Spartina alterniflora has Higher Methane Emissions in a Tidal Brackish Marsh than Other Plant Communities at Similar Salinities

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Carbon Sequestration: Methane and Marshes

• Tidal marshes sequester at least 44.6 Tg C/yr
• While marshes sequester large amounts of carbon, this is potentially offset by their methane emissions
• Some marshes emit more methane than others
• Originally thought that sulfate in seawater suppressed most methane emissions in salt and brackish marshes
Salinity versus methane flux

\[
\log(\text{CH}_4) = -0.055 \times \text{salinity} + 1.36
\]

\[
r^2 = 0.51; \ p < 0.0001
\]

From: Poffenbarger, Needelman & Megonigal, Wetlands 2011
Methane Emissions From Marshes

• Not well understood
  • Limited amounts of published methane flux data from brackish tidal wetland systems

• Generally accepted that polyhaline systems (>18ppt Salinity) have very low methane emissions
  • Likely due to high sulfate concentration in seawater

• Methane emissions in mesohaline and oligohaline systems are highly variable
  • But what causes this variation?
Objectives

• Determine if vegetation and hydrology change methane flux over a nine month period
  • Few, if any, studies have looked at the difference between vegetative/hydrologic communities within a tidal brackish marsh

• If fluxes vary, what other variables change along with flux?
Hypotheses

• Methane fluxes will differ between vegetative/hydrologic communities (strata)

• Strata with lower elevation (and therefore higher water level) will have higher methane fluxes
  • Higher water tables should make the soil more anaerobic, and therefore more favorable to methanogenesis

• Methane flux will be negatively correlated with pore water salinity, sulfate and hydrogen sulfide levels
  • According to Poffenbarger et al., methane production should be lower with higher salinities, and therefore, higher sulfate and hydrogen sulfide
Study Design

• Sampled monthly from April 2015 through December 2015 (9 events total)
• Four vegetation/elevation types (strata)
  • *Juncus roemerianus*
    • *J. roemerianus* (Low Marsh: 0.305m NAVD88)
    • *J. roemerianus* (High Marsh: 0.334m NAVD88)
  • *Spartina* spp.
    • *S. alterniflora* (Low Marsh: 0.299m NAVD88)
    • *S. patens* (High Marsh: 0.409m NAVD88)
Project Location

- Our field site is located on the Deal Island Peninsula in Somerset County, MD.
Deal 3: Unditched Marsh Methane Flux Plot Locations

Sites were randomly placed in representative areas of each strata (small inference space)
Deal 4: Restored-Ditched Marsh Methane Flux Plot Locations

+ Juncus roemerianus
Additional Site Information

- **Soils**
  - Sulfidic peat, overlying mineral coastal plain sediments
  - Soils onsite have peat depths less than 130cm

- **Observed tidal range**
  - Approx. 0.6m

- **Salinity Range (pore water)**
  - 9.0 ppt – 16.4 ppt

- **pH (pore water)**
  - 5.5 – 6.9
Methane Flux Chamber

Chambers clamped together to allow J. roemerianus to fit inside the chamber without breaking the stems.

Aluminum collar inserted into marsh surface.

Boardwalk.

Clear chamber.

Lid with clamps.

Sampling port.

Thermometer.
Results

- Methane Flux
- Pore water
  - Salinity
  - Hydrogen Sulfide
  - Sulfate
  - Reduced Iron (July Only)
- Water level
Mean Hourly Methane Flux

ANOVA Results log transformed Hourly Flux

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mg CH₄ m⁻² h⁻¹

- April
- May
- June
- July
- August
- September
- October
- November
- December

- Low J. roemerianus
- High J. roemerianus
- Low S. alterniflora
- High S. patens
Mean Hourly Methane Flux

mg CH$_4$ m$^{-2}$ yr$^{-1}$

Low J. roemerianus  High J. roemerianus  Low S. alterniflora  High S. patens
ANOVA Results of log transformed pore water $H_2S$ concentration

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ANOVA Results of log transformed pore water sulfate concentration

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**Sulfate Concentration (mg/L):**

- Low J. roemerianus
- High J. roemerianus
- Low S. alterniflora
- High S. patens
July Pore Water Reduced Iron Concentration
10 cm Depth

mg/L

Low J. roemerianus  High J. roemerianus  Low S. alterniflora  High S. patens
ANOVA Results water level

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Mean Water Level Relative to Soil Surface

- Strata: A > B > C > D > E
- Month: July > June > May > August > September > October > November > December

Legend:
- Blue: Low J. roemerianus
- Orange: High J. roemerianus
- Gray: Low S. alterniflora
- Yellow: High S. patens
Hypotheses Revisited

• Methane fluxes will differ between strata
  • Yes!
  • Low *S. alterniflora* had highest emissions (2.72 times higher than the next highest rate)
  • *J. roemerianus* (both elevations) had similar emissions
  • High *S. patens* had lowest emissions
• Strata with lower elevation (and therefore higher water level) will have higher methane fluxes
  • Yes, and No
  • *S. alterniflora* did not have the highest water level, but had the highest emissions
    • The differences in water level between both *Juncus* strata and *S. alterniflora* are very similar, and are likely not the driver of their emission differences
  • *S. patens* did have the lowest water level, and lowest emissions
    • These low water levels, coupled with the high reduced iron concentrations, likely suppressed methane emission in this stratum
Hypotheses Revisited

• Methane flux will be negatively correlated with pore water salinity, sulfate and hydrogen sulfide levels
  • No!*
  • Low *S. alterniflora* had similar salinity levels to the *J. roemerianus* strata, but significantly lower sulfate levels
  • High *S. patens* did have the highest sulfate, but also had the lowest salinity*
  • Hydrogen sulfide levels were significantly higher in *S. alterniflora* than any other stratum
Where do we fall on the “Poffenbarger Curve”?

- We observed much lower emissions at our sites than other marshes with similar salinities.

- While *S. alterniflora* has high emissions at our site, in context with other marshes of similar salinities, it is actually much lower.

Original Graph From: Poffenbarger, Needelman & Megonigal, Wetlands 2011
How do these rates impact Carbon Sequestration In Our Marsh?

- Marshes sequester a median rate of 1.46 Mg carbon per hectare each year (Chmura et al. 2003), but methane emissions offset these rates, and can account for a percentage of this sequestration.
- Methane emissions from *S. alterniflora* offset 45.9% of their carbon sequestration benefits, but according to Poffenbarger et al. (2011), this stratum should only have an offset of 19.9%.
- Methane emissions from *S. patens* offset only 4.8% of their sequestration benefits, but with our measured salinity, should offset 25.3%.
- Both High *J. roemerianus* (15.1% actual, 18.5% estimated) and Low *J. roemerianus* (11% actual, 18.5% estimated) have much closer percentages.
Conclusions and Implications

• Some local-scale hydrologic/vegetative communities were more prone to methane emissions than others within our study marsh
• Competition between methanogens and sulfate-reducing bacteria does not seem to explain methane flux variation
  • Labile carbon availability from plant productivity seems to be the primary driver of emissions in our marsh
  • Lab incubations of soil from these strata seems to show that *S. alterniflora* has more labile carbon available for methanogens
• Sulfate reduction is occurring concurrently with methane emissions at *S. alterniflora*
Conclusions and Implications

• While emissions followed the salinity/methane relationship established in Poffenbarger et al. (2011), predicted values were very different from actual measurements, and could have large implications for site-level greenhouse gas accounting.
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