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Department of Biological and Agricultural Engineering

Strategic restoration designs can maximize ecosystem services in tidal marshes

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Many natural tidal creeks and marshes are degraded, and many continue to be impacted

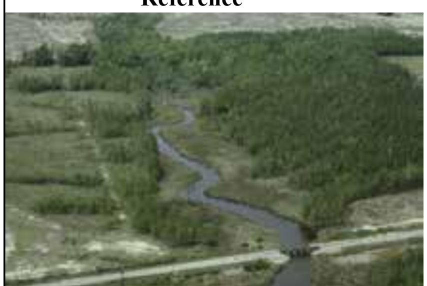
- So what are we going to do about it?
  - Outreach and Education
  - Legislation to impact development
  - Land use changes
  - Water management and pollutant abatement
  - Tidal creek and marsh *restoration*
  - Strategic tidal creek and marsh *creation*

Program focus

- Expand our understanding of key restoration design and implementation techniques to improve wetland restoration project success
- Advance the understanding of key engineering, ecological, and biogeochemical questions important to maximize ecosystem services of restored wetlands
- Promote more “science based restoration”

Tidal Marsh Mitigation – P mining

“Reference”



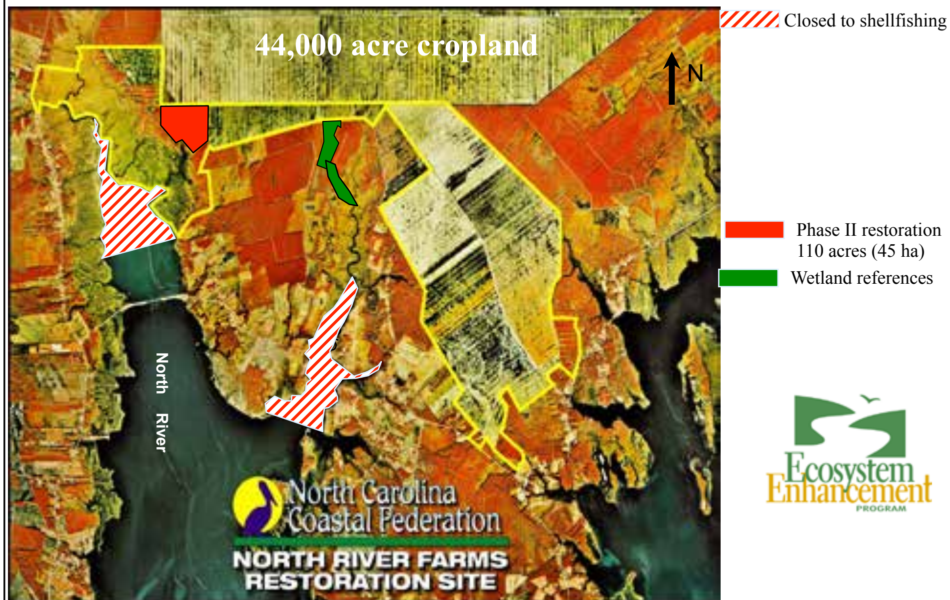
8 ac site after grading - 1983
(1.2 ft upper to lower marsh)

40,000 greenhouse seedlings planted
(*S. cynosuroides, alterniflora* and *patens*)
First *Juncus romerianus* test plots

1984 – after two growing seasons

Maximizing ecosystem services

- Tidal stream and marsh restoration has progressed, but the practice is still developing
- Restoring or creating tidal marshes at current rate will never result in reclaiming all of the ecosystem services once provided
- We need to take full advantage of opportunities to maximizing these services (like water quality, C sequestration) in these areas without jeopardizing habitat services
- Case study - Tidal stream and marsh complex - North River Farms near Beaufort, NC



Project Goals

- Demonstrate non-traditional design techniques for restoring wetlands to an agricultural landscape
- Create a stable tidal creek and marsh ecosystem that integrated into surrounding marsh
- Reduce exports of agricultural pollutants to the North River estuary
- Conduct research studies to evaluate stability of the design and other ecosystem services provided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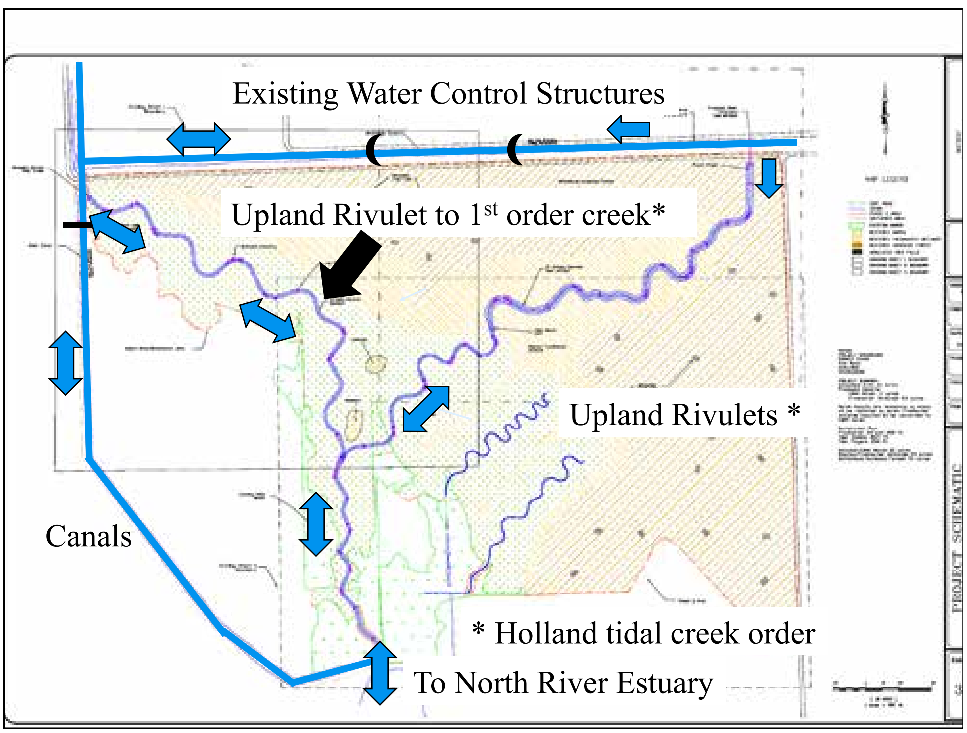
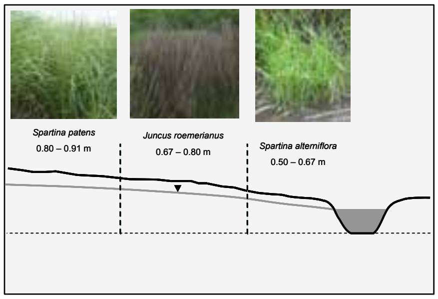

Existing Water Control Structures
Upland Rivulet to 1st order creek*
Upland Rivulets *
Canals
* Holland tidal creek order
To North River Estuary
PROJECT SCHEMATIC

Phase II images – 110 acres (35 tidal marsh)

Tidal Marsh Planting plan (150,000 plants)



Earthwork

Diversion from canal to tidal creek

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During Construction 2006 (courtesy NCCF)

Nov 28, 2009 – Photo by George Howard – Restoration systems

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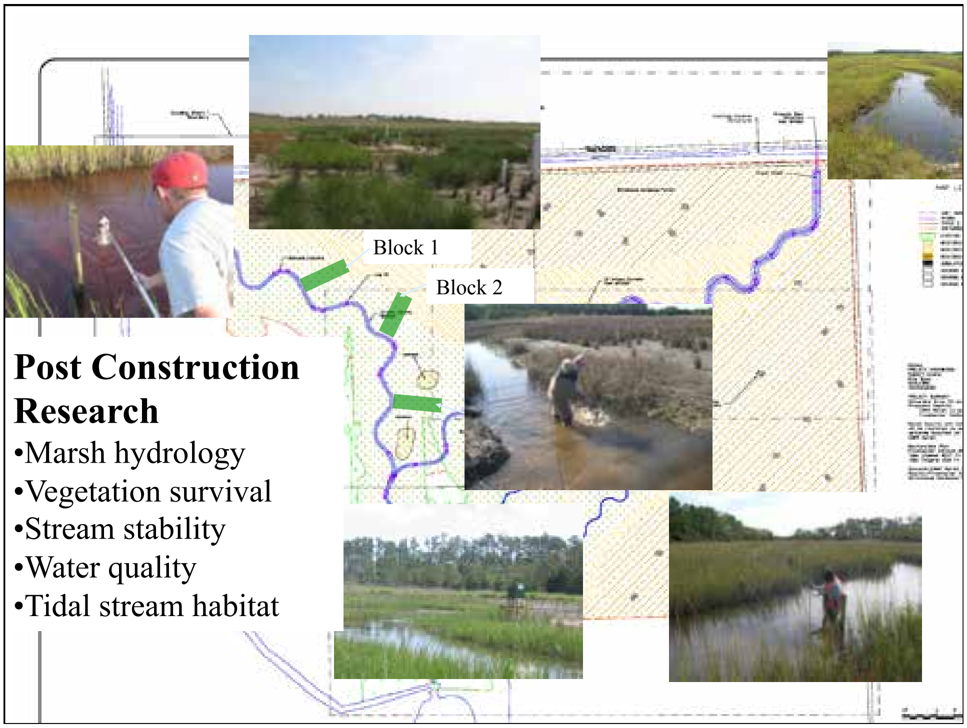
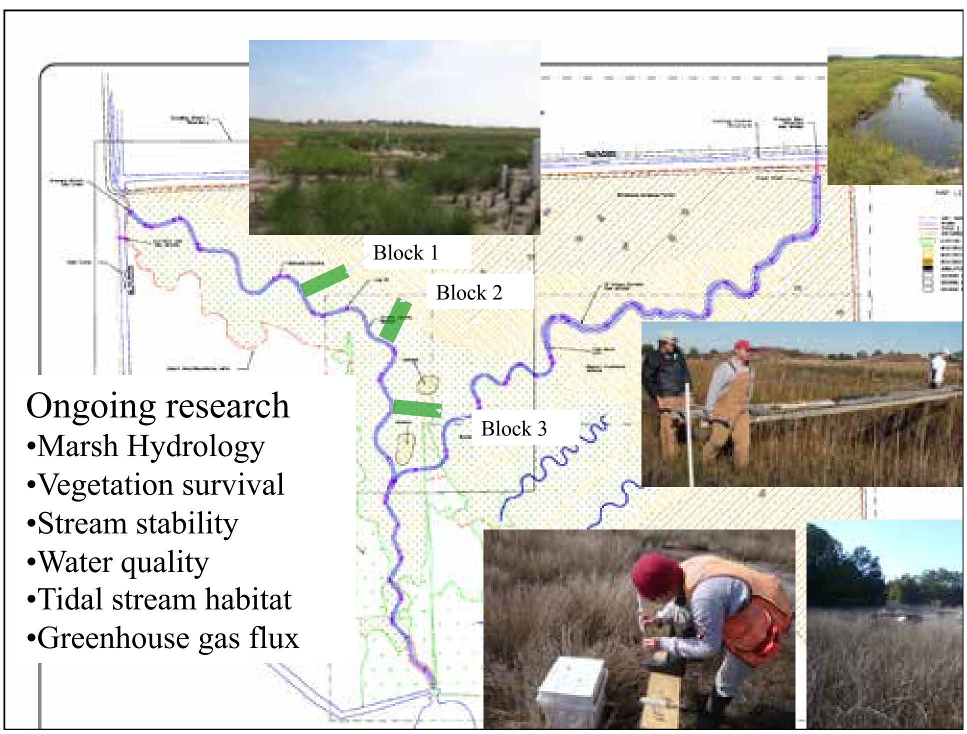
2008

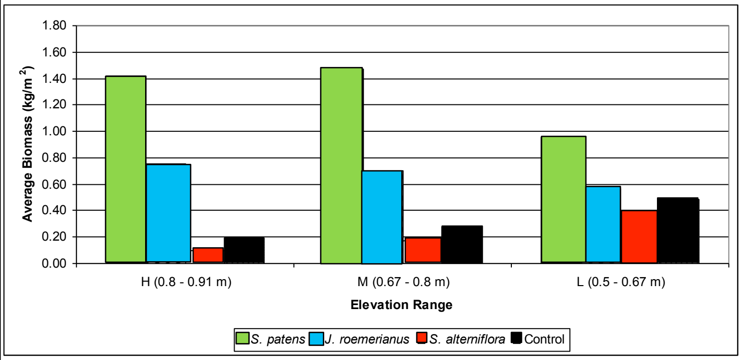

2010


Block 1
Block 2
Post Construction Research
•Marsh hydrology
•Vegetation survival
•Stream stability
•Water quality
•Tidal stream habitat

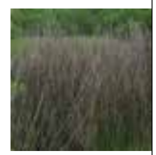

Block 1
Block 2
Block 3
Ongoing research
•Marsh Hydrology
•Vegetation survival
•Stream stability
•Water quality
•Tidal stream habitat
•Greenhouse gas flux

Key Phase II preliminary findings (1st 4 years)

- Planting plan successful
  - Highest survival rates at hypothesized elevations
  - *S. patens* #1 biomass producer
  - *S. alterniflora* a must for stabilizing banks (but not a big biomass producer)
  - *J. romerianus* good at mid elevations, but slow colonizer



S. alterniflora



J. romerianus

S. patens

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Key Phase II preliminary findings (ecosystem development)

- Planting plan and implementation successful
- Marsh and Tidal Steam Quickly stabilized
  - Sinuosity and bank form maintained
  - Some small cuts from exchanges between stream and marsh
  - No significant change in channel dimension or slope
  - <u>Runs</u> remained stable and <u>pools</u> did not form at bends with root wads (low velocity, bi-directional flow)
  - Salinity range 0.5-25 ppt - colonizers included both oligohaline (low salinity) and mesohaline species

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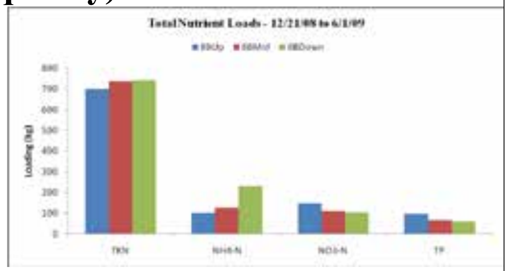
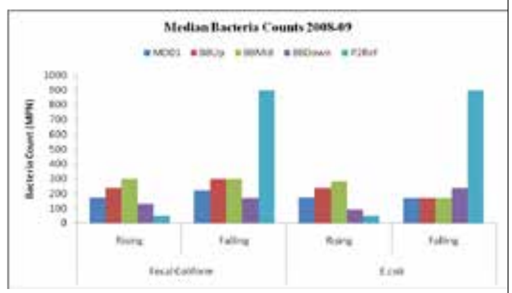
Key Phase II preliminary findings (water quality)

- Travel time of diverted drainage water increased by 54%
- Incoming nutrients rather low
  - Mean NO_3-N = 0.4 mg/L
  - Mean TP = 0.2 mg/L
- Some NO_3-N and TP retention
- Fecal bacteria unclear
  - May be a source?





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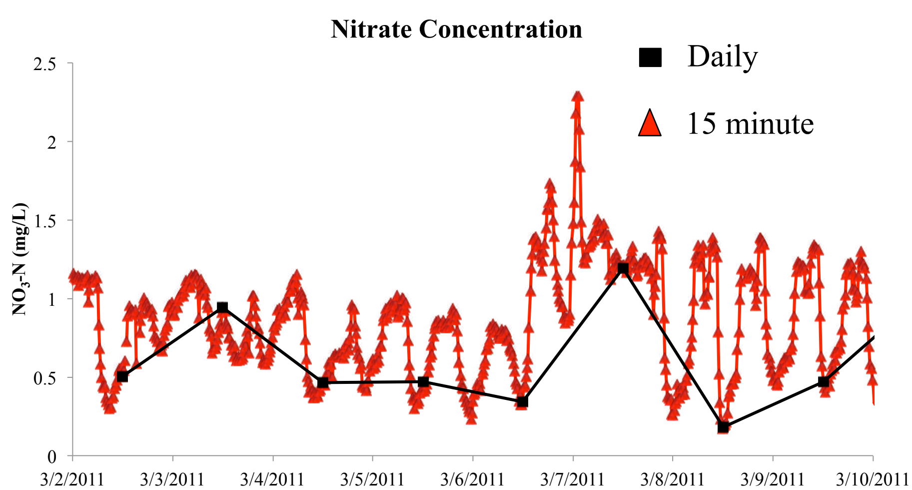
Time-based or flow proportional sampling limit our understanding of the dynamic tidal marsh processes



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Advanced hydrology and water quality monitoring in the marsh

Objectives:

- Quantify the effects of in-stream and in-marsh processes on nutrients from Ag land draining through the marsh (focus on NO_3-N)
  - At the tidal cycle, monthly, seasonally and yearly scales
- Quantify the kinetics of the biogeochemical processes at play
- Quantify the role of the tidal marsh in the production/sequestration of OM

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Flumes and diversions essential for water balance calculations

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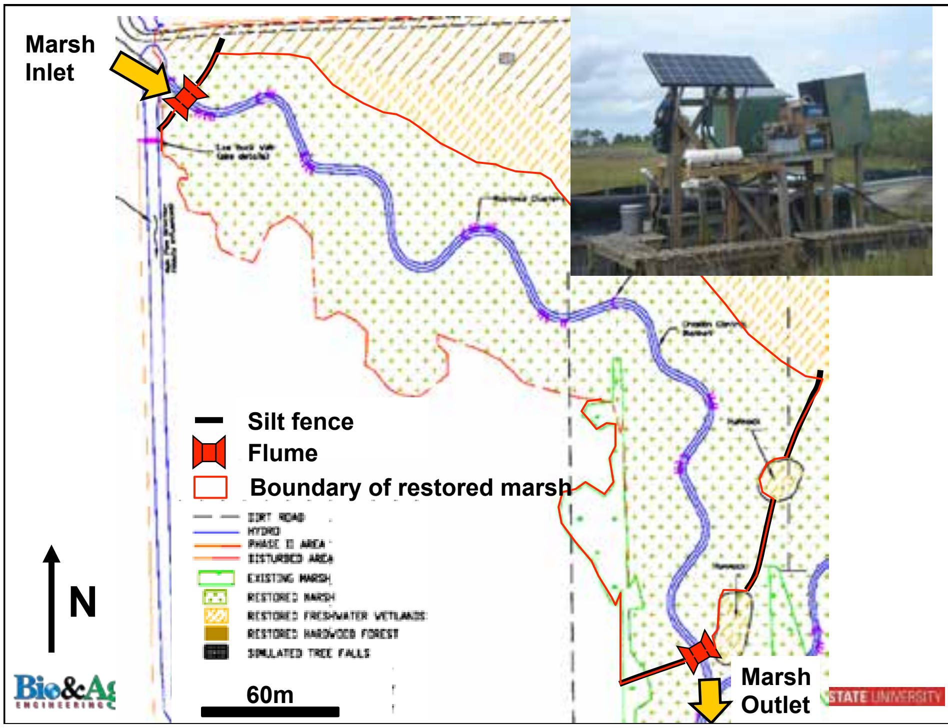
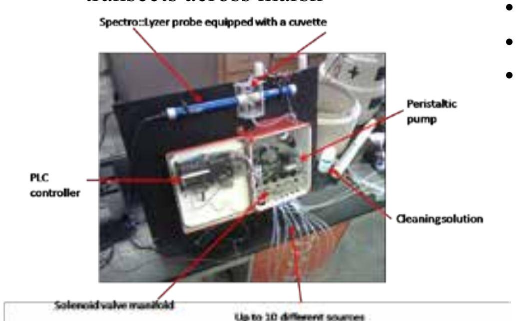


Methods: continuous measurements

- Hydrodynamics:
  - Continuous bi-directional flow
    - Stage+velocity meters installed in wooden flumes
  - 16 water table wells in 3 transects across marsh



- Water Quality
  - nitrate
  - turbidity
  - Dissolved Organic Carbon
  - CDOM fluorescence in situ
  - Salinity
  - Dissolved Oxygen
  - pH
  - Temperature

Methods: discrete measurements

- Hydrodynamics:
  - Manual gauging to calibrate water level and velocity meters
- Water quality
  - Automatic samplers collect samples – lab analyzed
  - NO_3, **NH_4**, DON, PON, PO_4, TP, TSS, DOC, CDOM fluorescence, salinity

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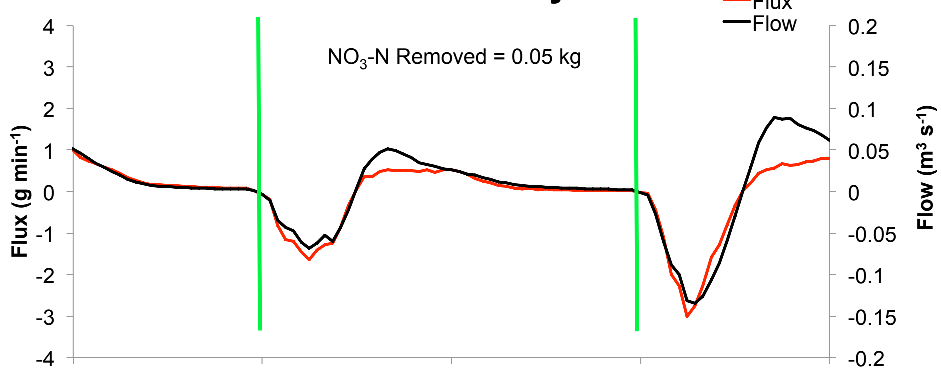
Nitrate Flux and Stream Flow During a Normal Day



- Positive flow = out to the estuary
- Negative flow = into the marsh

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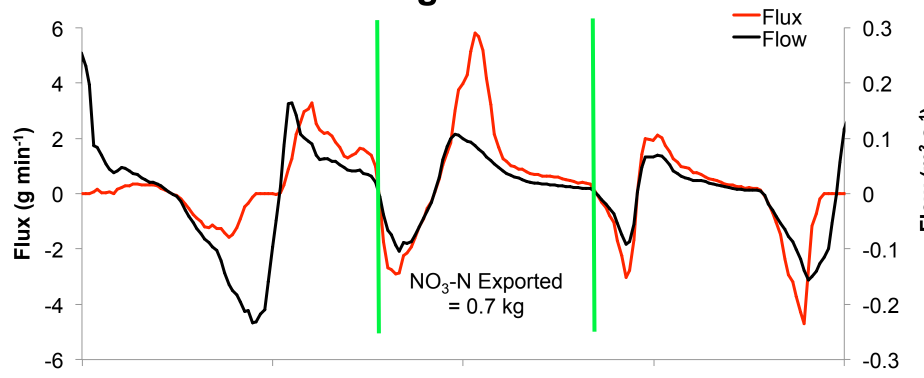
Nitrate Flux and Stream Flow During and Following a Rain Event



- Peak in NO_3-N flux caused by peak in NO_3-N concentration
- Storm flow = reduction in magnitude of flow into the marsh

NO_3-N Mass Balance Example

- 2 kg of NO_3-N removed during one week in March
- Total mass of NO_3-N to pass the downstream flume in one week = 10 kg
- Does not account for ammonium flux
- Future research goals: mass balance over multiple months – correlate to other nutrients

Gas Fluxes
(with USGS – Wetlands Research Center)

- 18 in restored marsh (2 blocks, 3 eleva vegetation communities)
- 6 in undisturbed marsh (2 vegetation c
- Gases collected every 2 months
- Analyzed for CH_4, CO_2, N_2O
- Temp, salinity, WT measurements
- Seasonal biomass harvest

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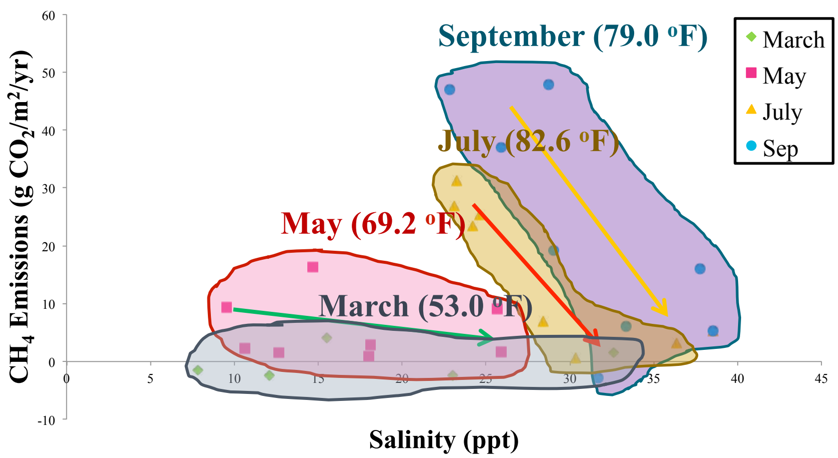
Preliminary results

Since March 2011:
Average CH_4 emissions from the marsh is 11.24 ±14.05 (g CO_2 m^{-2} yr^{-1})



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Final thoughts

- The art of restoration still new
- More “science based” restoration
- We can maximize the impact of restorations by considering other ecosystem services these tidal streams and marshes can provide.
- We need to intensify monitoring efforts and methods to accurately quantify realistic expectations for the services tidal creek and marsh systems can provide
- More definitive results of these services could provide financial motivation for more tidal marsh restorations and creations

Final thoughts

- Additional design – structures in low g streams are not always necessary to help develop permanenet bed features. They help, but for instance features will be much more subtle. But woody debris (root wads) rock checks can provide structure for colonization. Root wads can help stablize relic ditch crossings.
- Building stream from the center and not the sides can help build stable banks for planting

Questions?

General Method

- Isolate a 5.7 ha portion of the marsh with inlet and outlet measuring stations
- Continuous nutrient mass balance at both ends
- Tracer and benthic chamber experiments for kinetics measurements
- DOM and POM monitoring continuously and at the tidal cycle scale

Methods: continuous measurements

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Methods: discrete measurements

- Hydrodynamics:
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- Water quality
  - Automatic samplers
  - NO_3, NH_4, DON, PON, PO_4, TP, TSS, DOC, CDOM fluo., salinity

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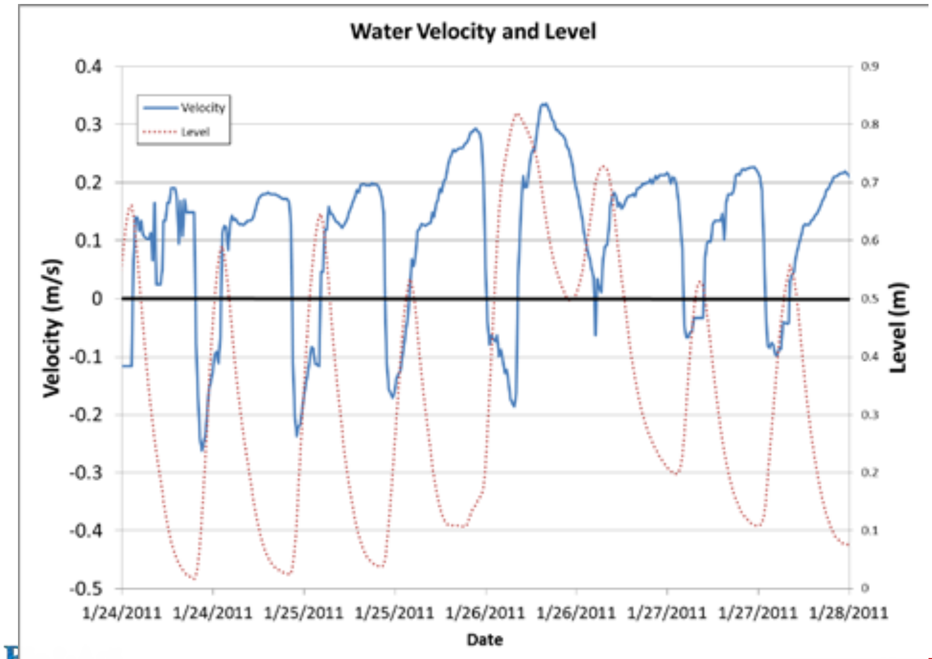

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