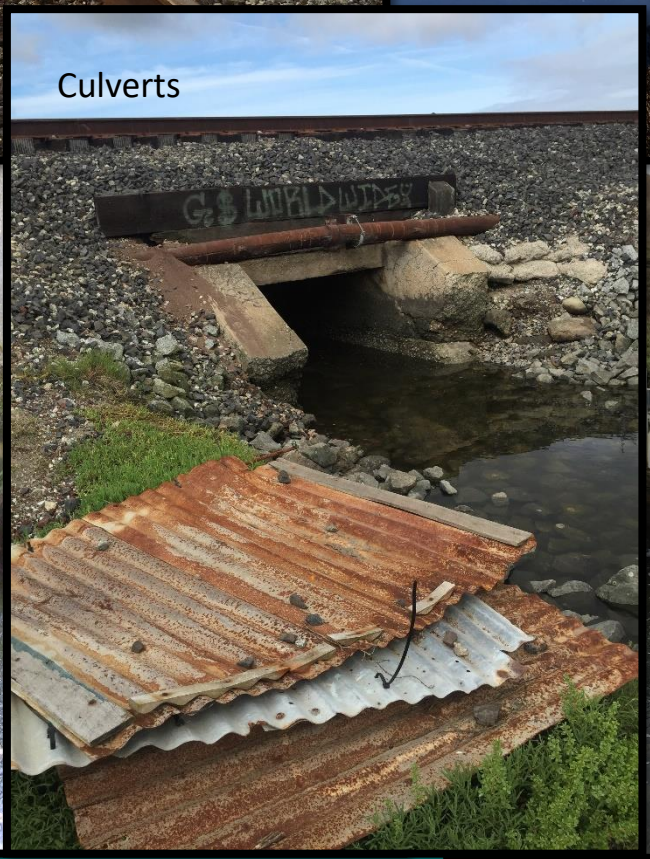
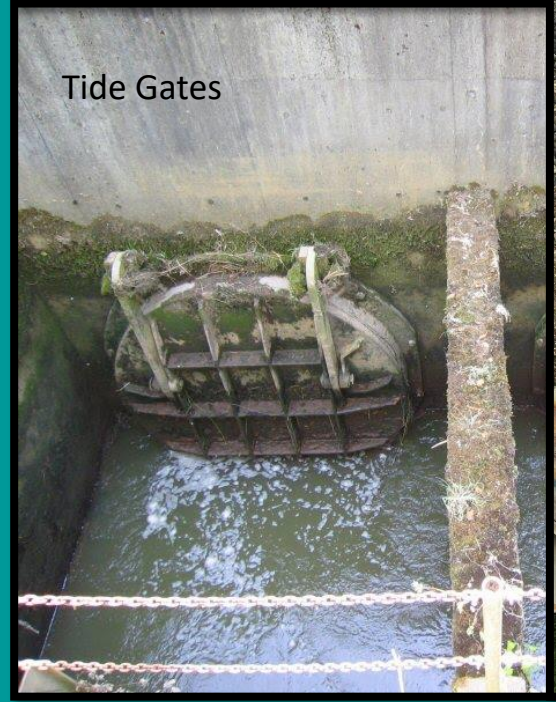
Nutrient Dynamics in Tidally Restricted Regions of the Elkhorn Slough National Estuarine Research Reserve

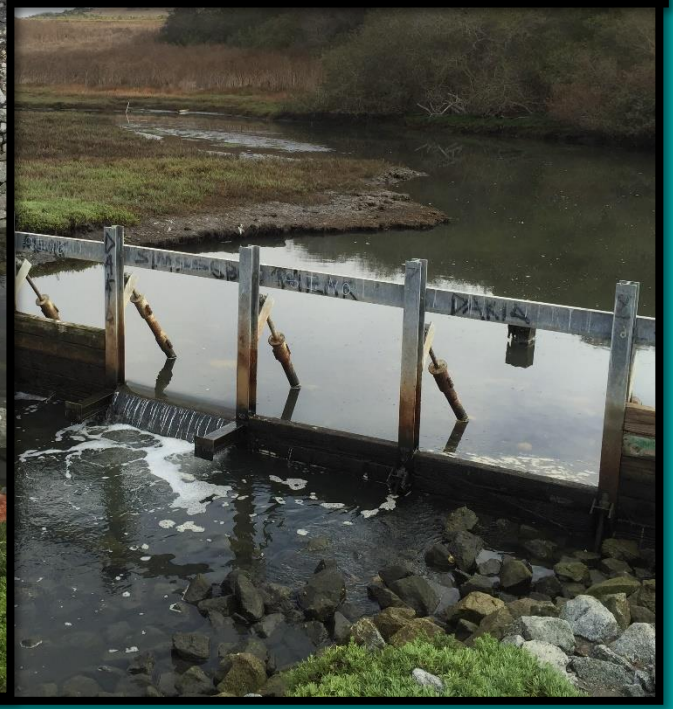
Mo Wise Fall 2017


Southern Pacific Railroad


Old agricultural berms


Culverts


Tide Gates

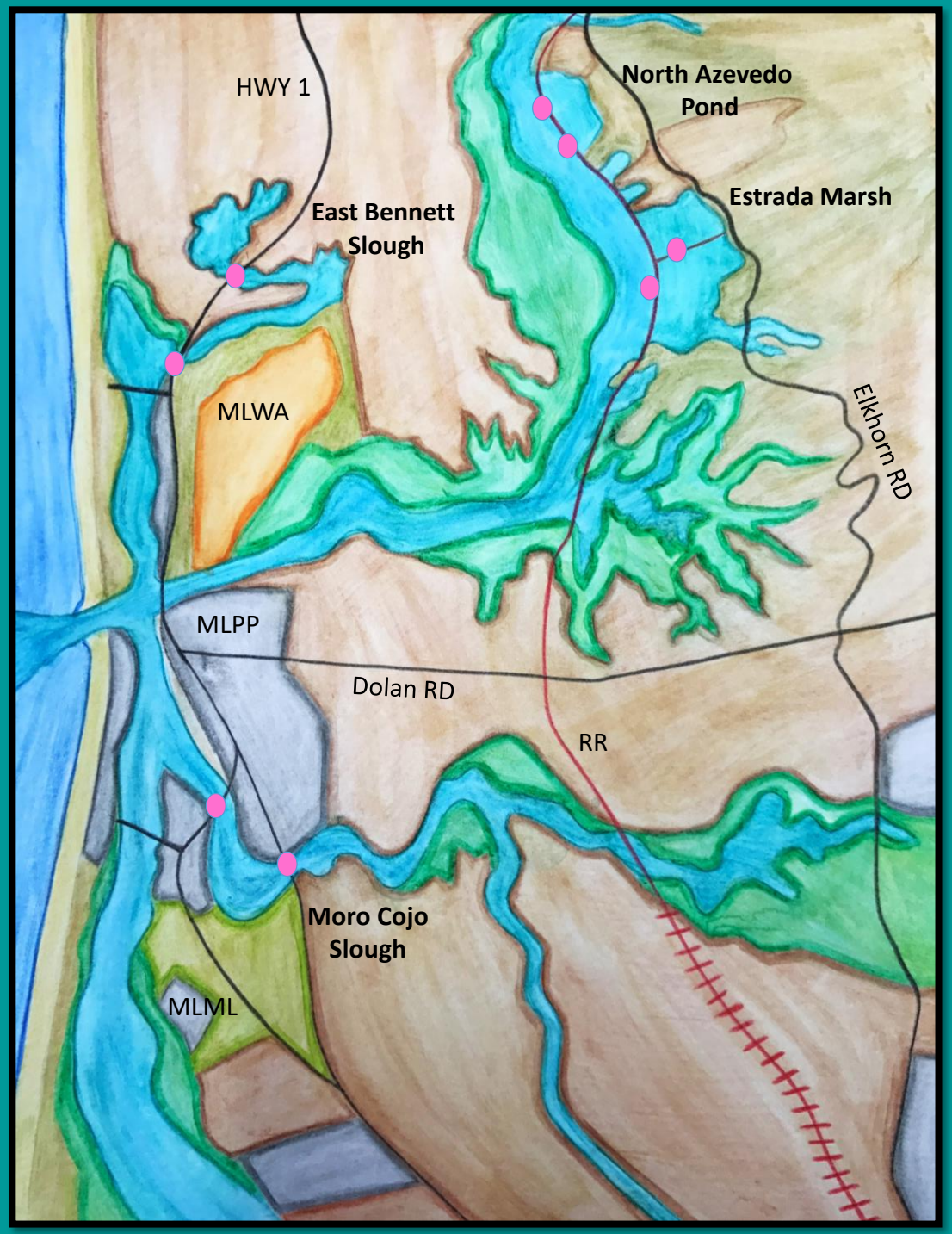


Research Questions

- What is the source and relative magnitude of nutrients from groundwater, surface water, sediments and biota in tidally restricted regions on the Elkhorn Slough?

- Which of these nutrient sources and sinks change on a seasonal basis, and what is the magnitude of their temporal variability?

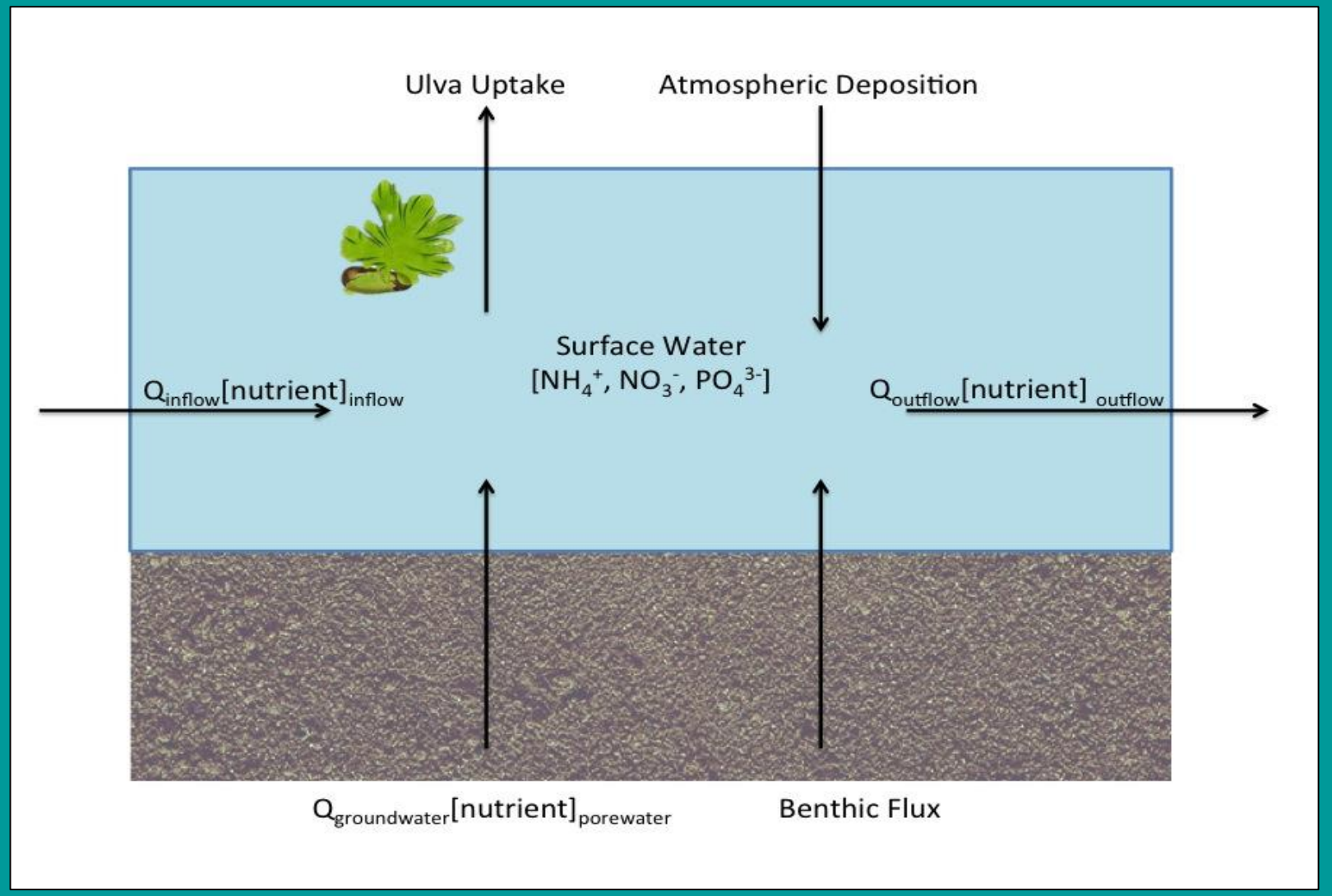
Study Sites



Mo Wise

METHODS

Box Model Approach



Water Column processes = Sources – Sinks

Water Column Characteristics:

Measuring temp, pH, salinity, DO, Flow

Weekly

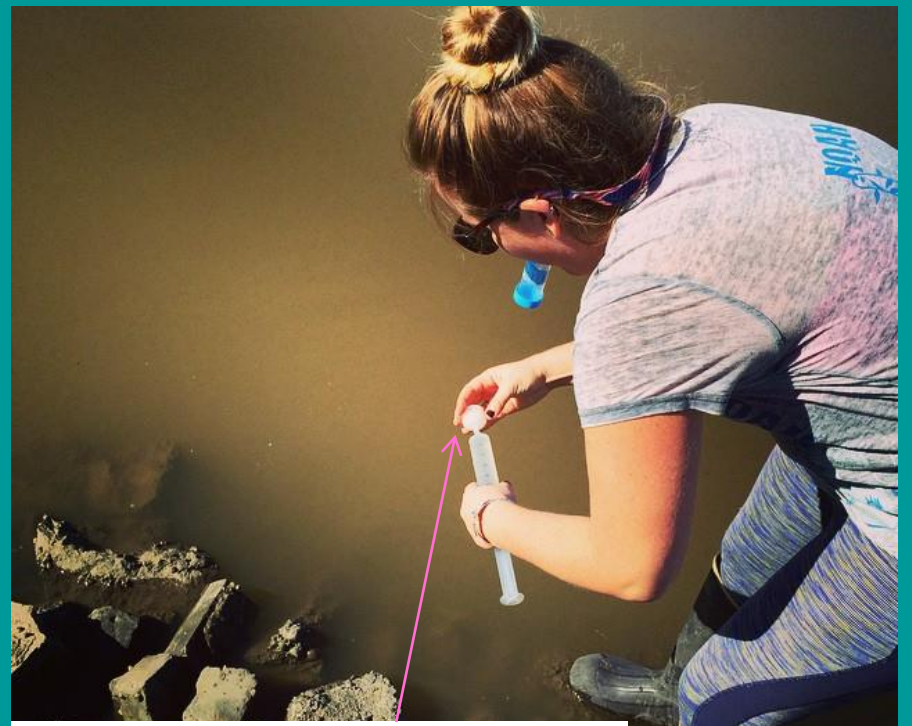
Methods

Nutrient Monitoring in Surface Waters:

Methods

Grab Samples

Weekly

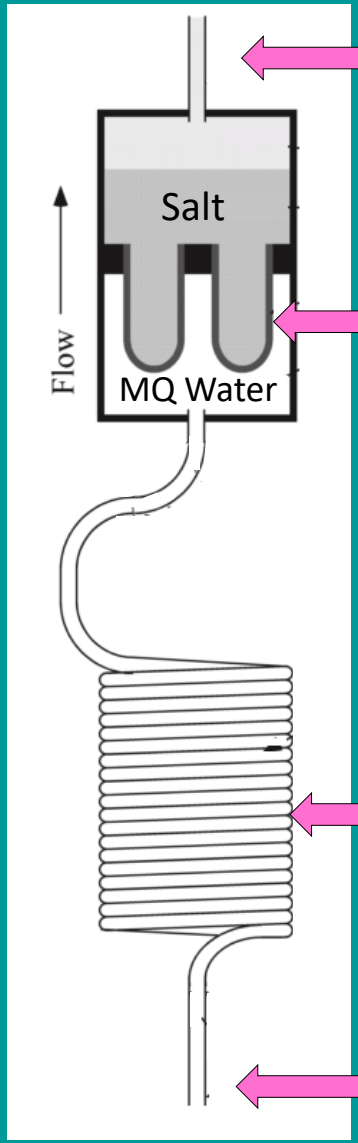


Nutrient Monitoring in Surface Waters:

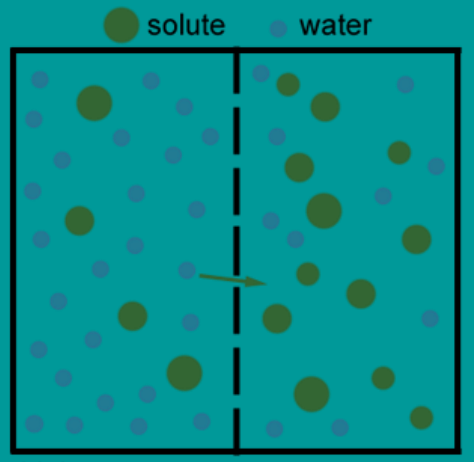
Methods

OsmoSamplers

Continuous



Jannasch *et al.,* 2004

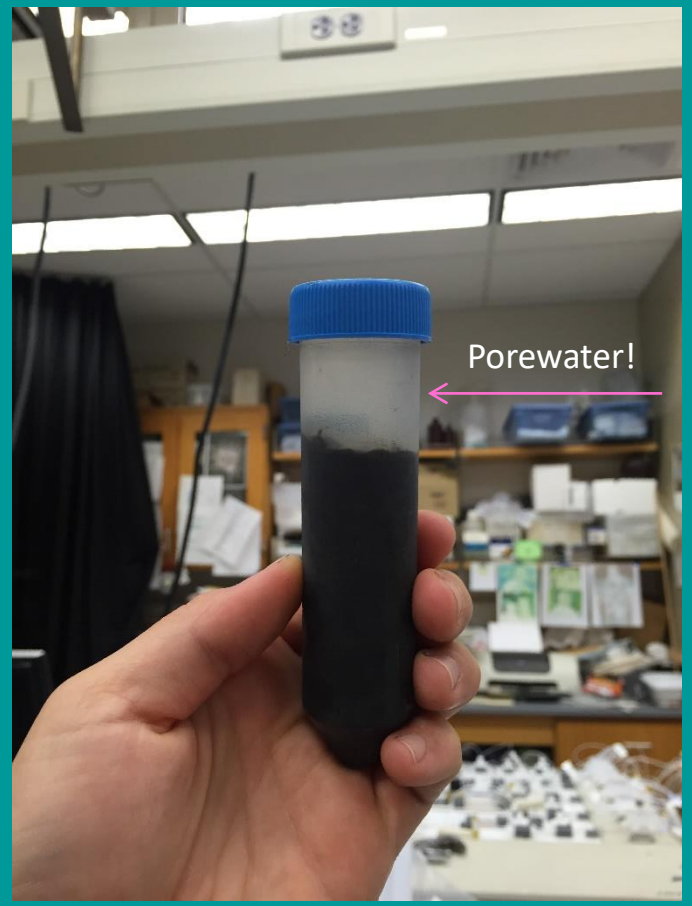


Porewater Nutrient Concentrations:

Methods

Porewater: Diffusive Flux

Seasonal

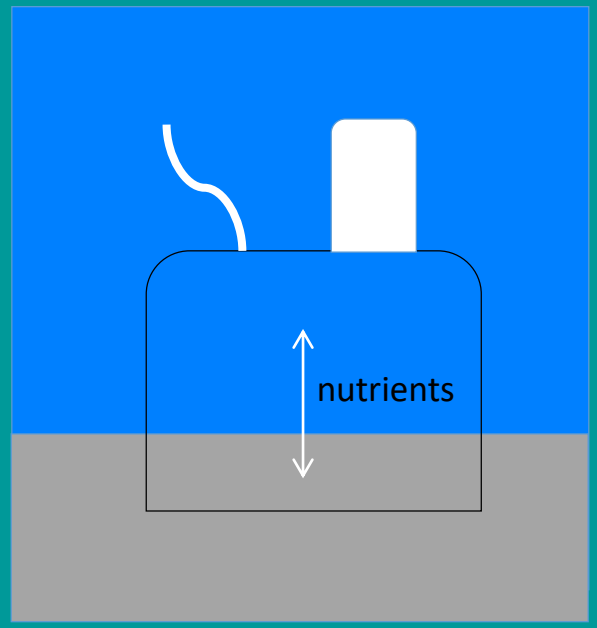


Benthic Flux Chambers:

Methods

Diffusive and Advective flux

Seasonally



$$\text{Flux} = \frac{\Delta \text{ nutrients}}{m^2 \text{ day}}$$

Organic Carbon cores

Loss On Ignition “LOI”

Methods

$$\% \text{ Organic Material} = \left[\frac{\text{pre-ignition weight (g)} - \text{post-ignition weight (g)}}{\text{pre-ignition weight (g)}} \right] * 100$$

Groundwater Discharge

- Correlate with porewater nutrient concentrations

$$GW_{flux} = \{[(A_{box} - A_{out})V_{box}]/\tau\}/A_{PW}$$

Results in the amount of groundwater attributing to surface water per day ($m^3\ m^{-1}\ d^{-1}$)

Ulva Biomass

Methods

- Percent Cover

Ulva Biomass

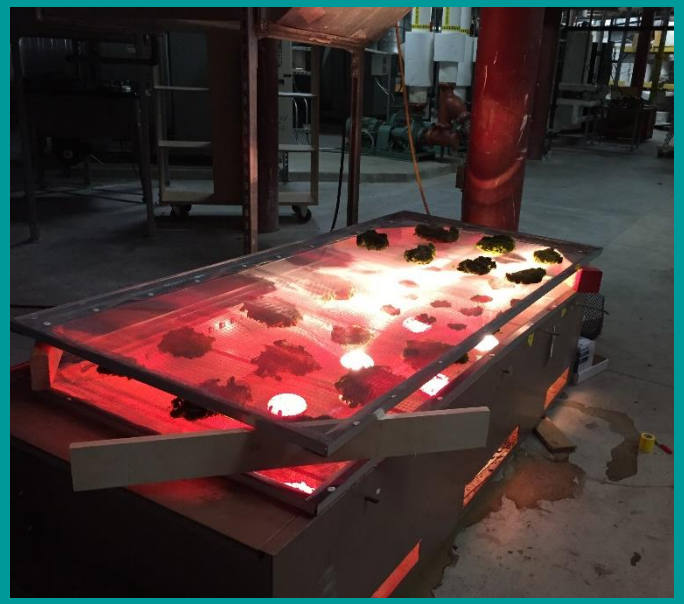
- Percent Cover

Moro Cojo Slough

East Bennett Slough

Ulva Biomass

Methods



Ulva Biomass

Aerial Photos: M^2 of Algal Cover Each Month

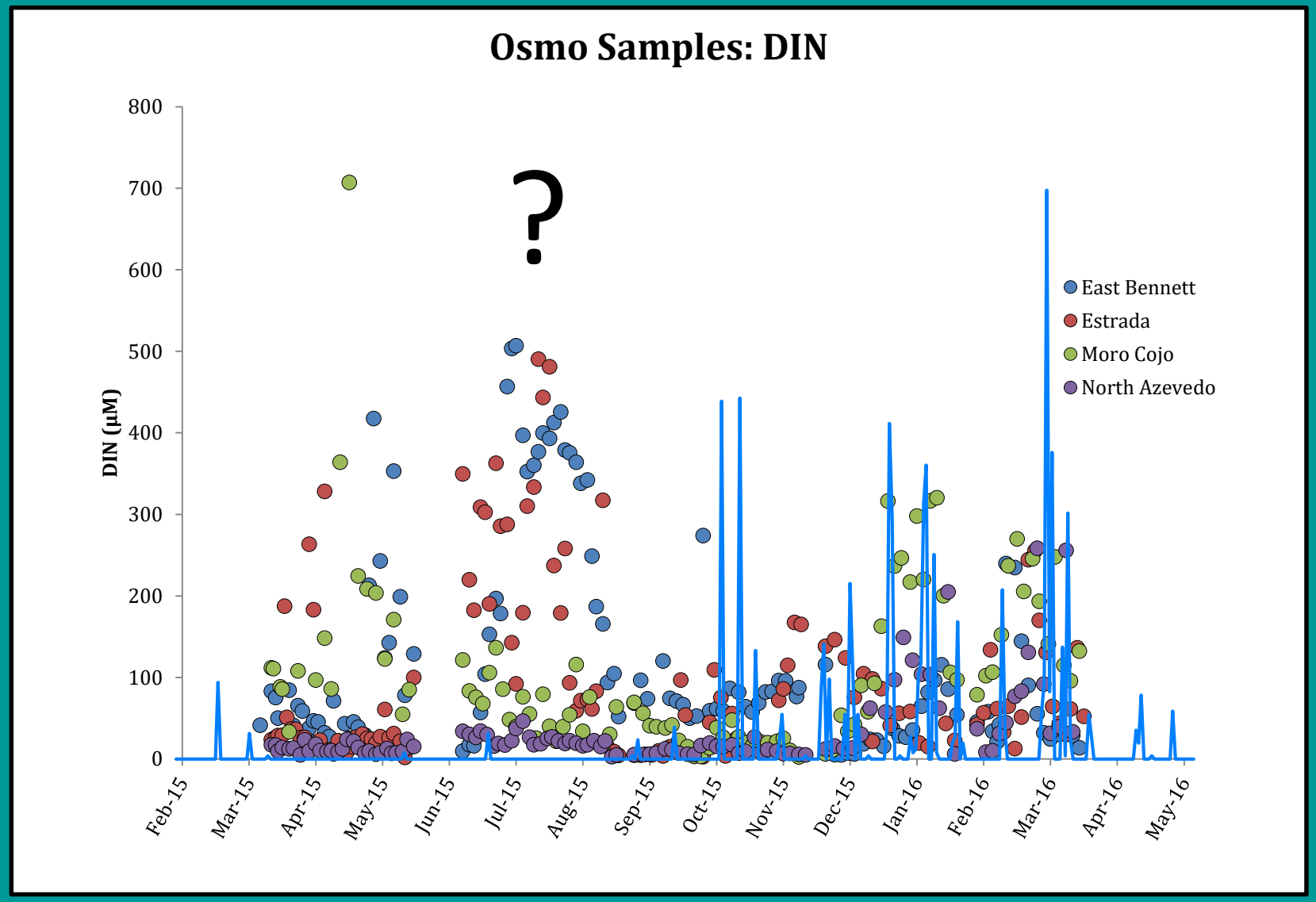
Algae Cores: Grams M^{-2} Each Month

$$M^2 \times \left(\frac{\text{algae (grams)}}{M^2} \right) = \textbf{Total Algae (grams)}$$

RESULTS

Surface Water Nutrients

OsmoSampler: Dissolved Inorganic Nitrogen



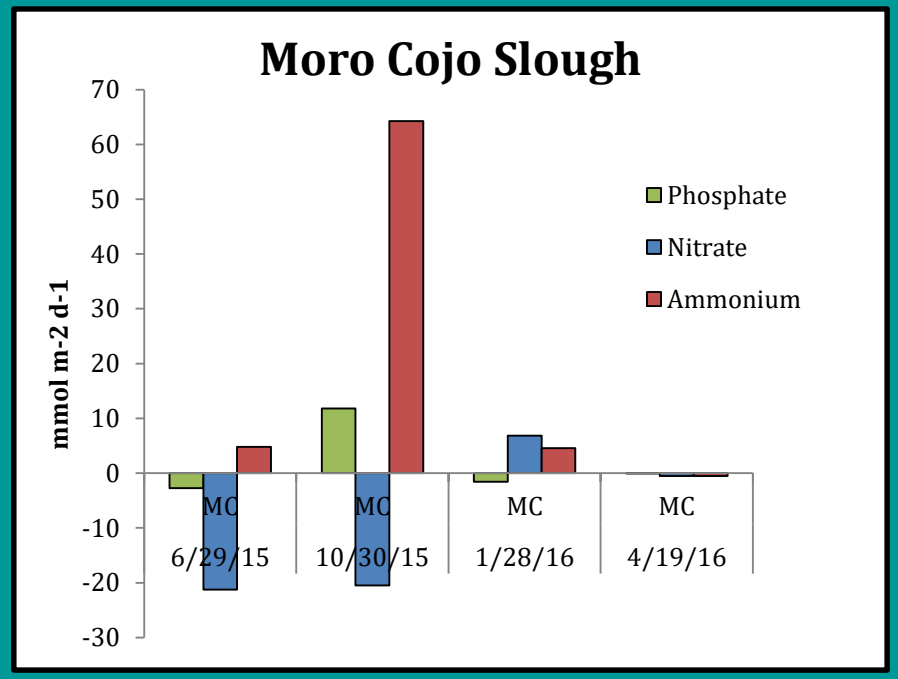
DIN = Ammonium + Nitrate + Nitrite

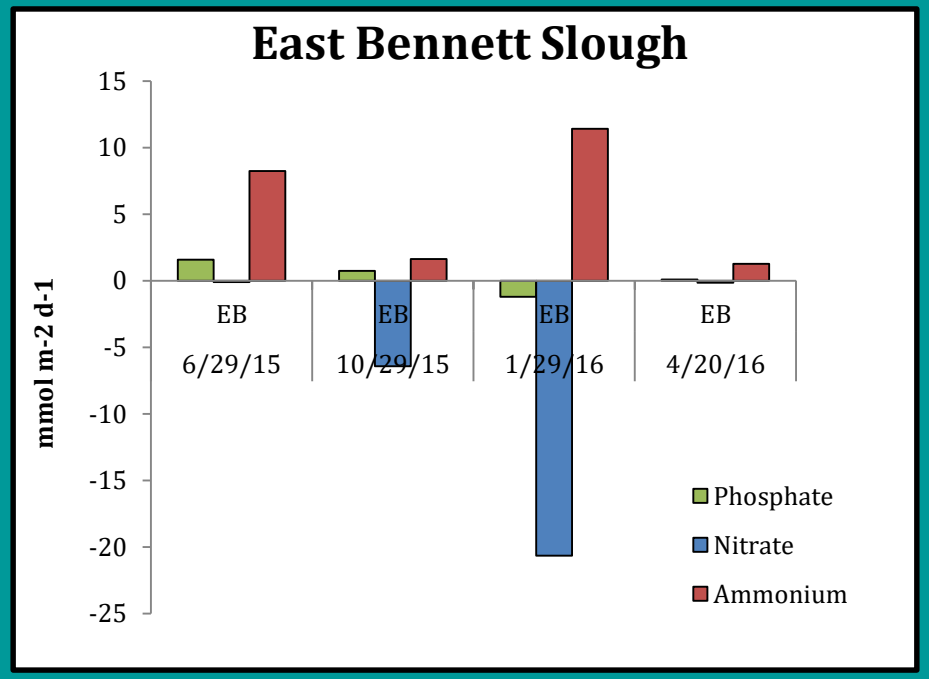
Benthic Flux Measurements

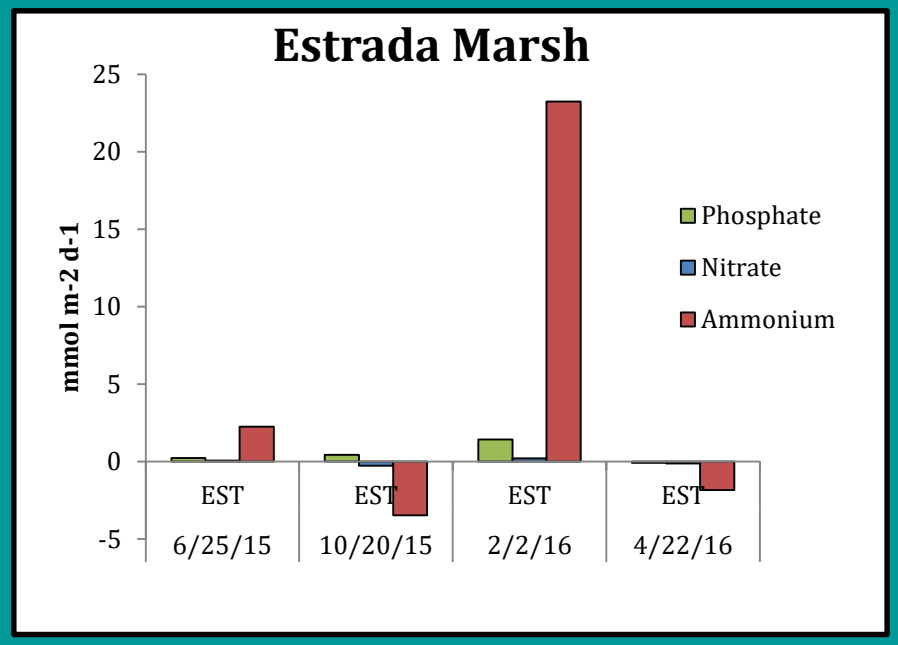
Results

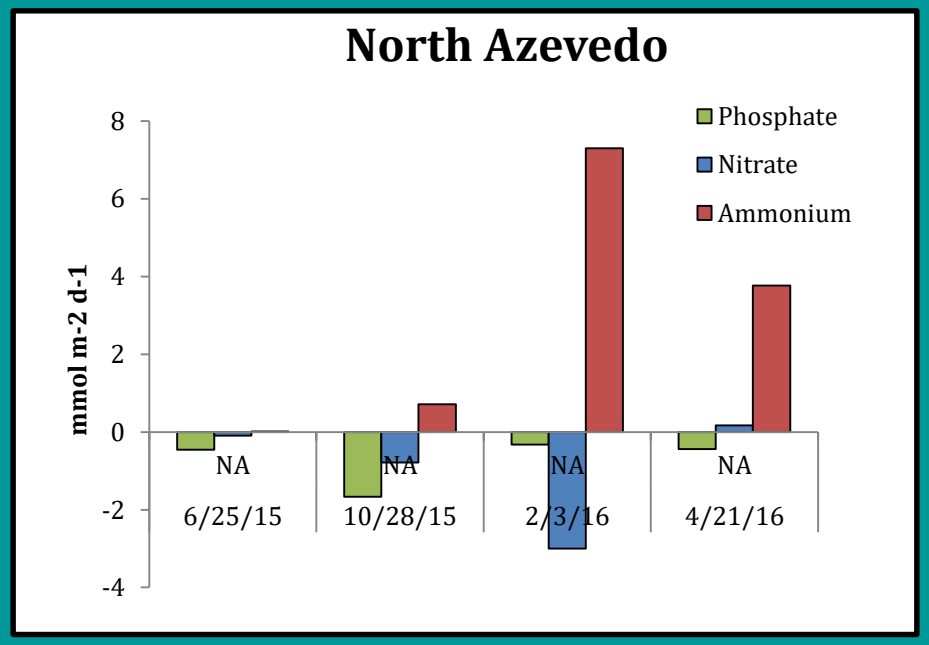
Ammonium

Nitrate









Groundwater Flux

Results

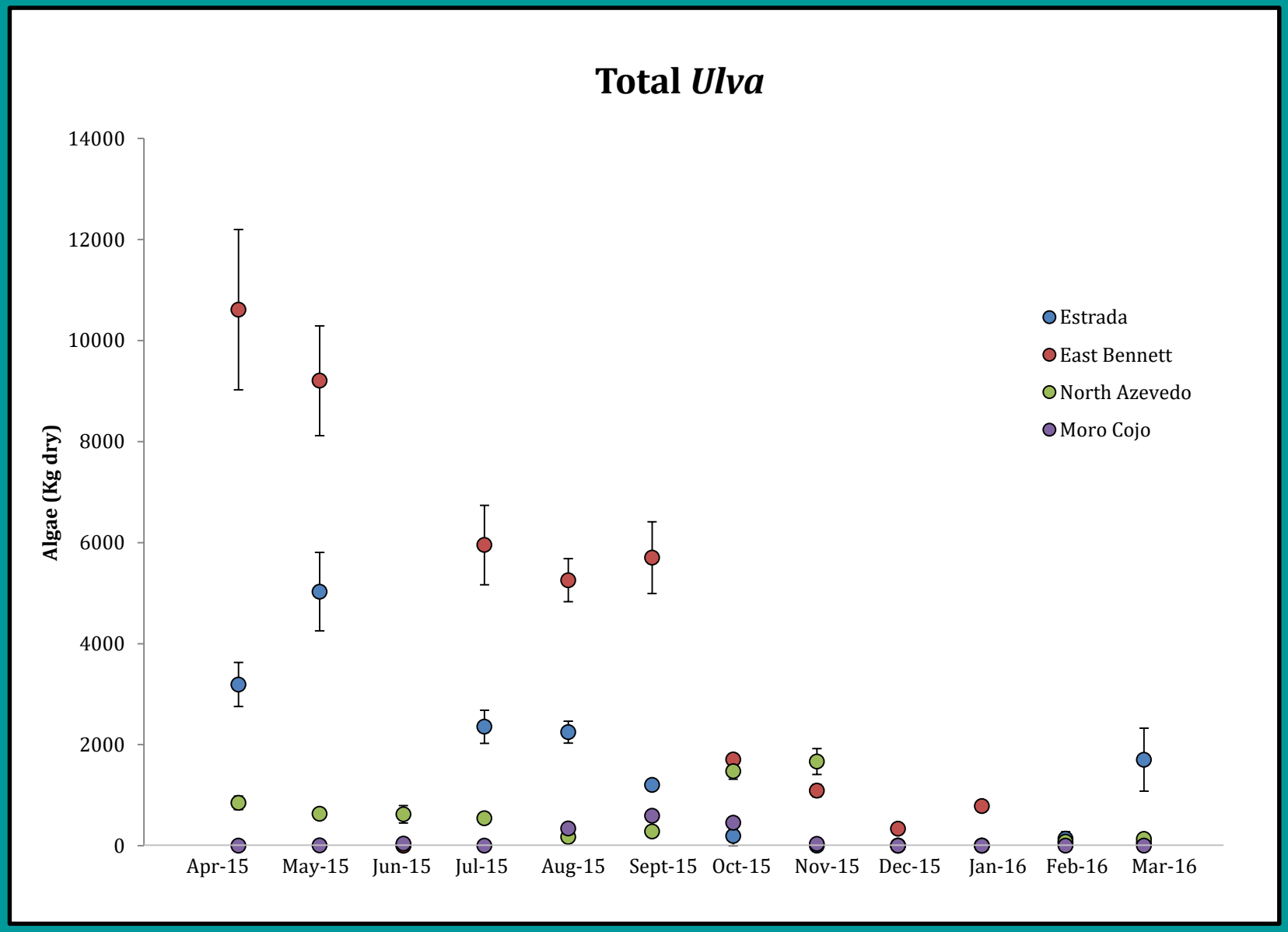
Groundwater Flux		
	September 2015 – Dry Season	**March 2016 – Wet Season**
Moro Cojo Slough	398.64 m^3/day	1304.64 m^3/day
East Bennett Slough	4500.76 m^3/day	4670.6 m^3/day
Estrada Marsh	3730.14 m^3/day	6775.52 m^3/day
North Azevedo Pond	880.6 m^3/day	1610.24 m^3/day

Ulva Cover

East Bennett Slough

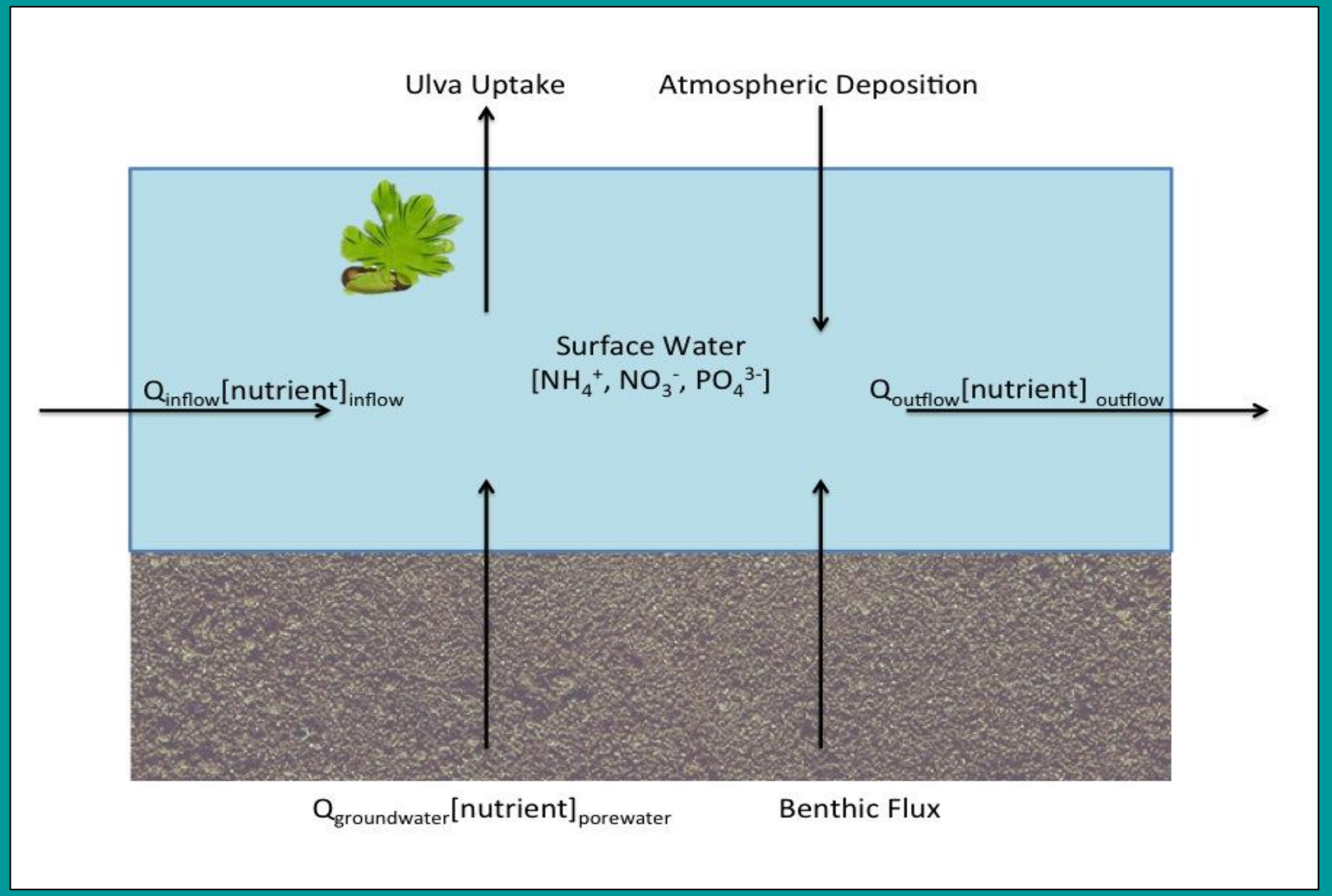
North Azevedo Pond

Total *Ulva*


Total Ulva
Algae (Kg dry)
14000
12000
10000
8000
6000
4000
2000
0
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sept-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Estrada
East Bennett
North Azevedo
Moro Cojo

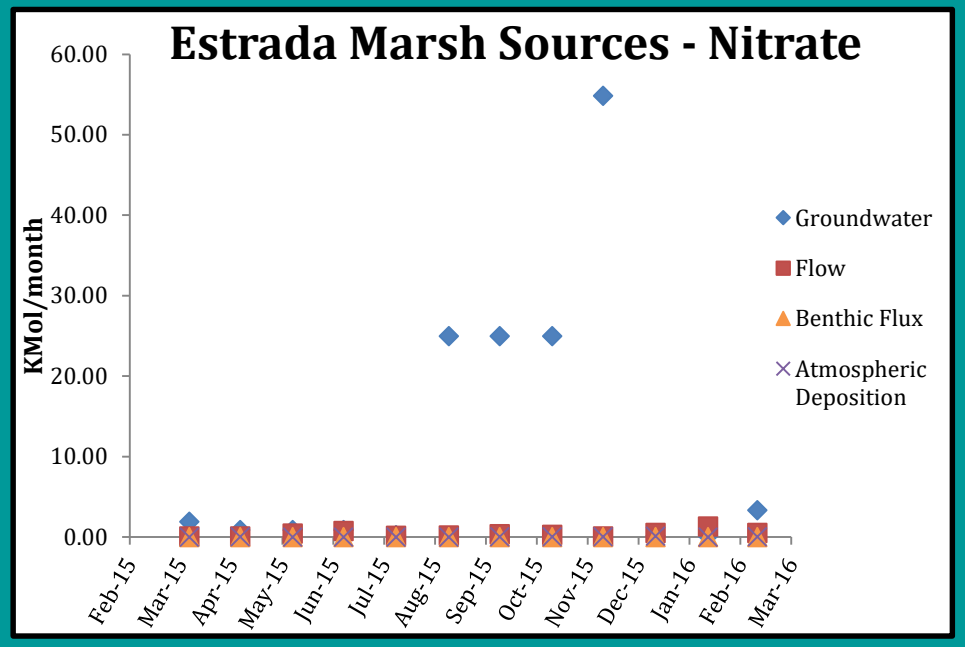
DISCUSSION

Box Model Approach

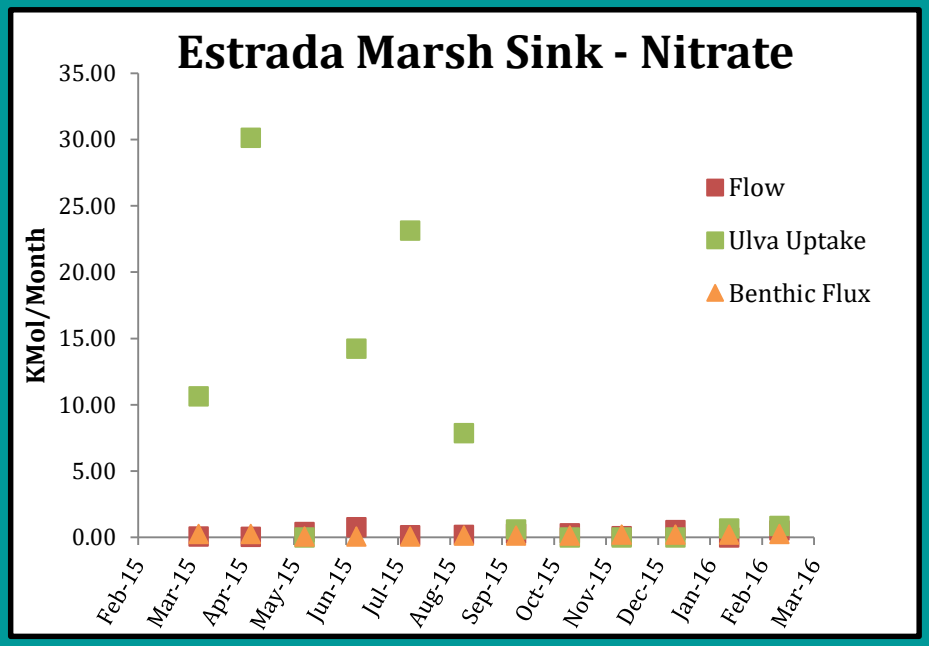


Water Column processes = Sources – Sinks

Box Model: Nutrient Drivers



Main Nitrate Source: **Groundwater**



Main Nitrate Sink: ***Ulva*** **Uptake**

Box Model: Nutrient Drivers

Groundwater Flux		
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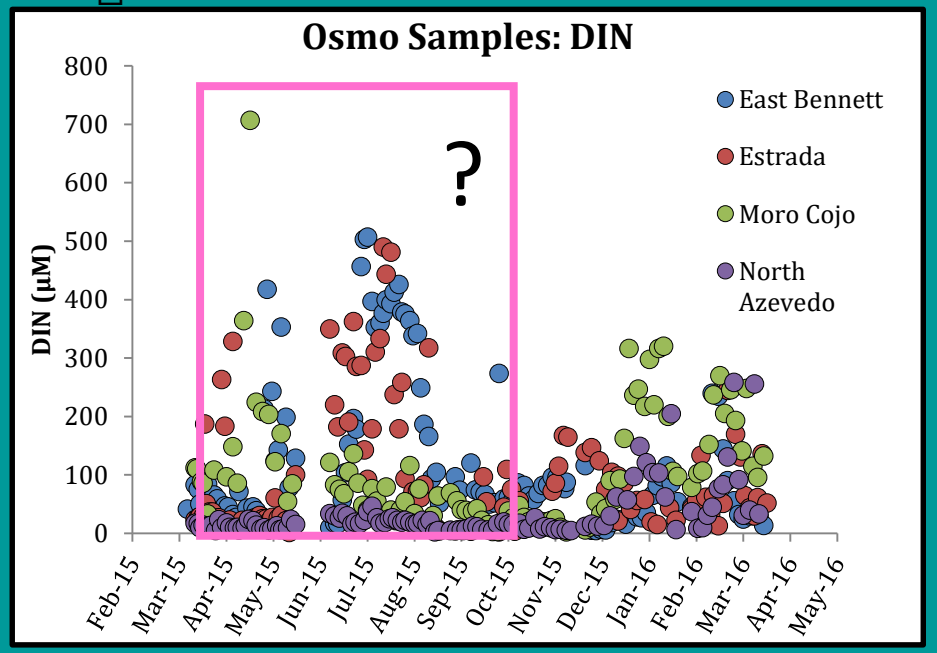
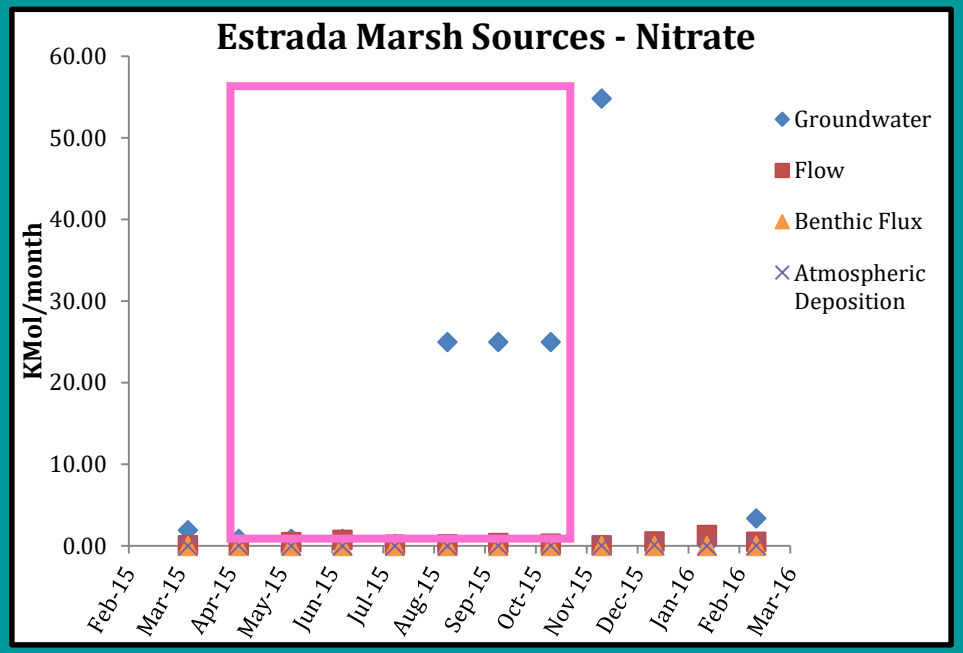




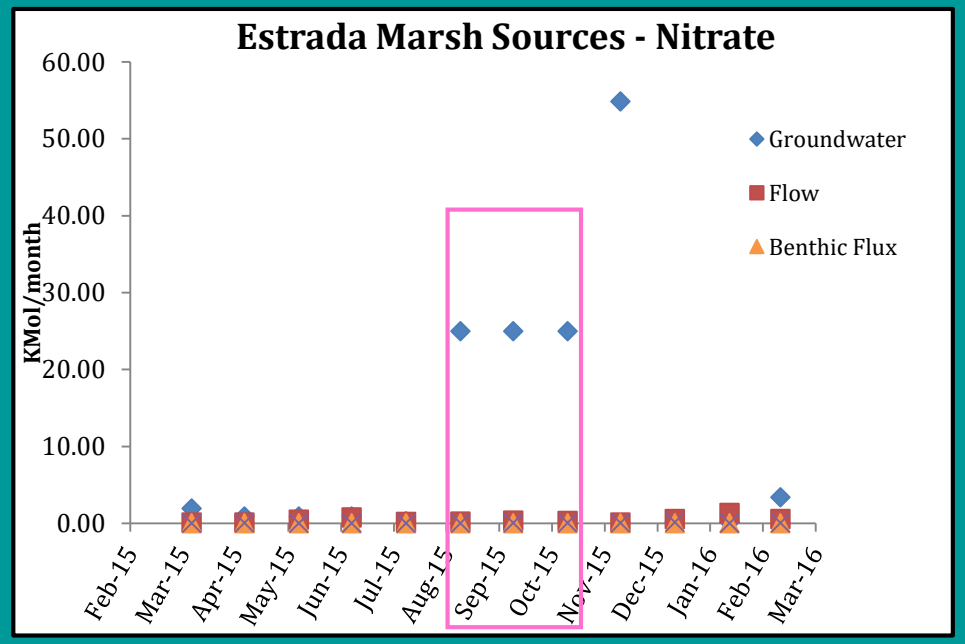
Low Groundwater Flow In Dry Season

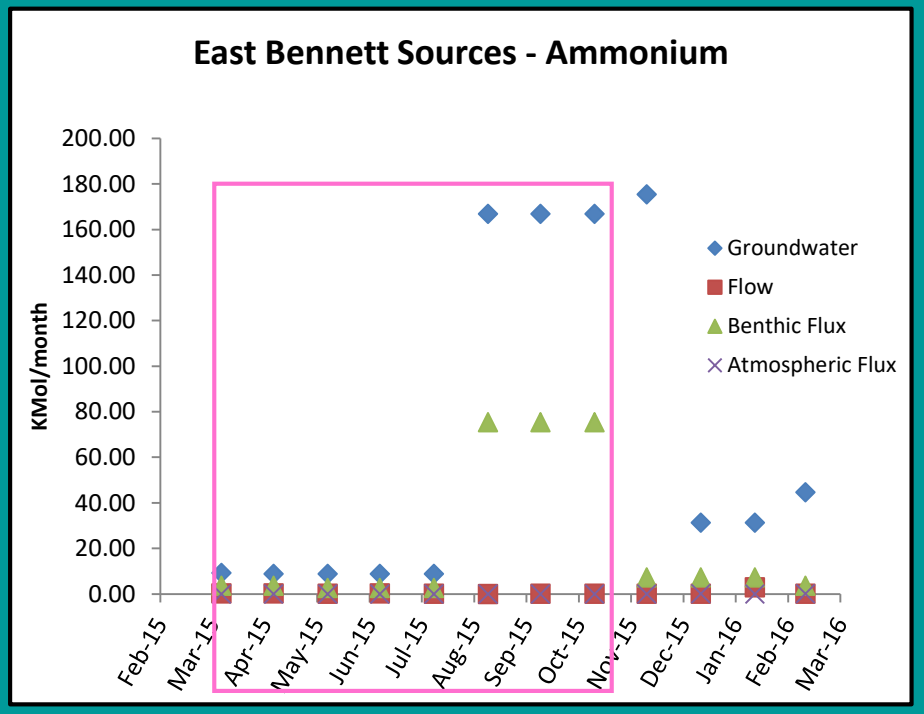
High Nutrient Concentrations In Dry Season

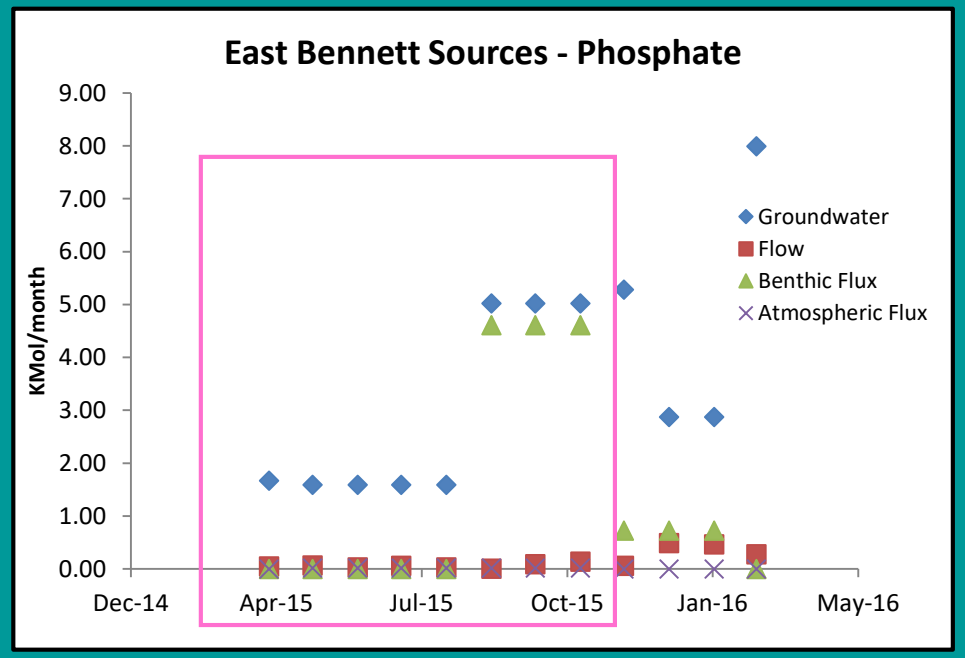
Discussion

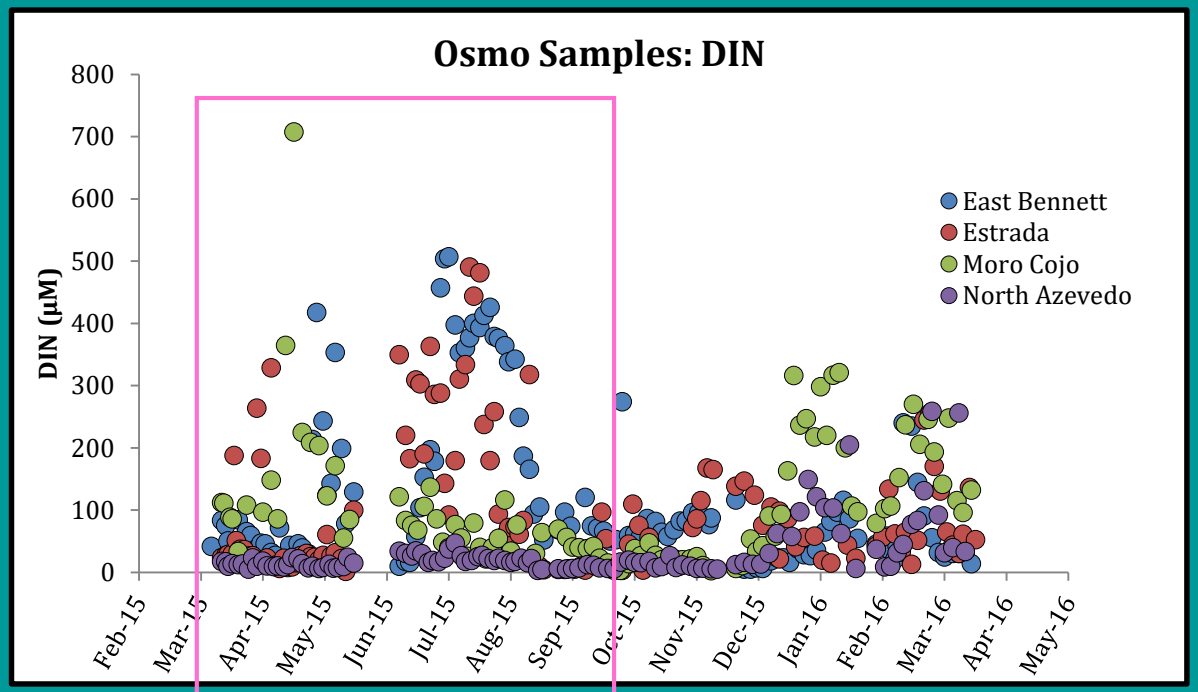
Monthly Averages & Records - **°F** | °C

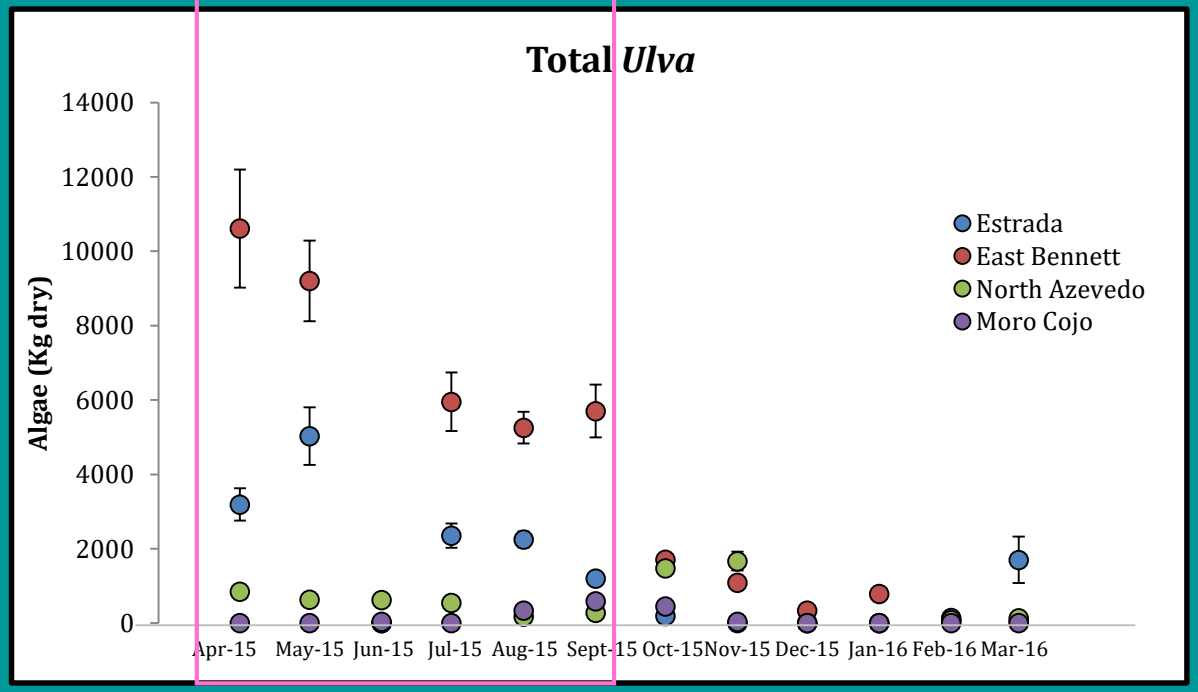
Date	Average Low	Average High	Record Low	Record High	Average Precipitation
January	39°	61°	20° (1949)	81° (1962)	4.46"
February	42°	63°	24° (1989)	85° (1986)	4.84"
March	44°	64°	28° (1966)	87° (2005)	3.63"
April	46°	68°	31° (1953)	98° (2004)	1.69"
May	49°	69°	31° (1978)	98° (1997)	0.6"
June	52°	71°	38° (1952)	103° (1973)	0.11"
July	54°	72°	40° (1948)	103° (1959)	0.01"
August	54°	72°	41° (1963)	98° (1993)	0.02"
September	53°	74°	37° (1950)	105° (1971)	0.21"
October	48°	72°	29° (1949)	106° (1987)	1.1"
November	43°	67°	25° (1991)	93° (1956)	2.74"
December	39°	61°	12° (1990)	84° (1958)	4.25"


Estrada Marsh Sources - Nitrate
KMol/month
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Groundwater
Flow
Benthic Flux


East Bennett Sources - Ammonium
KMol/month
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Groundwater
Flow
Benthic Flux
Atmospheric Flux


East Bennett Sources - Phosphate
KMol/month
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Dec-14
Apr-15
Jul-15
Oct-15
Jan-16
May-16
Groundwater
Flow
Benthic Flux
Atmospheric Flux


Osmo Samples: DIN
DIN (µM)
800
700
600
500
400
300
200
100
0
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Apr-16
May-16
East Bennett
Estrada
Moro Cojo
North Azevedo


Total Ulva
Algae (Kg dry)
14000
12000
10000
8000
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4000
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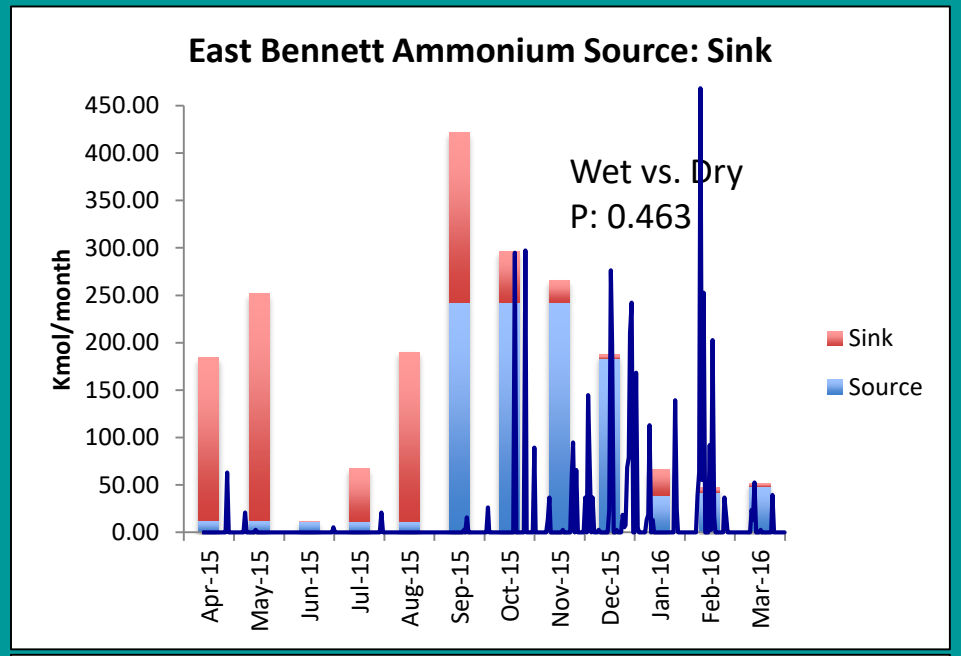
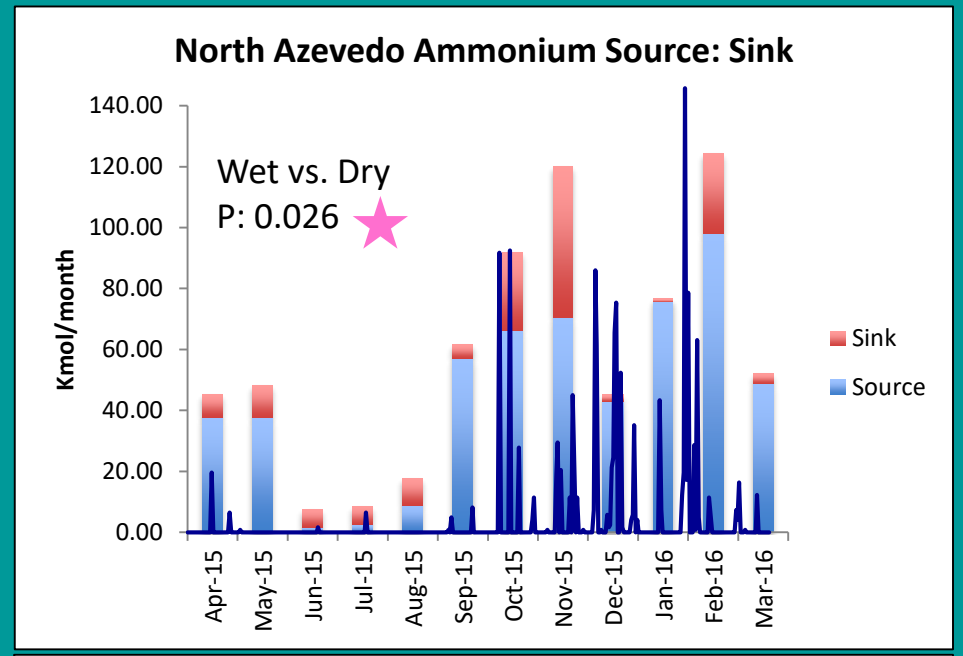
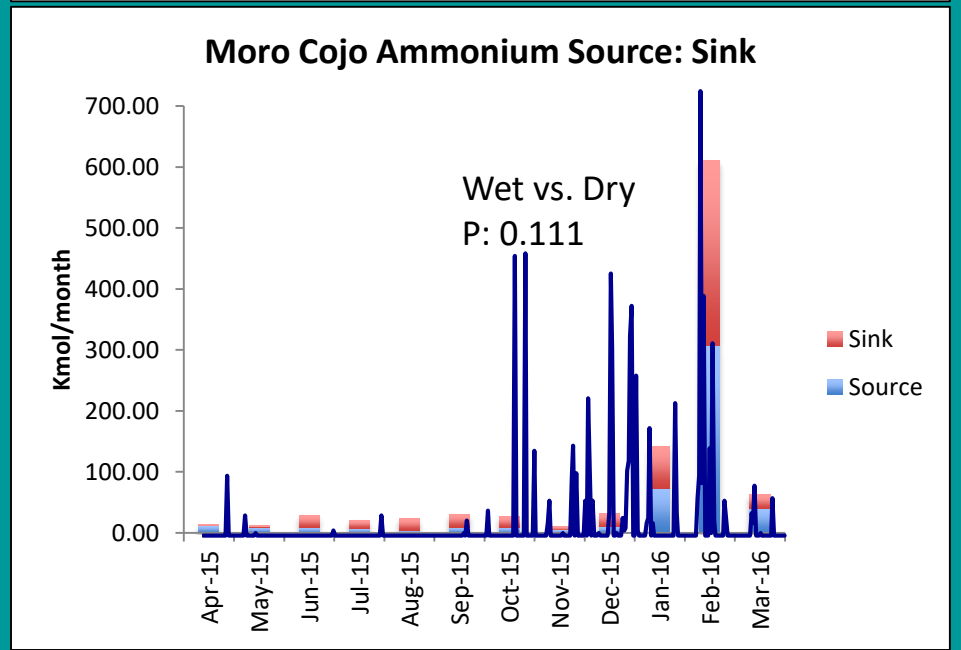
Aug-15
Sept-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Estrada
East Bennett
North Azevedo
Moro Cojo

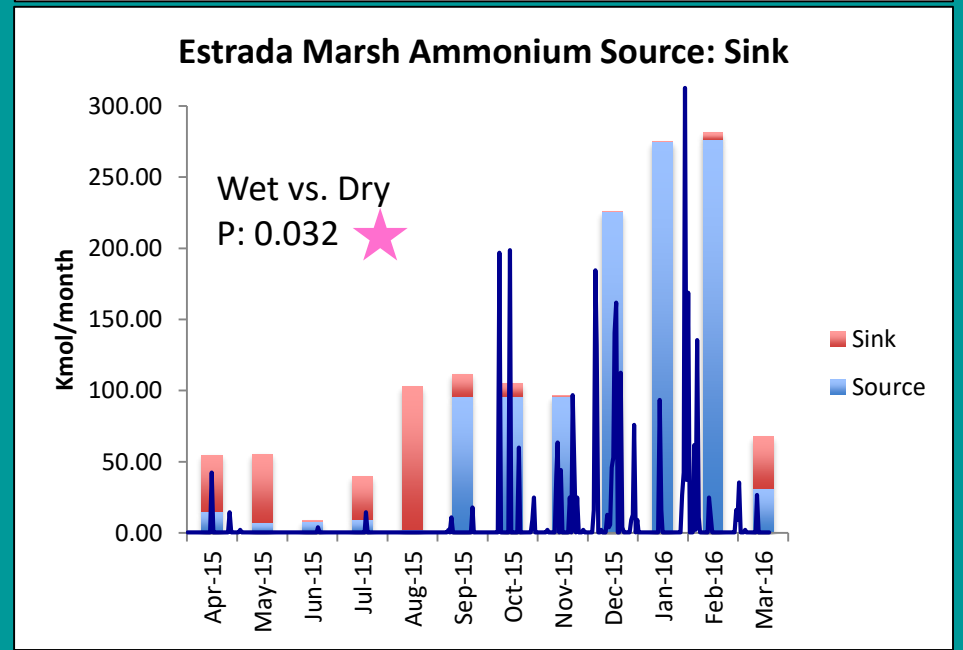
Box Model: Nutrient Loading Source: Sink

Discussion

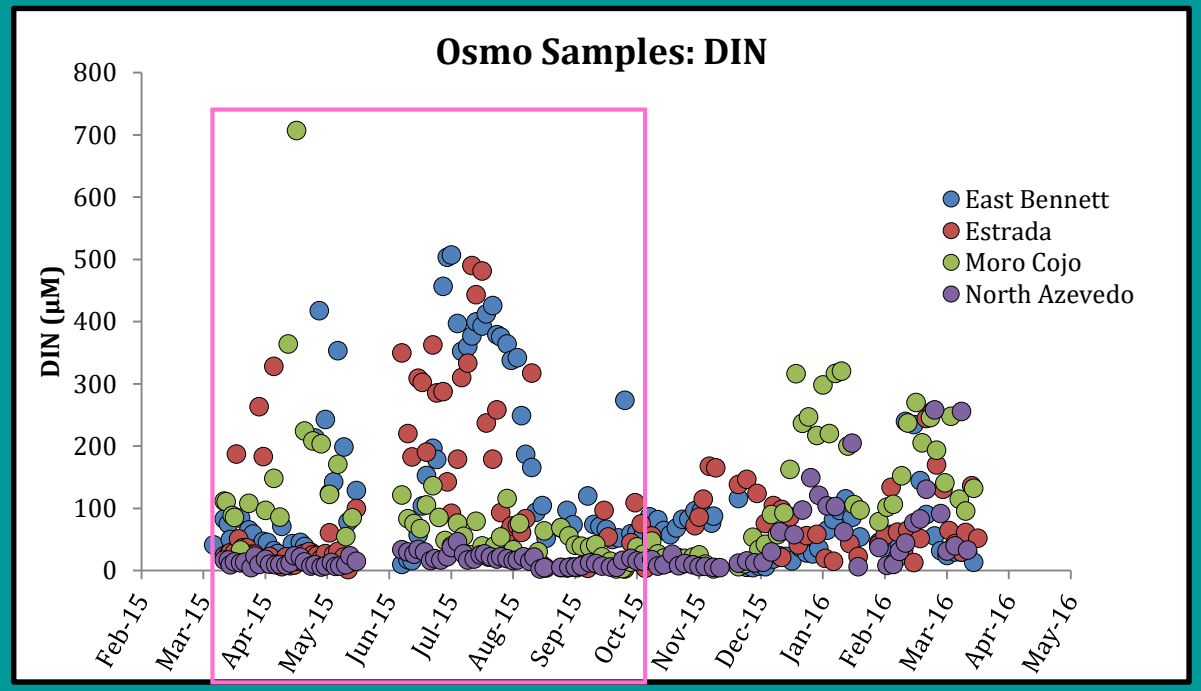








Dry Season Nutrient Concentrations Can Be Higher Than Wet Season Nutrient Concentrations



Wet Season/Dry Season Dichotomy

	Sources	**Sinks**
Wet Season	Surface Water Flow	Surface Water Flow
Dry Season	Groundwater Flux	Ulva Uptake

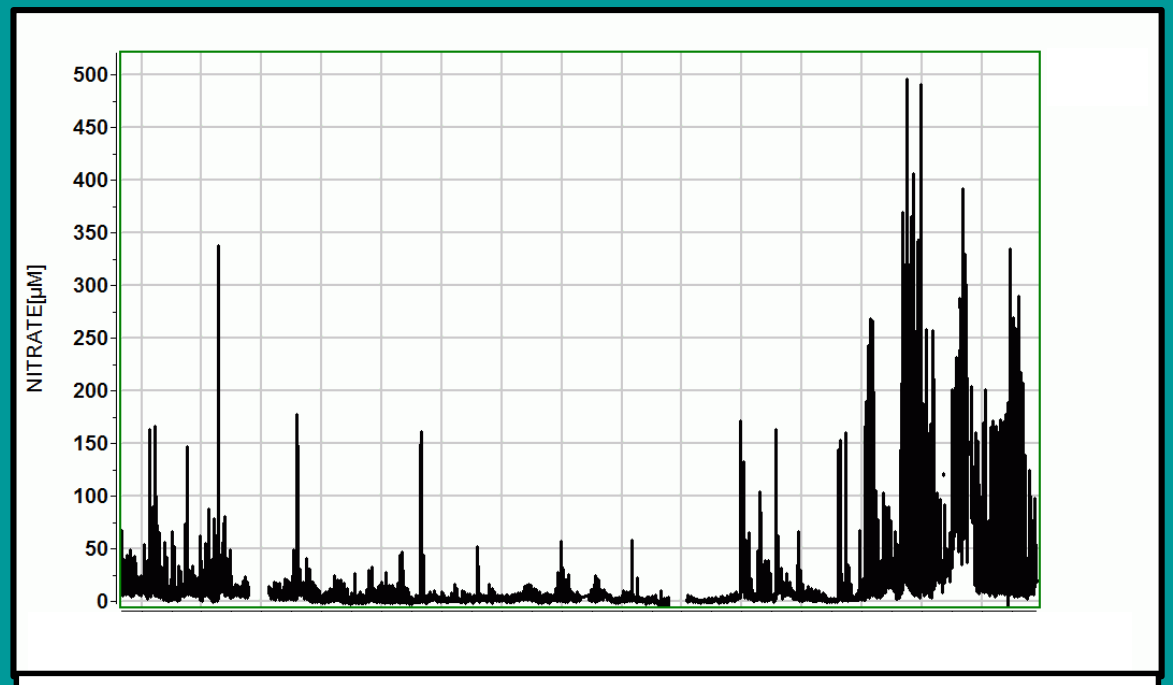
Ulva Rapidly Responds to Variability in Nutrient Concentrations → Dominant Feature In These Regions

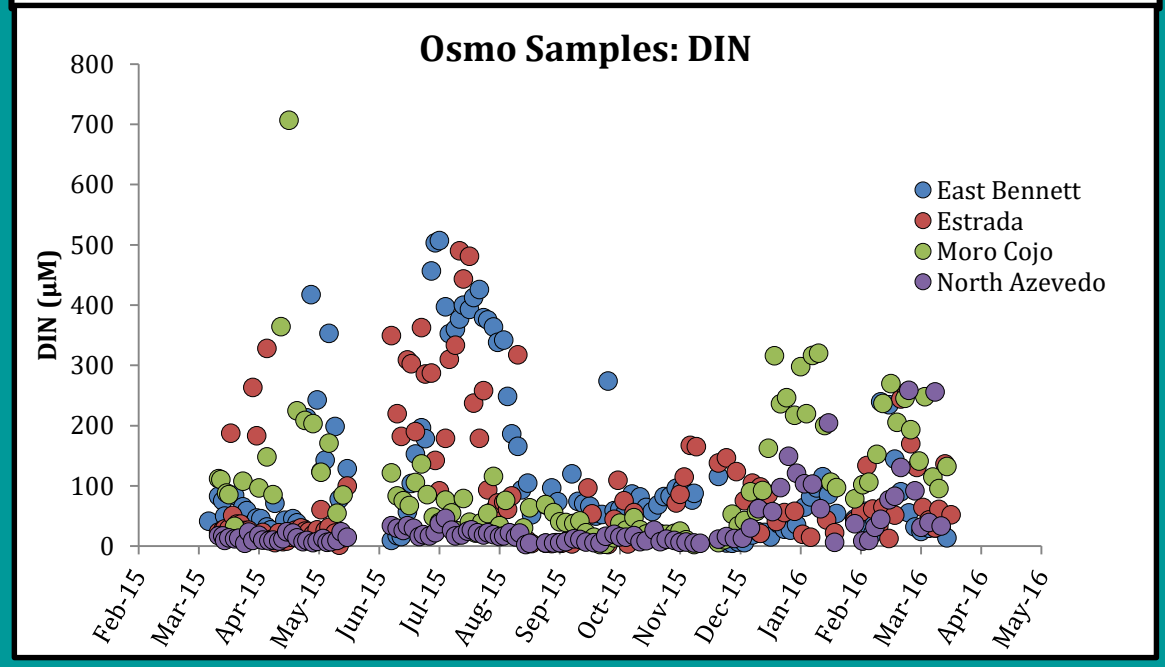
- Decrease Marsh Stability
- Increase Erosion

Wasson *et al.*, 2017

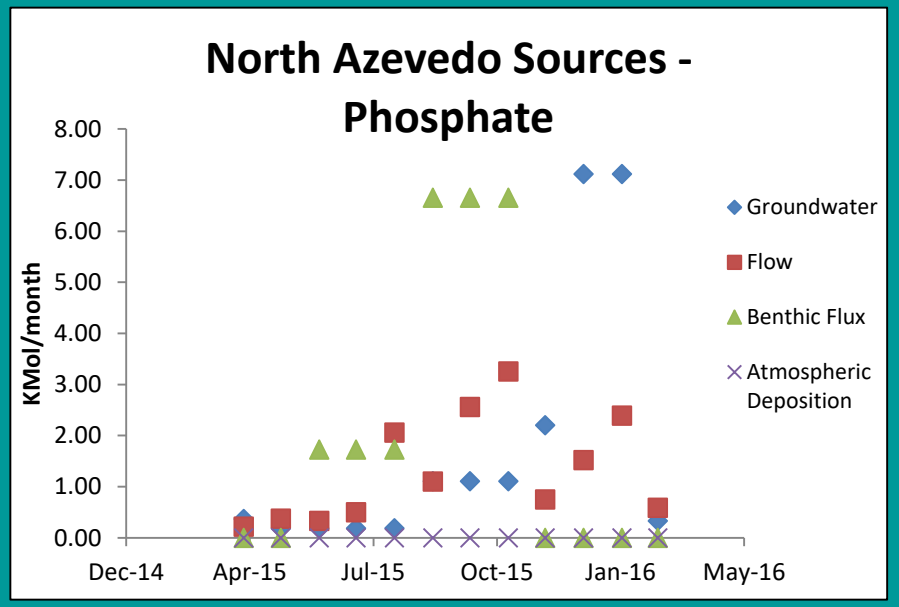
The End!

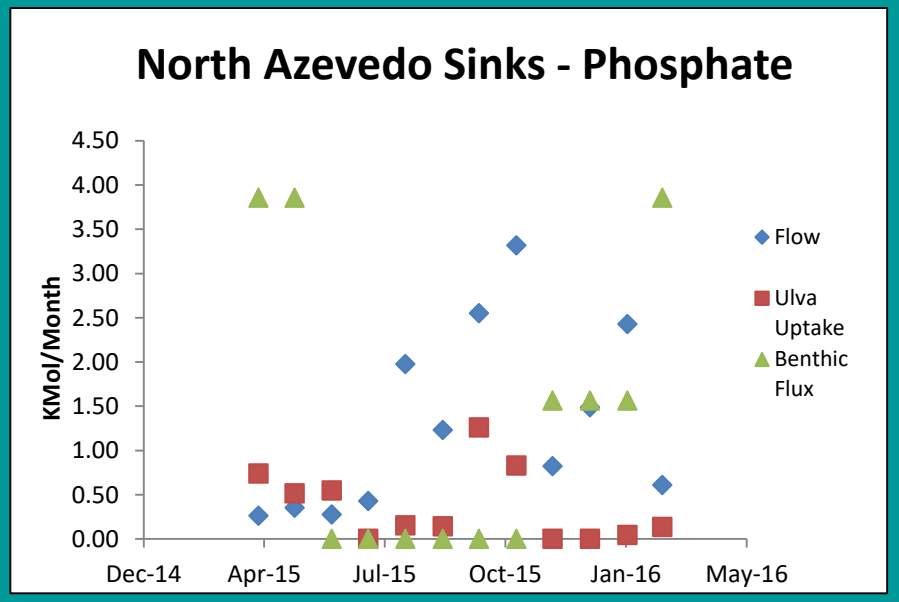
Discussion

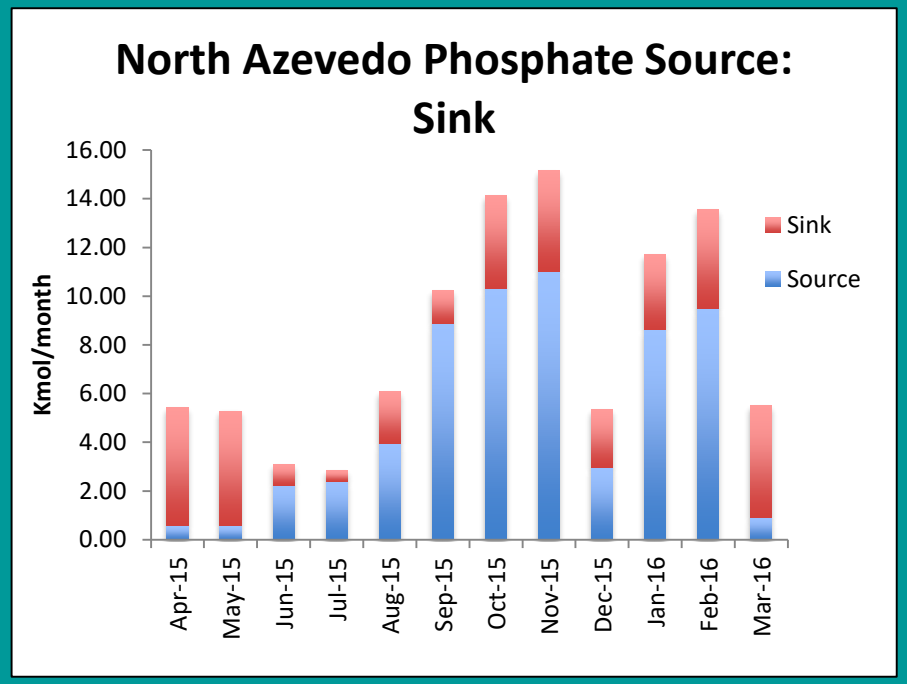

NITRATE[µM]
500
450
400
350
300
250
200
150
100
50
0


Osmo Samples: DIN
DIN (µM)
800
700
600
500
400
300
200
100
0
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Apr-16
May-16
East Bennett
Estrada
Moro Cojo
North Azevedo

Box Model: Summary







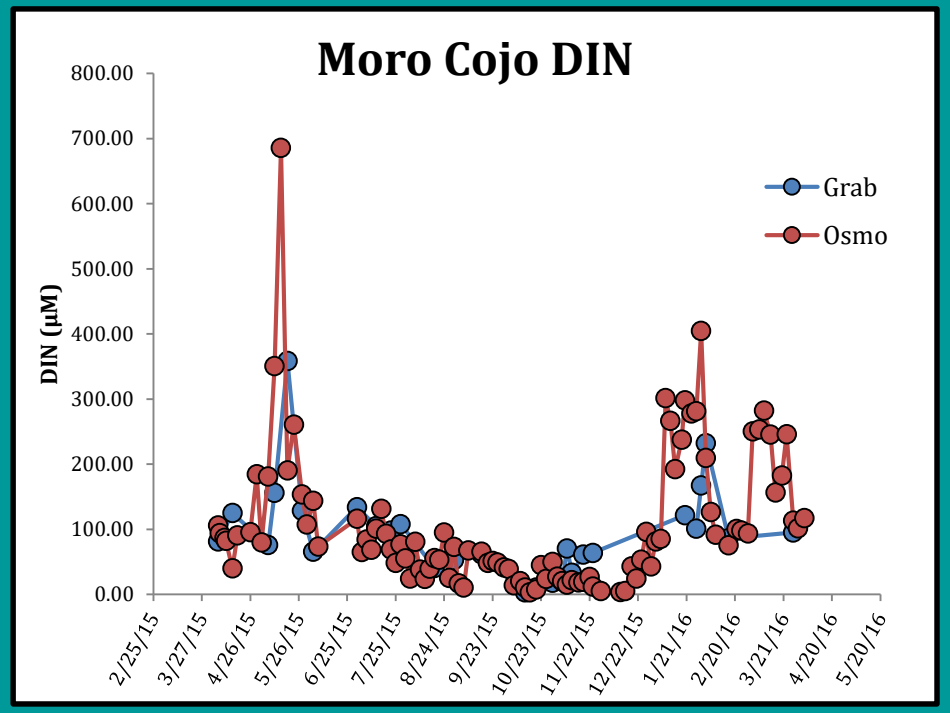
Box Model: Source & Sink Sum

Site	Month	Source (Kmol)	Sink (Kmol)	Nutrient	Source - Sink	Yearly Sum
East Bennett	Apr-15	12.97	171.85	Ammonium	-158.88	155.75
	May-15	12.54	239.50		-226.95	
	Jun-15	11.46	0.14		11.32	
	Jul-15	11.55	55.21		-43.66	
	Aug-15	11.42	178.71		-167.29	
	Sep-15	242.23	179.66		62.57	
	Oct-15	242.37	53.59		188.78	
	Nov-15	242.39	23.25		219.15	
	Dec-15	182.89	4.25		178.64	
	Jan-16	38.72	27.91		10.81	
	Feb-16	41.47	5.36		36.10	
	Mar-16	48.38	3.22		45.16	

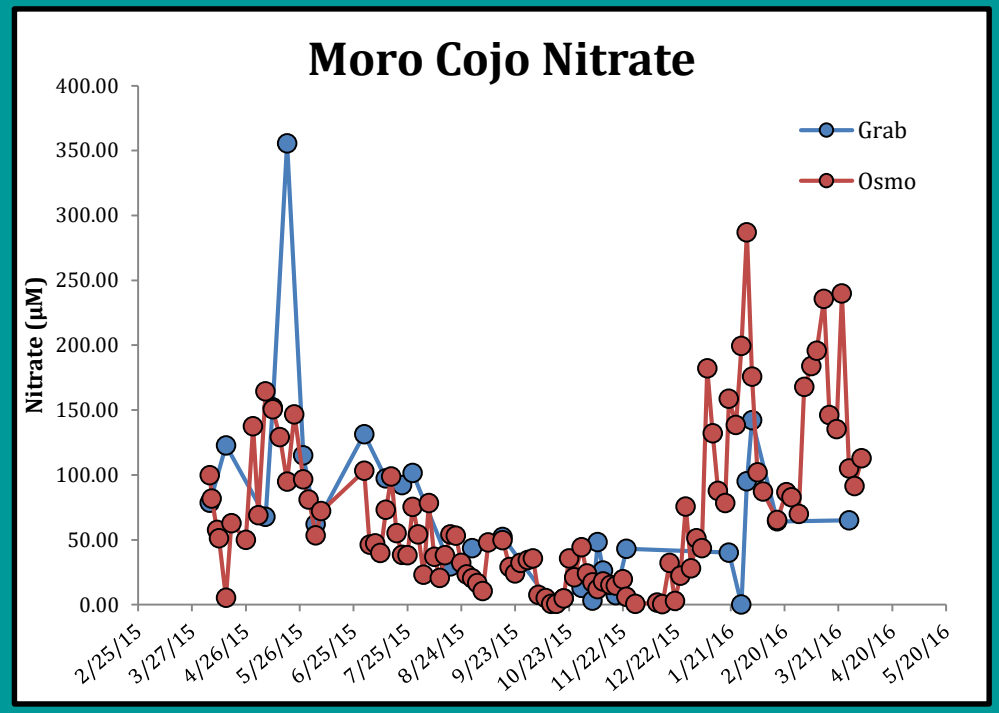
Steady State: Sources = Sinks

Never Reached 0, Never Reached Steady State

Osmo Sampler vs. Grab sampler



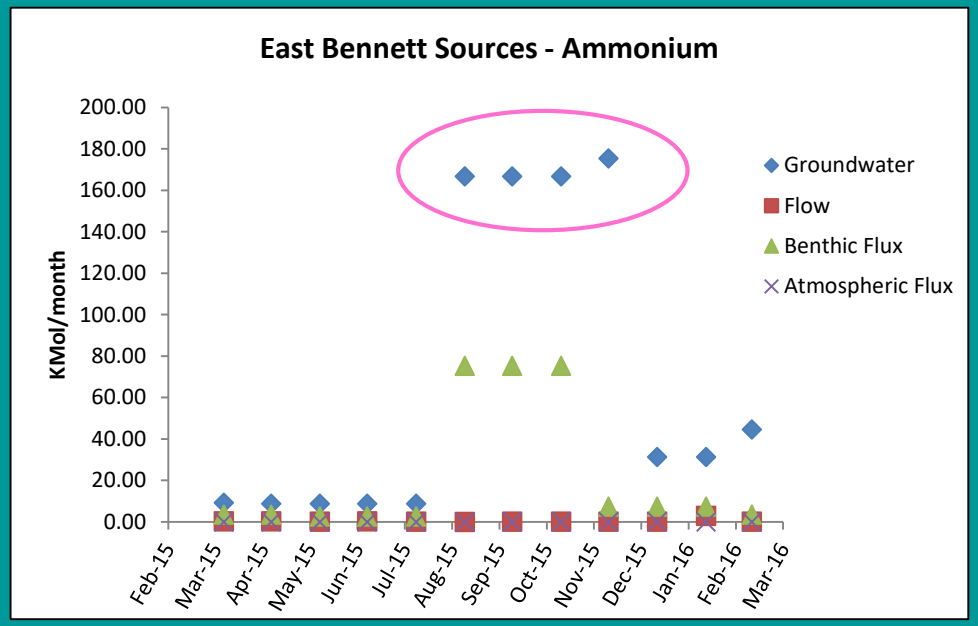
Osmo Sampler
Nitrate vs. Grab
Sample DIN
$R^2 = 0.17$

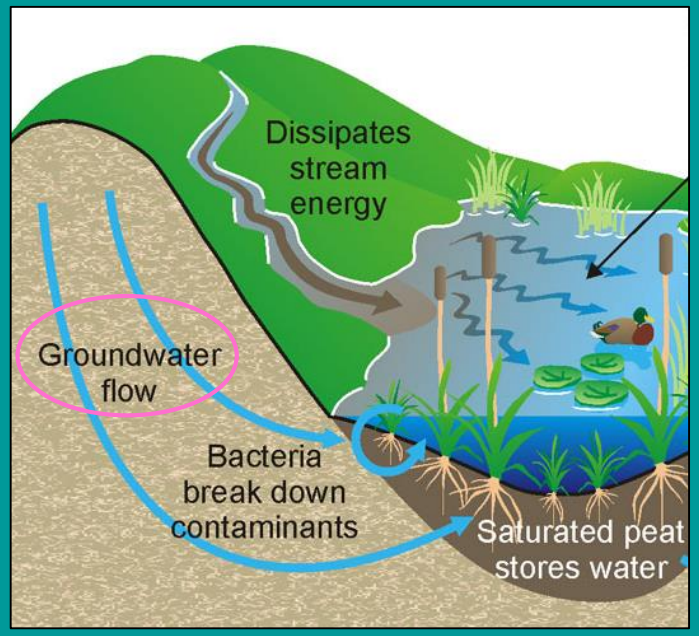


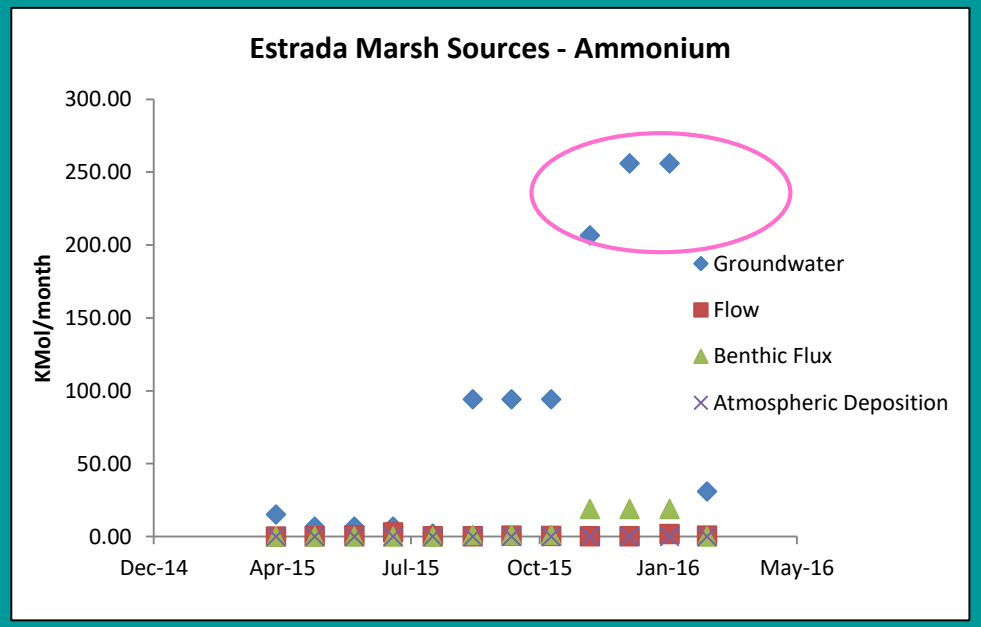
Osmo Sampler
Nitrate vs. Grab
Sample Nitrate
$R^2 = 0.05$

Interesting Finding → Future Work

Conclusion





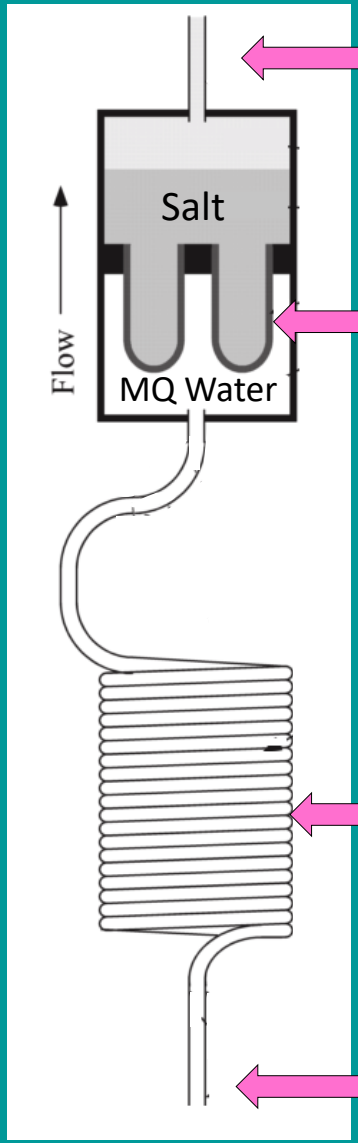


Nutrient Monitoring in Surface Waters:

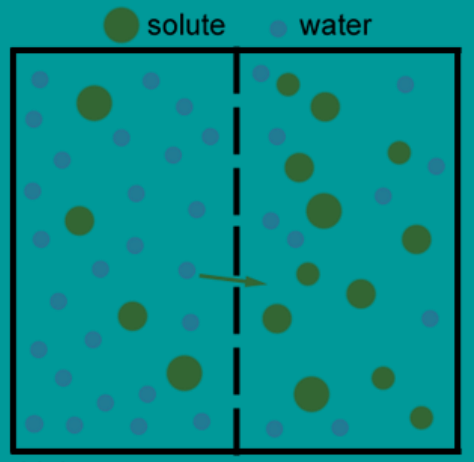
Methods

OsmoSamplers

Continuous

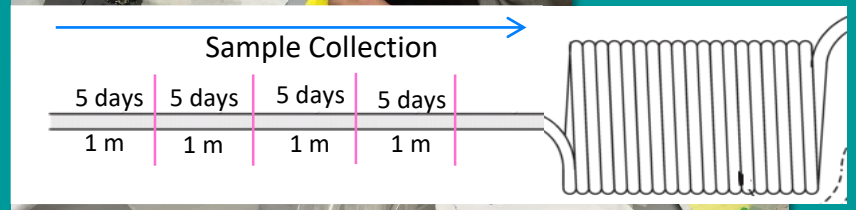


Jannasch *et al.,* 2004



Nutrient Monitoring in Surface Waters:

OsmoSamplers



Porewater Nutrient Concentrations:

Methods

Porewater: Diffusive Flux

Seasonal

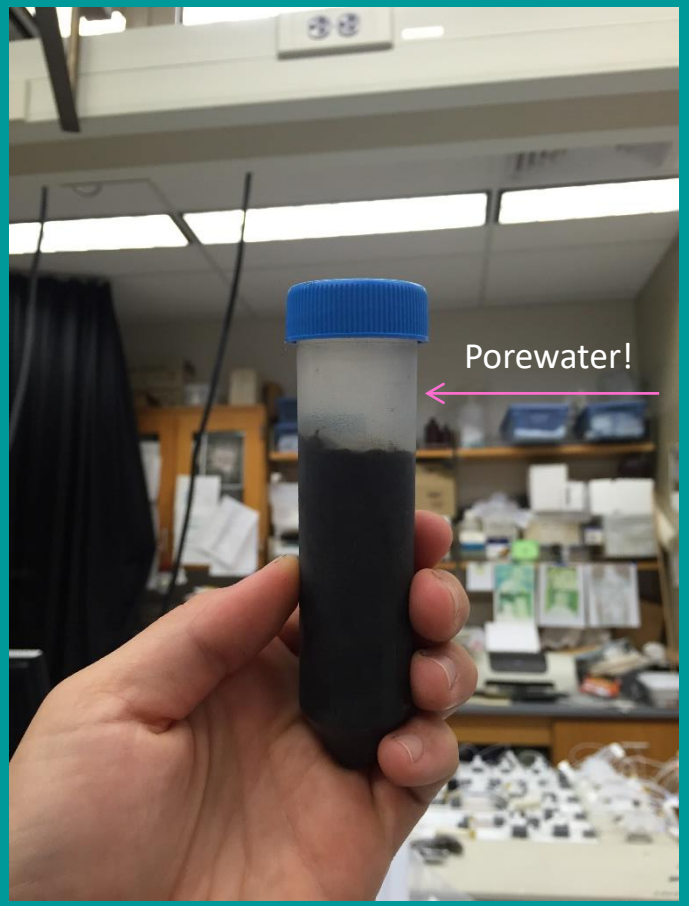
$$F_D = -(\phi D_w/\theta^2)\,(\delta C/\delta_x)$$

F= flux of solute with concentration C at depth x

Θ = tortuosity (dimensionless)

Φ = porosity

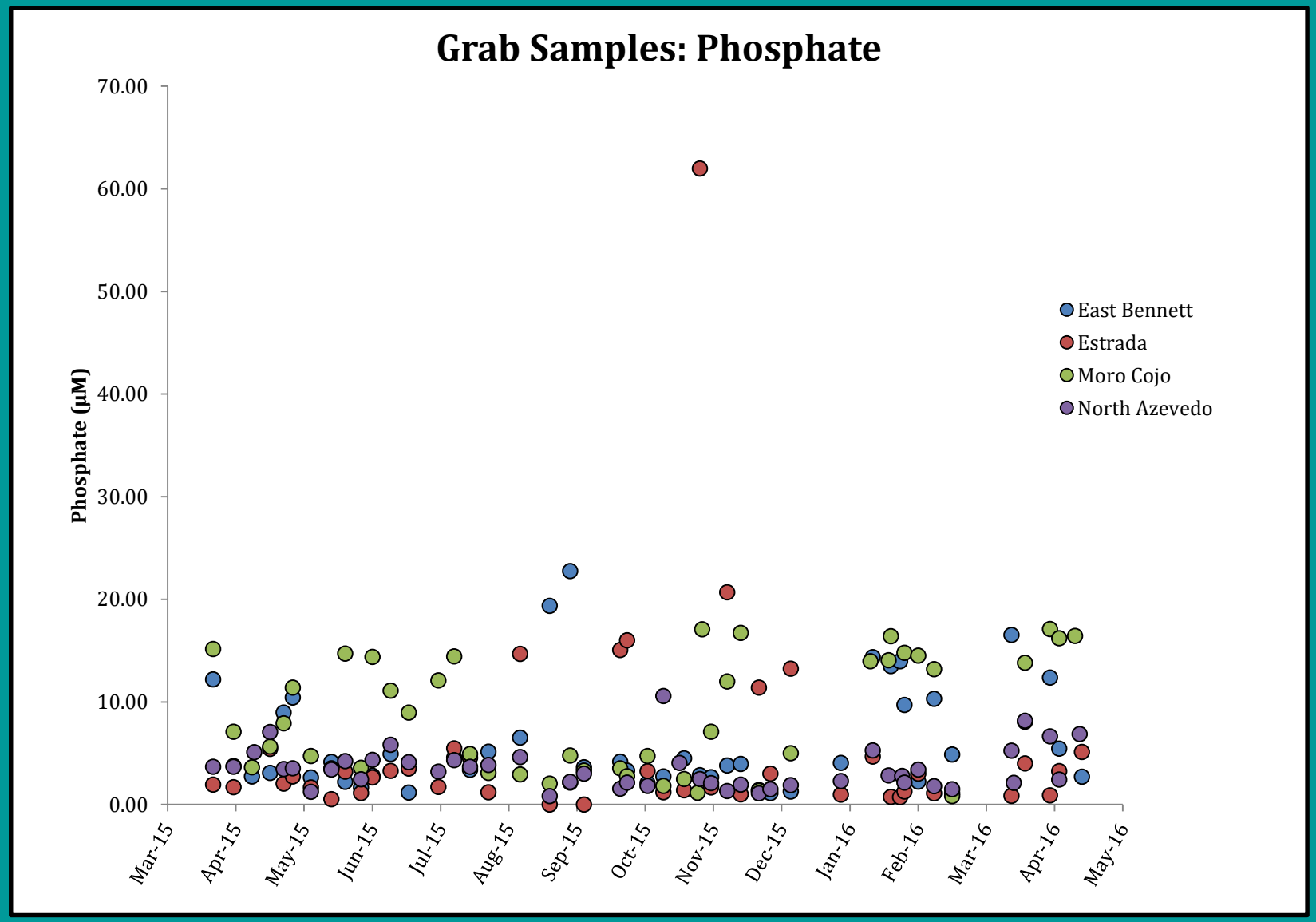
D_w = molecular diffusion coefficient



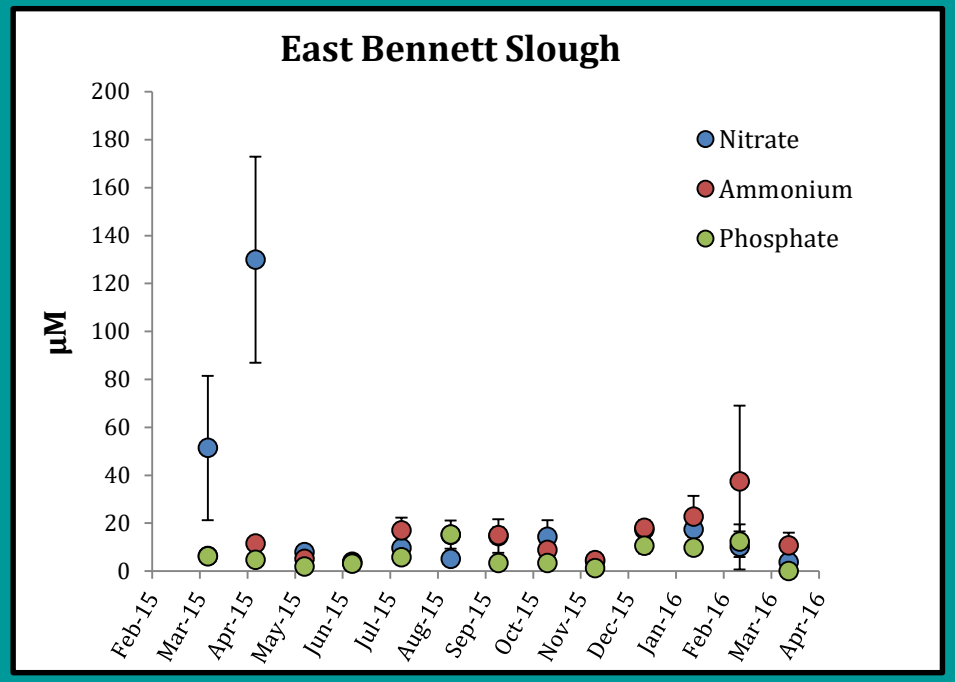
Diffusive Flux Measurements

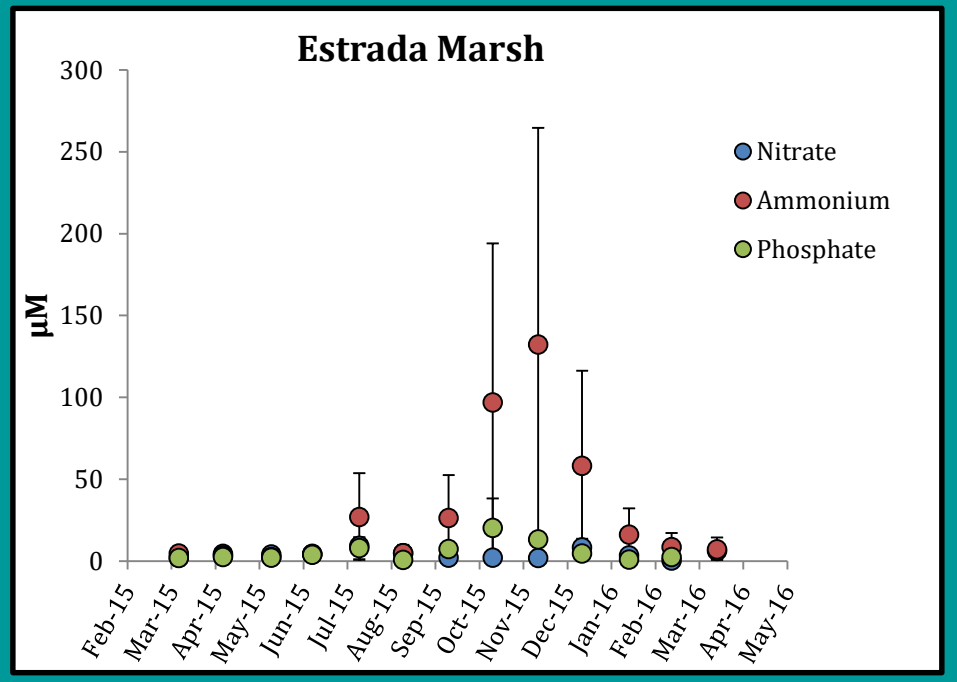
		Phosphate µmol/m2/day	Nitrate µmol/m2/day	Ammonium µmol/m2/day
East Bennett	Summer 2015	3.57	3.72	33.40
	Fall 2015	16.81	107.31	590.52
	Winter 2016	6.05	234.02	92.51
	Spring 2016	22.35	★ 0.50	142.83
Estrada Marsh	Summer 2015	-1.17	-78.66	45.20
	Fall 2015	31.66	138.97	523.17
	Winter 2016	34.10	★ -0.59	646.15
	Spring 2016	51.15	-73.91	81.81
Moro Cojo	Summer 2015	3.27	-0.85	21.58
	Fall 2015	-0.49	76.50	420.98
	Winter 2016	2.95	★ -37.66	99.90
	Spring 2016	0.25	-18.72	63.48
North Azevedo	Summer 2015	0.47	-0.18	1.21
	Fall 2015	4.63	0.14	101.78
	Winter 2016	18.71	★ -2.15	188.55
	Spring 2016	2.32	0.40	20.16

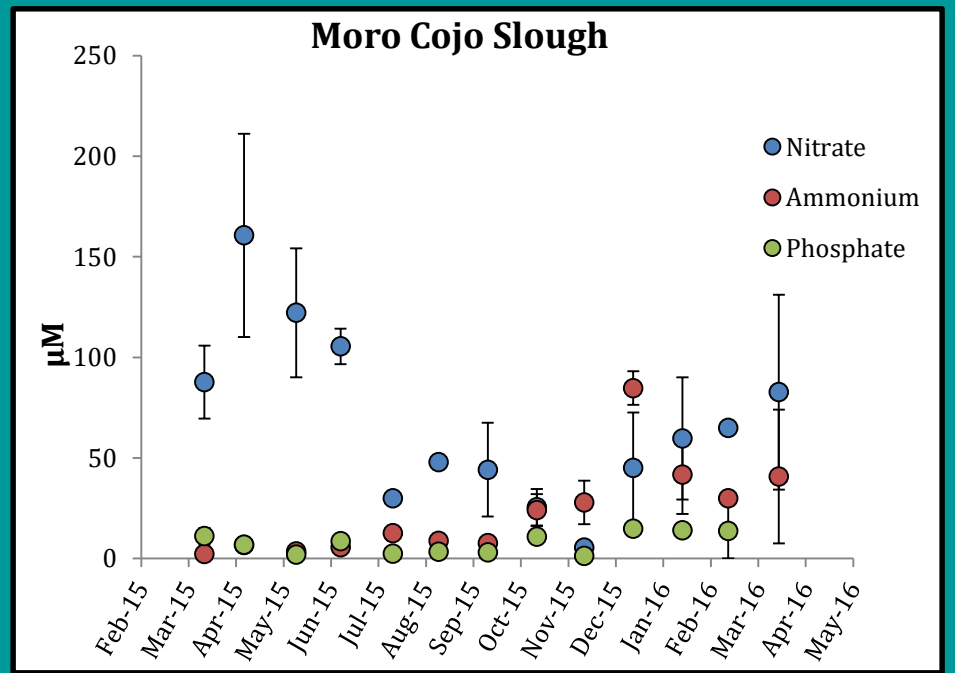
Surface Water Nutrients
Grab Samples: Phosphate

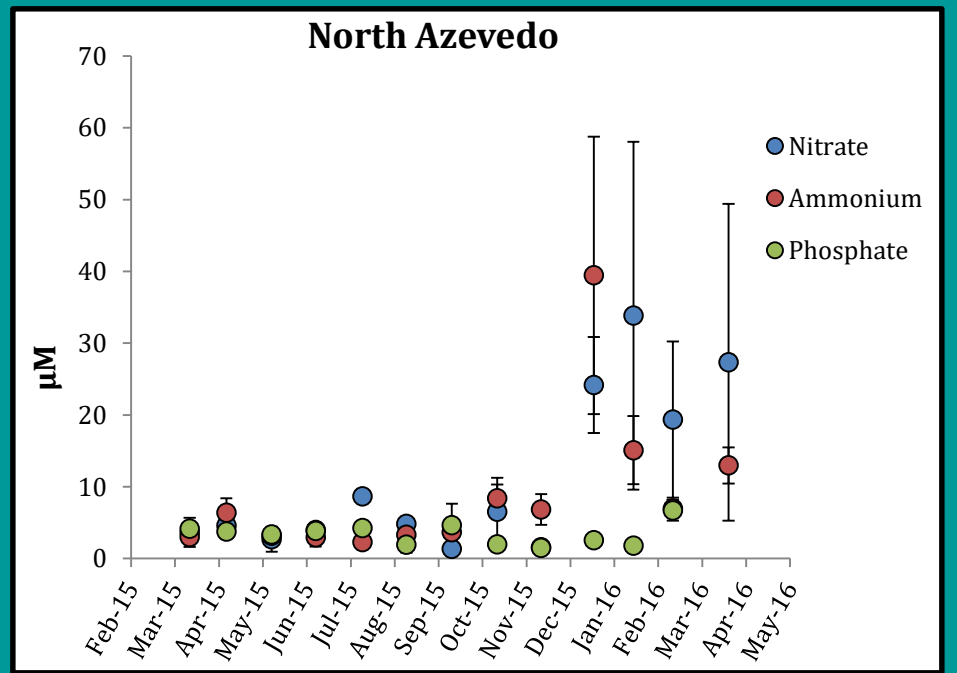


Surface Water Nutrients (mean grab samples)

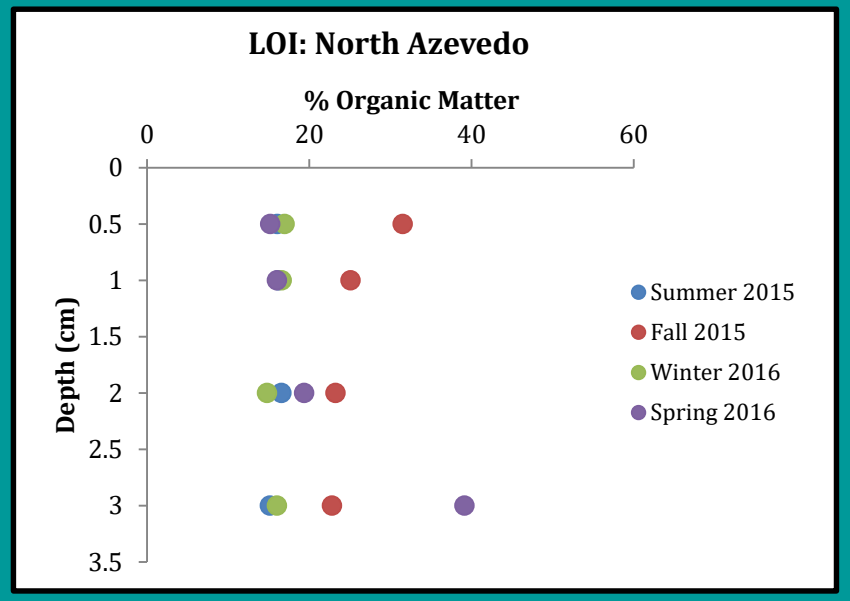


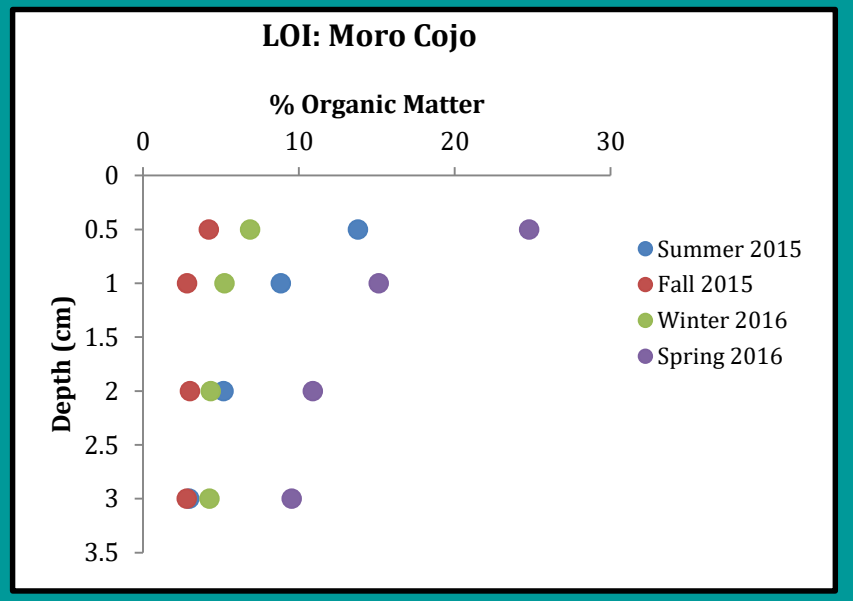


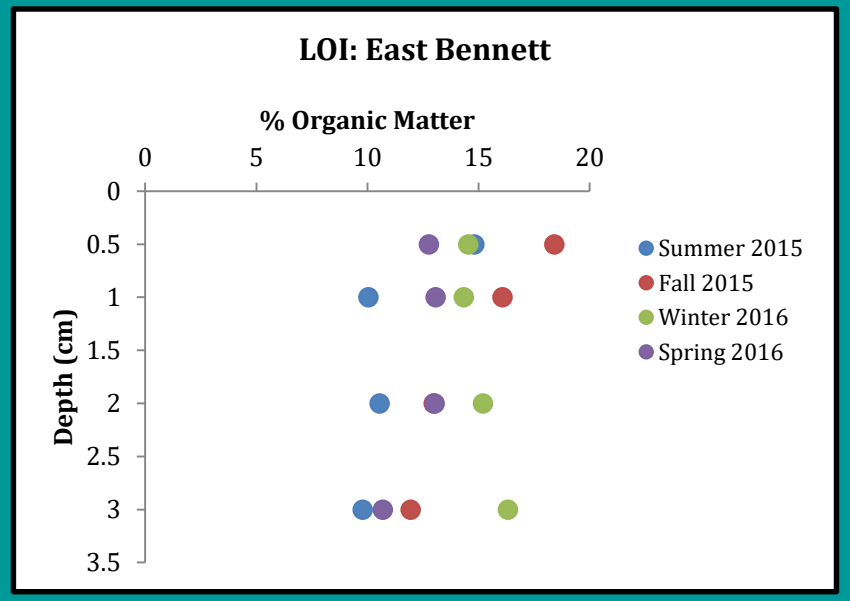


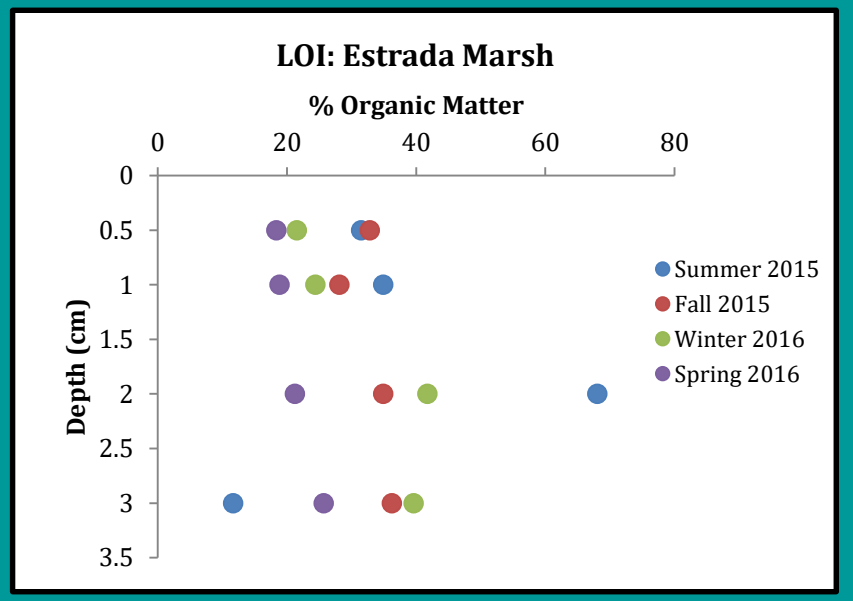


Sediment Organic Carbon Cores



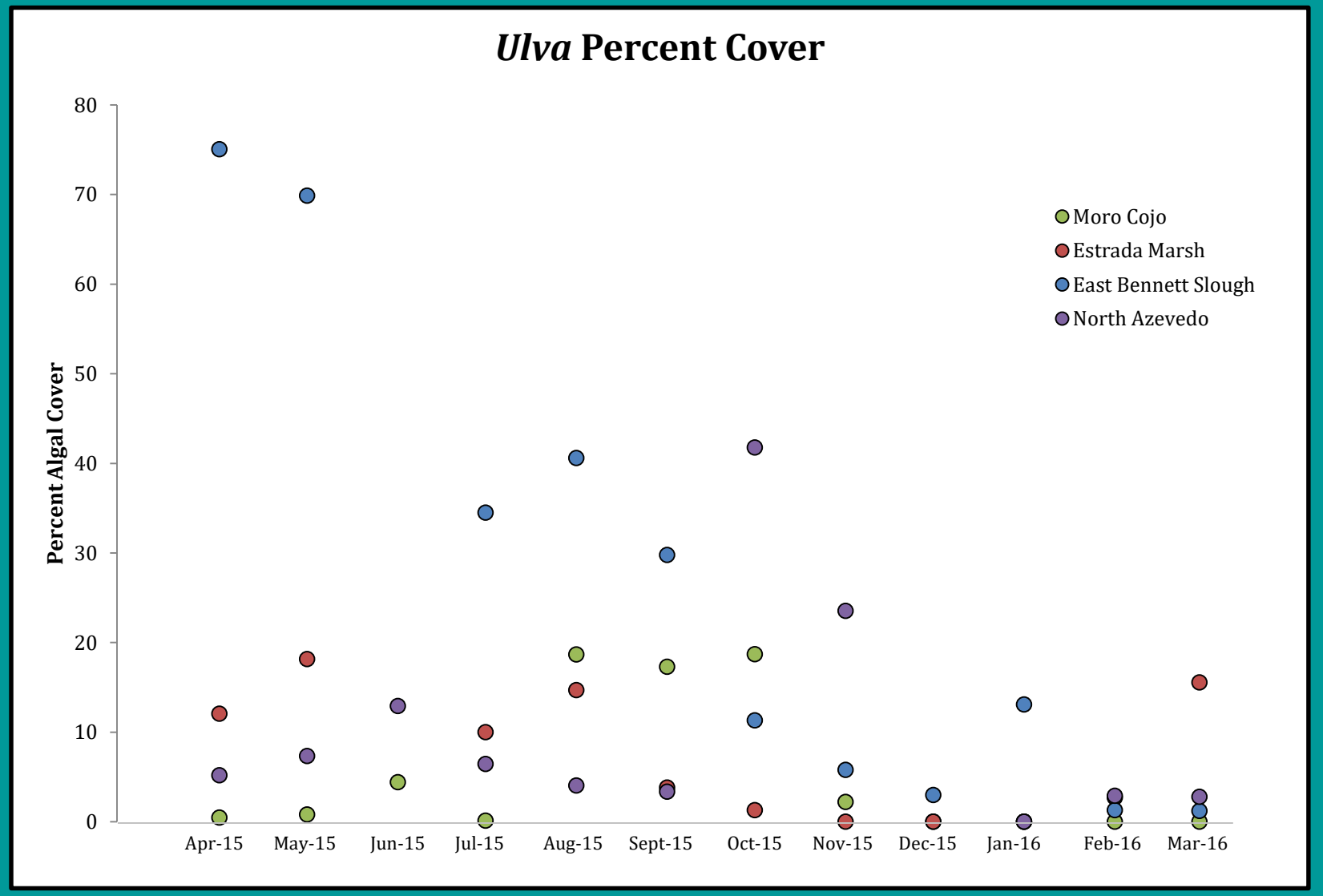




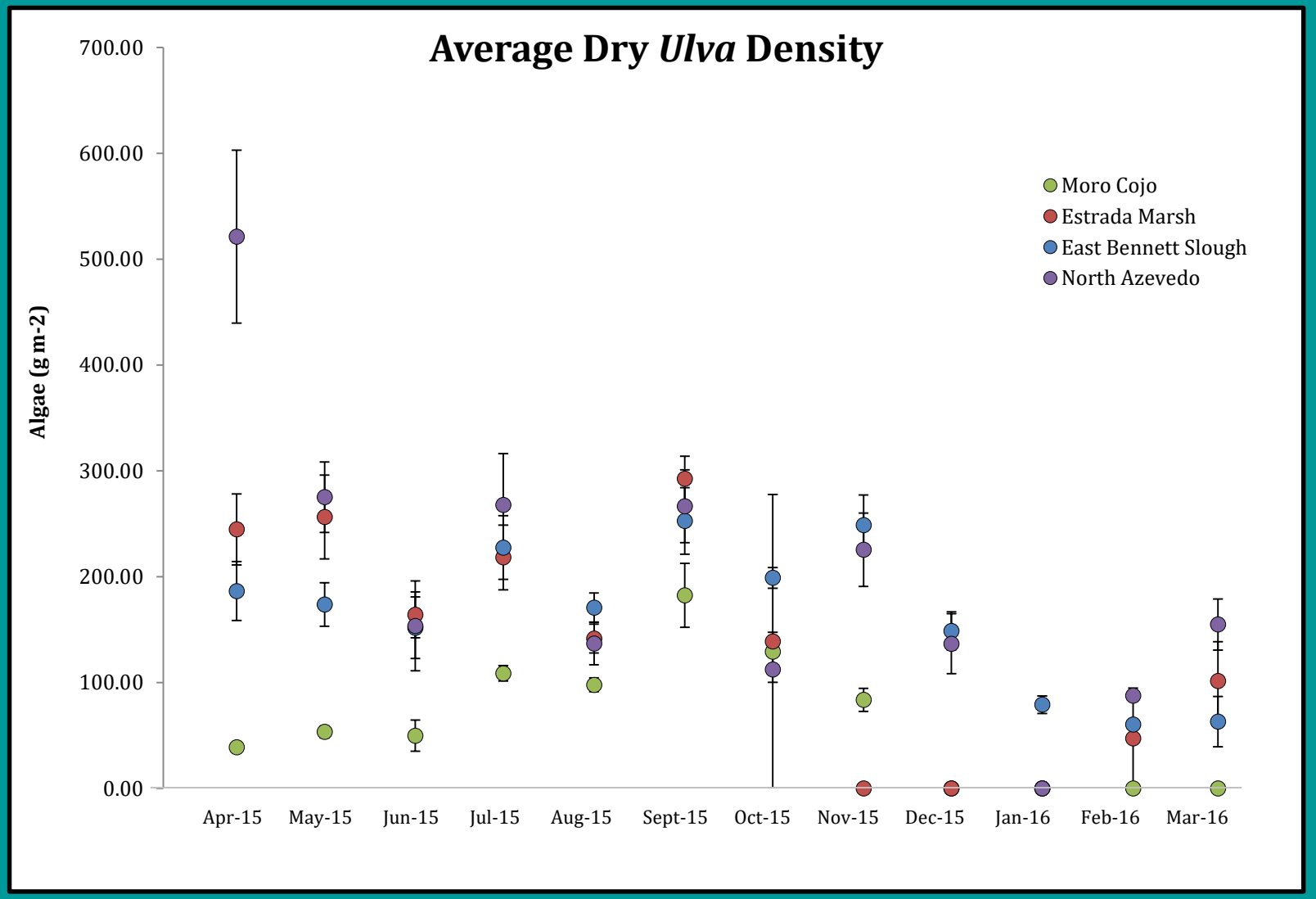


LOI: Loss On Ignition

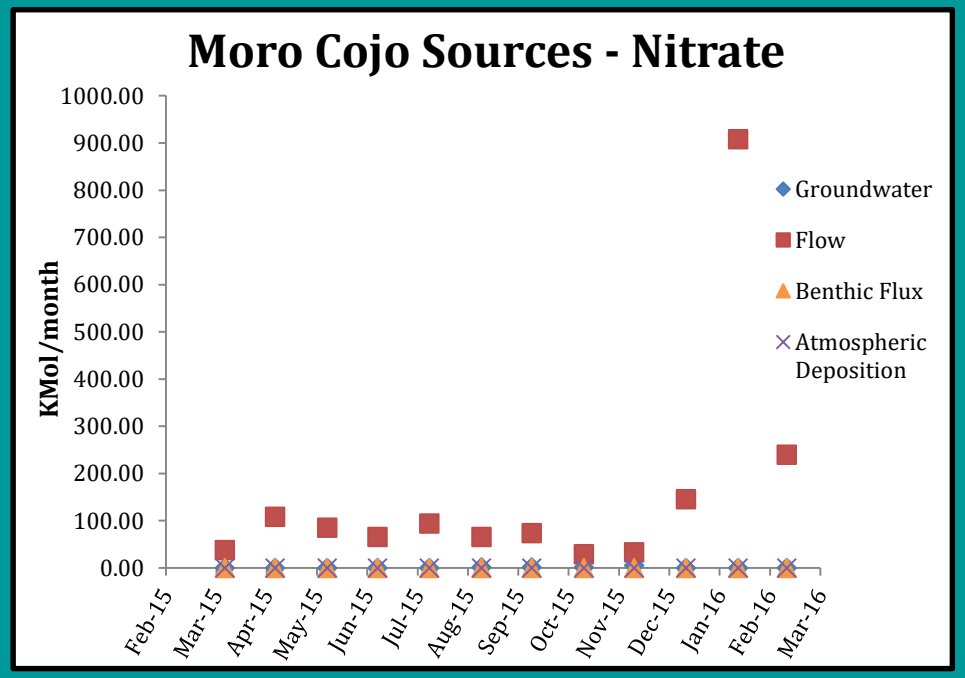
Ulva Cover


Ulva Percent Cover
Percent Algal Cover
80
70
60
50
40
30
20
10
0
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sept-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Moro Cojo
Estrada Marsh
East Bennett Slough
North Azevedo

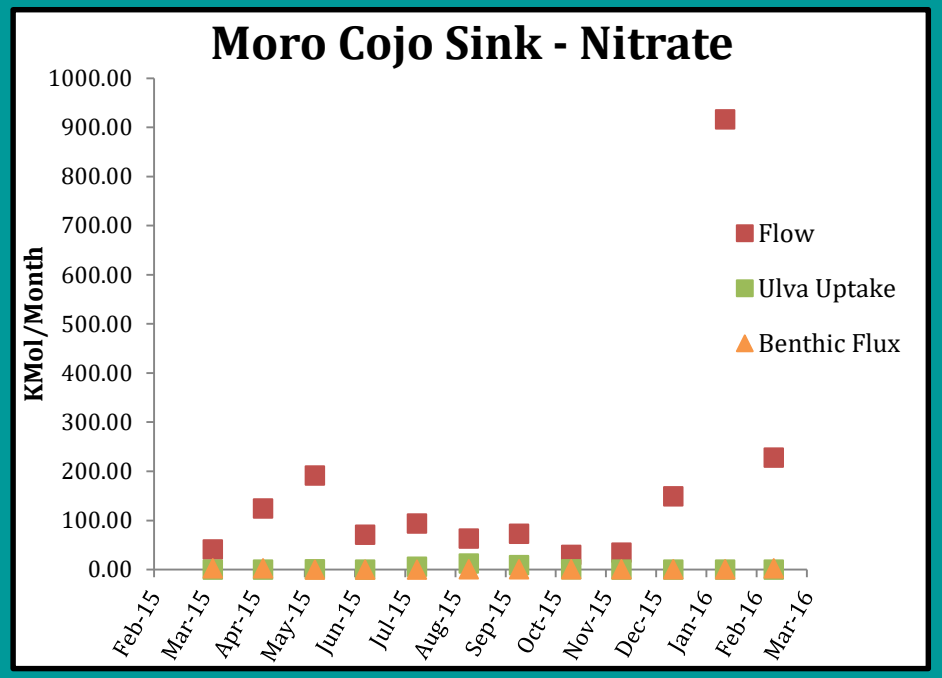
Ulva Biomass Density



Box Model: Nutrient Drivers



Main Nitrate Source: **Flow**



Main Nitrate Sink: **Flow**