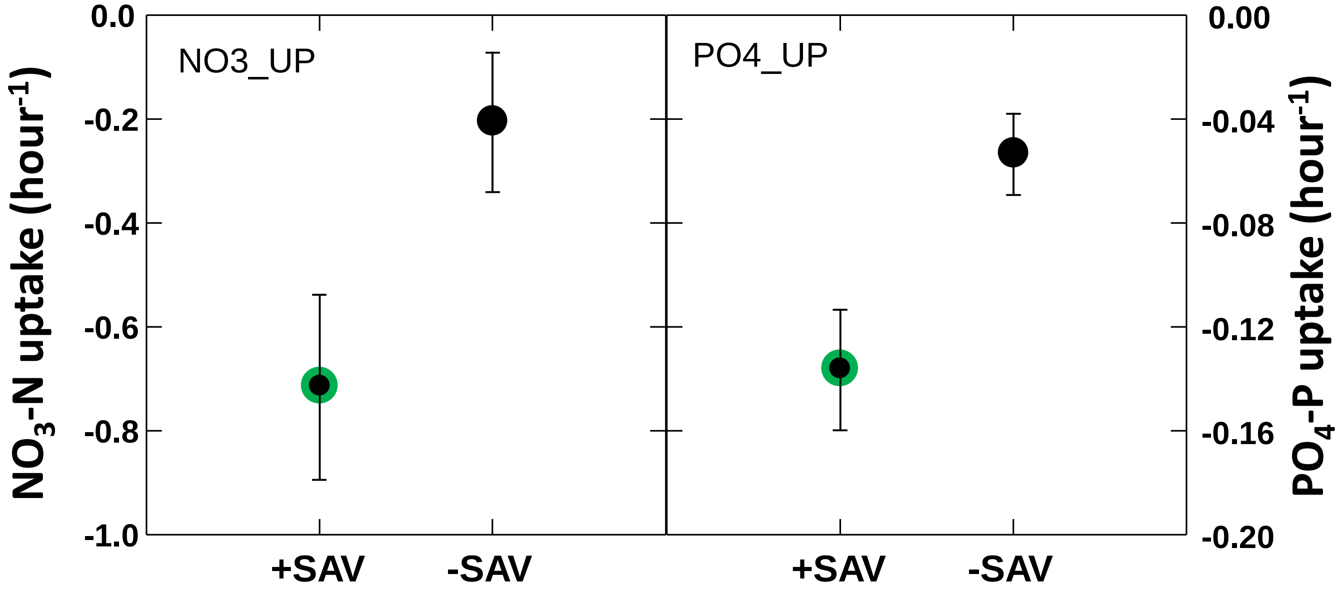


Results:

- Initial NO3 and PO4 pools were not significantly different among chambers
- Dissolved concentrations: NO3 > PO4
- Nutrient Additions → Approx. *doubling of NO3 pool*
  PO4 addition followed NO3 (1:1)

Trip #1 – June 2013



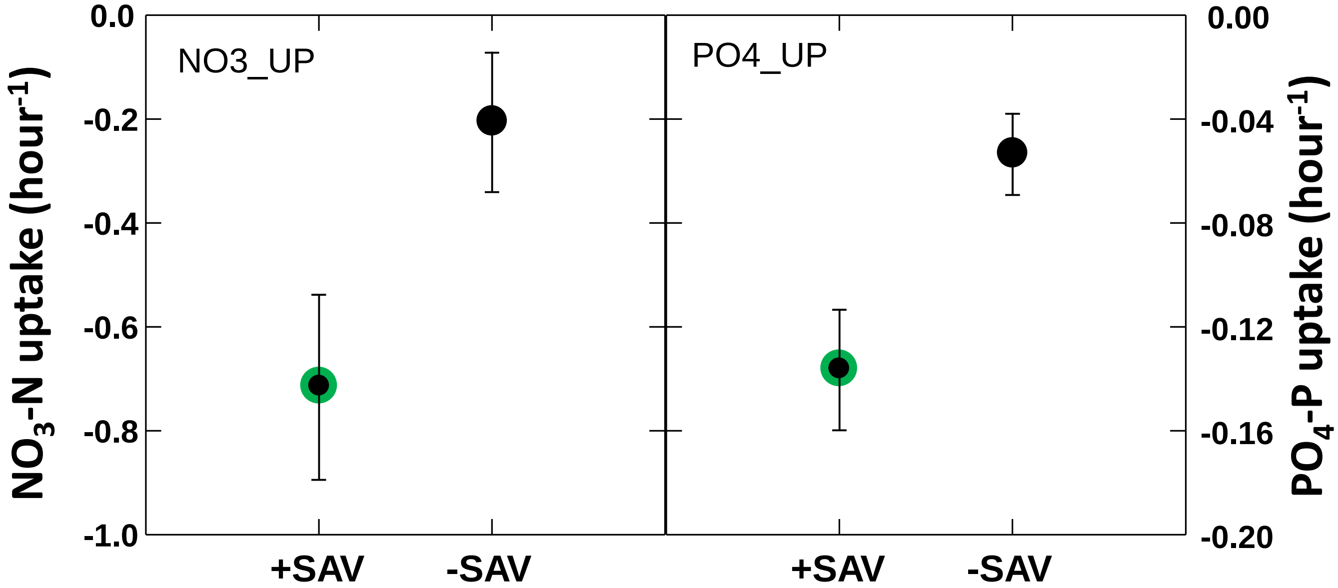
Results:

Note:

Results are expressed as *Rate Constants* (per unit time)

More negative rate-constant → *Faster*

Trip #1 – June 2013



	NO_3 Uptake	PO_4 Uptake
+ SAV	-0.72 ± 0.16	-0.14 ± 0.02
- SAV	-0.21 ± 0.12	-0.05 ± 0.01

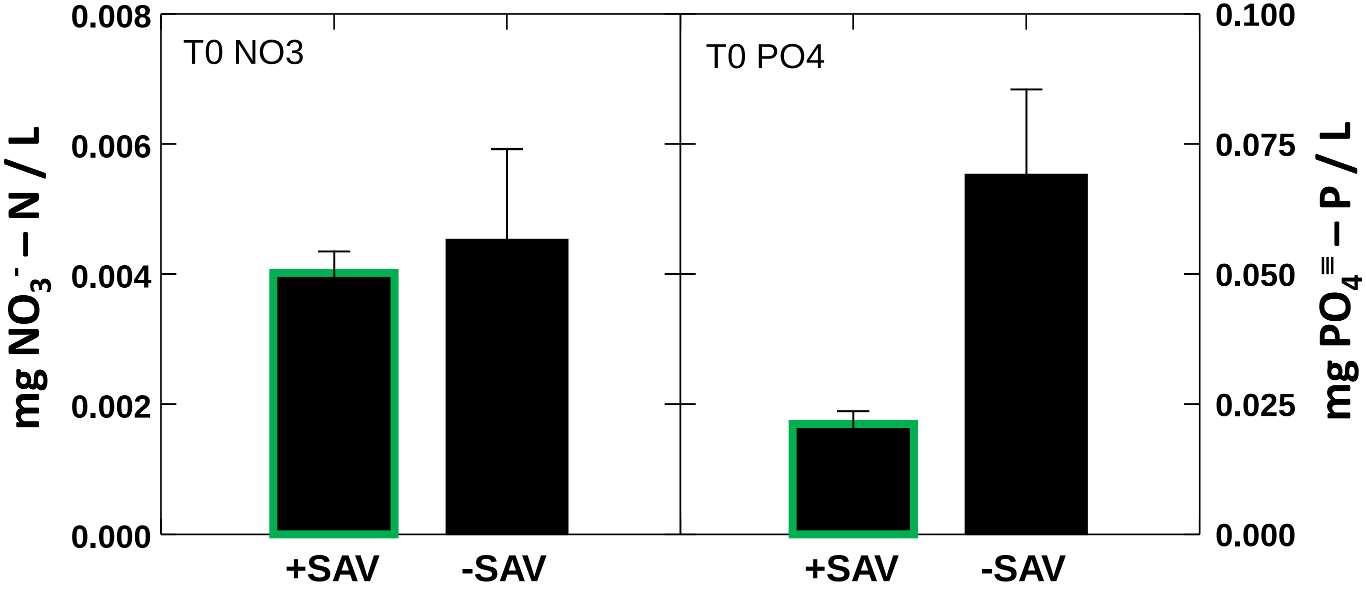
Results:

- Uptake rates in plots with SAV faster than without SAV
- NO3 uptake ≈ 5 times faster than PO4 uptake

Trip #2 – August 2013 (Daytime)

- Moved eight (8) mesocosms to new location, 8 days prior to experiment
- -SAV mesocosms were placed in area of low SAV cover, adjacent to +SAV patch
- Added 0.12 mg NO3-N / L and 0.12 mg PO4-P / L to each mesocosm
- Collected 50 mL of filtered water over 6 hours (15 min x 8, 30 min x 8)

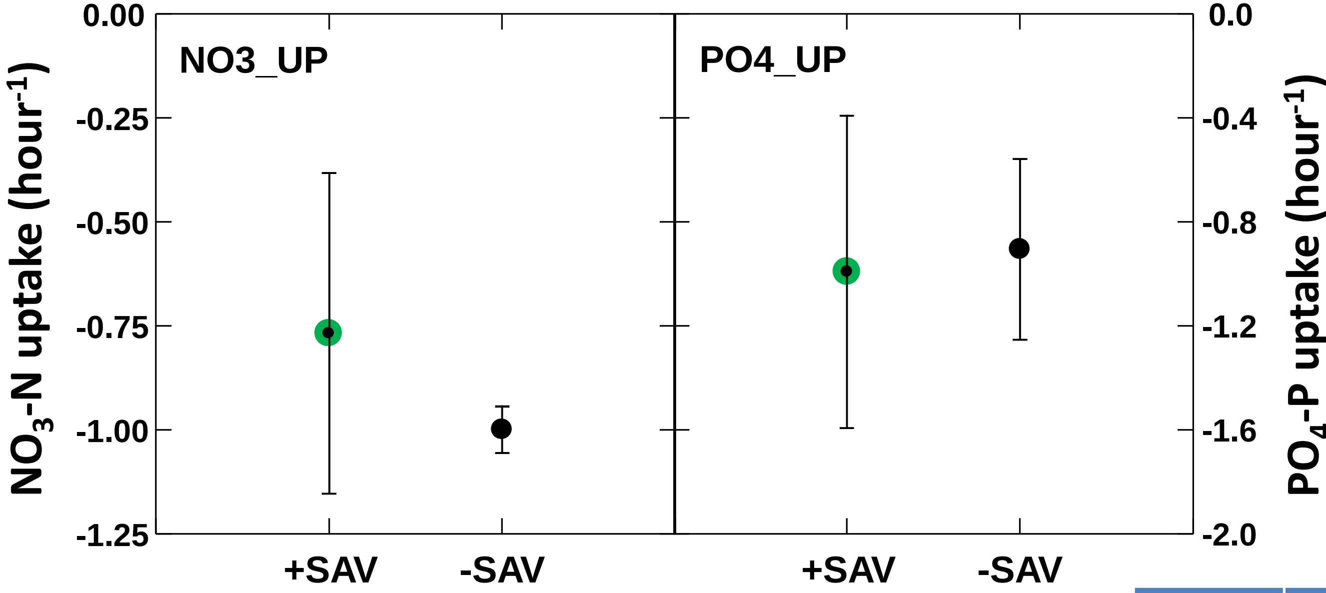
Trip #2 – August 2013 (Daytime)



Results:

- No sig. difference in initial (T0) NO3 pools between treatments
- -SAV had greater dissolved PO4 concentrations than +SAV ($p<0.001$)
- PO4 pools were greater than NO3 pools

Trip #2 – August 2013 (Daytime)



	NO_3 Uptake	PO_4 Uptake
+ SAV	-0.83 ± 0.23	-0.99 ± 0.51
- SAV	-1.00 ± 0.05	-0.90 ± 0.31

Results:

- Uptake rates in plots with SAV not significantly different than –SAV plots
- NO3 uptake of similar magnitude to PO4 uptake

Trip #3 – August 2013 (Nighttime)

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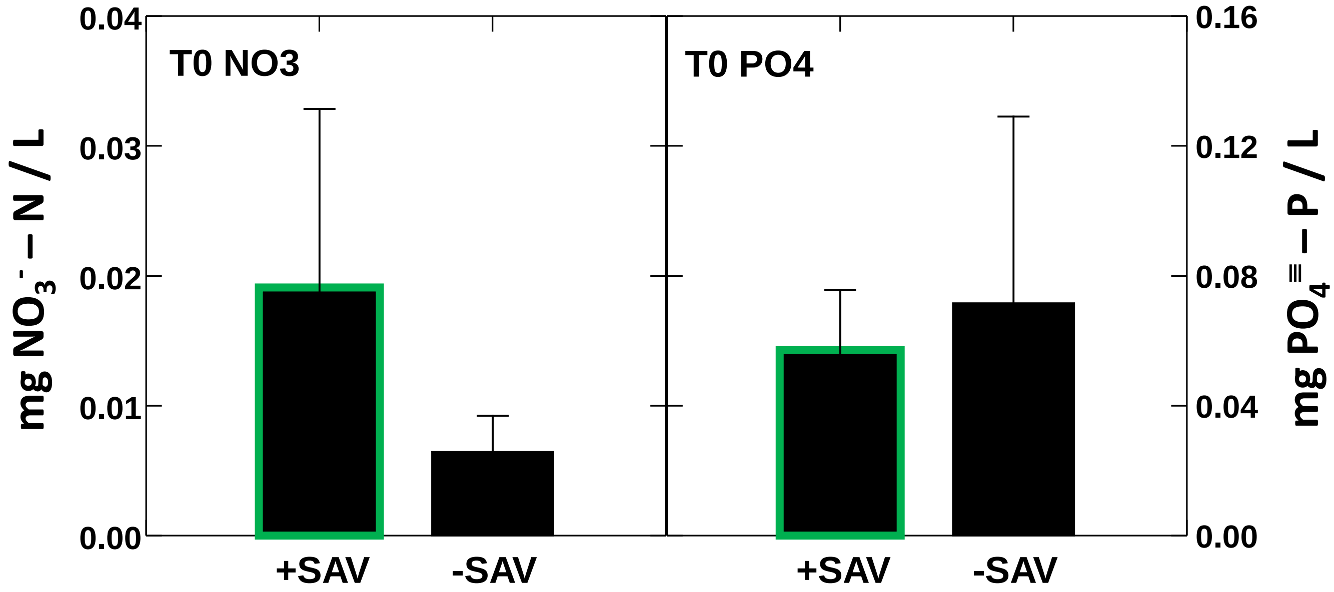
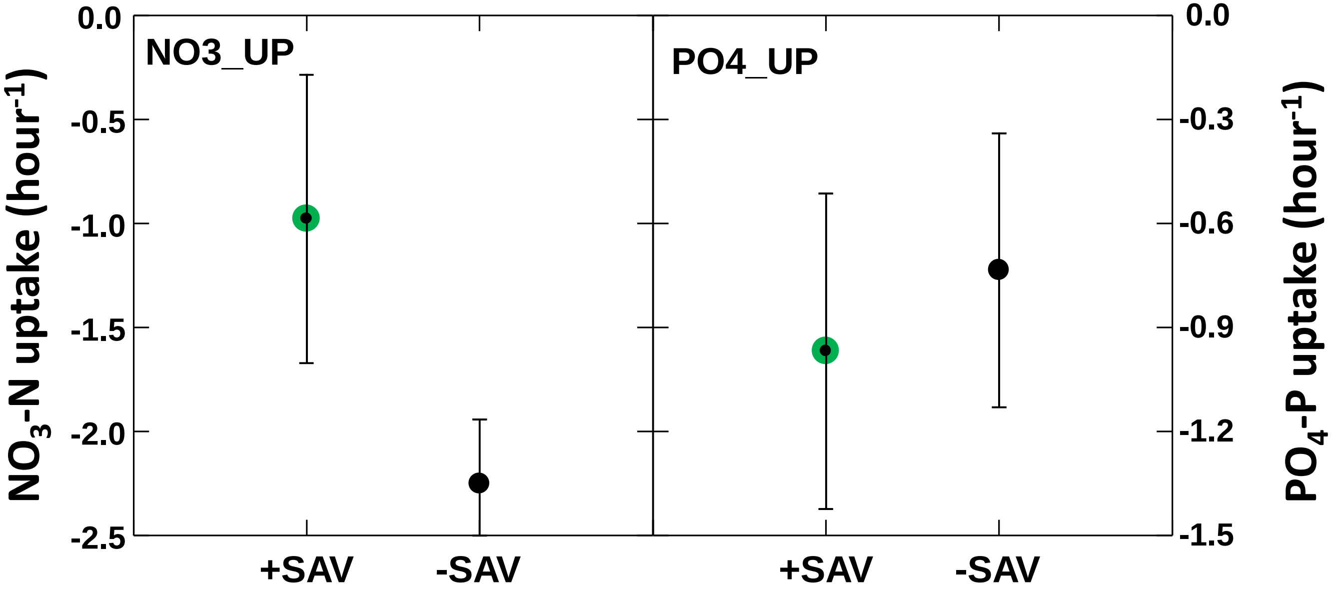


Results:

- Plots w/ SAV had slightly greater initial NO3 concentrations than –SAV plots (p=0.054), while PO4 concentrations did not differ
- Initial concentrations were generally higher at night than the previous (3 days prior) sampling during the day
- PO4 concentrations about 6 to 8 times the size of NO3 pools

Trip #3 – August 2013 (Nighttime)



	NO_3 Uptake	PO_4 Uptake
+ SAV	-0.98 ± 0.62	-0.97 ± 0.41
- SAV	-2.25 ± 0.28	-0.74 ± 0.36

Results:

- *Interestingly*, -SAV plots had greater NO3 uptake than +SAV plots
- NO3 uptake in –SAV plots was very rapid
- In +SAV plots, NO3 uptake similar to PO4 uptake
- For –SAV plots, NO3 uptake >> PO3 uptake

Trip #4 – September 2013 ** Tailrace **

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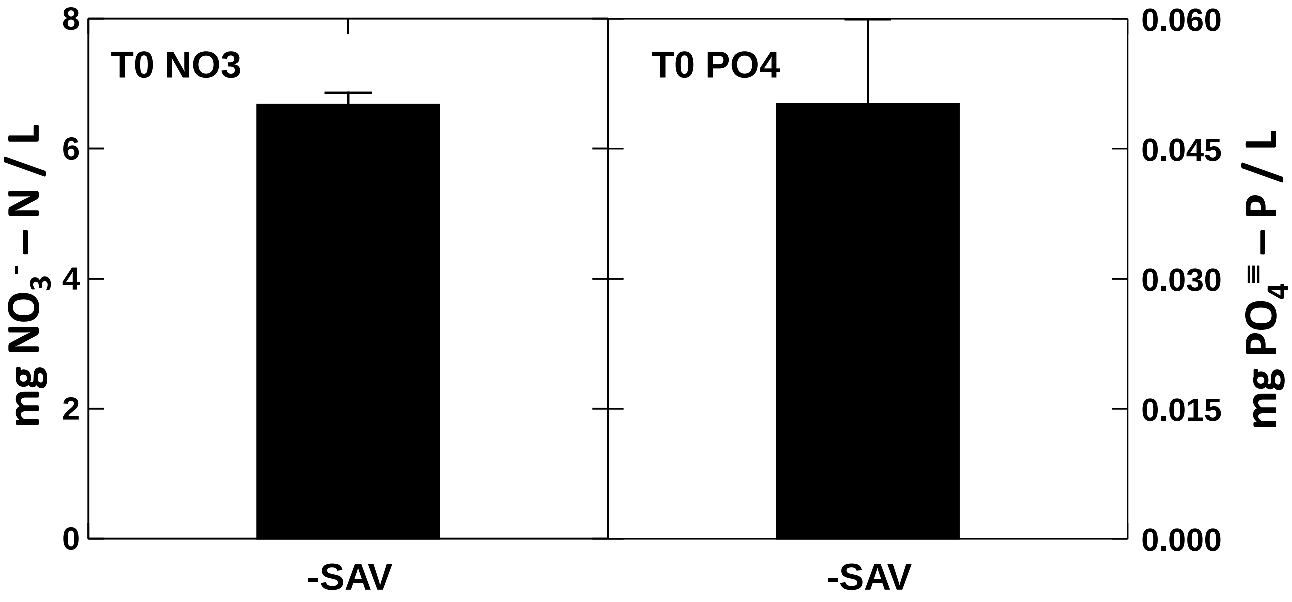
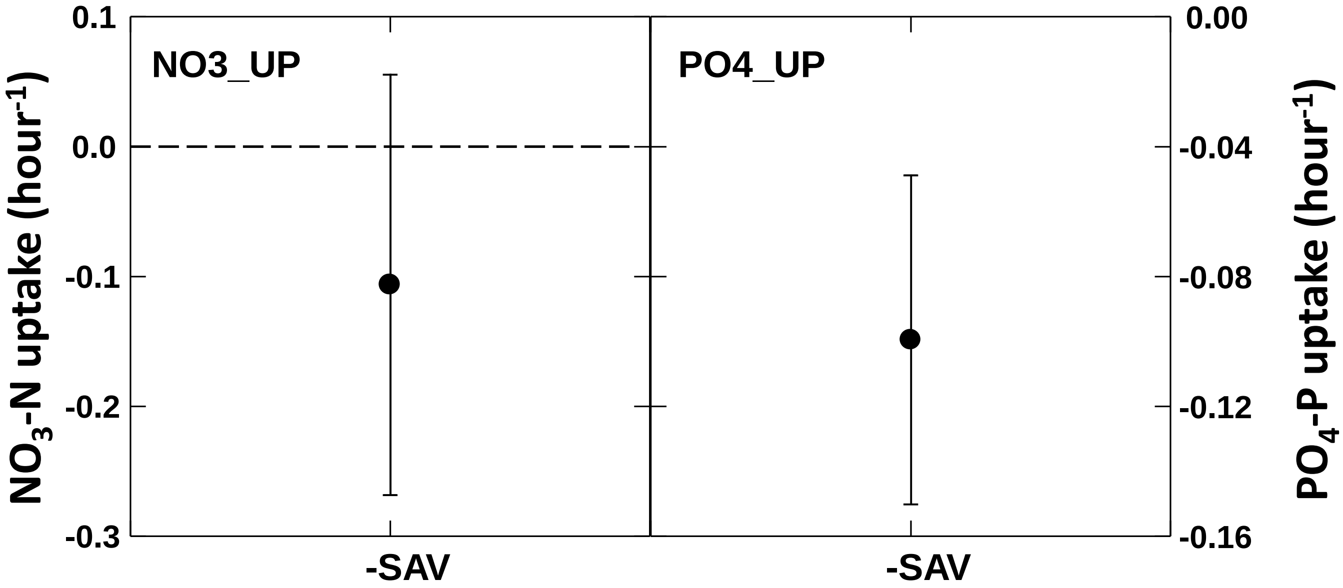


Results:

- No SAV were observed in the Tailrace
- Initial NO3 pools were very, very high. Approx. 2 orders of magnitude greater than previous measurements in open water areas of Willard Spur
- Initial PO4 concentrations were similar to other late-summer pools
- Because of large NO3 pools – the NO3 spike was quite small (in a relative sense)

Trip #4 – September 2013 ** Tailrace **

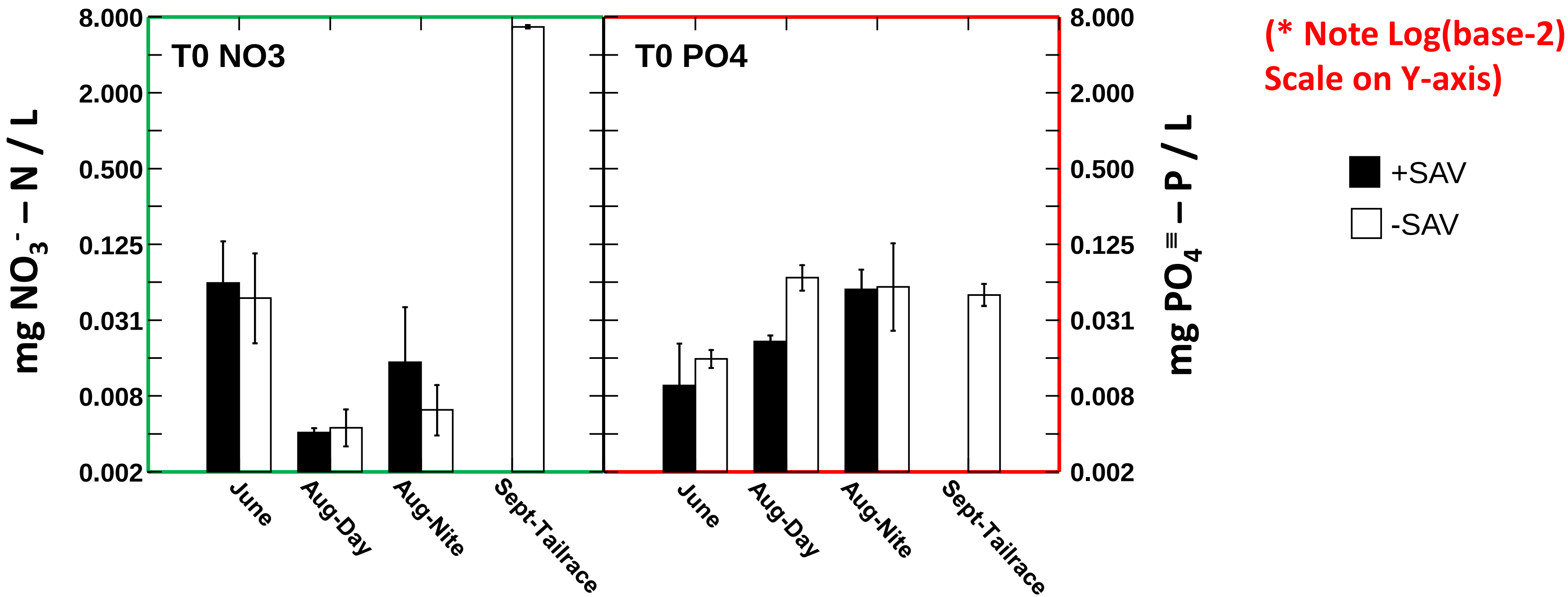


	NO_3 Uptake	PO_4 Uptake
- SAV	-0.11 ± 0.15	-0.10 ± 0.05

Results:

- Uptake rate constants similar between NO3 and PO4
- Considerable variability in NO3 uptake; two measurements have $r^2 < 0.50$
- Use of Br^- tracer may help clear up methodological issues

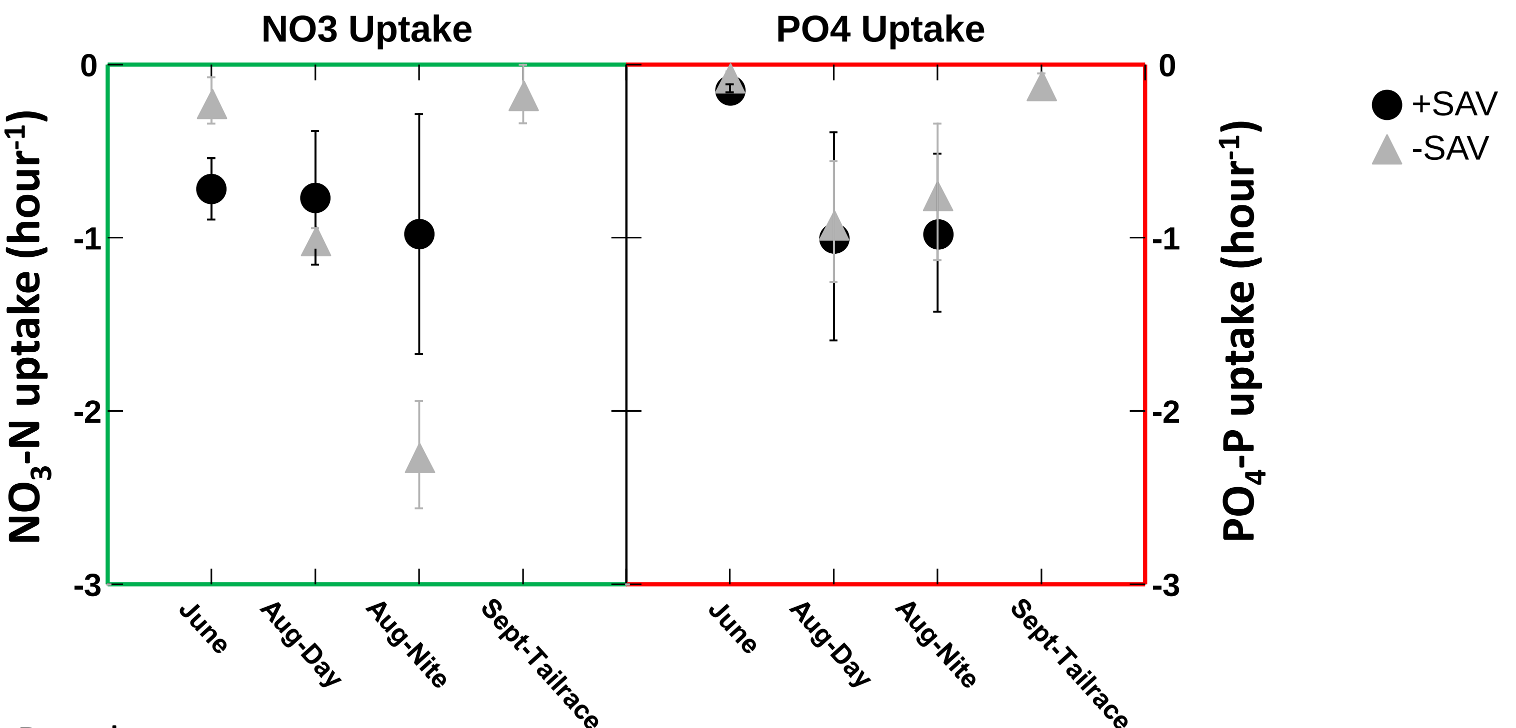
All Sampling Trips Combined



Results:

- NO3 concentrations tended to decrease over time within the Spur, but were much higher in the Tailrace
- NO3 concentrations were slightly higher at night than during the day
- PO4 concentrations increased from June through August

All Sampling Trips Combined



<u>Results</u>:

- NO3 Uptake with SAV: Generally similar over time, but variability increases over time
- NO3 Uptake w/o SAV: Rate constants increase in magnitude from June to August
- PO4 Uptake – Slow in June and Sept (tailrace), faster in August
- PO4 – less sensitive to SAV presence than NO3

Scaling of Rate Constants...

$$Rate = \frac{(-k) \cdot Vol \cdot (T_0 Pool)}{Area} = \frac{1}{hour} \cdot \frac{m^3}{m^2} \cdot \frac{g(X)}{m^3} = \frac{g(X)}{m^2 \cdot hour}$$

NO_3 Uptake Rates

Date	TRT	MRT	Rate *	Uptake – Low Water **	Uptake – High Water **	Uptake – Tailrace **
<Units>		hr	$gN \cdot m^{-2} \cdot d^{-1}$	lbs N / day	lbs N / day	
mid-June	+SAV	0.97	0.56	30,824	106,717	
mid-June	-SAV	3.36	0.12	6,709	23,227	10.1
August – Day	+SAV	0.90	0.0035	193	668	
August – Day	-SAV	0.69	0.0052	283	980	0.43
August – Night	+SAV	0.71	0.014	781	2,705	
August – Night	-SAV	0.31	0.011	609	2,107	0.92
Sept – Tailrace	-SAV	6.53	10.34	566,865	1,962,600	**857**

* Uptake rate ($gX \cdot m^{-2} \cdot hr^{-1}$), based on T0 concentrations

** Area basis = 24,877,000 m^2 of open water habitat for low water, and 86,129,000 m^2 for high water conditions

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PO_4 Uptake Rates

Date	TRT	MRT	Rate *	Uptake – Low Water **	Uptake – High Water **	Uptake – Tailrace **
<Units>		hr	$gP \cdot m^{-2} \cdot d^{-1}$	lbs P / day	lbs P / day	
mid-June	+SAV	5.1	0.013	743	2,571	
mid-June	-SAV	12.9	0.009	477	1,650	0.72
August – Day	+SAV	0.70	0.024	1,316	4,556	
August – Day	-SAV	0.77	0.071	3,913	13,548	5.92
August – Night	+SAV	0.72	0.042	2,312	8,006	
August – Night	-SAV	0.94	0.040	2,199	7,613	3.33
Sept – Tailrace	-SAV	6.97	0.073	3,997	13,839	**6.04**

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Scaling of Rate Constants...And comparing Rates to External Loads

NO_3 Turnover (Load / Uptake Rate)

		N Load (lbs N / day)						
Trip	TRT	**25**	**50**	**75**	**250**	**500**	**1000**	**4000**
1	+SAV	<0.01 <0.01	<0.01 <0.01	<0.01 <0.01	<0.01 <0.01	0.02 <0.01	0.03 0.01	0.13 0.04
1	-SAV	<0.01 <0.01	<0.01 0.01	<0.01 0.01	0.04 0.01	0.07 0.02	0.15 0.04	0.60 0.17
2 – Day	+SAV	0.13 0.04	0.26 0.07	0.39 0.11	**1.30** 0.37	**2.59** 0.75	**5.19** **1.50**	**20.8** **6.0**
2 – Day	-SAV	0.09 0.03	0.18 0.05	0.26 0.08	0.88 0.25	**1.77** 0.51	**3.53** **1.02**	**14.1** **4.1**
3 – Night	+SAV	0.03 0.01	0.06 0.02	0.10 0.03	0.32 0.09	0.64 0.18	**1.28** 0.37	**5.12** **1.48**
3 – Night	-SAV	0.04 0.01	0.08 0.02	0.12 0.04	0.41 0.12	0.82 0.24	**1.64** 0.47	**6.57** **1.90**
4 - Tailrace	-SAV	0.03	0.06	0.09	0.29	0.58	**1.17**	**4.67**

Values are Estimate of Nutrient Load divided by Uptake Rate, by Trip and Vegetation Type. Upper values are for Low Water conditions, Lower values for High Water Conditions. Trip 4 shown only for Tailrace area

Scaling of Rate Constants...And comparing Rates to External Loads

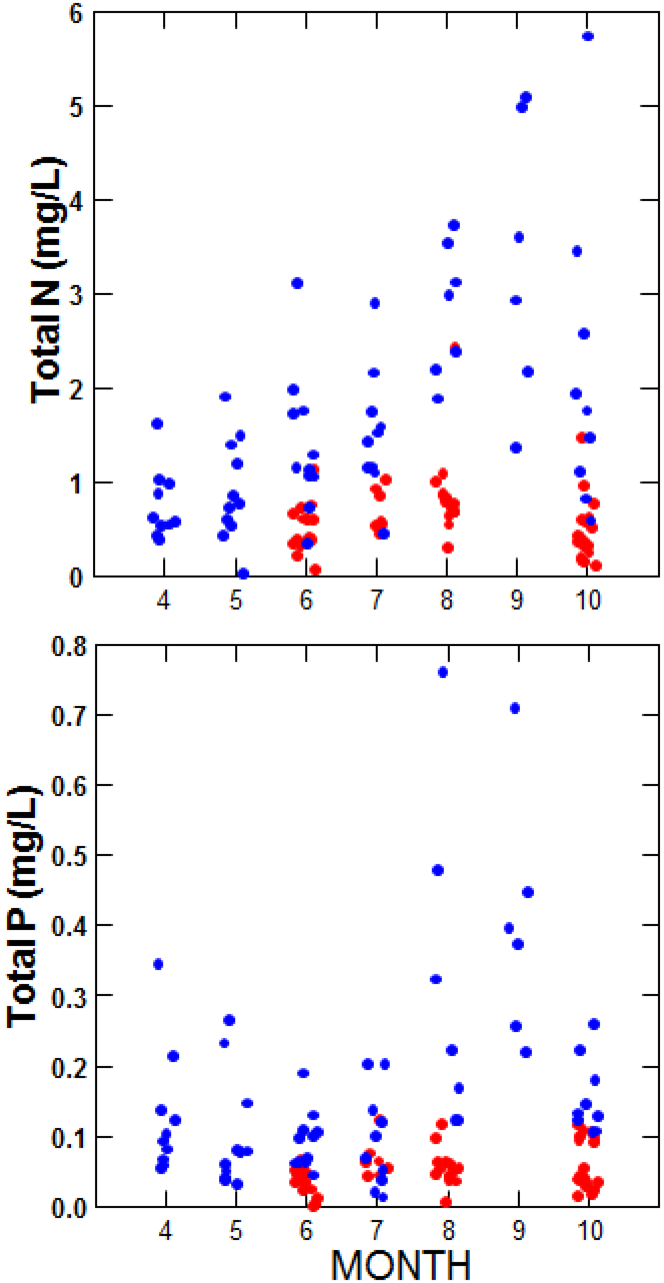
PO_4 Turnover (Load / Uptake Rate)

		N Load (lbs N / day)						
Trip	TRT	**2.2**	**6**	**17**	**35**	**70**	**140**	**750**
1	+SAV	<0.01 <0.01	<0.01 <0.01	0.02 0.01	0.05 0.01	0.09 0.03	0.19 0.05	**1.01** 0.29
1	-SAV	<0.01 <0.01	<0.01 <0.01	0.04 0.01	0.07 0.02	0.15 0.04	0.29 0.08	**1.57** 0.45
2 – Day	+SAV	<0.01 <0.01	<0.01 <0.01	<0.01 <0.01	0.03 0.01	0.05 0.02	0.11 0.03	0.57 0.16
2 – Day	-SAV	<0.01 <0.01	<0.01 <0.01	<0.01 <0.01	0.01 0.01	0.02 0.01	0.04 0.01	0.19 0.06
3 – Night	+SAV	<0.01 <0.01	<0.01 <0.01	<0.01 <0.01	0.02 <0.01	0.03 0.01	0.06 0.02	0.32 0.09
3 – Night	-SAV	<0.01 <0.01	<0.01 <0.01	<0.01 <0.01	0.02 <0.01	0.03 0.01	0.06 0.02	0.34 0.10
4 - Tailrace	-SAV	0.36	**0.99**	**2.81**	**5.79**	**11.58**	**23.2**	**124.1**

Values are Estimate of Nutrient Load divided by Uptake Rate, by Trip and Vegetation Type. Upper values are for Low Water conditions, Lower values for High Water Conditions. Trip 4 shown only for Tailrace area

What does this mean in the context of minimizing the potential risk of the discharge?

High Water vs. Low Water Years



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TP

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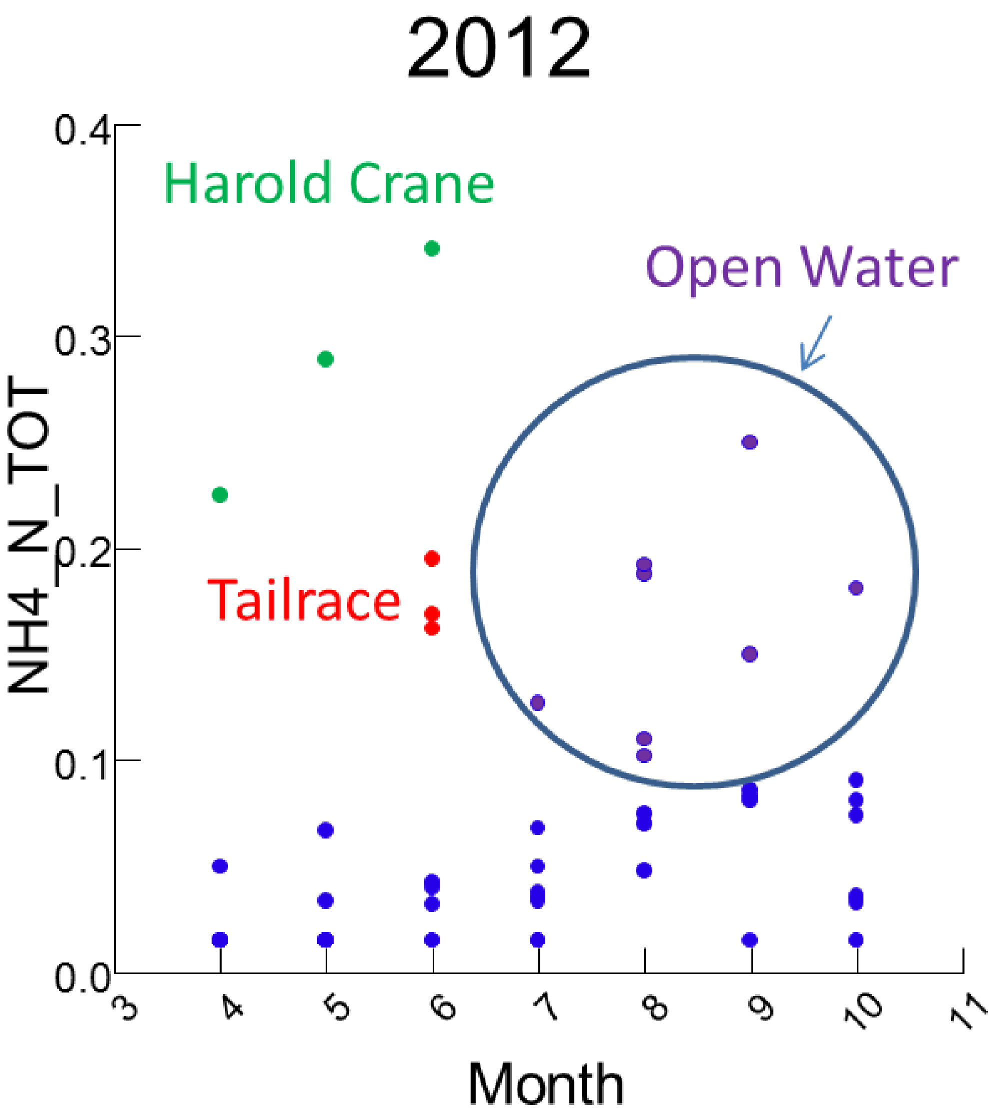
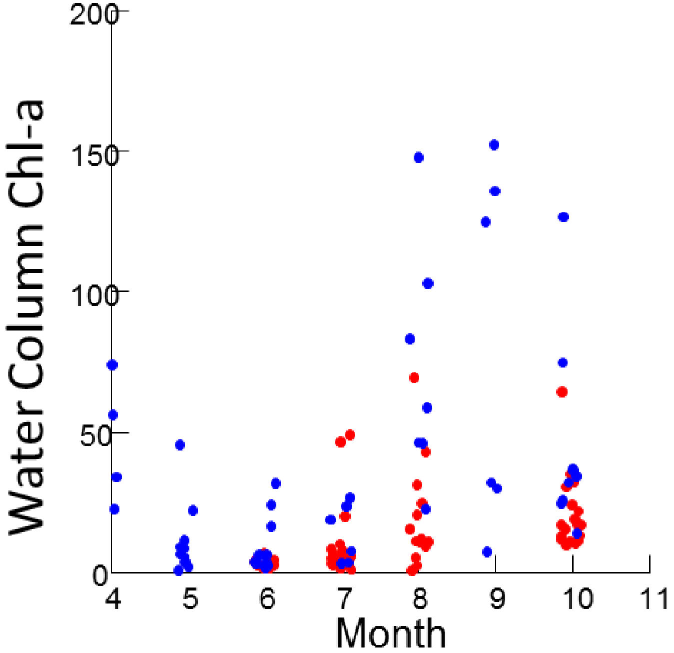
Internal Cycling: Mineralization

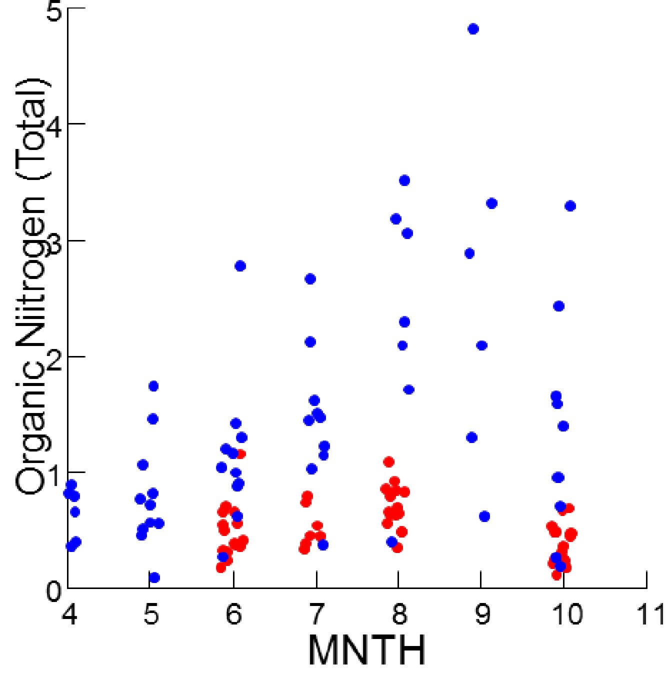


- DO Data in 2012 showed fairly long periods of anoxic conditions (<1 mg/l)
- Evidence of mineralization: ON to NH_4
- ***Reflects importance of internal nutrient cycling***: higher values, in more places after the Spur is mostly isolated.

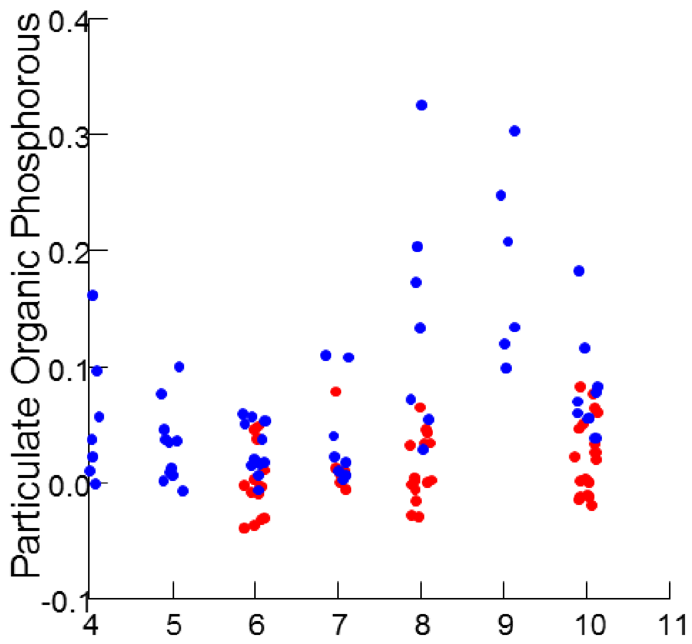
Organic N & P



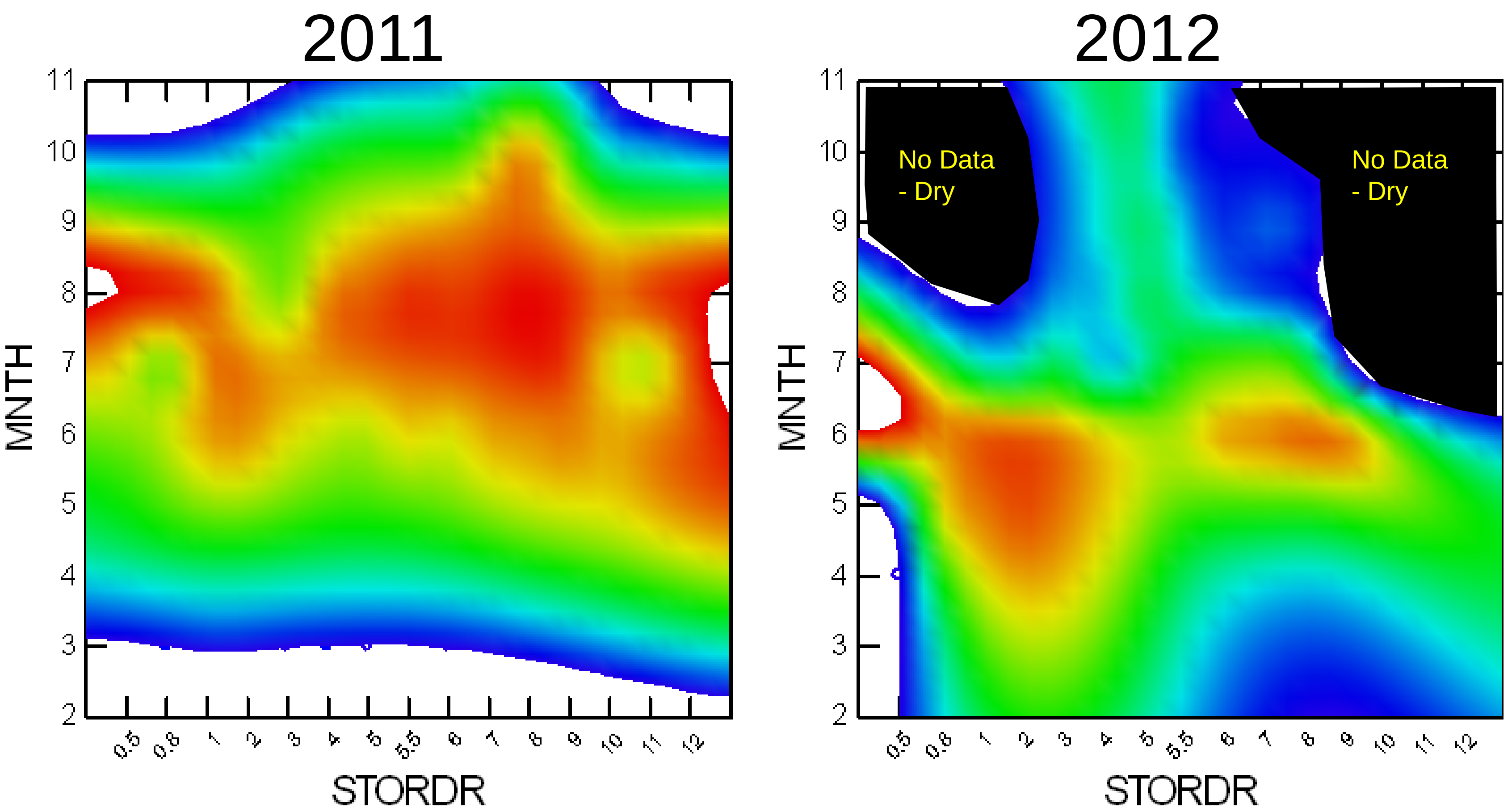
Water Column Chl-a
Month
0
50
100
150
200
4
5
6
7
8
9
10
11



Organic Nitrogen (Total)
MNTH
0
1
2
3
4
5
4
5
6
7
8
9
10
11



Particulate Organic Phosphorous
-0.1
0.0
0.1
0.2
0.3
0.4
4
5
6
7
8
9
10
11



Red = High Cover

Blue = Low Cover

The Relative Threat of Nutrient Inputs Depends on the Timing

- Springtime loads are appreciable, but transient
  - Export or uptake
  - Assimilative capacity of the spur is high

- Summertime loads, from the organic nutrient pools are most important

- During periods where the spur is isolated, the potential risk of the plant is greatest

Quantifying Internal Cycling

Next Steps

Internal Cycling

- Nutrient spiraling within the tailrace
- Estimate the mass of the organic nutrient pool associated with macrophytes
- Quantify the potential load from these sources in comparison with the discharge

Ecosystem Metabolism

- Link rates to processes

Others Summaries of Background Monitoring

- Many ways to do this, what would be most useful in the context of potential panel recommendations?

High Ecological Resilience: How to maintain this characteristic?