Meta-analysis Describing How Plant Species Composition Drives Salt Marsh Methane Fluxes

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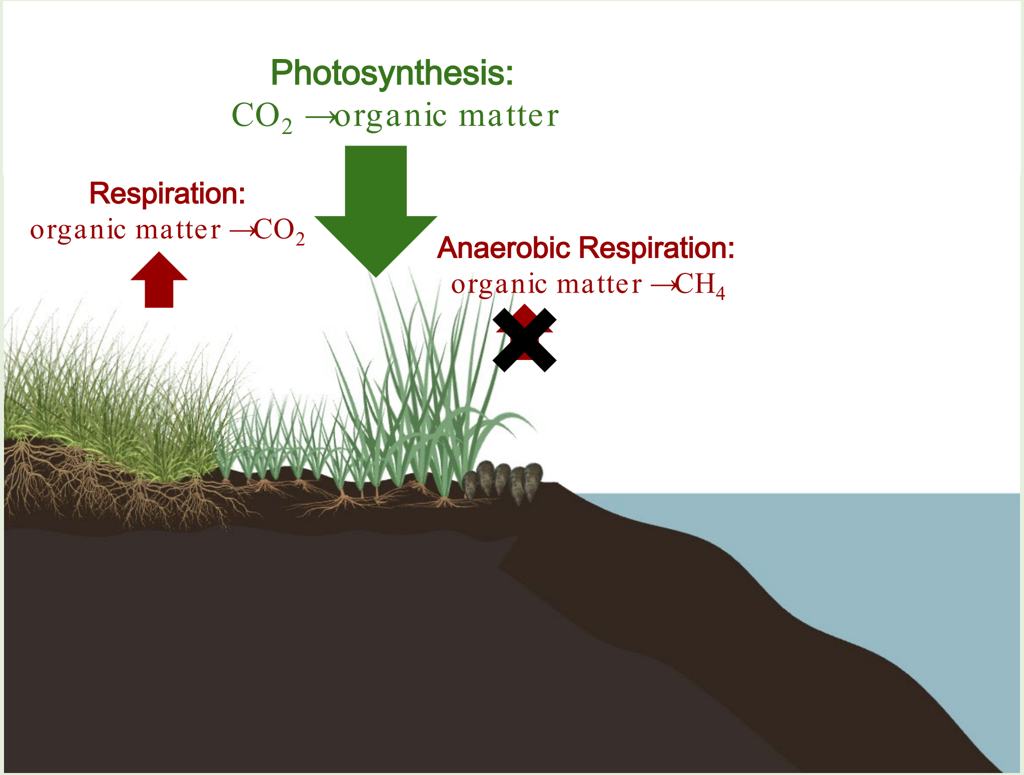
Boston University

Icons from Biorender; Tracey Saxby and Jane Hawkey, Integration and Application Network

When estimating the carbon sink capacity of salt marshes, the prevailing paradigm is that salinity is the main driver of methane emissions



Arias-Ortiz et al. 2024, Poffenbarger et al. 2011

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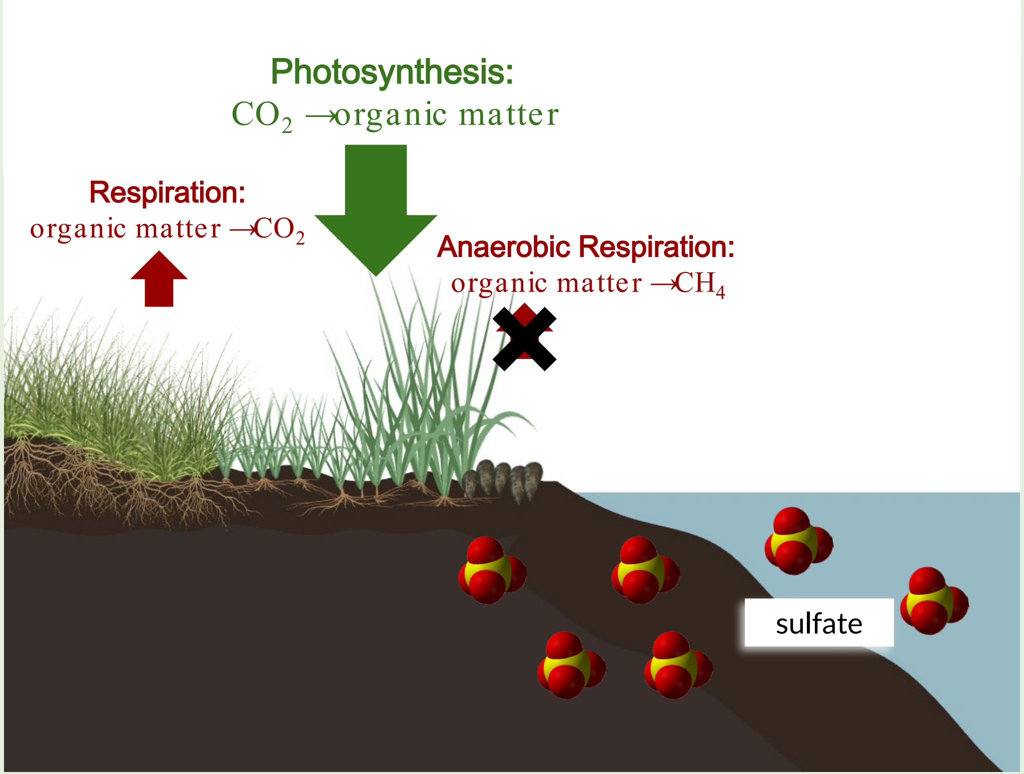

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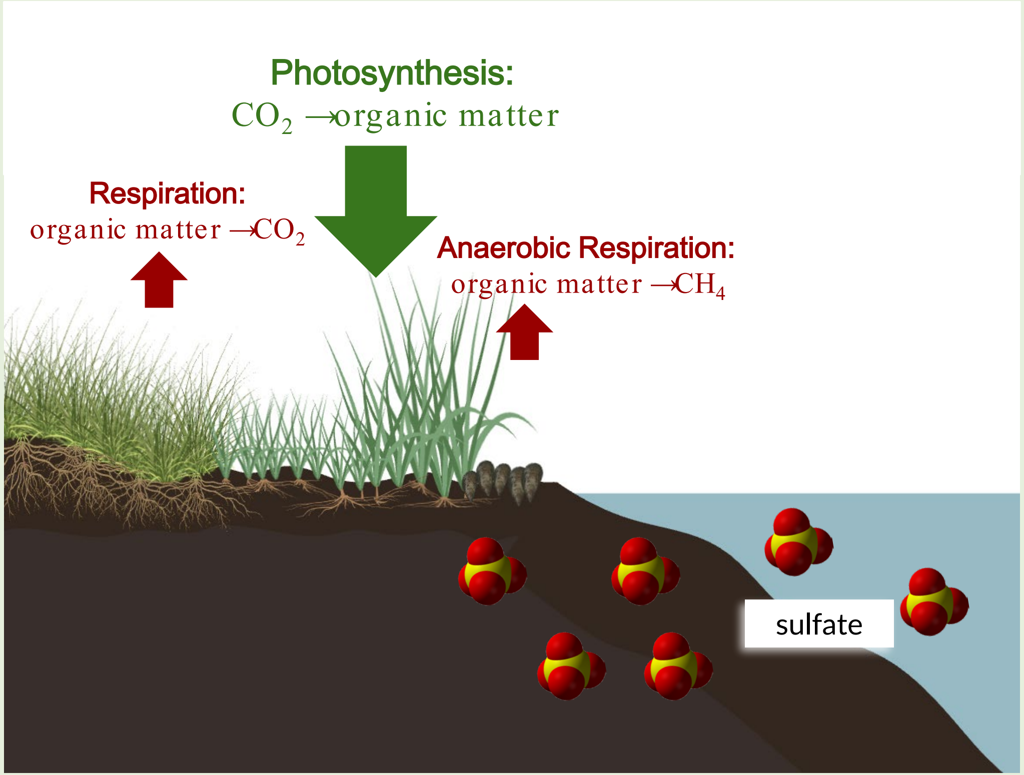
Recent studies demonstrate that high salinity salt marshes can produce methane, and the main drivers of methane emissions remain uncertain



Al-Haj and Fulweiler (2020); Capooci et al. (2024); Yuan et al. (2019)

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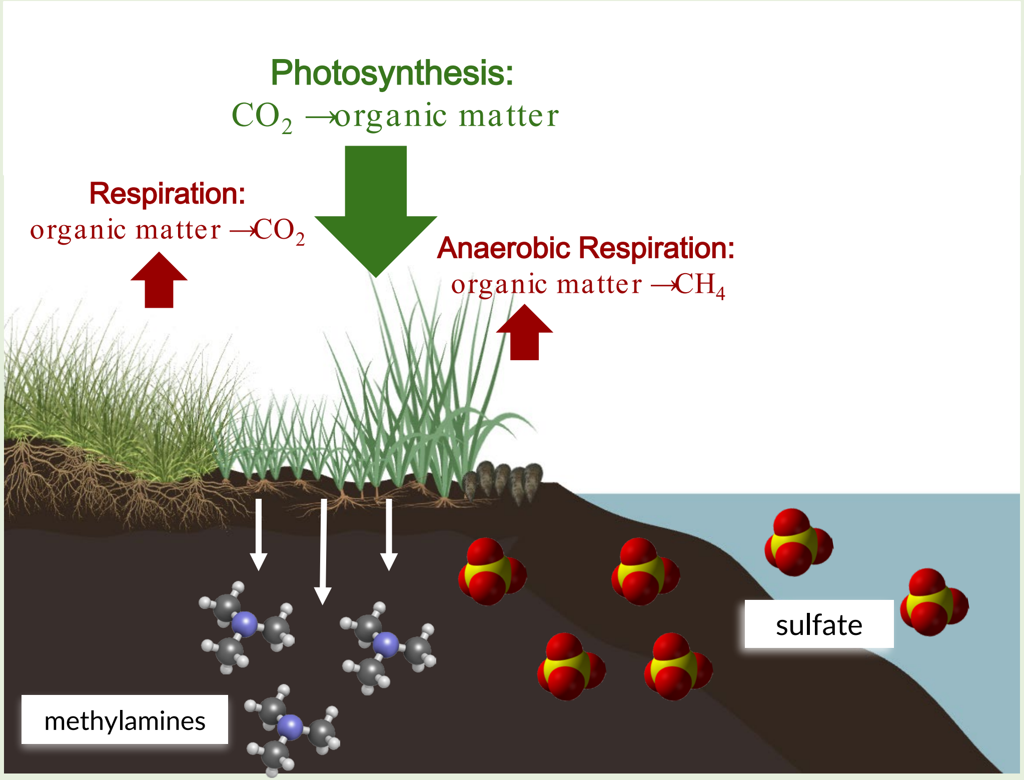

Plant species can release non-competitive substrates for microbial metabolism.

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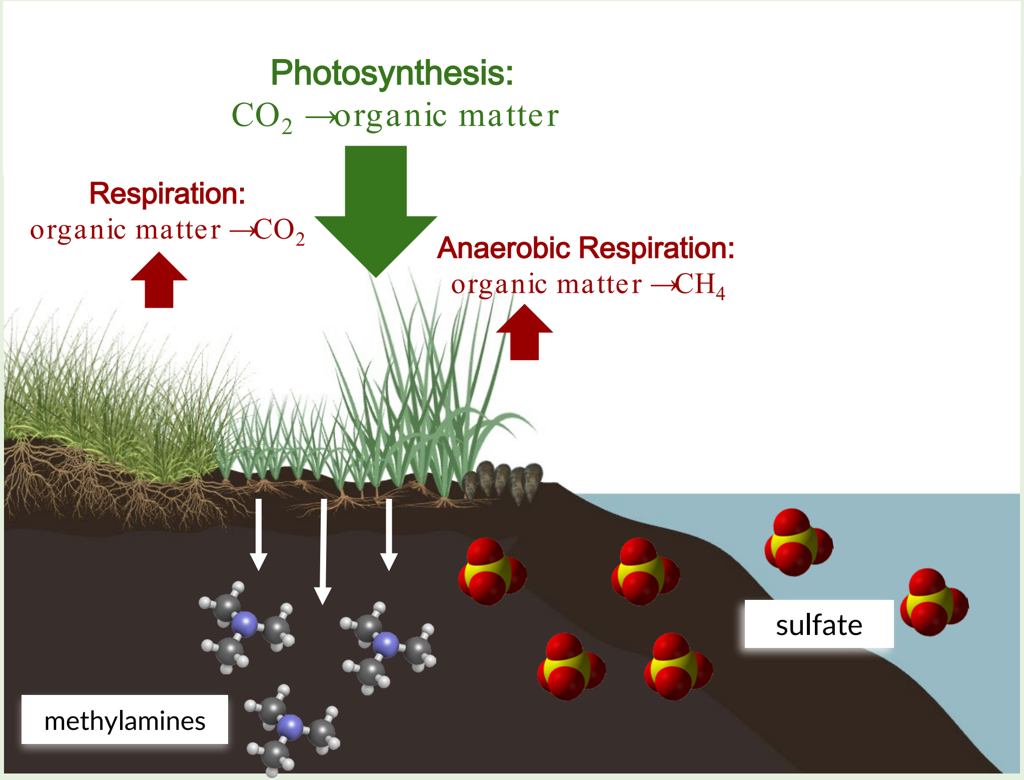

Plant species can release non-competitive substrates for microbial metabolism.

Sulfate reduction and methanogenesis can co-occur.

Al-Haj and Fulweiler (2020); Capooci et al. (2024); Yuan et al. (2019)

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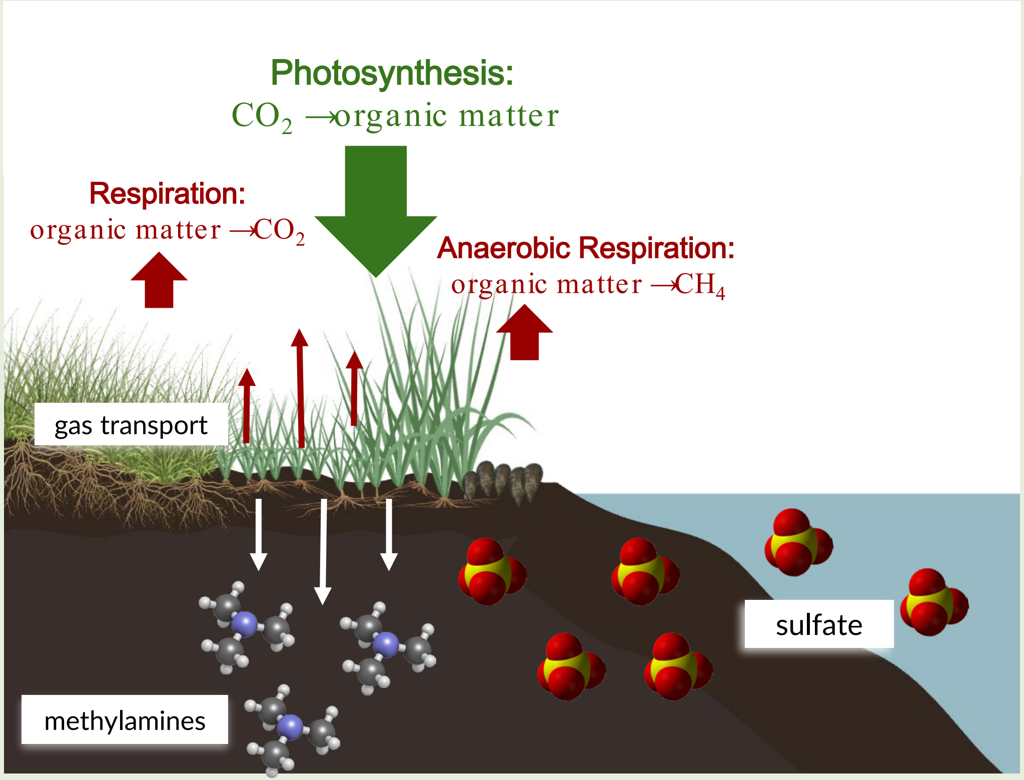

Flood tolerant species have enhanced gas transport capabilities.

Photo: Ron Vanderhoff, Al-Haj and Fulweiler (2020); Capooci et al. (2024); Yuan et al. (2019)

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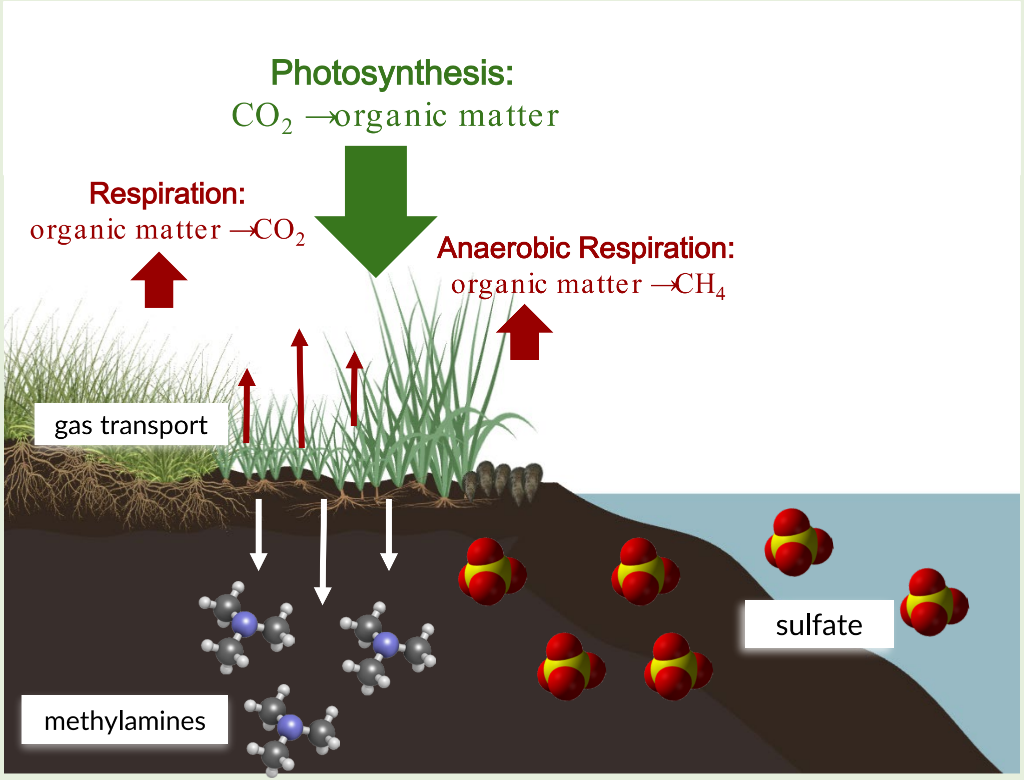

Flood tolerant species have enhanced gas transport capabilities

This allows release of methane before it is oxidized.

Photo: Ron Vanderhoff, Al-Haj and Fulweiler (2020); Capooci et al. (2024); Yuan et al. (2019)

Can plant species explain variability in CH_4 fluxes?

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- Individual studies demonstrate that methane fluxes vary across plant species within a marsh.
- There is no global analysis compiling CH_4 fluxes across plant species.
- Existing studies should be leveraged to determine if plant species can enhance predictions of methane that currently rely on salinity alone.

Meta-analysis workflow

Question: Are plants a strong predictor of salt marsh methane fluxes?

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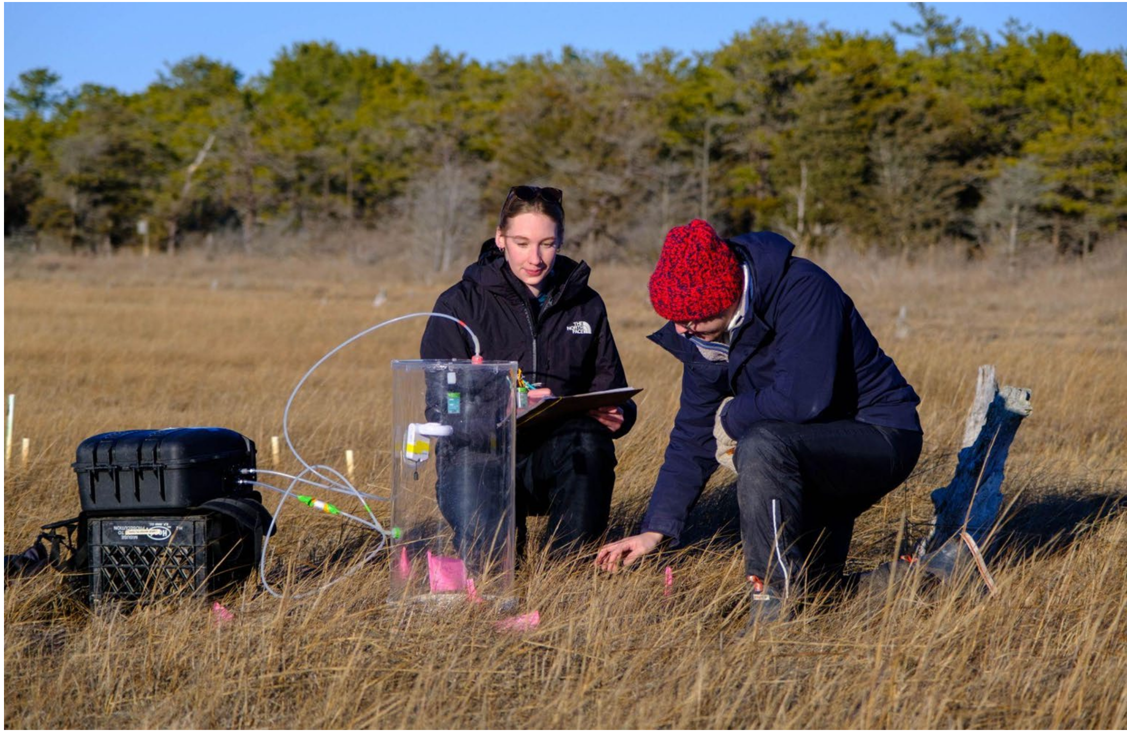

Meta-analysis workflow

Question: Are plants a strong predictor of salt marsh methane fluxes?

Moderator variables: Plants species, season, salinity, tidal range, latitude, climate region, sampling method.

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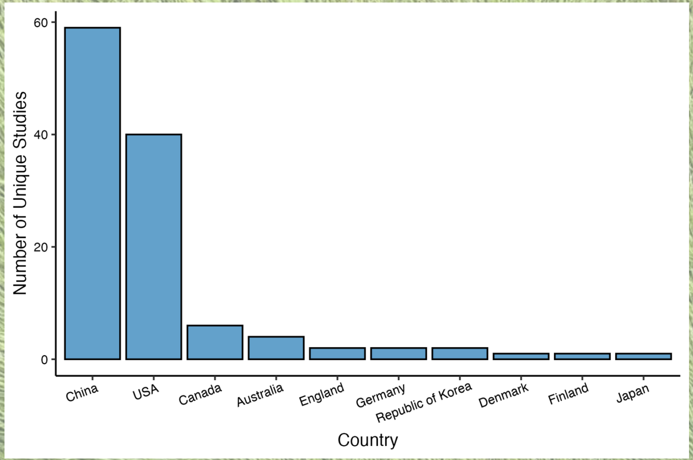
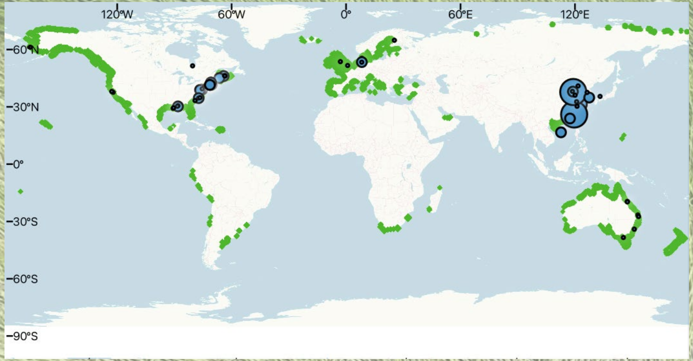
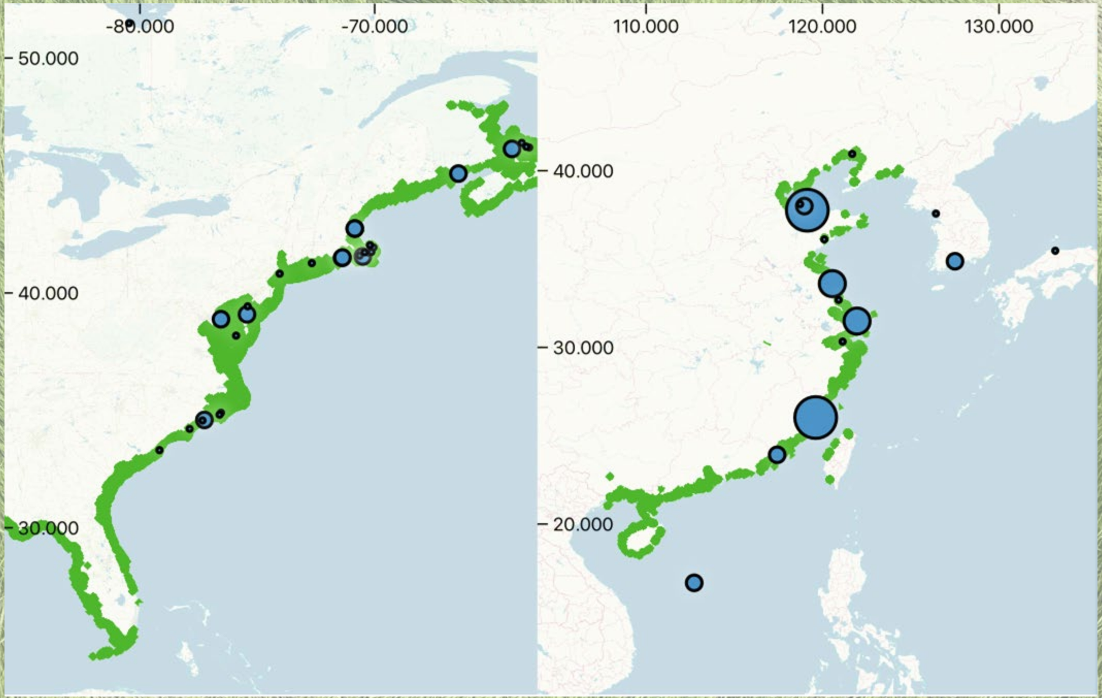
Today's presentation: What is the relationship between plant species and salinity in predicting methane fluxes?

Majority of studies are from US East Coast and China





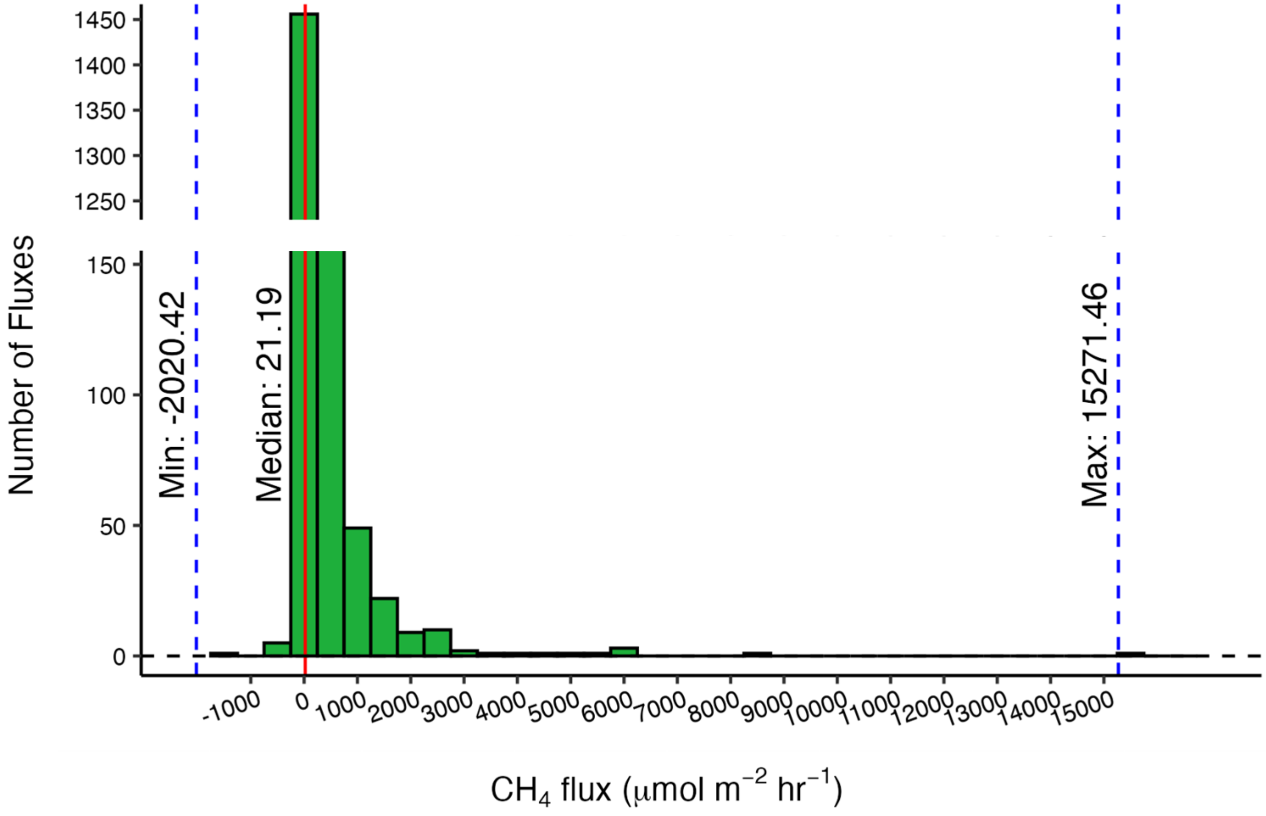


: study location, size corresponds to number of studies in a location

: salt marsh extent

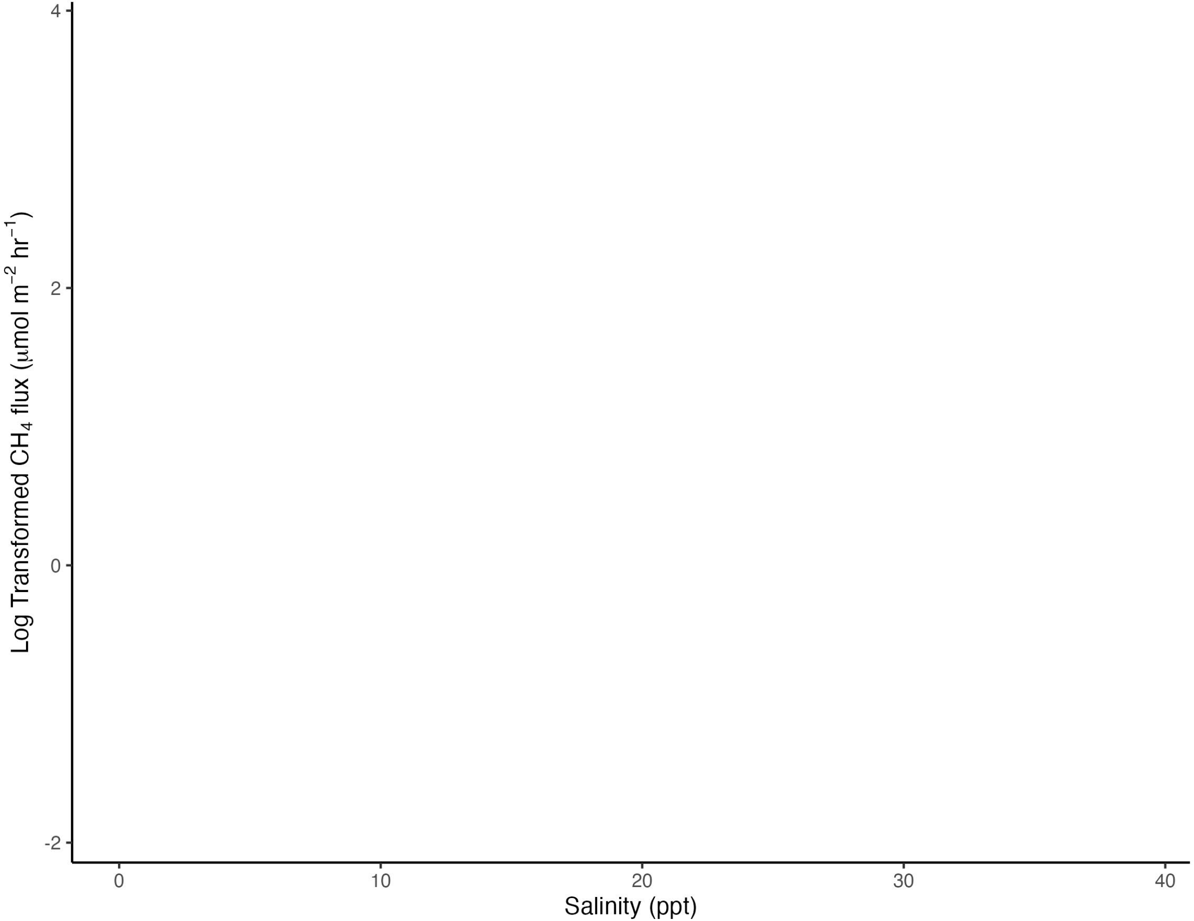
Mcowen et al. 2017

There is high variability in CH_4 fluxes



CH_4 Flux (µmol*m^{-2}*hr^{-1})	
Minimum	-2020.42
Median	21.19
Maximum	15271.46

CH_4 flux has a complex relationship with salinity



GAM
n=701

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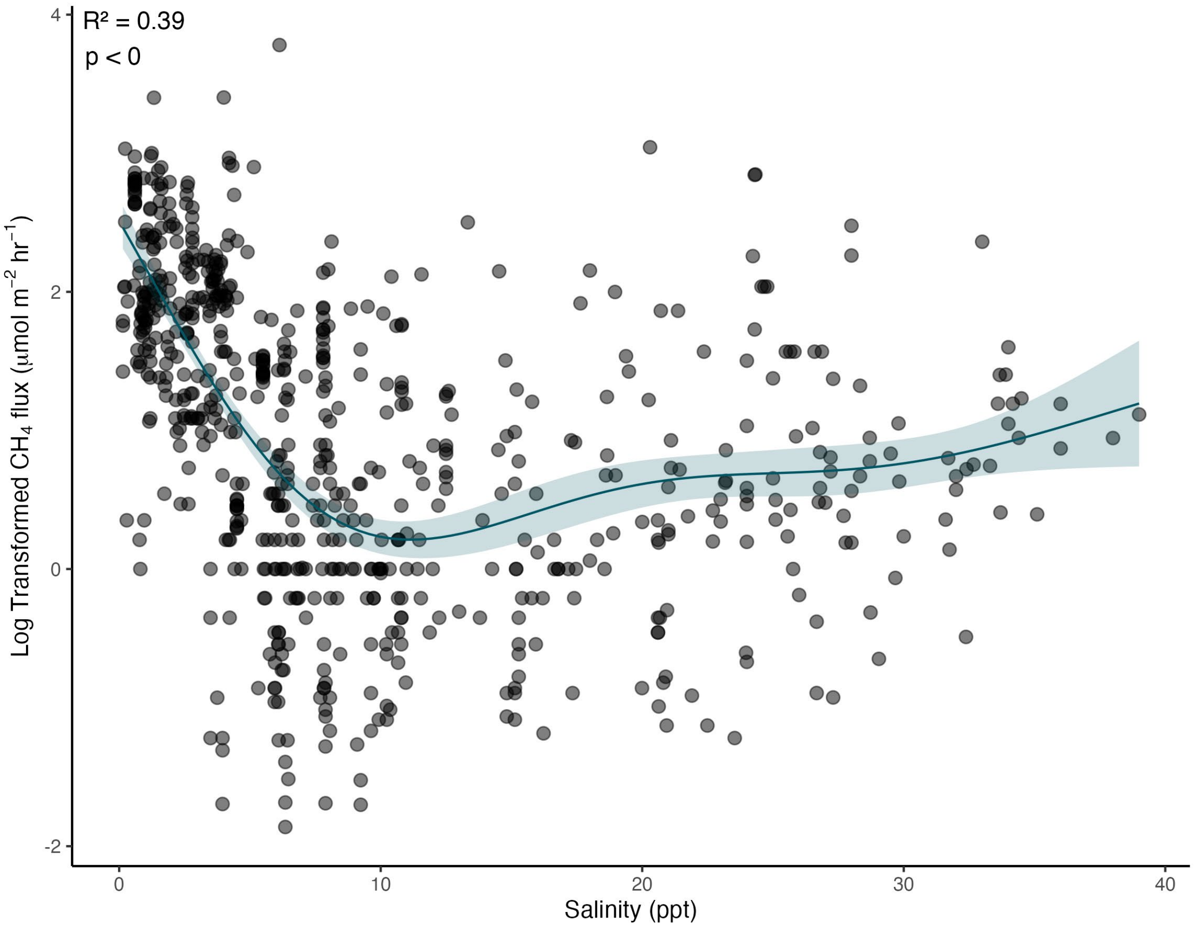

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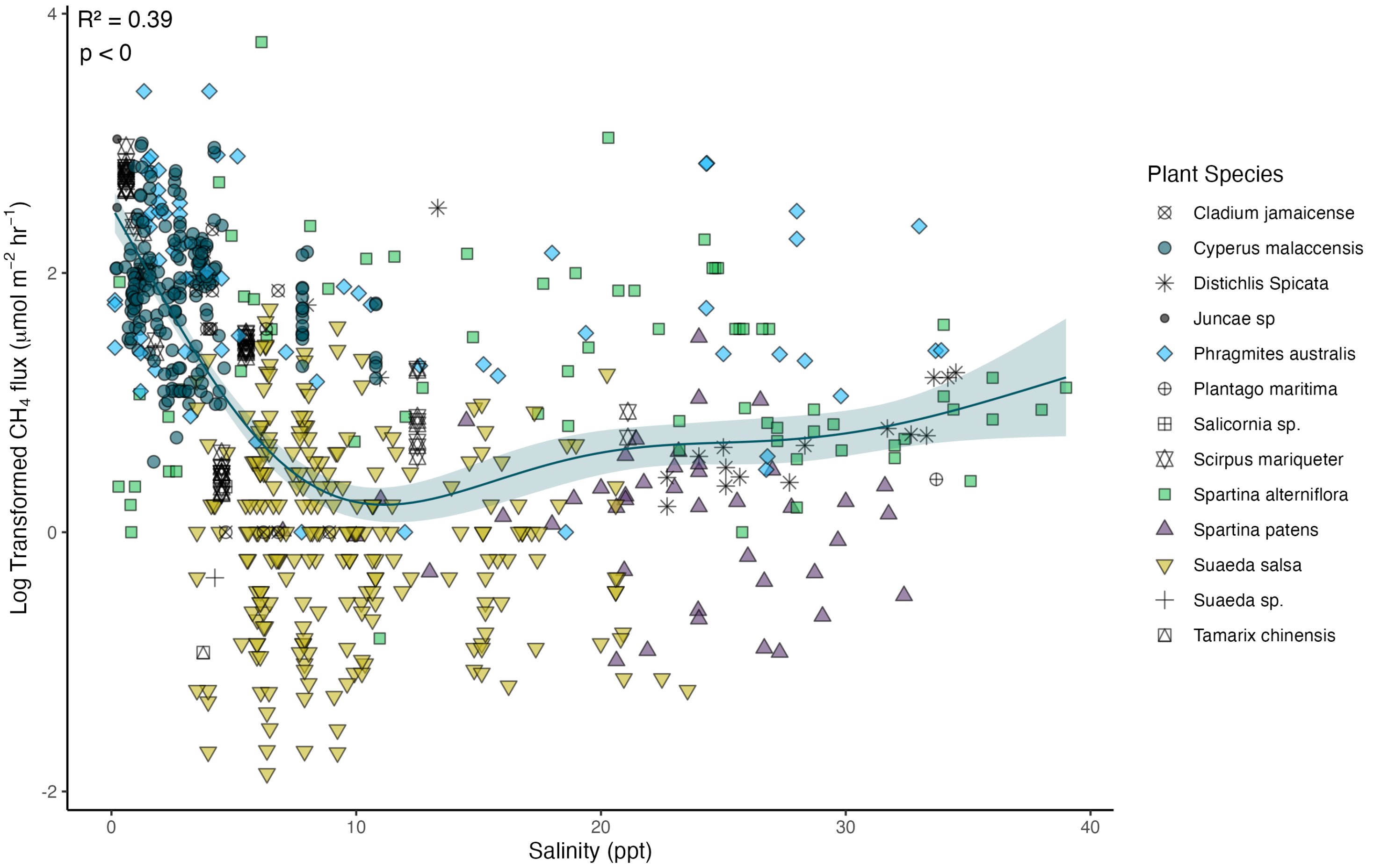
Plants appear to be driving the complex relationship between salinity and CH_4



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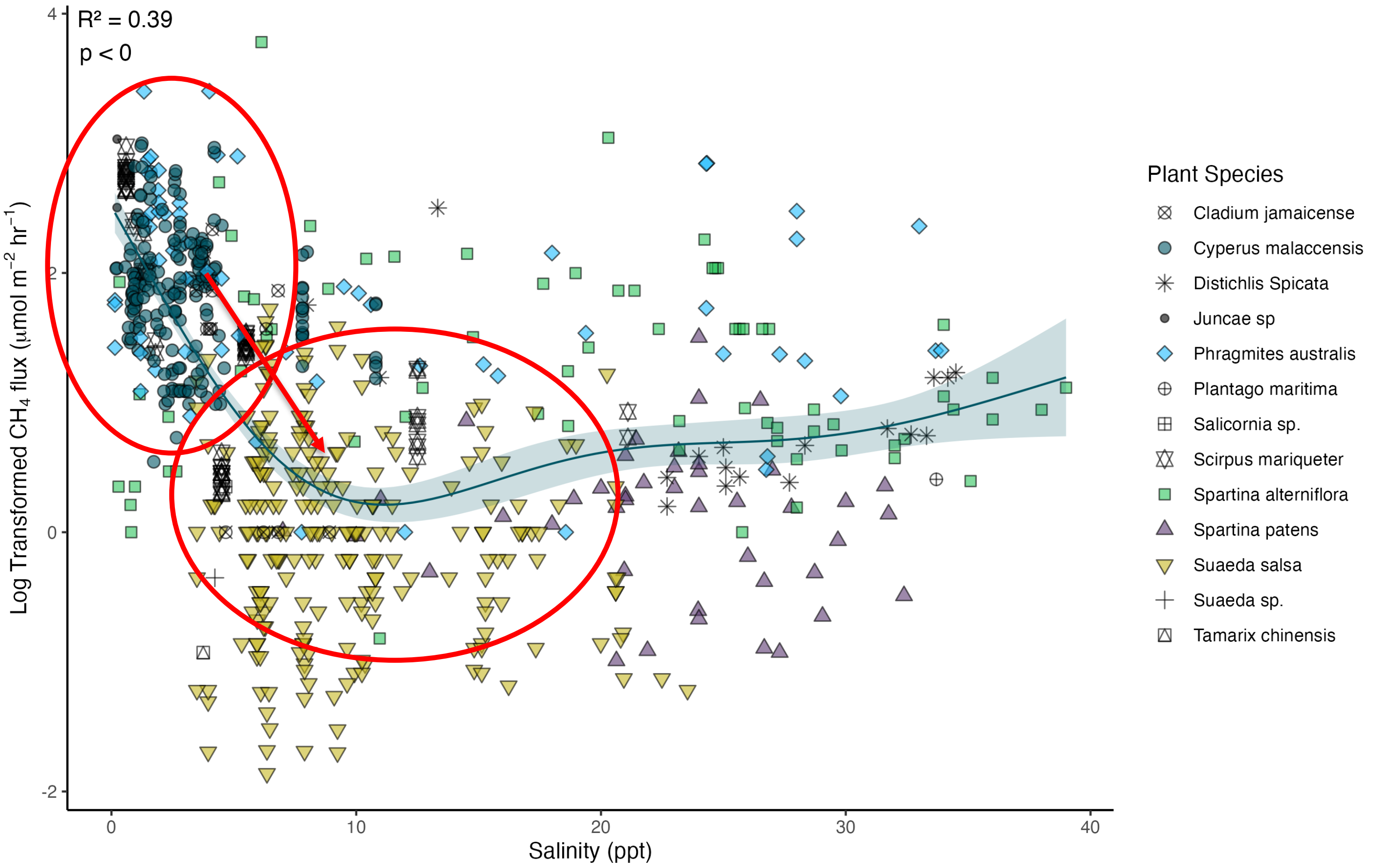

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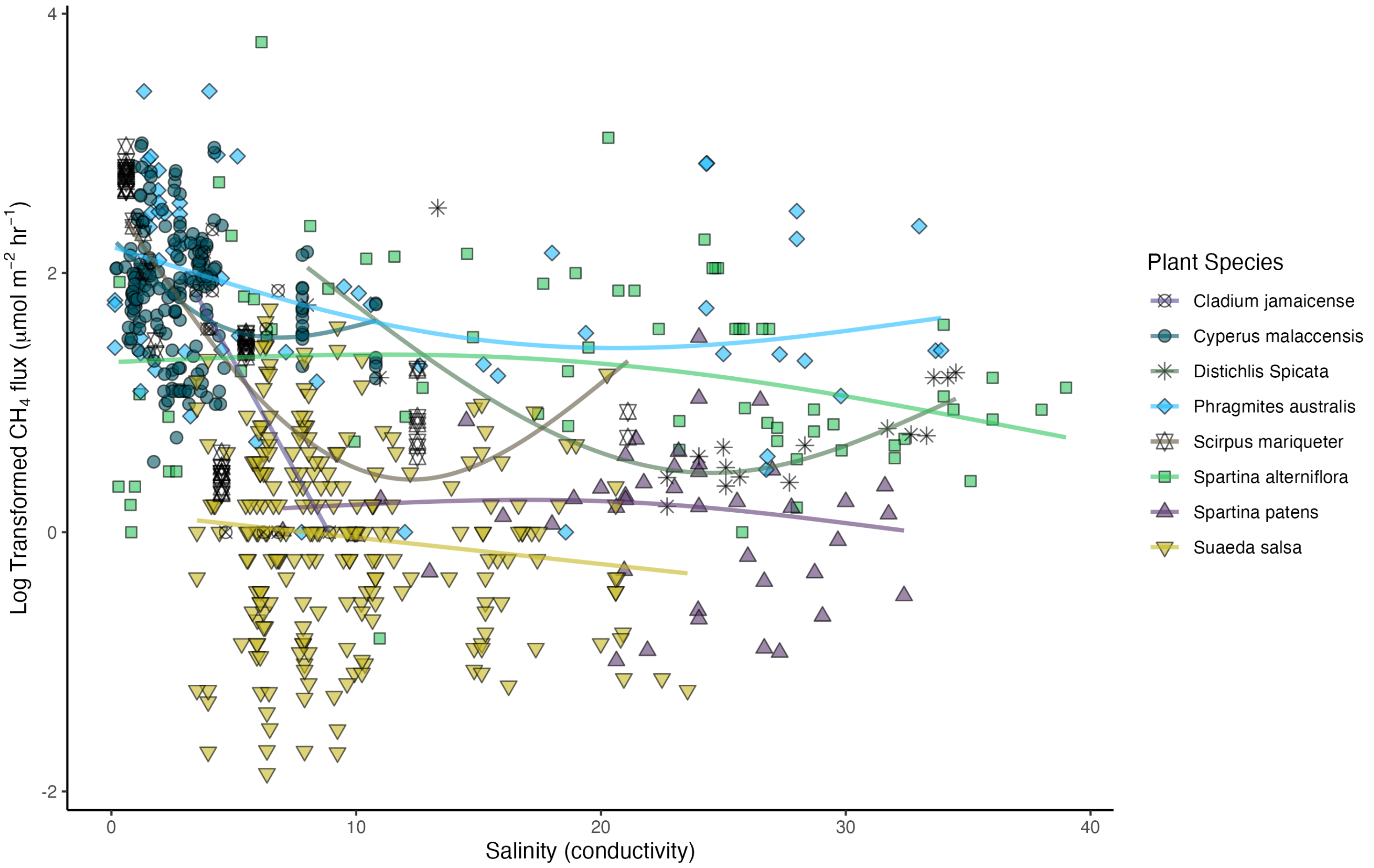
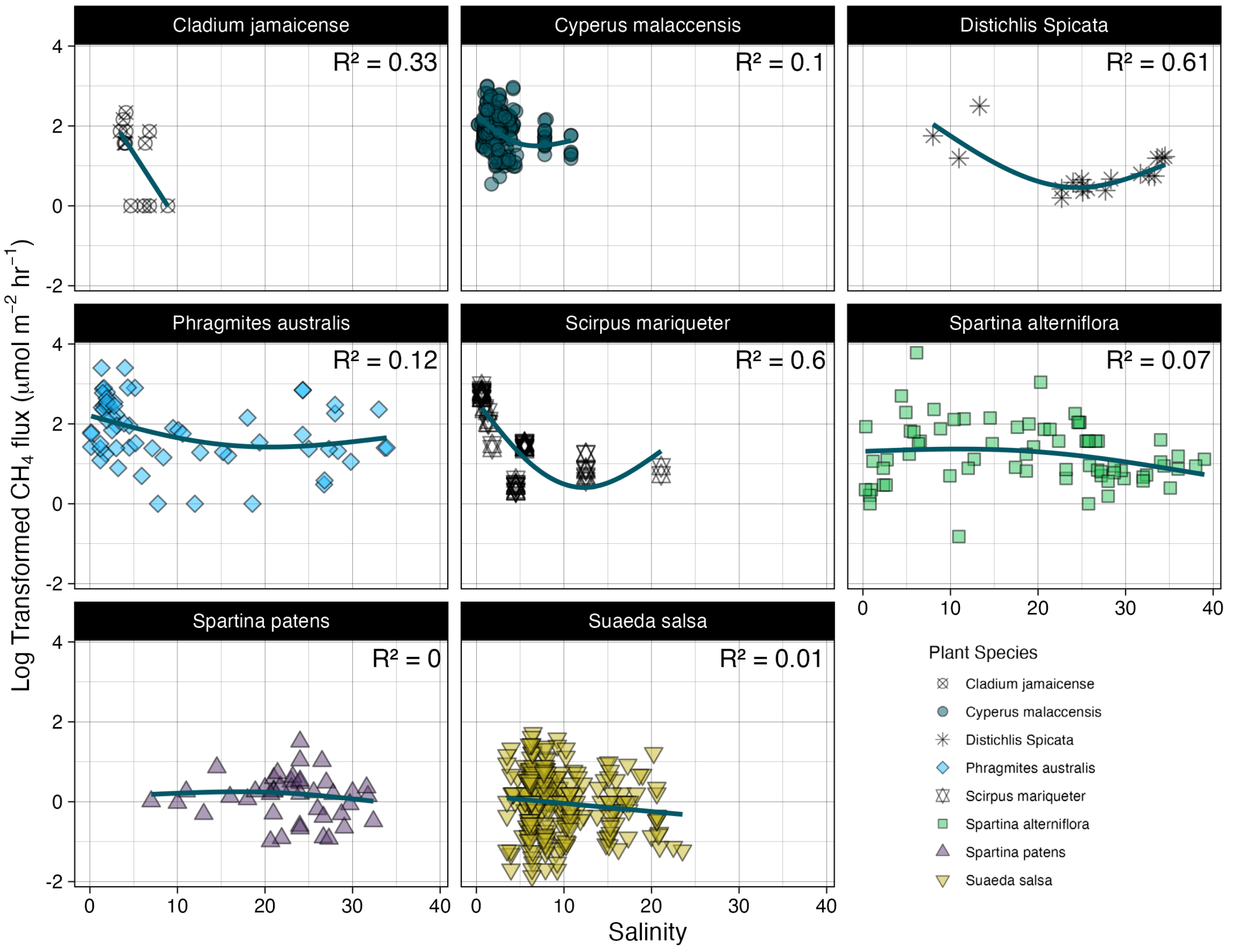
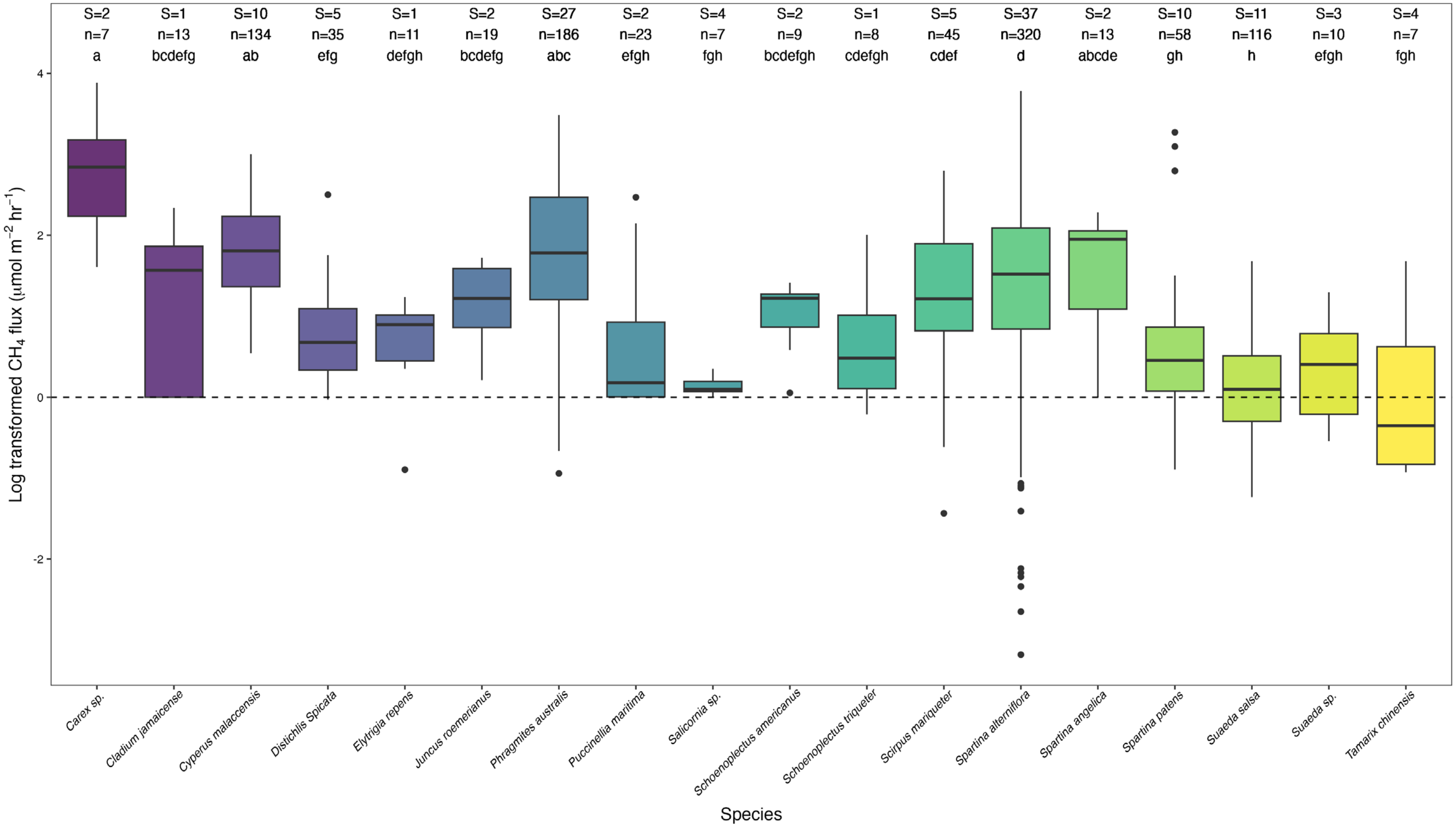


Strength of relationship between salinity and CH_4 flux depends on the plant species



Methane fluxes vary based on plant species



Predicting methane flux using GAM and Random Forest

Full Data Set

n=984 (1635 aggregated observations)

Predictors:

1. Plant species,
2. salinity (categorical),
3. absolute latitude,
4. season,
5. tidal range,
6. climate region,
7. sampling method (in situ or discrete samples)

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Soil Salinity Dataset

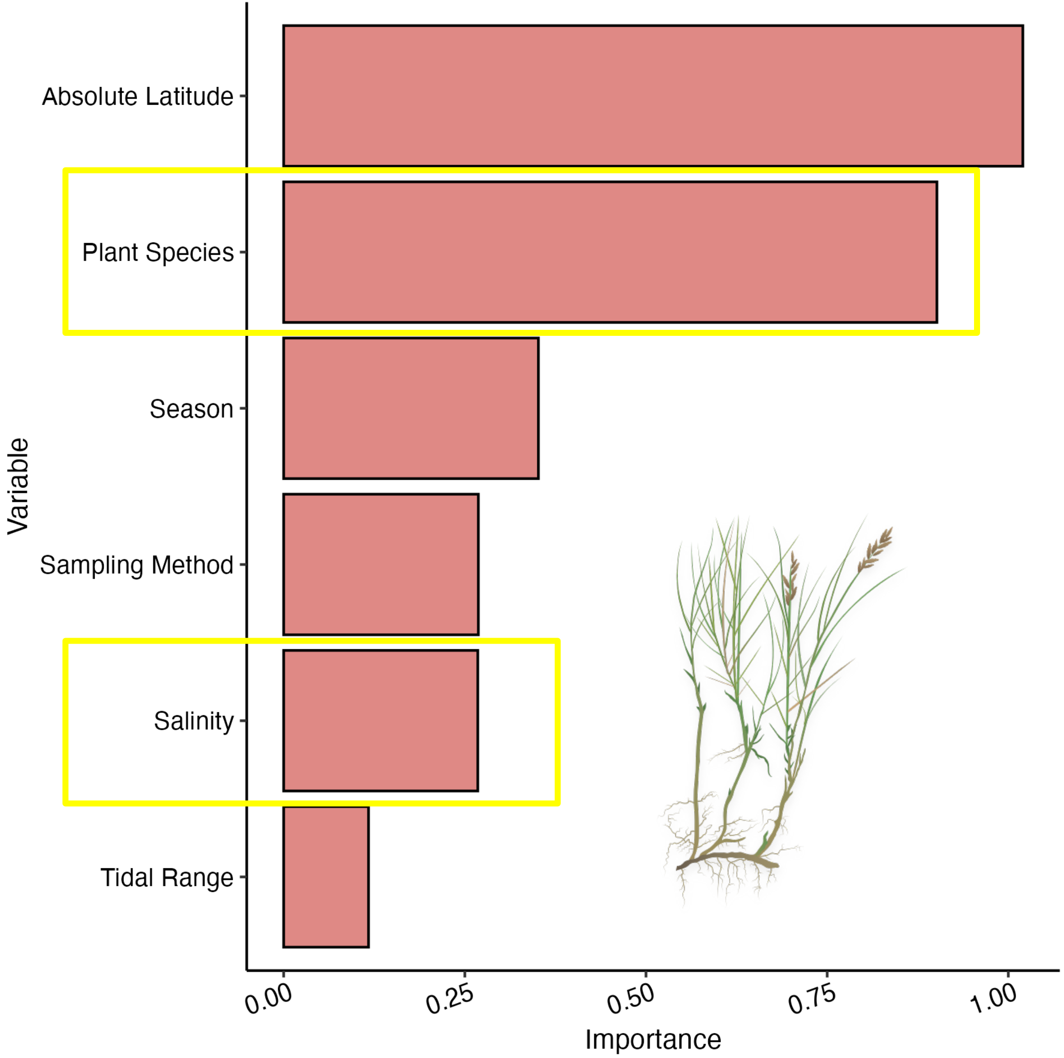
n=701, unaggregated

Predictors: Includes predictors from full data set AND porewater salinity

Plant species is a top predictor of methane flux

Full Data Set

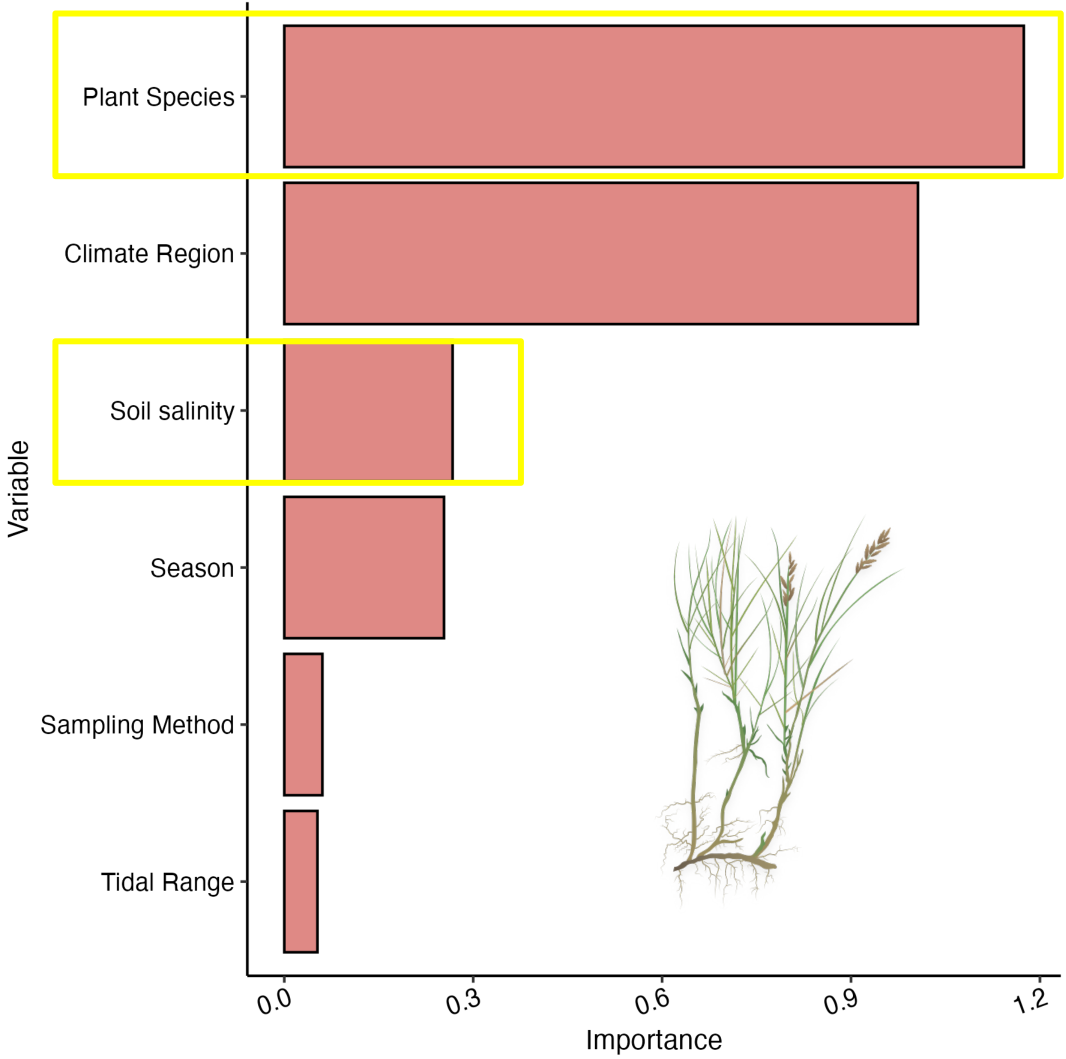
n = 984
GAM: R^2= **0.62**
RF: R^2= **0.59**



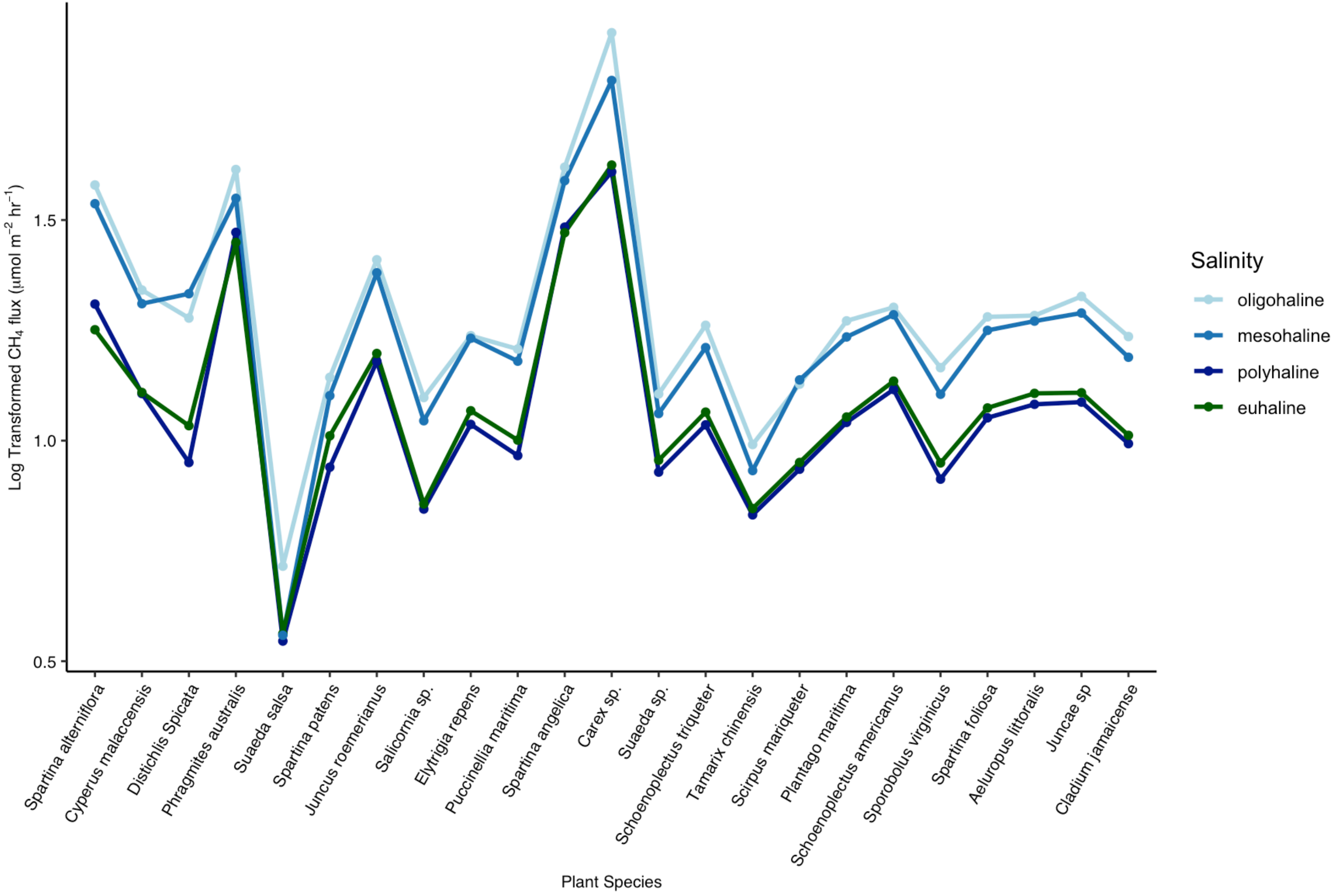
Plant species is the most important predictor of methane flux

Soil Salinity Data Set

n = 701
GAM: R^2= **0.73**
RF: R^2= **0.66**



Methane emissions depend on the interaction between plants and salinity



Salinity Range	
oligo	<5
meso	>5
poly	>18
euhaline	>30

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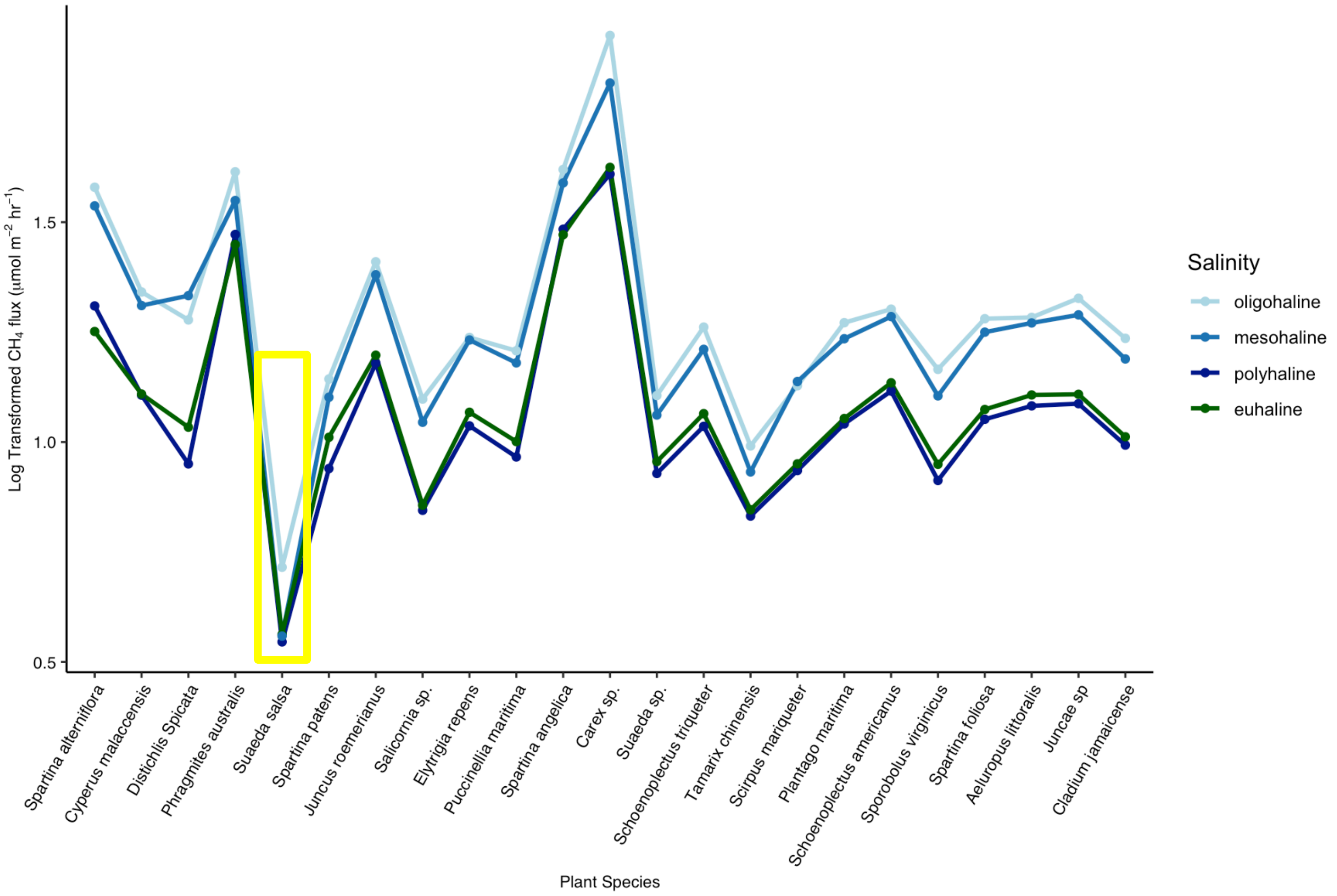

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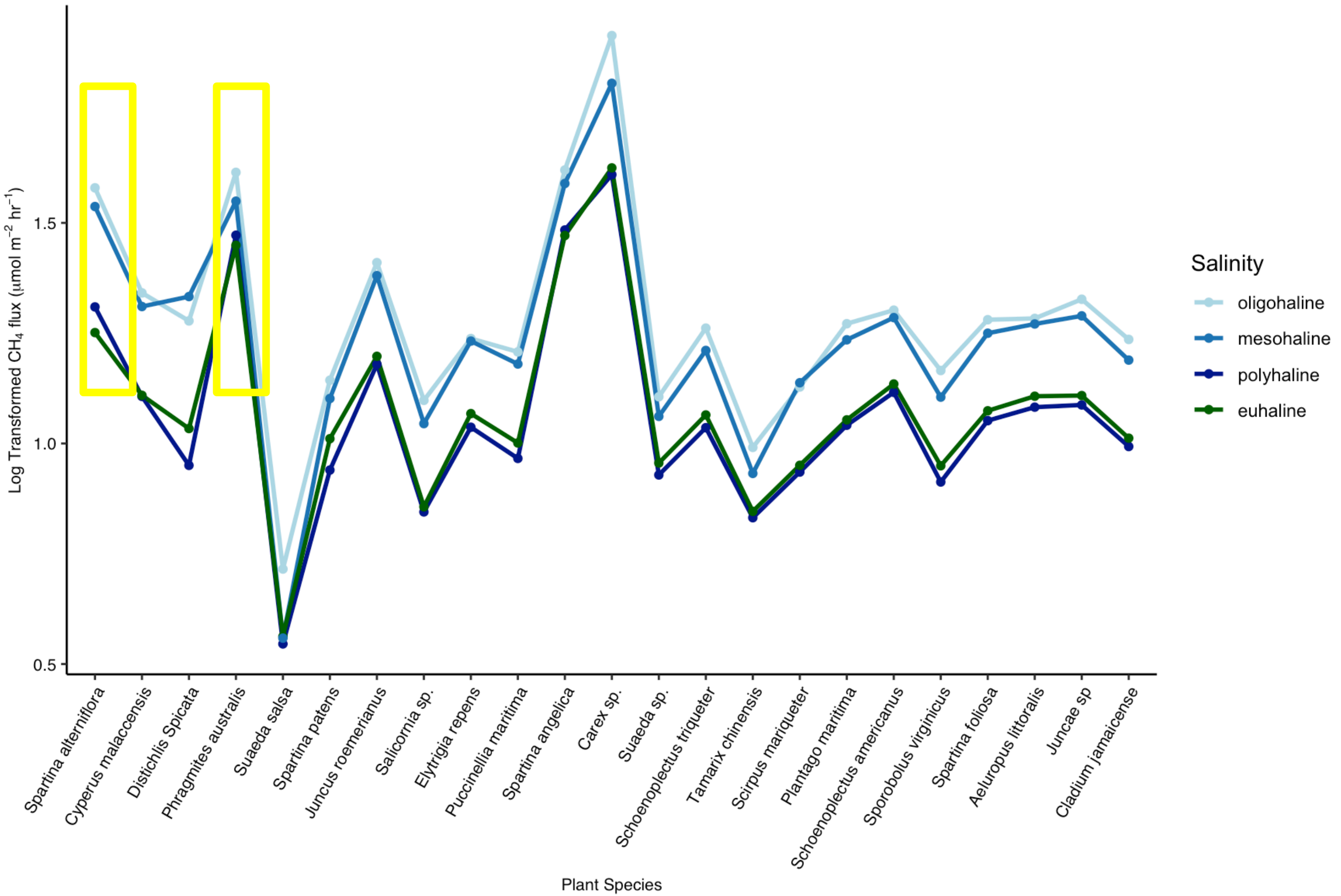

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Case study: Estimating methane emissions for a New England marsh using salinity and plants

Narragansett Bay, RI

Polyhaline

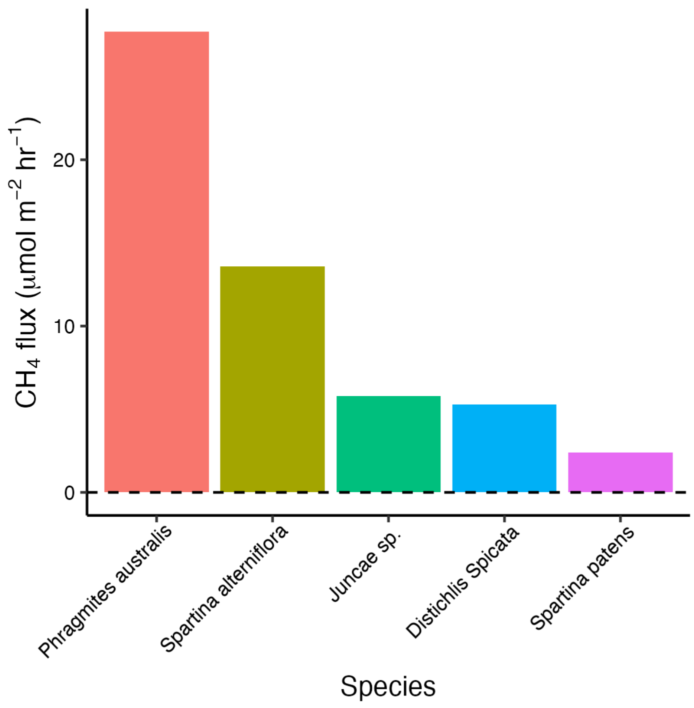
Narragansett Bay National Estuarine Research Reserve

Case study: Modeling fluxes with plant species and salinity enhances predictions compared to models with salinity alone

Salinity	**Predicted CH_4 Flux** umol $*m^{-2}*hr^{-1}$
Polyhaline	8.8

Plant Species	**Predicted CH_4 Flux** umol $*m^{-2}*hr^{-1}$
Phragmites australis	27.7
Spartina alterniflora	13.6
Juncae sp.	5.8
Distichlis Spicata	5.3
Spartina patens	2.4

Data Validation	**Average CH_4 Flux** umol $*m^{-2}*hr^{-1}$
July measurements (n=5) in mixed plots with *S. alterniflora, S. patens, D. spicata*	9.34 (4.6-21.6)



Case study: Modeling fluxes with plant species and salinity enhances predictions compared to models with salinity alone

Salinity	Predicted CH_4 Flux umol $*m^{-2}*hr^{-1}$		Area (m^2)
Polyhaline	8.8	x	8225745

= 8,985,343 umol $* hr^{-2}$

Plant Species	Predicted CH_4 Flux umol $*m^{-2}*hr^{-1}$		Area (m^2)
Phragmites australis	27.7	x	30019
Spartina alterniflora	13.6	x	481453
Juncae sp.	5.8	x	20821
Distichlis Spicata	5.3	x	96761
Spartina patens	2.4	x	193522

= 11,128,600umol $* hr^{-2}$

Model with plant species increases predicted flux by 24%

Case study: Modeling fluxes with plant species and salinity enhances predictions compared to models with salinity alone

Salinity	Predicted CH_4 Flux umol *m^{-2}*hr^{-1}	Predicted CH_4 Flux umol *hr^{-1}
Polyhaline	8.8	8,985,343

Plant Species	Predicted CH_4 Flux umol *m^{-2}*hr^{-1}	Predicted CH_4 Flux umol *hr^{-1}
Phragmites australis	27.7	11,128,600
Spartina alterniflora	13.6	
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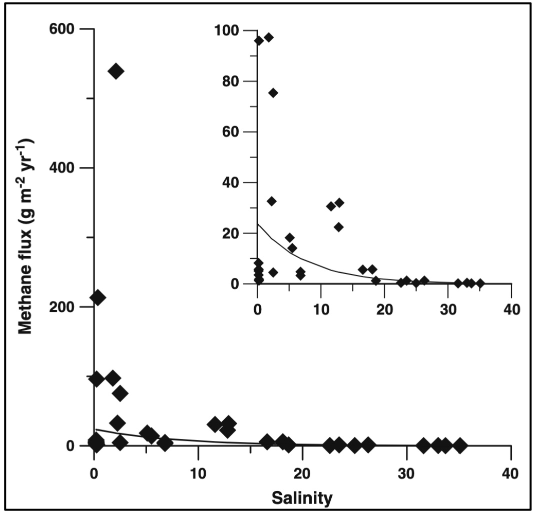
Spartina patens	2.4	

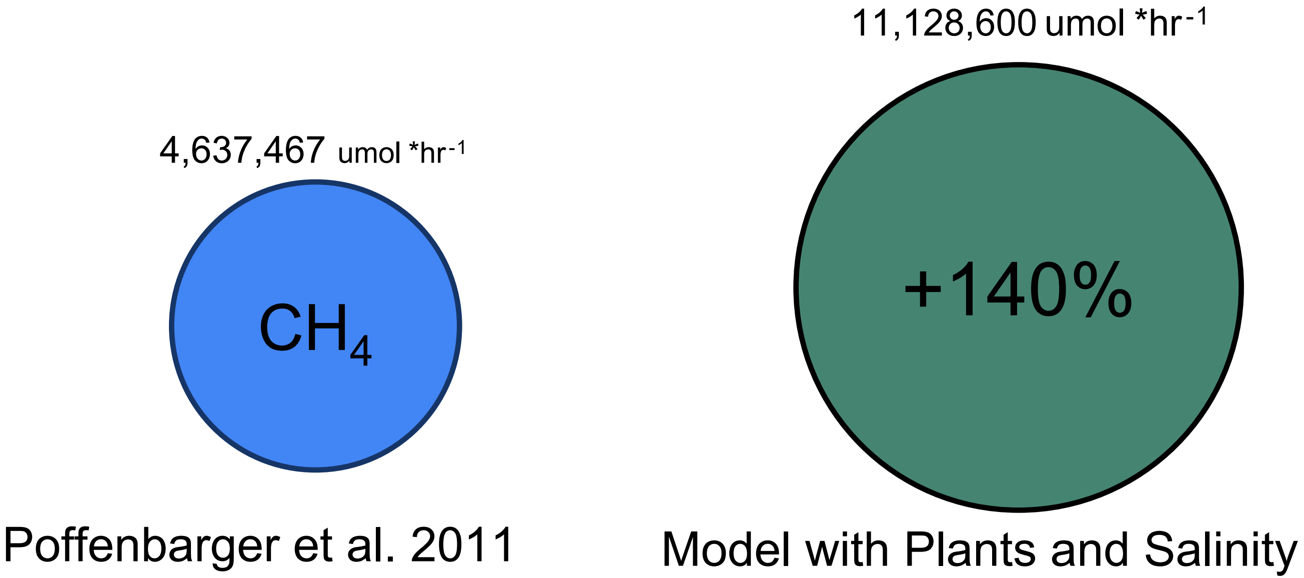
Poffenbarger et al. 2011:

$\log(CH_4\ g*m^{-2}*yr^{-1}) = -0.056 \times \text{salinity} + 1.38$

Salinity of **27** predicts a flux of 4,637,467 umol*hr^{-1}



Case study: Including plant species increased predicted emissions for a New England marsh by 140% compared to Poffenbarger et al. 2011



Plant species should be used as a predictor for salt marsh blue carbon along with salinity

Plants can inform low cost blue carbon assessments.

It is necessary to determine the impacts of **invasive plant species** and **sea level -rise mediated vegetation migration** on the carbon sink capacity of salt marshes.

Icons from Biorender; Tracey Saxby and Jane Hawkey, Integration and Application Network

Thank you!

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NOAA DAVIDSON FELLOWSHIP

WAQUOIT BAY National Estuarine Research Reserve

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