Evaluating greenhouse gas efflux across both rural-urban and salinity gradients in the Hudson River Estuary

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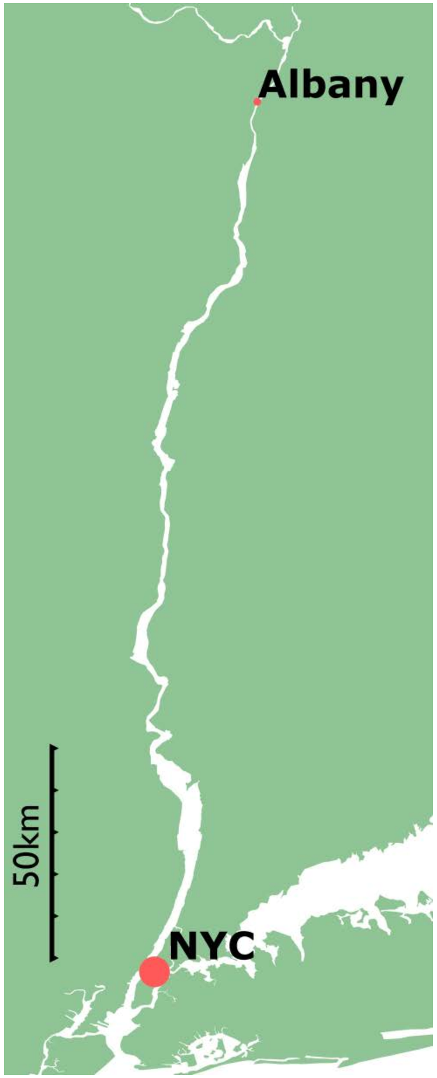
Hudson tidal estuary



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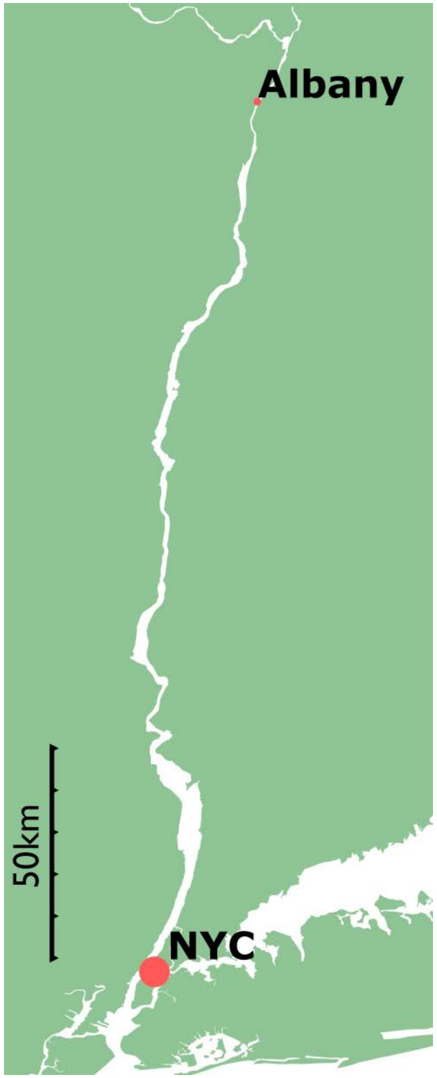

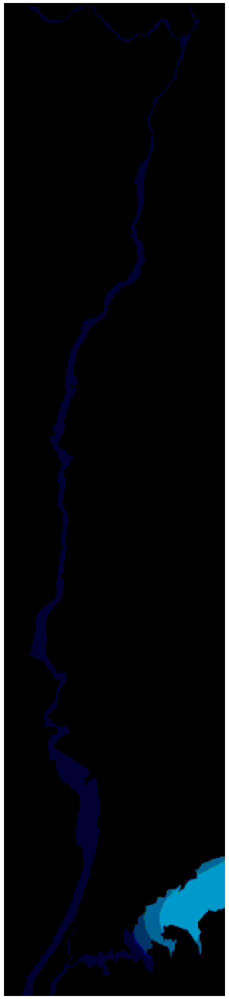

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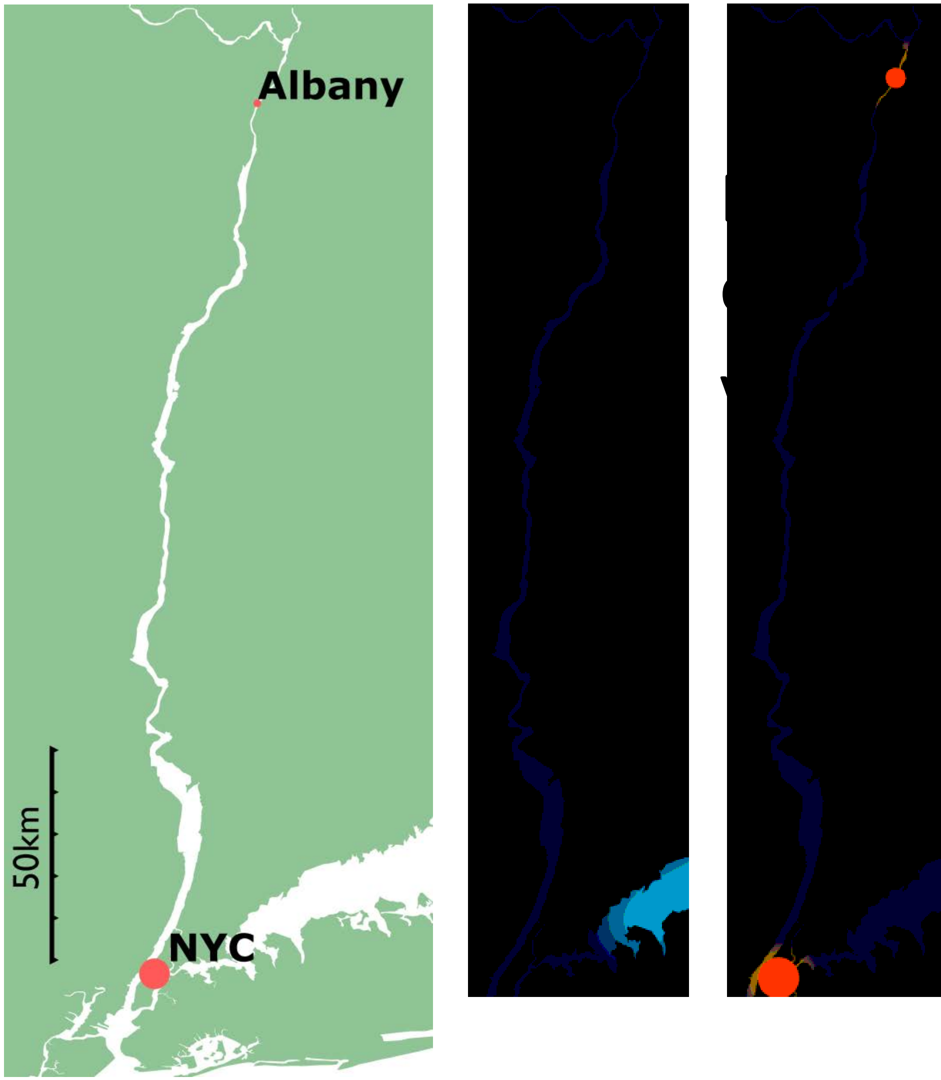
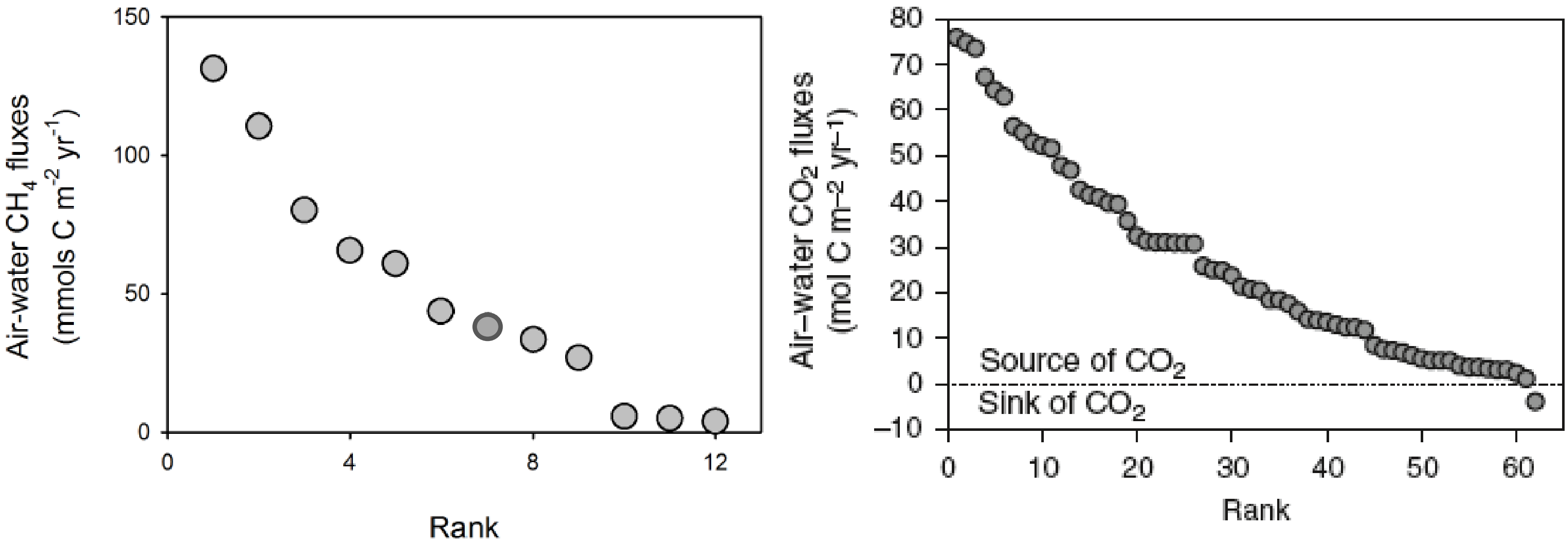
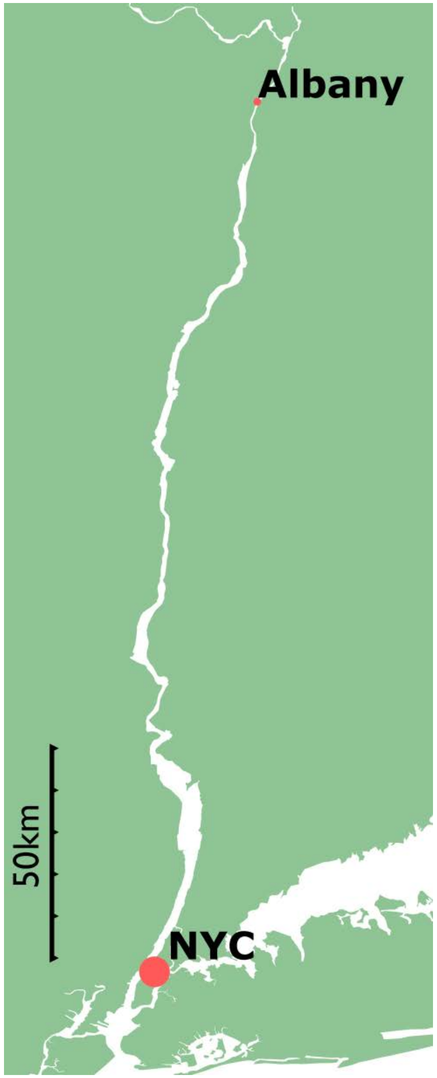


…es of GHG efflux from …es are extremely …e (Borges and Abril 2011)

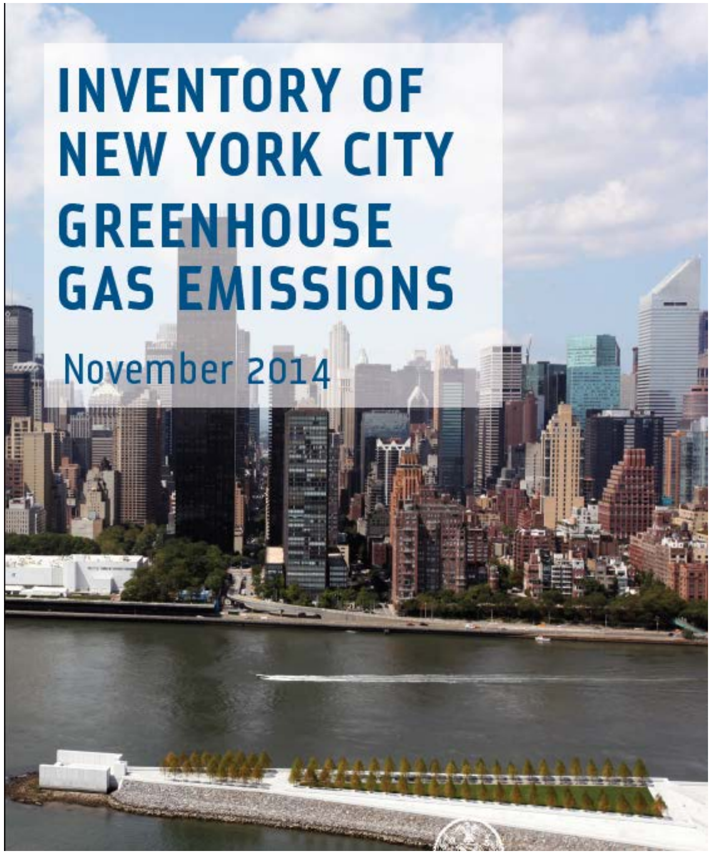


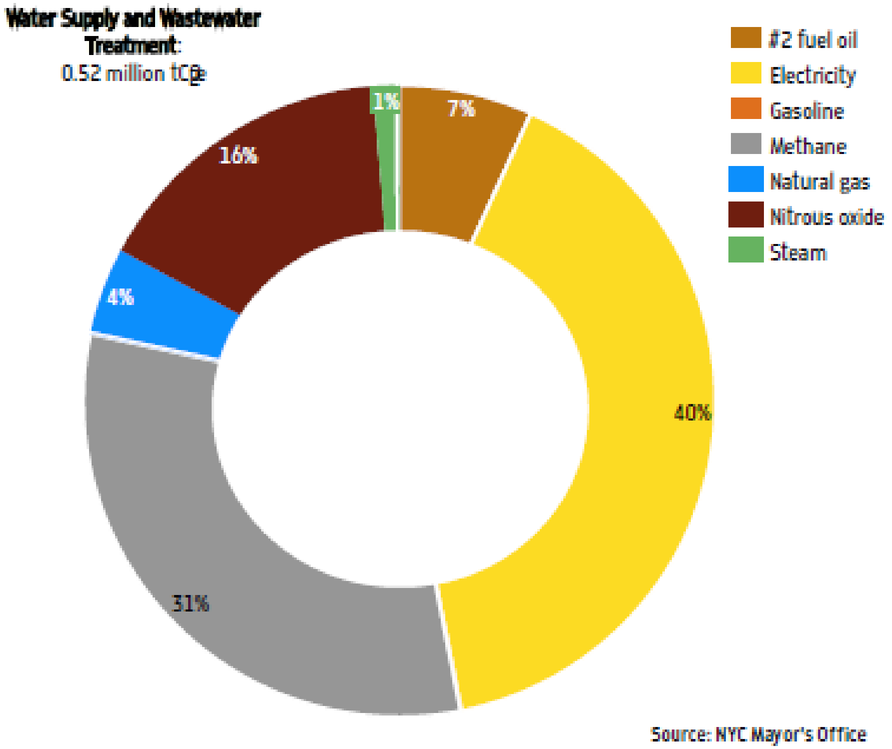
Abril and Borges (2011)

Hudson tidal estuary



- Estimates of GHG efflux from estuaries are extremely variable (Borges and Abril 2011)
- NYC is invested in identifying and managing sources of GHGs (Plan NYC 2014)

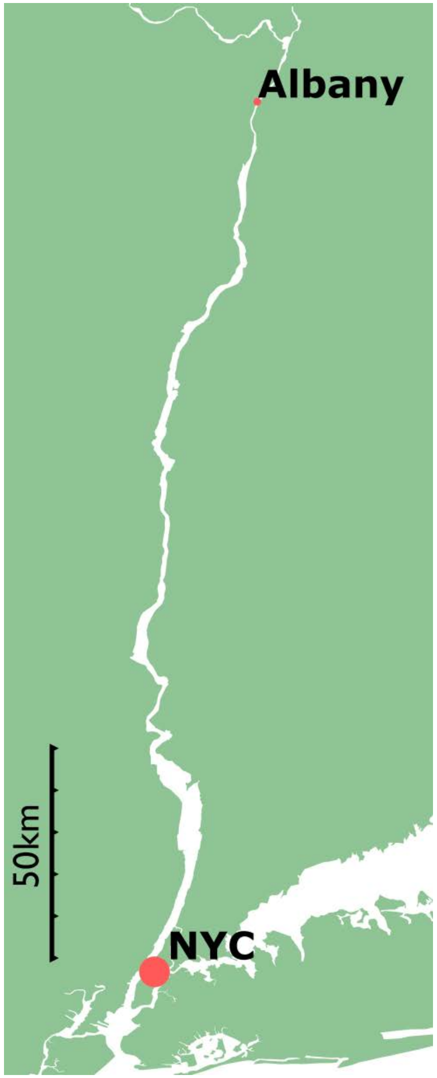




"Better data allow for more rigorous analysis … provides strong evidence for the City's data-driven approach to management: you can't manage what you do not measure"

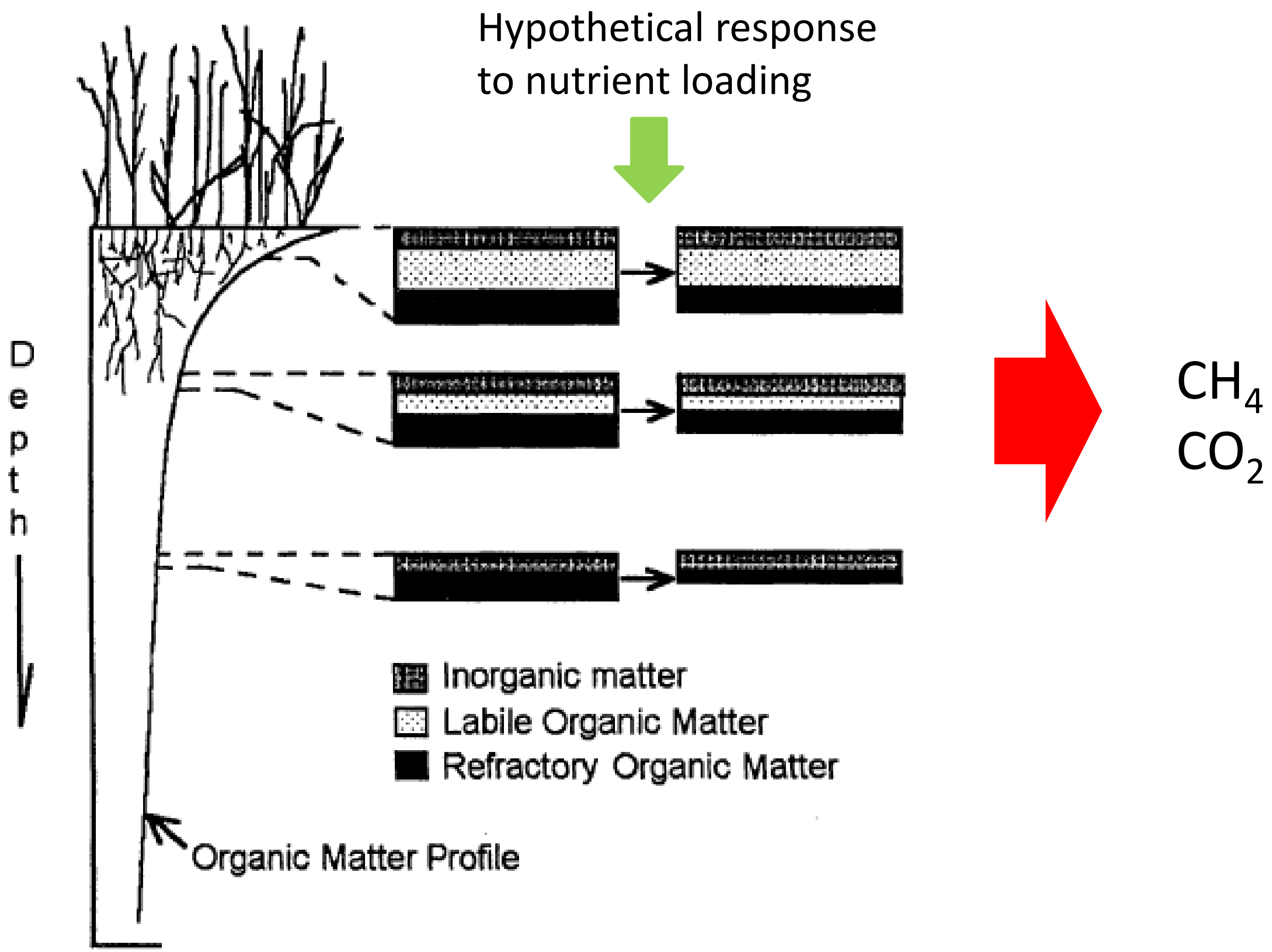
PlanNYC 2014

Hudson tidal estuary



- Estimates of GHG efflux from estuaries are extremely variable (Borges and Abril 2011)
- NYC is invested in identifying and managing sources of GHGs (PlanNYC 2014)
- Impact of wastewater pollution on carbon cycling

What is the fate of nutrient additions in the environment?



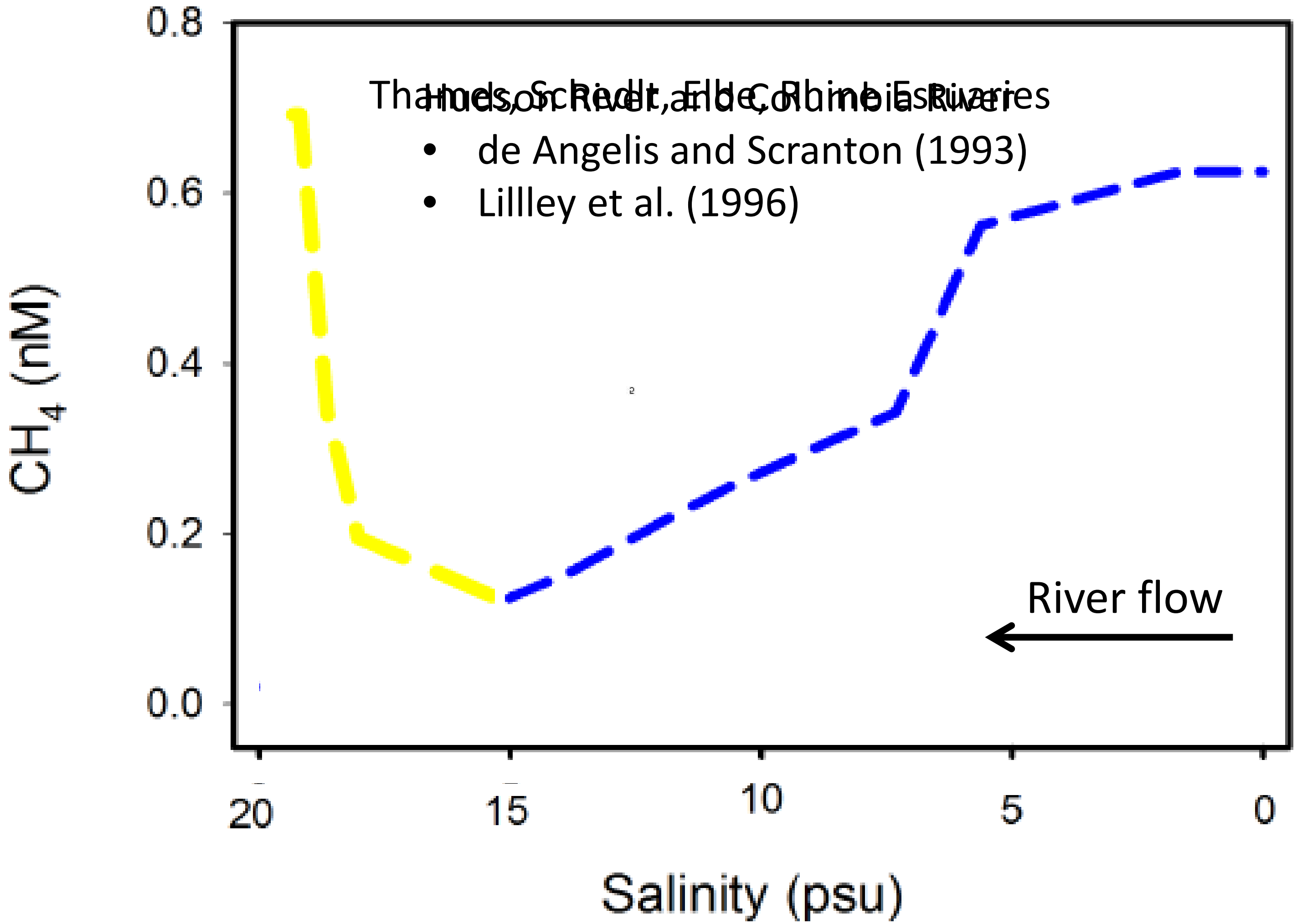
Modified from Morris and Bradley 1999

Outline

i. CH_4 and CO_2 efflux in the tidal Hudson River Estuary (HRE)
ii. Linkages to urban centers and combined sewer overflow (CSO) events
iii. Effect of nutrient loading on wetland soils
iv. Conclusion

Part I: HRE greenhouse gas efflux

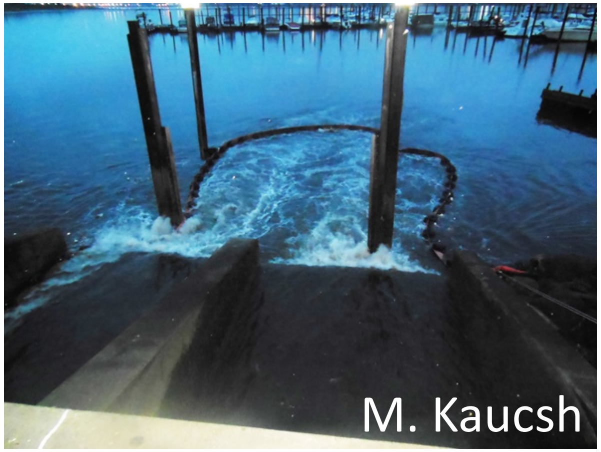
CH_4 across a salinity gradient



Based on Abril and Borges (2011)

Combined sewer overflows

- 27 billion gallons of raw sewage and polluted storm water is delivered to New York Harbor ever year (Ward et al. 2004)
  - ~ 7 mmol N and 33 mmol C m^{-2} d^{-1} (Griffith and Raymond 2011)



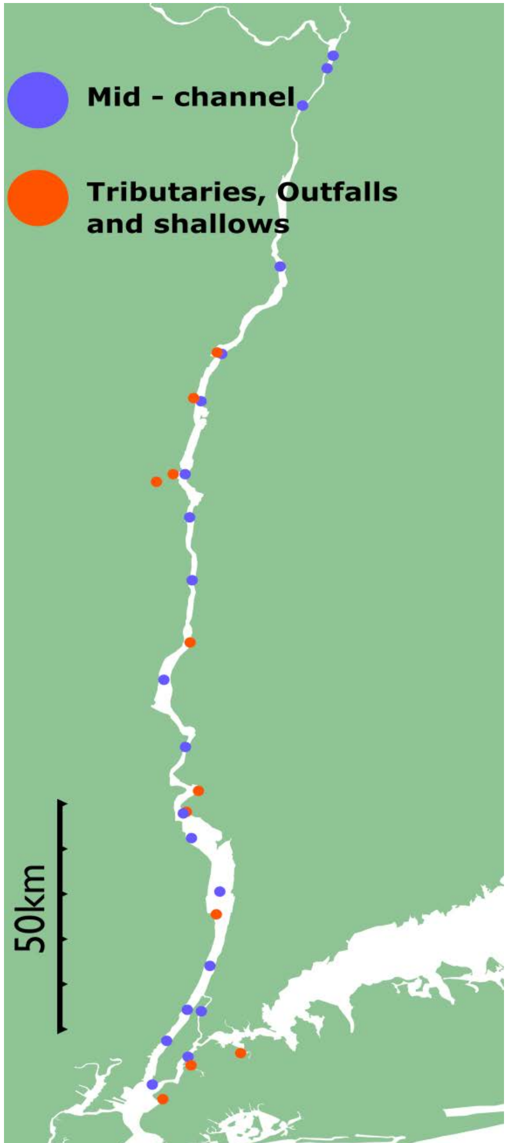
- The majority of nutrient pollution to the lower tidal HRE originates in NYC from CSO events

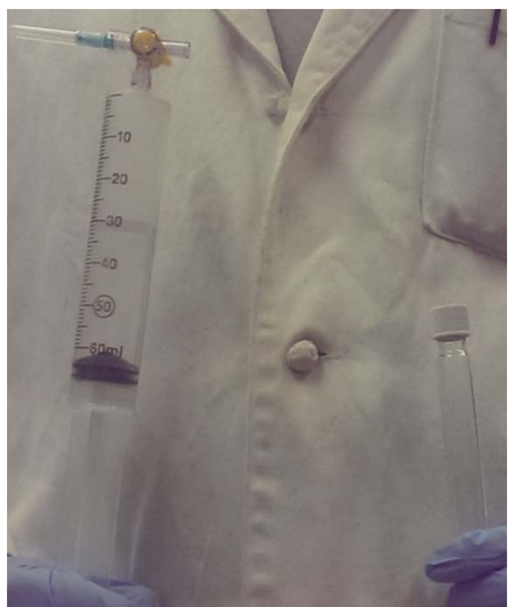
Research questions

- What is the pattern of CH_4 and CO_2 efflux across the HRE estuary?
  - Does efflux vary across the HRE salinity gradient?
  - Are there hotspots of efflux associated with urban regions?

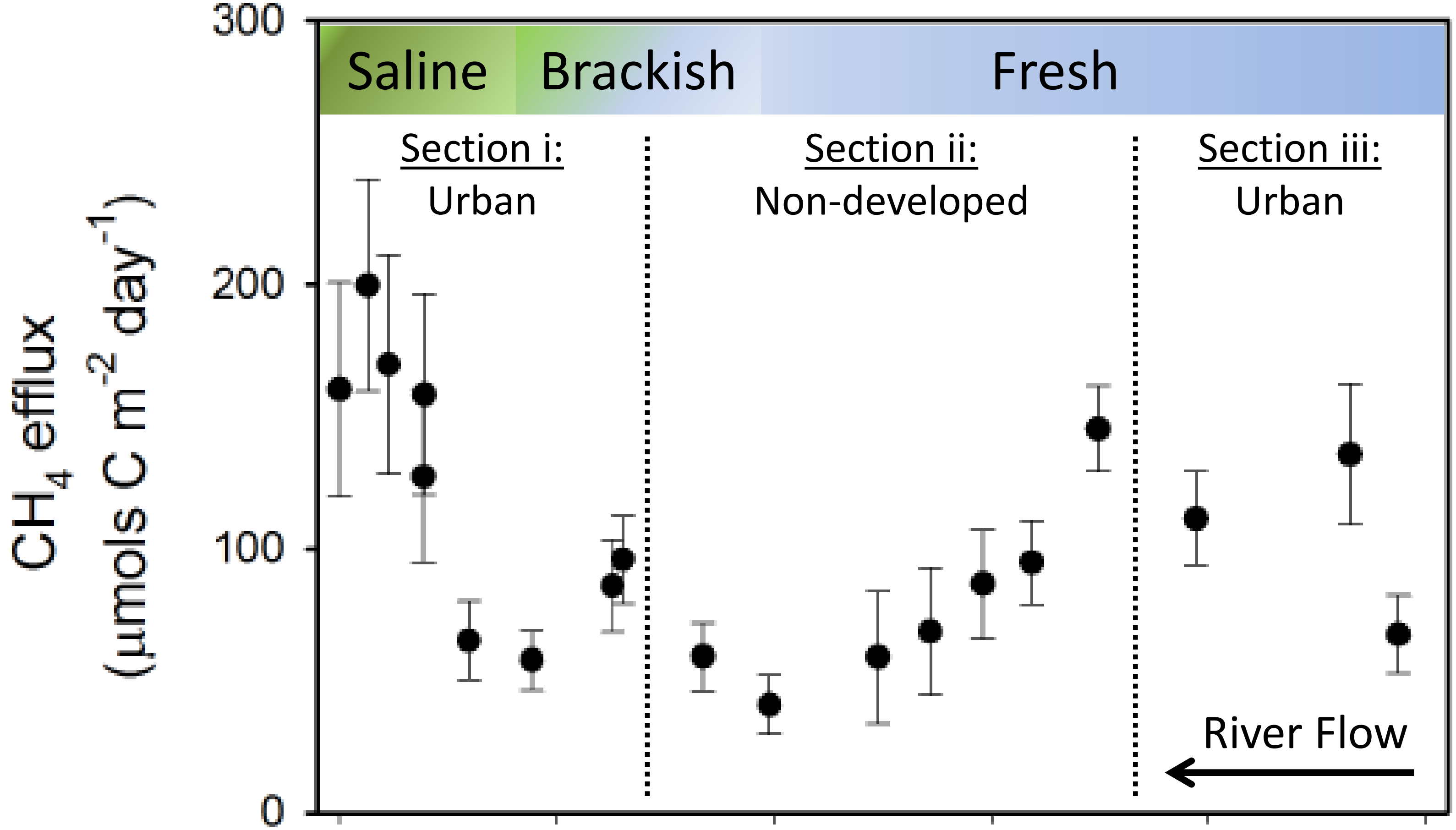
Part I: HRE greenhouse gas efflux

Methods



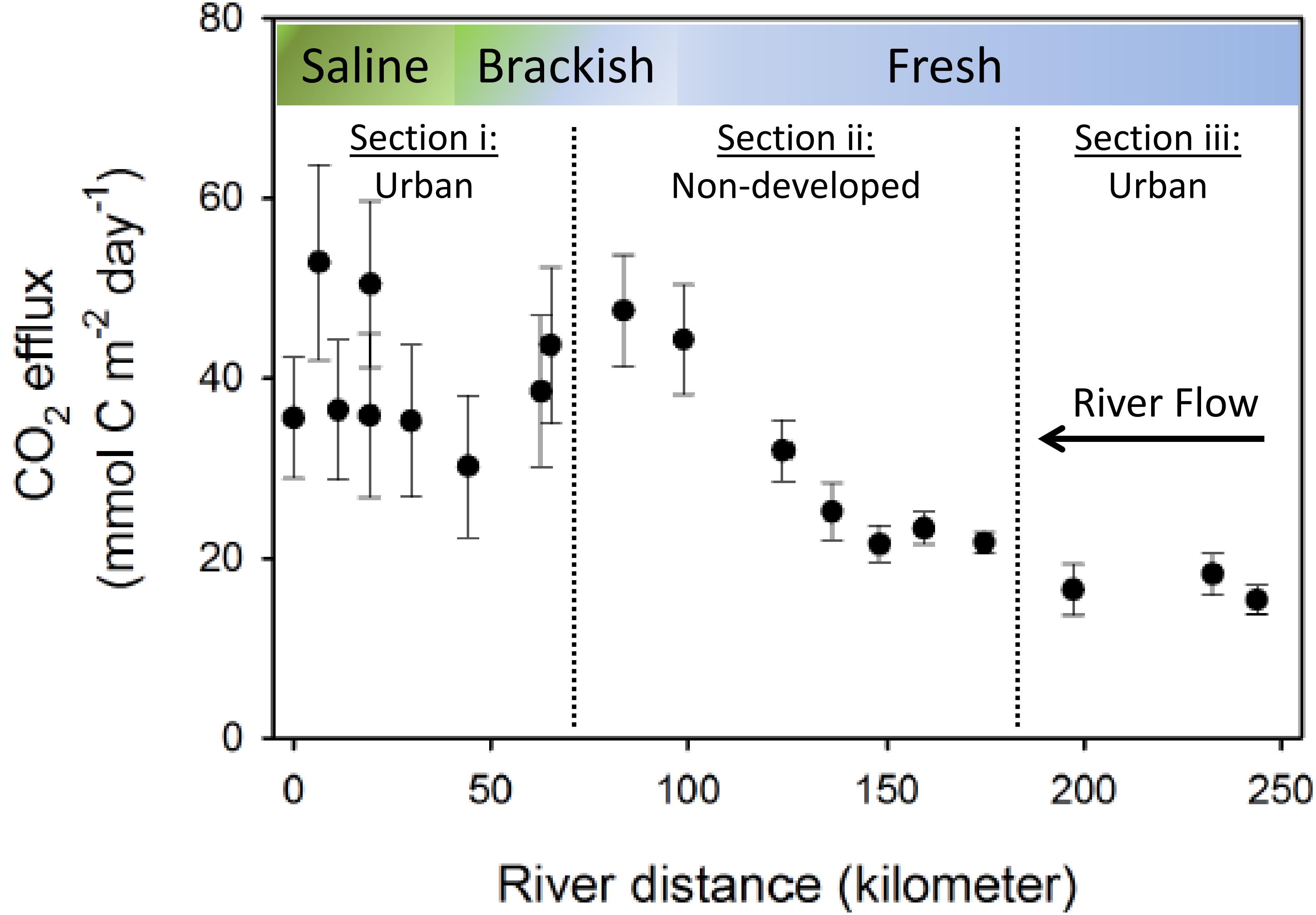


Part I: HRE greenhouse gas efflux

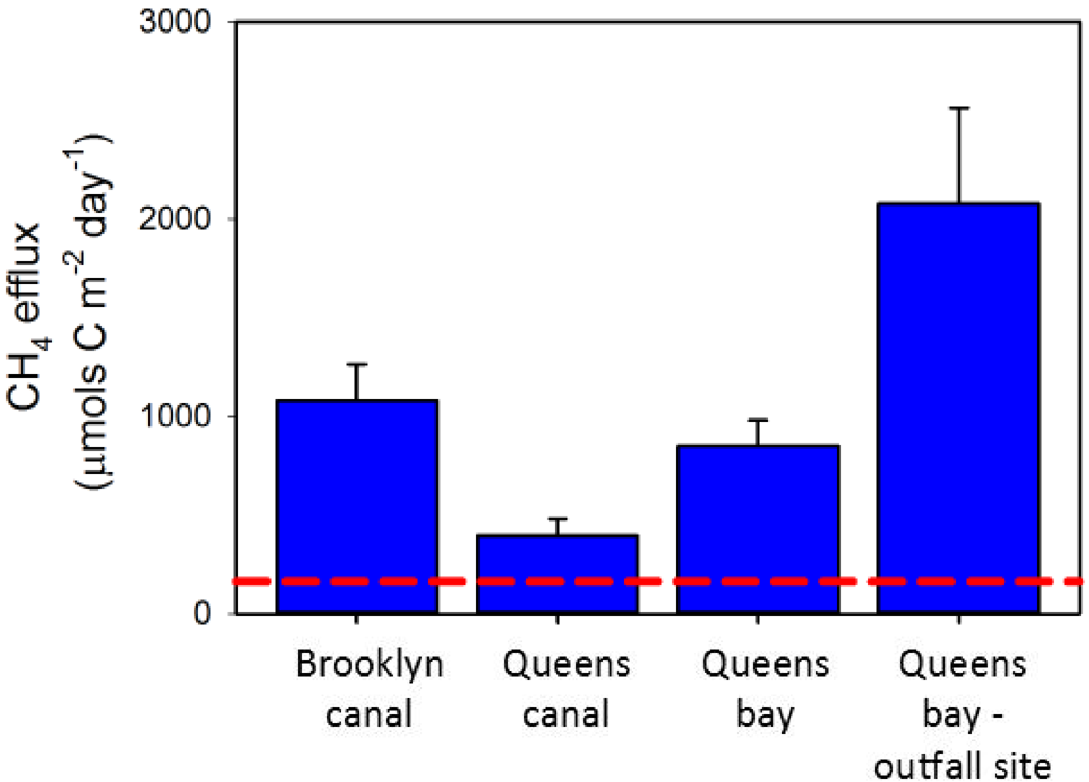


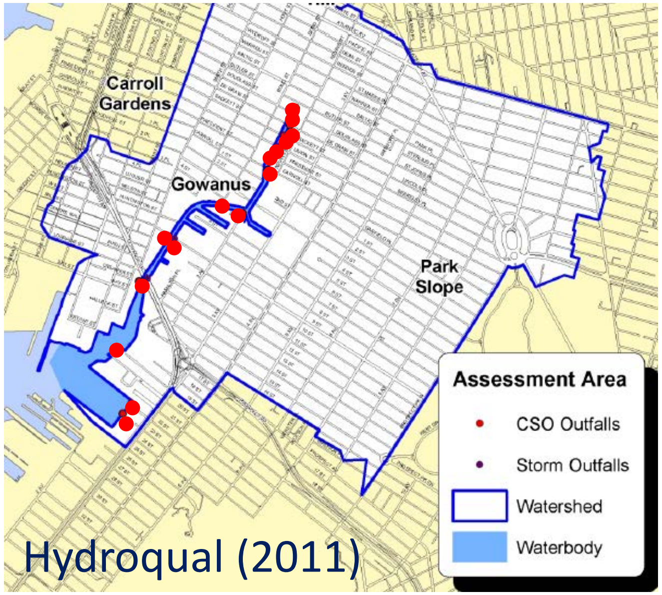
- No significant correlation between salinity and CH_4 concentrations

Part I: HRE greenhouse gas efflux



Hot spots of CH_4 efflux





Hydroqual (2011)

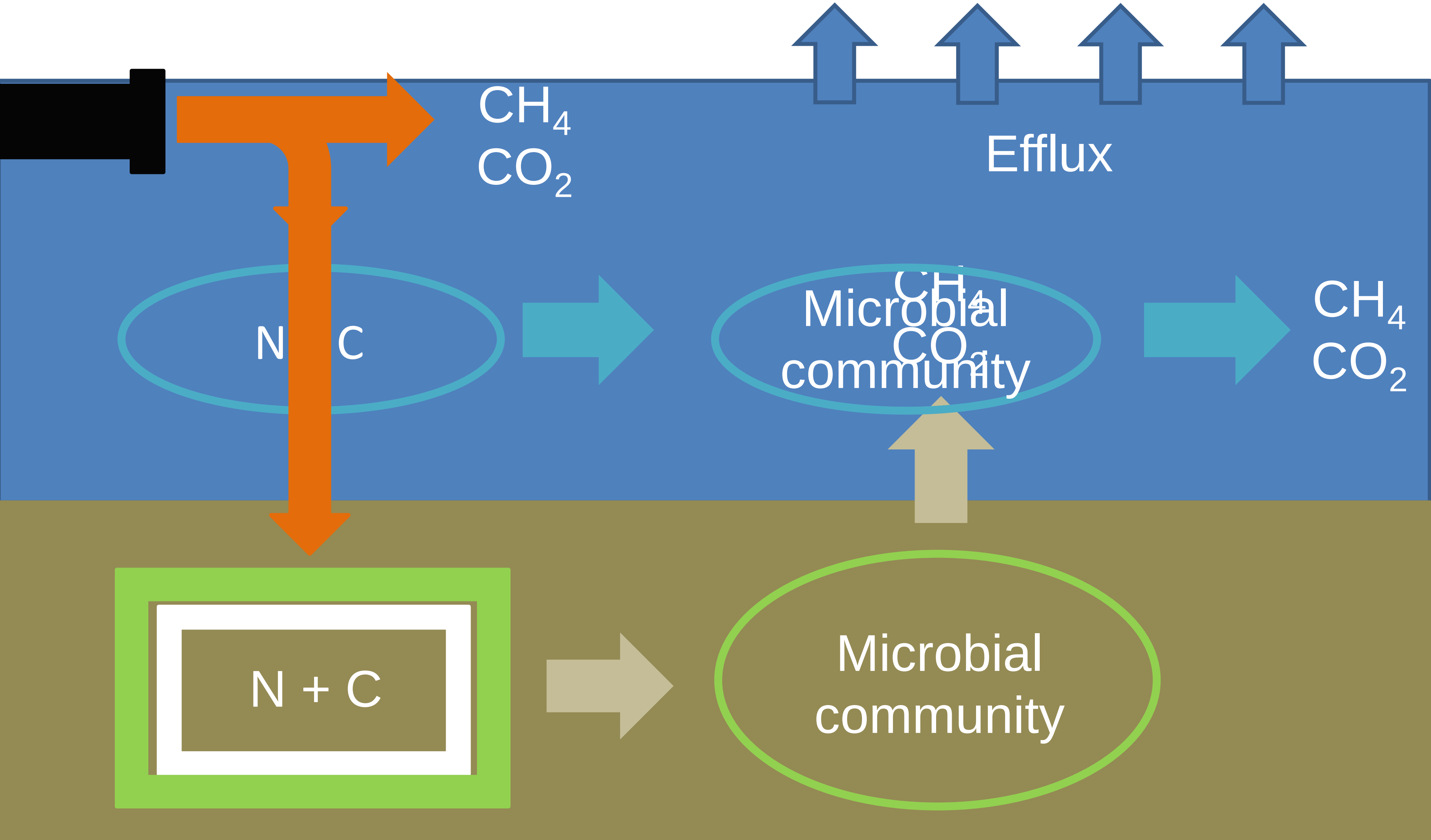
NY Times (2014)

Part I: HRE greenhouse gas efflux

Conclusions

- CH_4 efflux had a U-shaped pattern across the HRE likely heavily influenced by urban centers
  - CO_2 efflux had an alternative pattern
  - Salinity gradient may also interact but is confounded by other factors
- Untreated sewage/wastewater are likely sources of GHG
  - Significantly increased efflux observed in CSO delivery areas

Potential CH_4 sources



Part II: Connections to CSO events

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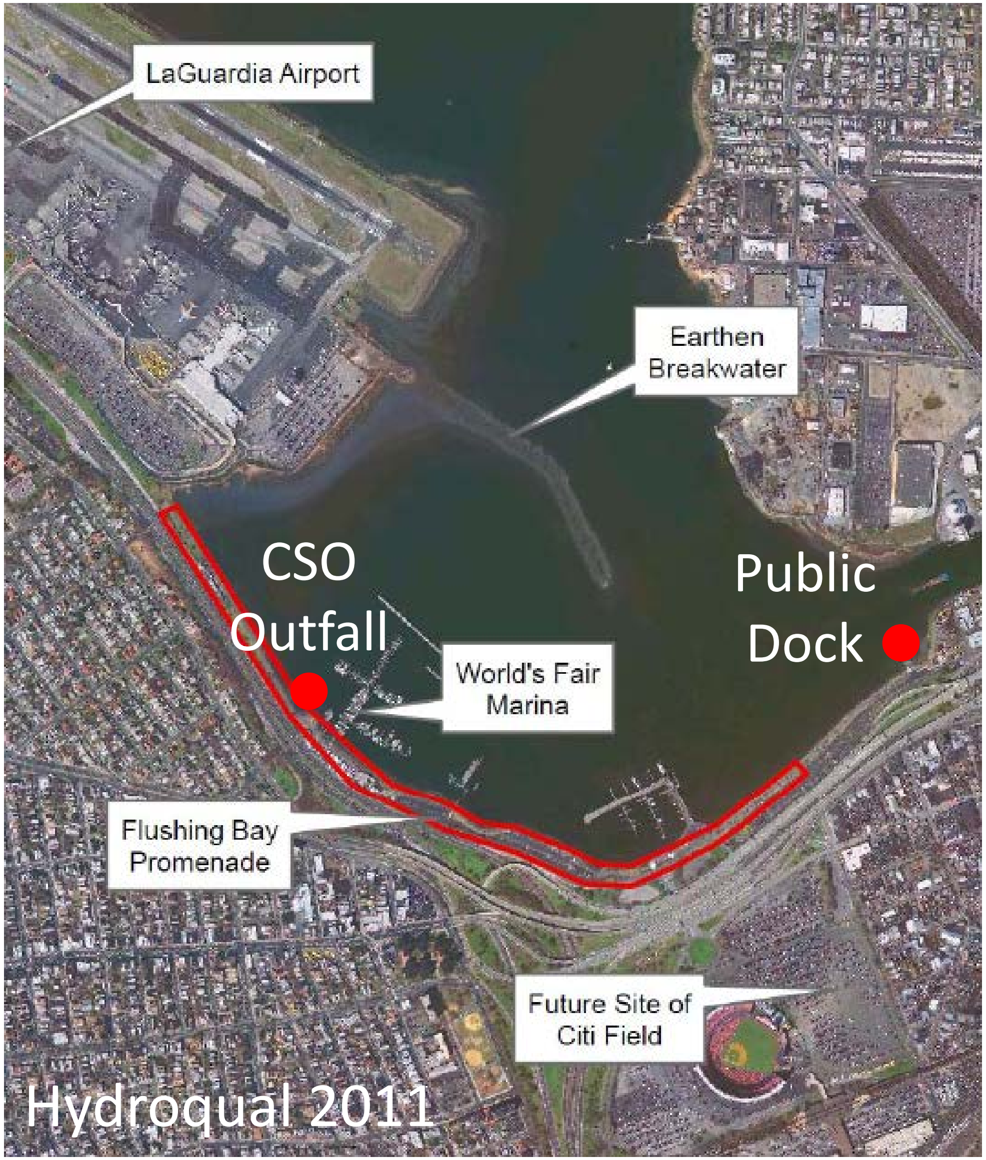
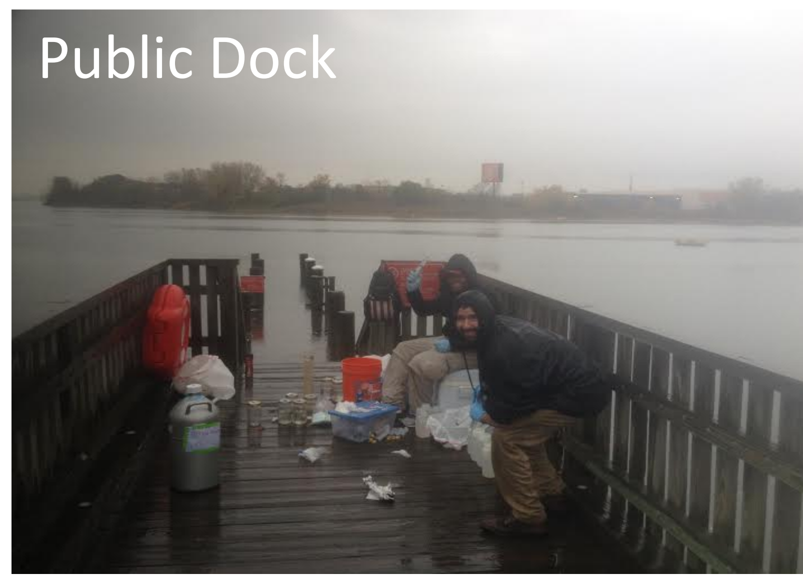
Research questions

- Will CSOs be a direct source of GHGs?
  - Will GHG concentrations be elevated at sites in close proximity to CSOs compared to reference sites
  - Will they be a direct source of nutrients?
- Will precipitation events result in a short-lived increase in GHG concentrations?

Part II: Connections to CSO events

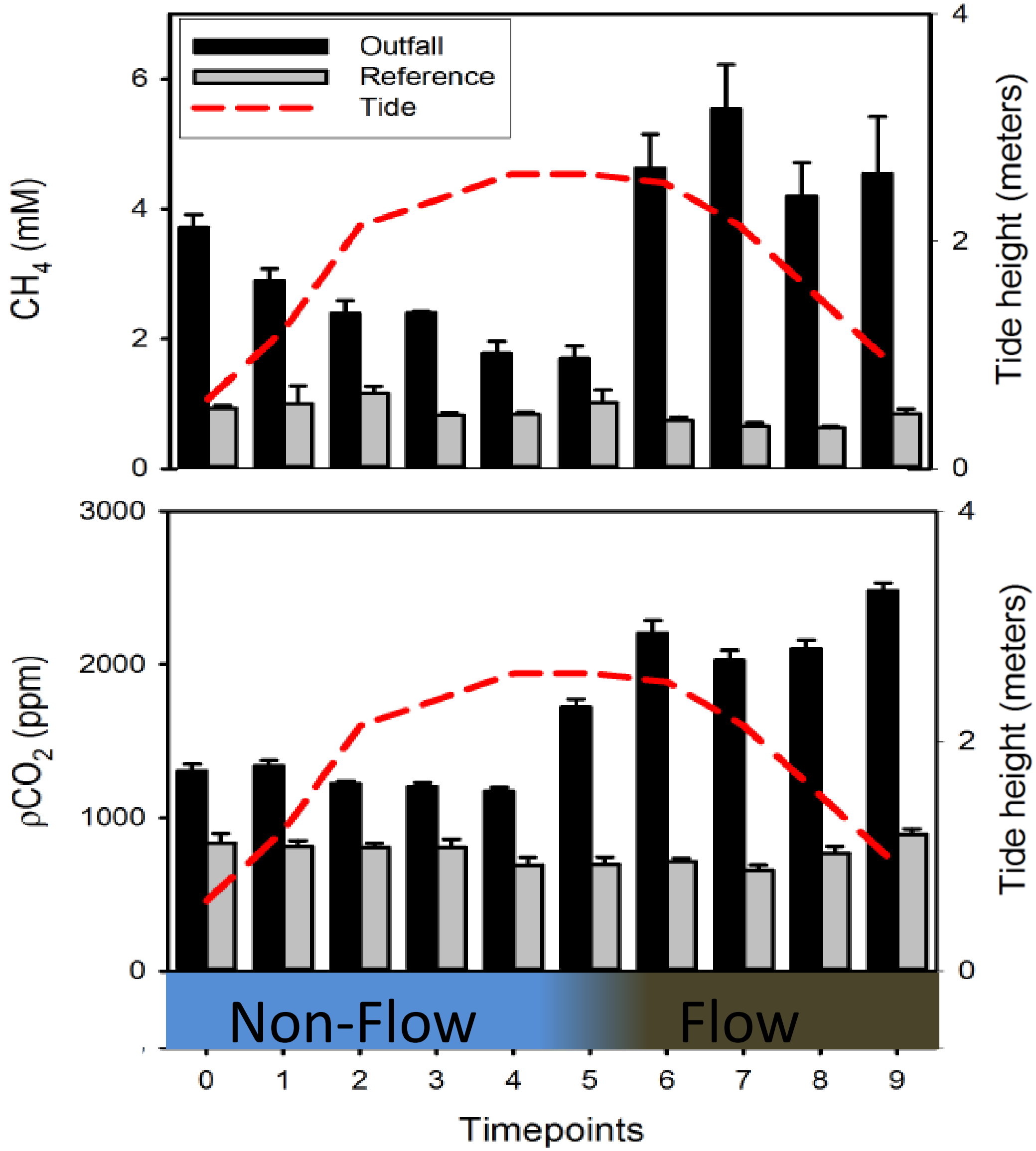
Field sites





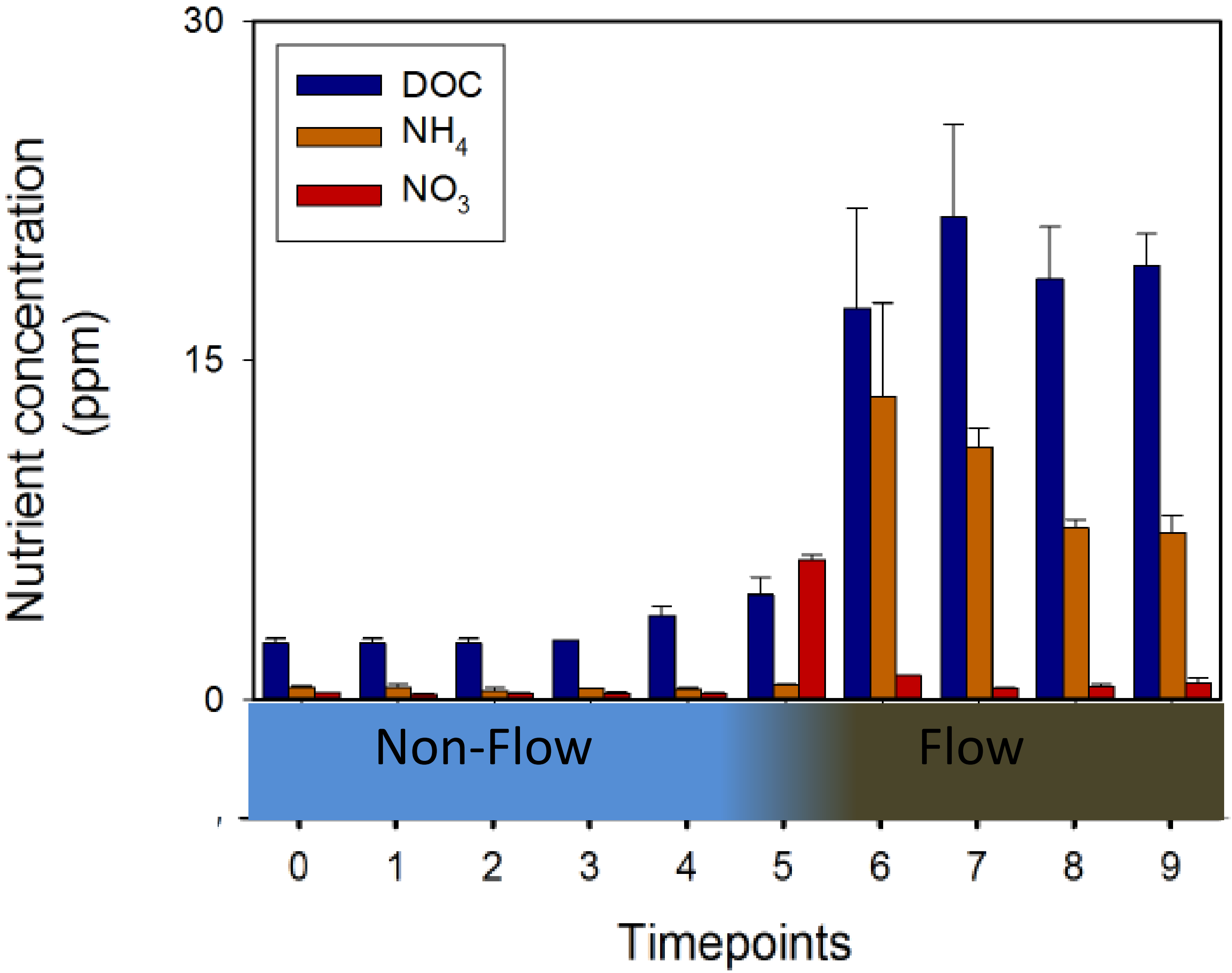
Part II: Connections to CSO events

Direct GHG source



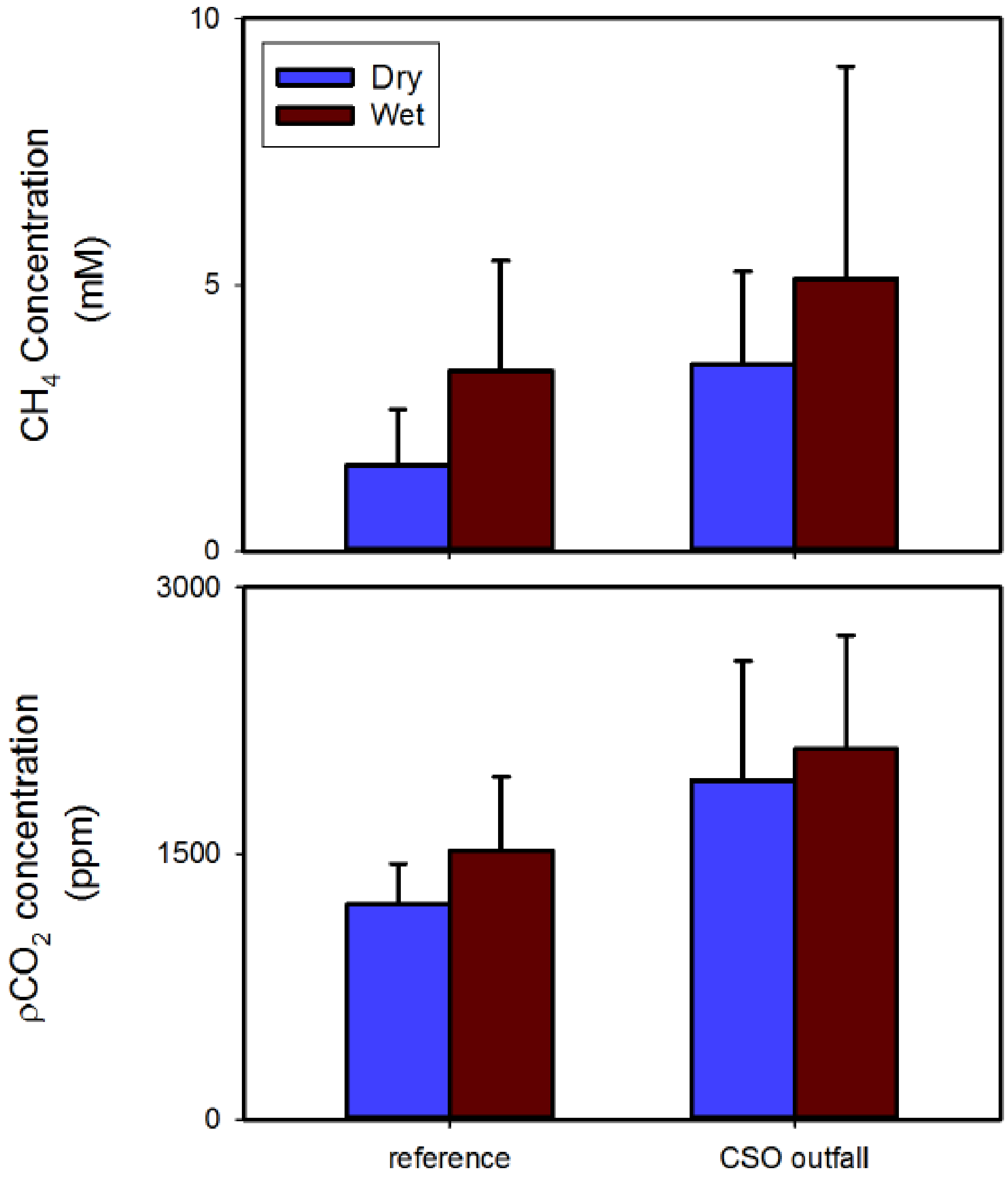
Part II: Connections to CSO events

Direct nutrient source



Part II: Connections to CSO events

Wet vs. dry weather conditions



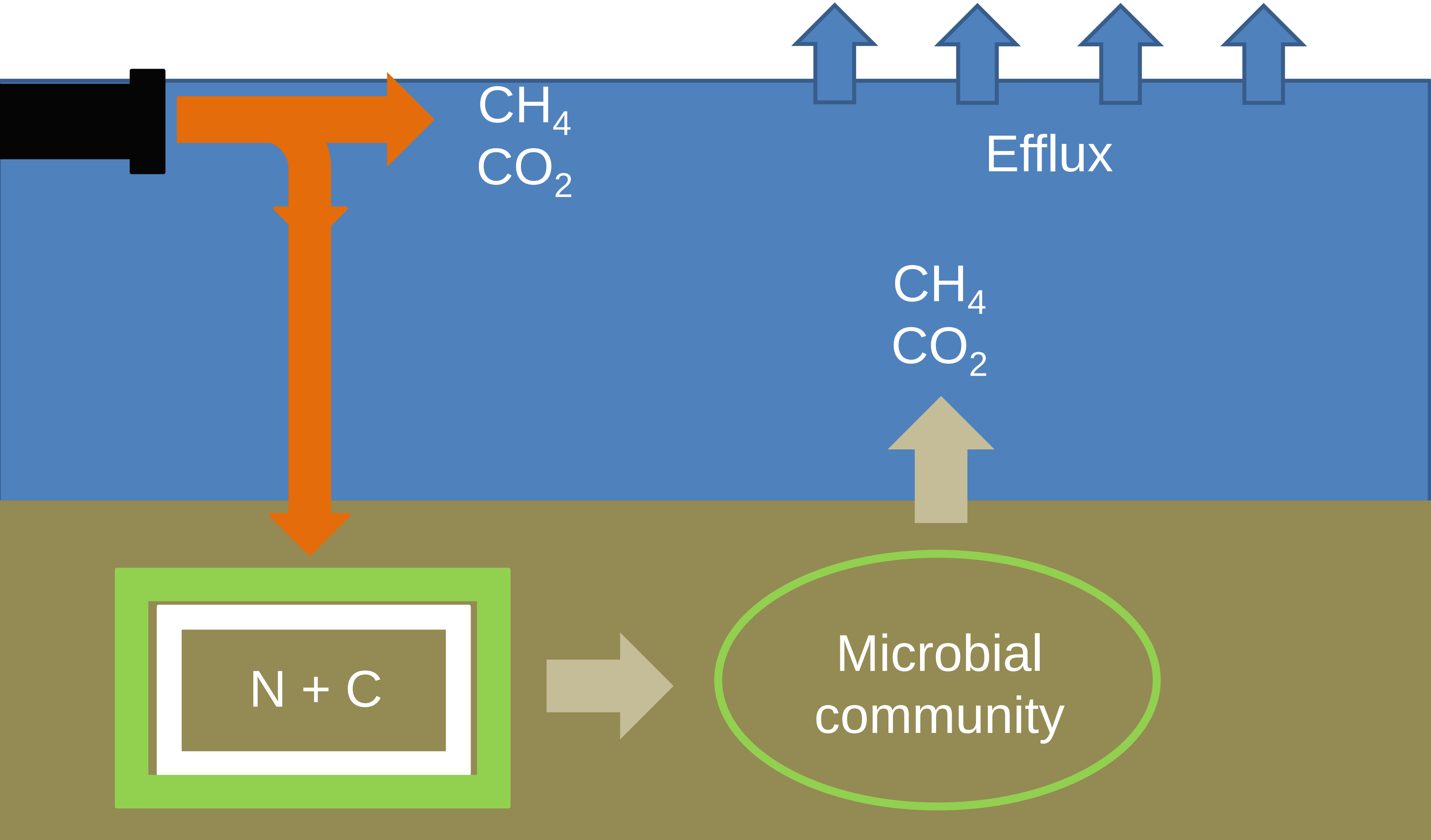
Part II: Connections to CSO events

Conclusions

- Untreated sewage/wastewater was a direct sources of GHG
  - Direct source of DOC and inorganic N
  - Possible indirect GHG source
- Amount of GHG contributed directly from CSO events did not cause:
  - Observable difference in GHG surface concentrations between wet and dry conditions
  - Contribute enough GHG to explain differences observed between urban vs. rural sites

Part III: Wetland soil response

Potential CH_4 sources



Part III: Wetland soil response

Saturated conditions

- Low energy metabolic pathways establish unique energetic constraints (Canfield et al. 2004)
  - Limited growth results in unutilized total soil N (Reddy and DeLaune 2008)
    - Accessible C limits microbial growth and activity (Vidon et al. 2011)
    - Concentration of electron acceptors act as a secondary control (Guenot et al. 2011)
- Additions of labile carbon may stimulate microbial mediated metabolism (Fontaine 2003, Bianchi 2012)

Part III: Wetland soil response

Research questions

- Do labile C and/or N additions increase GHG production rates?
  - Do nutrient additions result in mineralization of native organic C observed via CO_2 and CH_4 production?
  - Will the ratio of CO_2/CH_4 production vary across the HRE salinity gradient?
- Will microbial groups associated with anaerobic metabolic pathways in wetland systems respond to nutrient additions through community shifts?

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Part III: Wetland soil response

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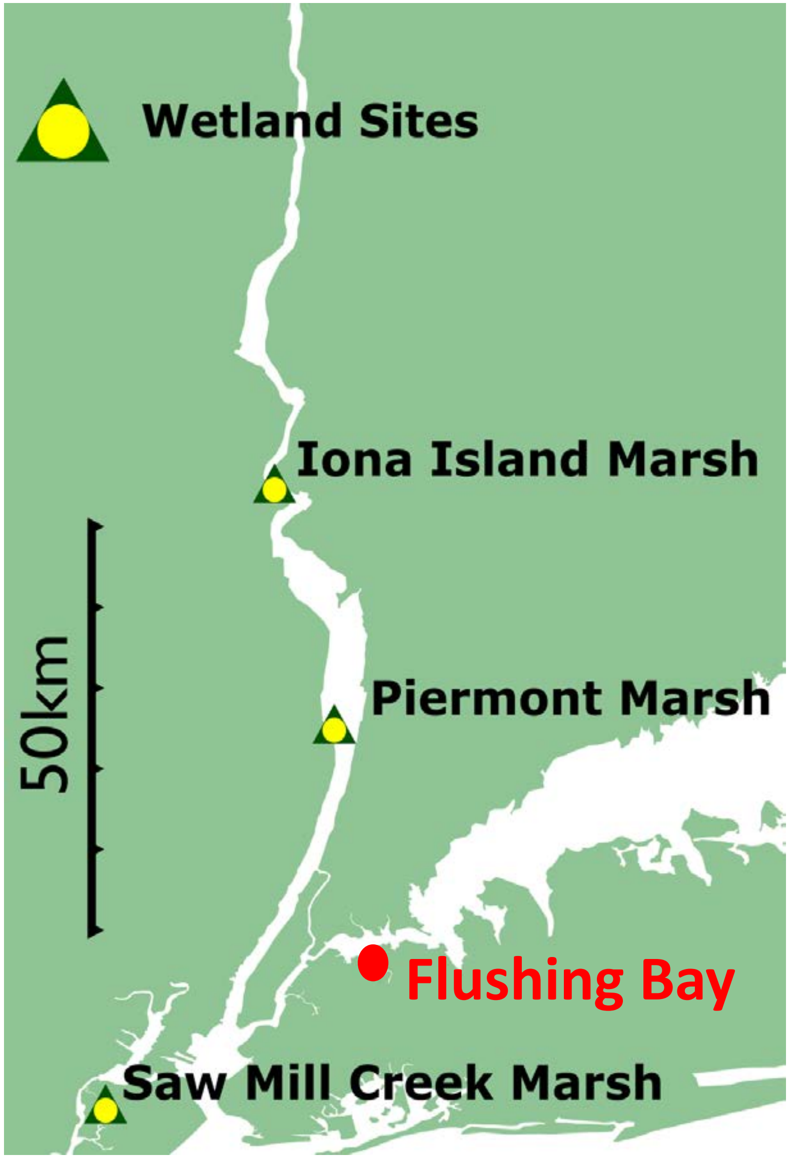
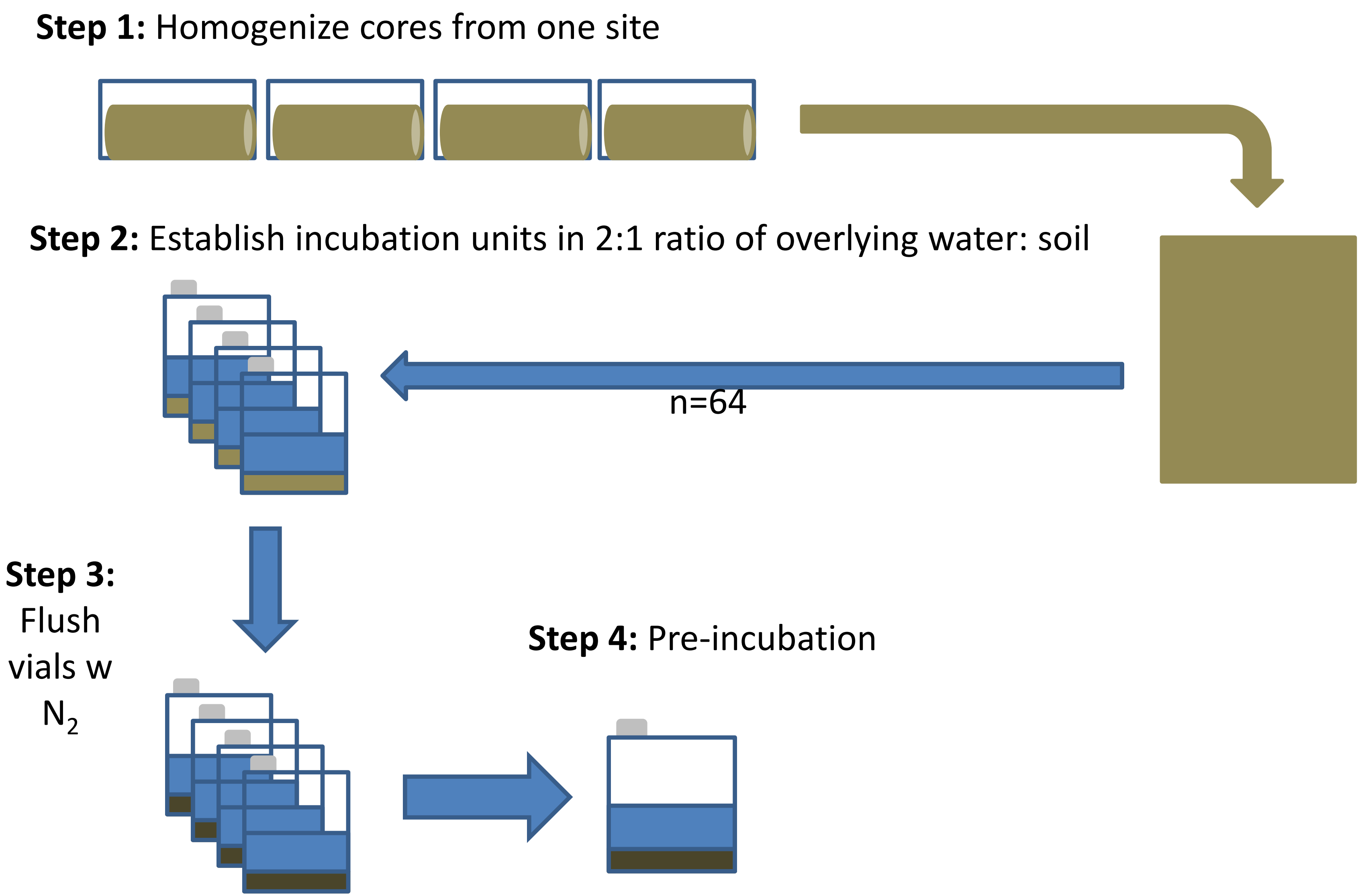


Part III: Wetland soil response

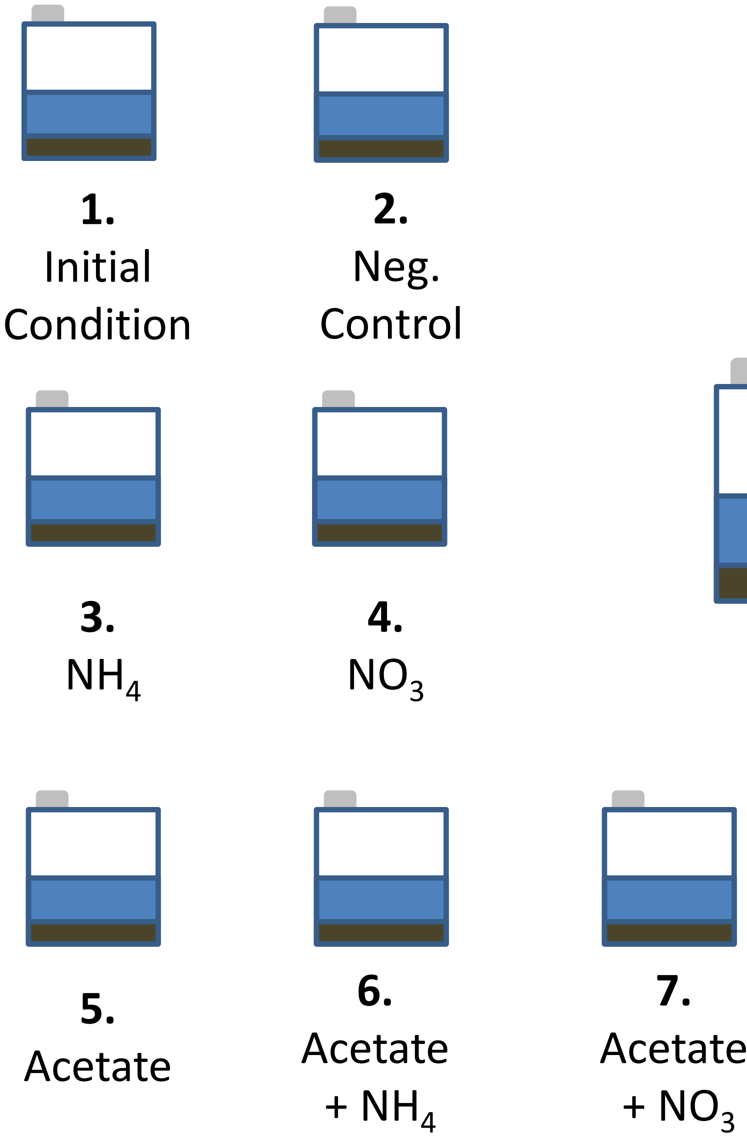
Methods

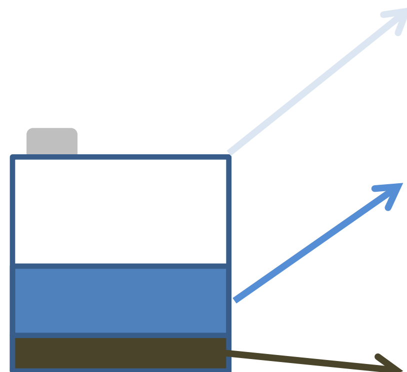
Part III: Wetland soil response

Incubation flowchart



Step 5: Add nutrients [begin experiment]



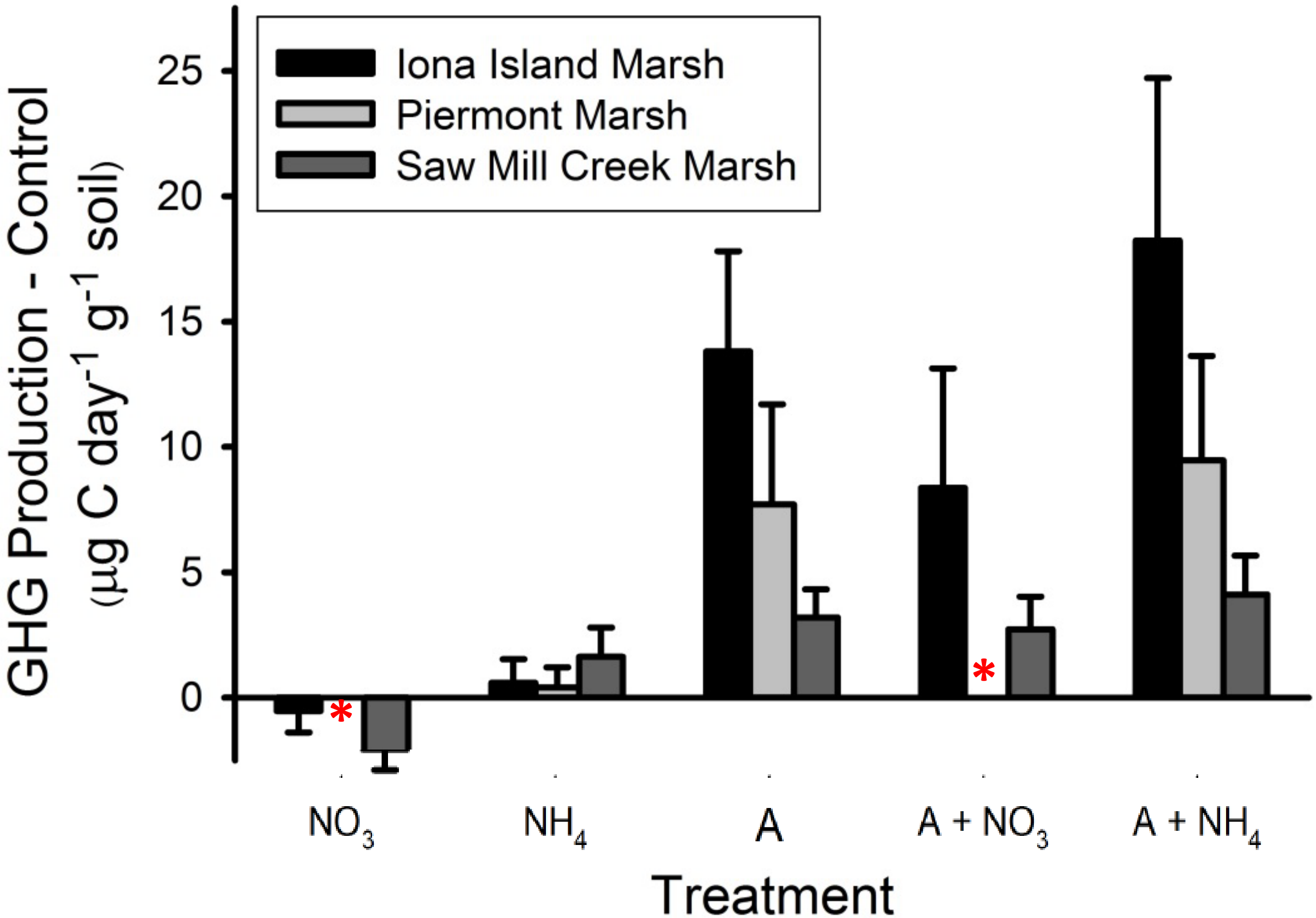


Step 6: Measurements

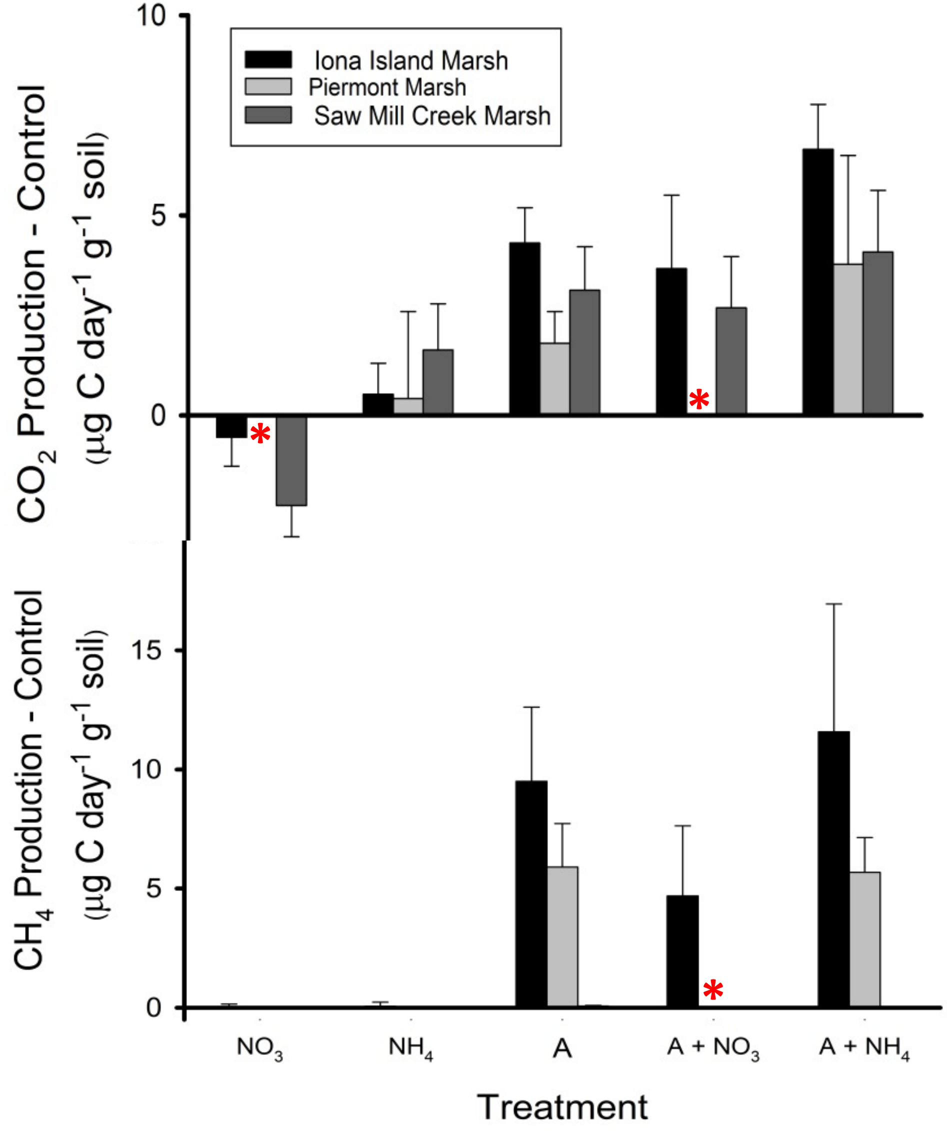
- Headspace
  - CH_4 every two days (HP)
  - CO_2 every day (PP systems)
- Extractable water
  - DOC (Shimadzu)
  - NH_4^+, NO_3^-, PO_4^{3-} (Plate reader)
  - Probe measurements
- Soil
  - Total C:N after HCl fumigation (CHN analyzer)
  - 454 sequencing

Part III: Wetland soils response

Total C produced

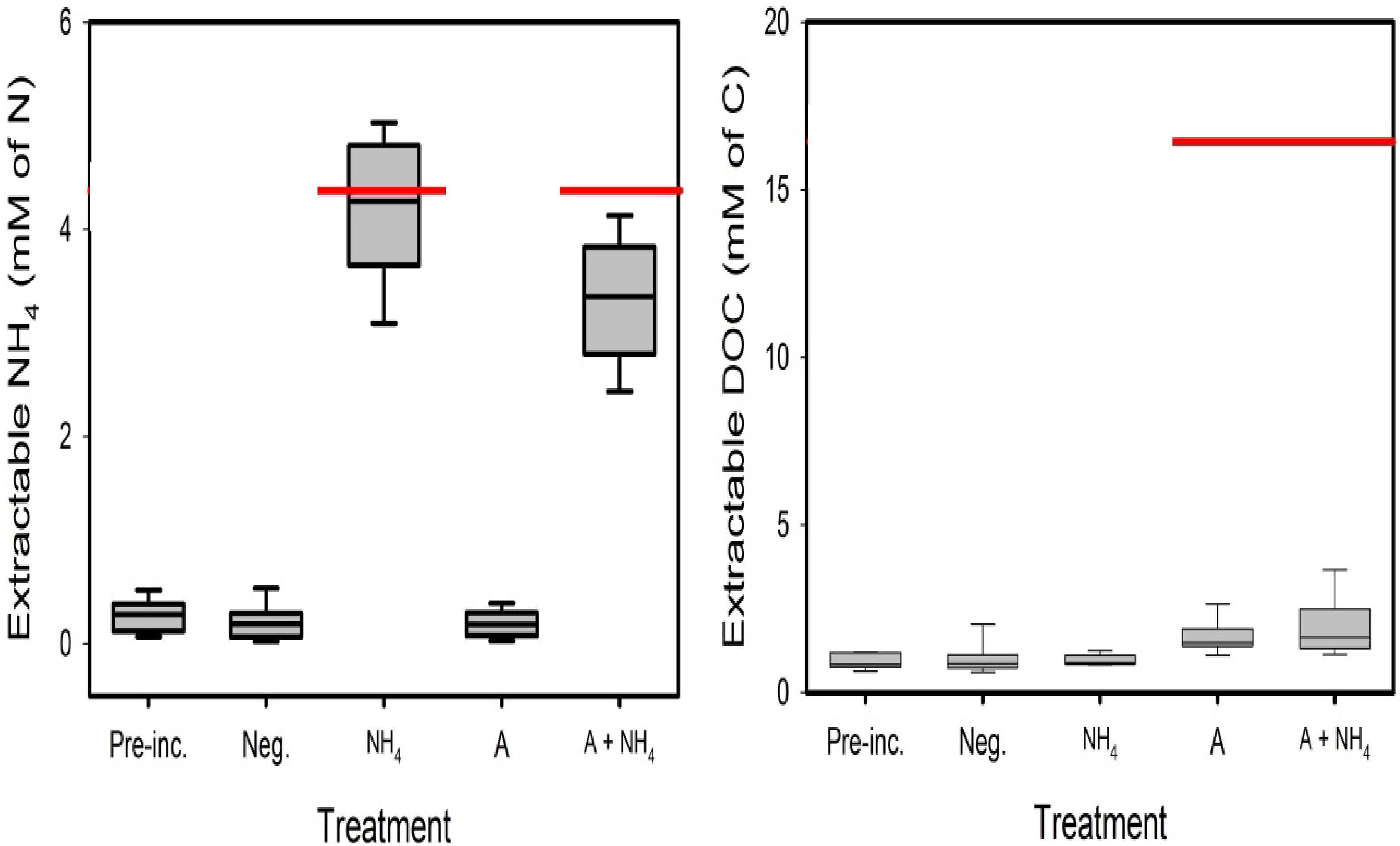


Part III: Wetland soils response
CO_2 vs. CH_4



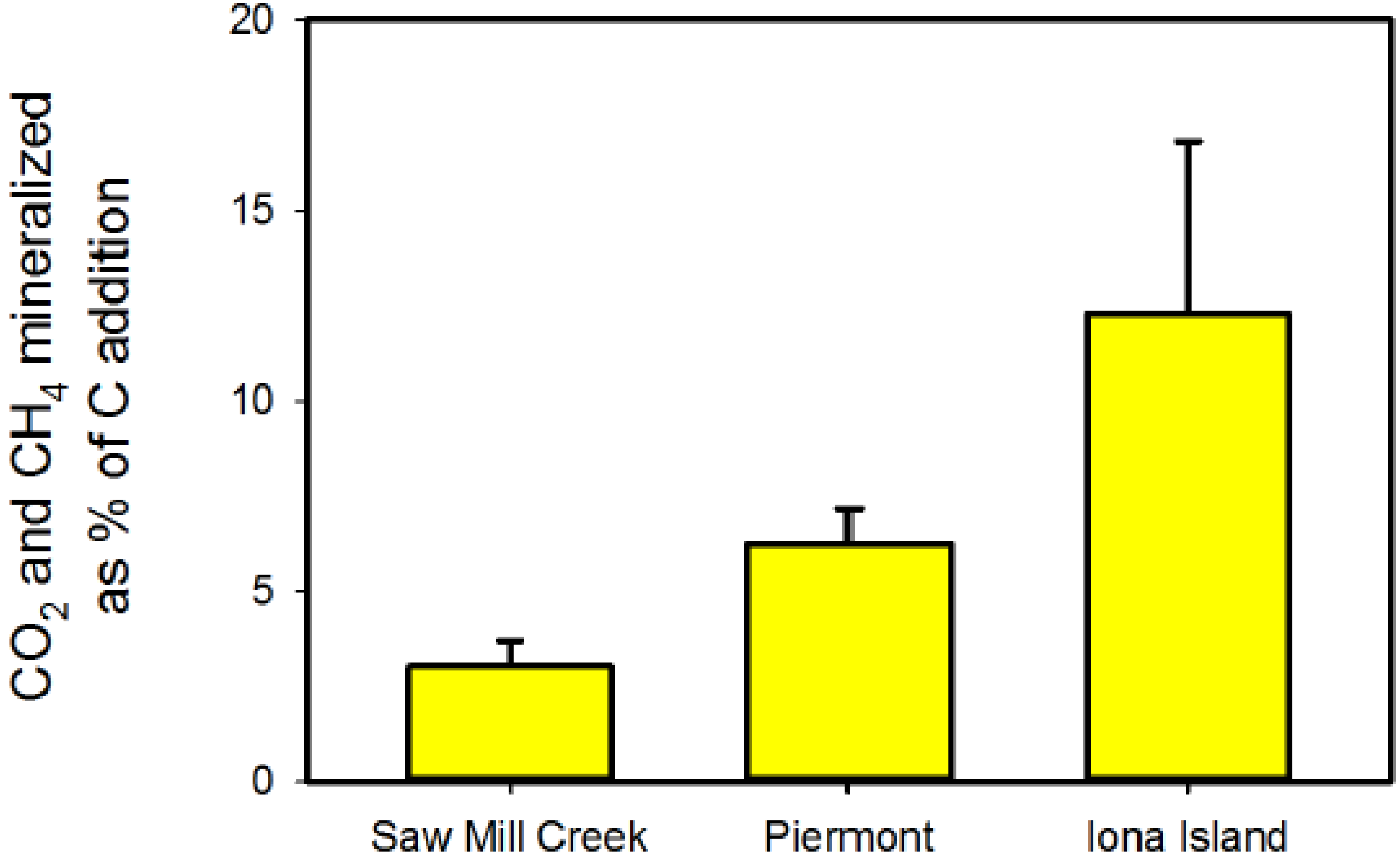
Part III: Wetland soils response

Nutrient utilization in Piermont Marsh



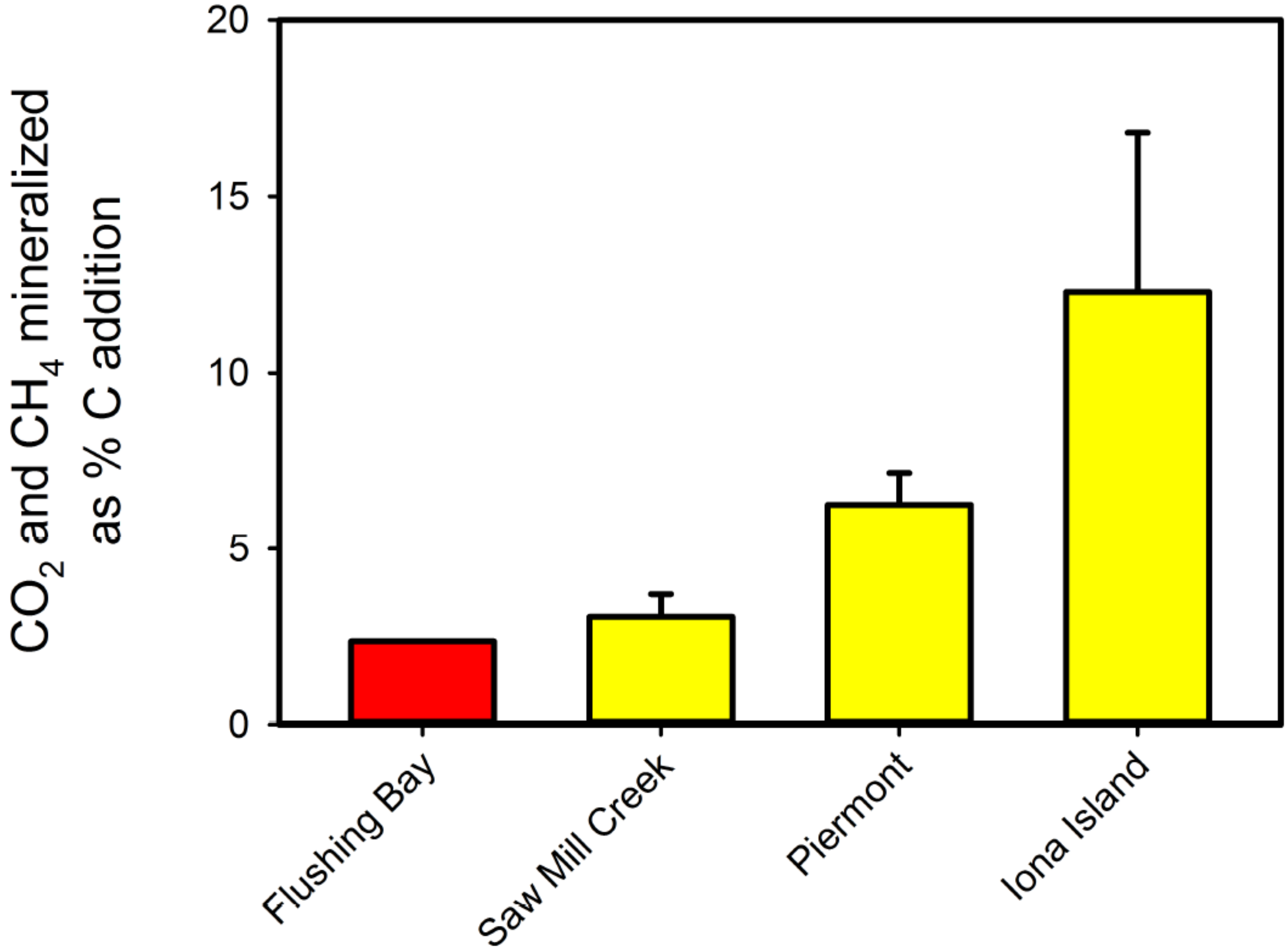
Part III: Wetland soils response

Mineralization of C



Part III: Wetland soils response

Mineralization of C



Part III: Wetland soils response

GHG warming potential

Site	Salinity	Total C-CO_2e production	
		Control	C Addition
Iona Island	0.75	9	229
Piermont	6	5.5	144
Saw Mill Creek	20	5	11
Flushing Bay	23	7	50

Conclusion

- Total GHG production in response to C additions varied among sites by salinity
  - CO_2 production rates were not significantly different between sites
  - CH_4 productions rates were inversely correlated to salinity
- No evidence of native organic C mineralization was observed
- C- CO_2e production was similar across sites for the control treatment but an order of magnitude greater for brackish and fresh sites for C additions

On-going research

- Finish analytical analyses of HRC, soil extraction, and dry soil samples
  - Normalize production to C present in the soil
- Multivariate analysis of HRC and incubation data
- Conclude sequencing analysis from three incubation experiments and Flushing Bay
- Finish analysis of recently completed sediment experiment from Flushing Bay
  - Intact cores and soil slurry units

General conclusions and management applications

- Wastewater from CSO events was a direct source of GHG and indirect *in situ* production in the HRE
  - Another consideration that could contribute to CSO mitigation
- Wetlands were C sinks even under heavy nutrient loading conditions
  - Fresh marshes have greater potential production of CO_2e
  - Therefore it matters where discharge occurs

Acknowledgments

- Angel Montero
- Bird Lab
  - P.J. Hatton, Mark Gormley, Fernanda Santos, Rahul Singh
- O'Mullan Lab
  - Roman Reichert, Suzanne Young, Eli Dueker, Michael Kausch
- LDEO/Riverkeeper
  - Andrew Juhl, Carol Knudson, John Lipscomb
- Funding sources
  - NOAA GRF, Hudson River Foundation, Queens College, CUNY

QUEENS COLLEGE

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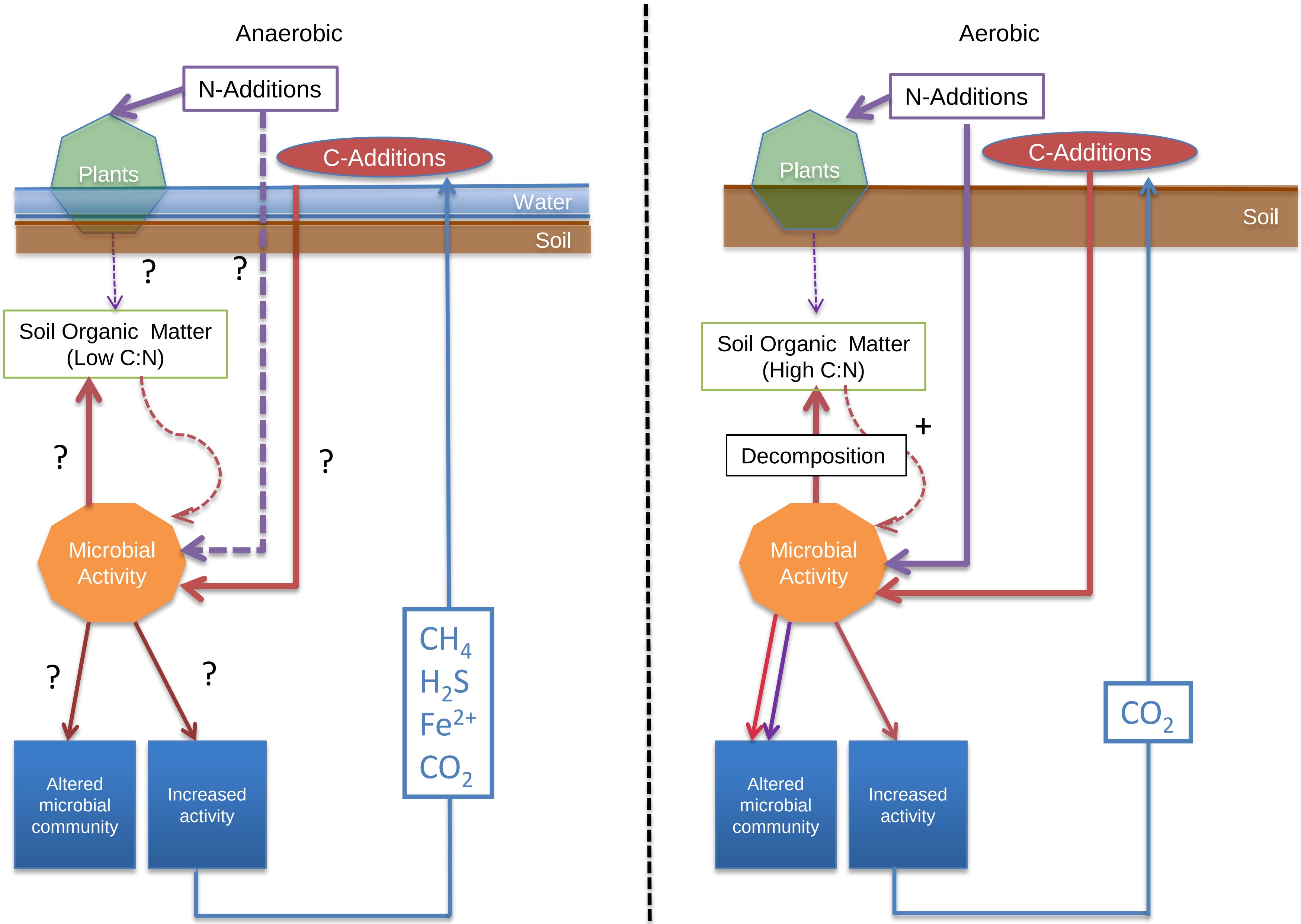
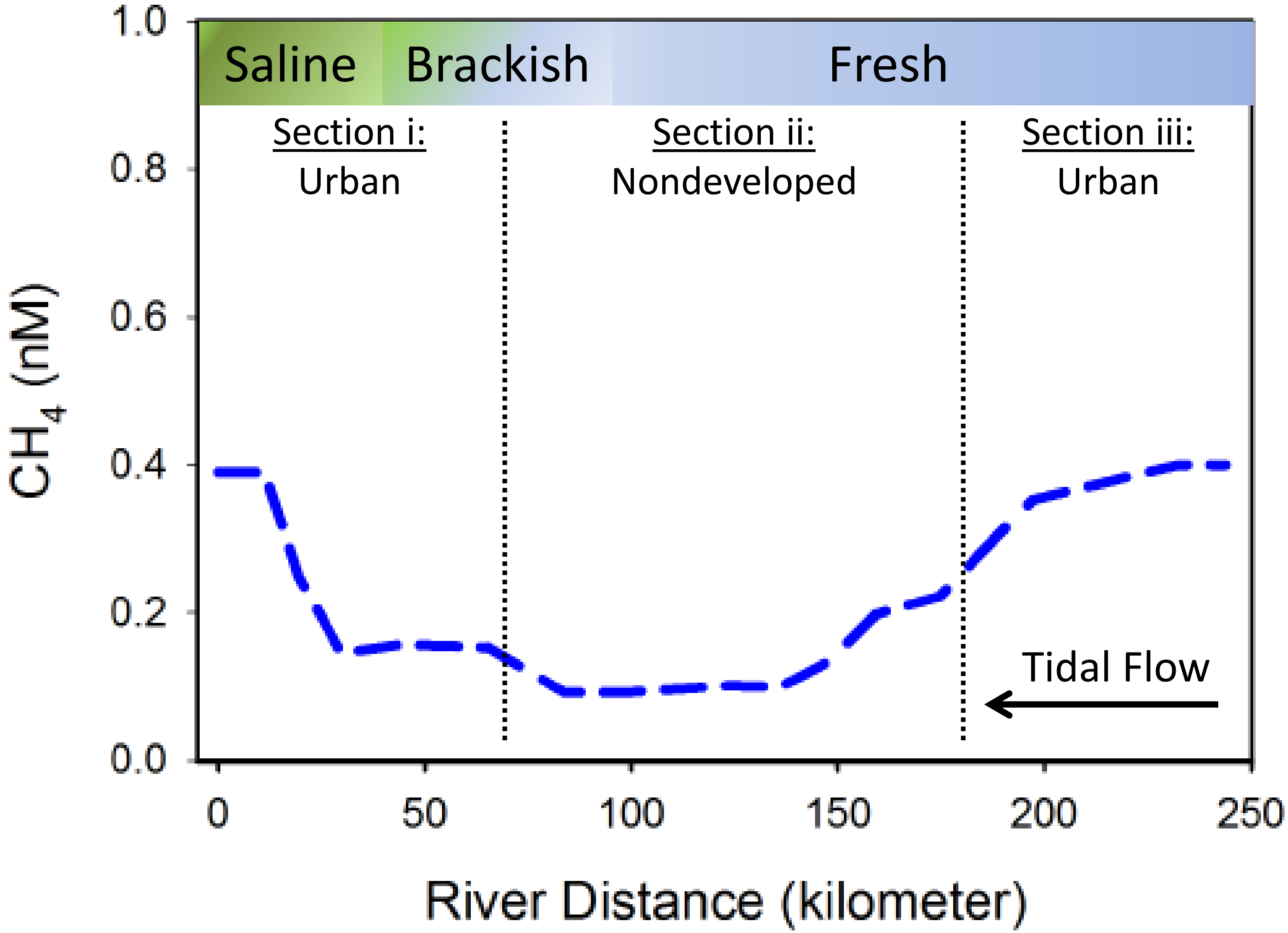
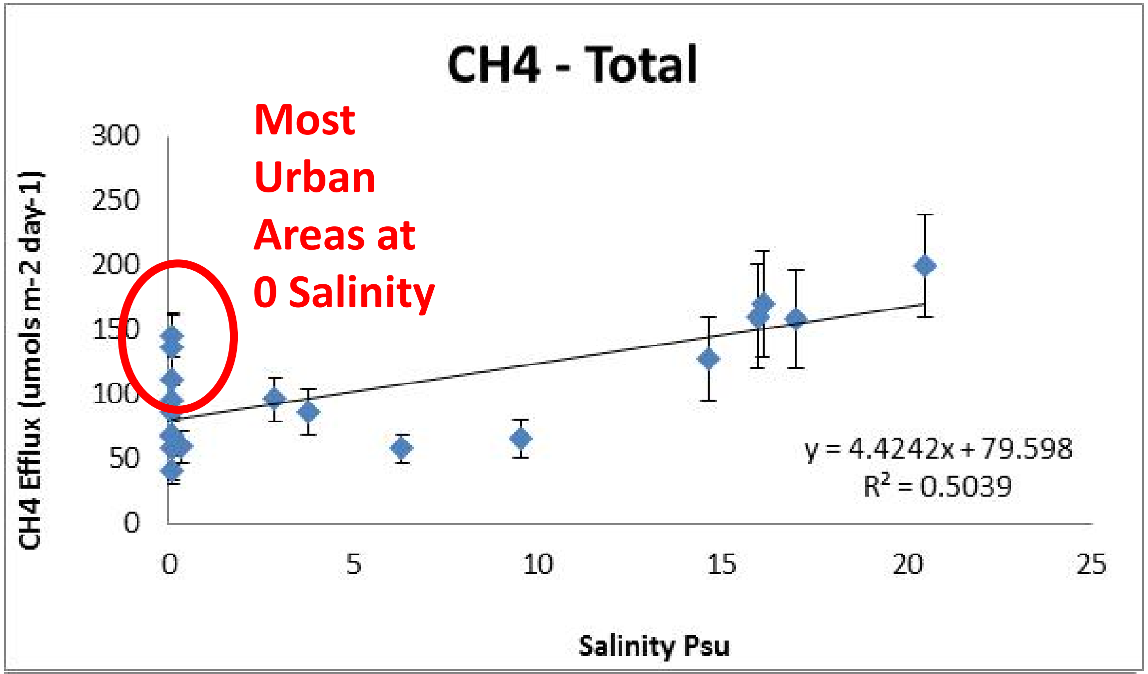
THE GRADUATE CENTER CITY UNIVERSITY OF NEW YORK

EXTRA

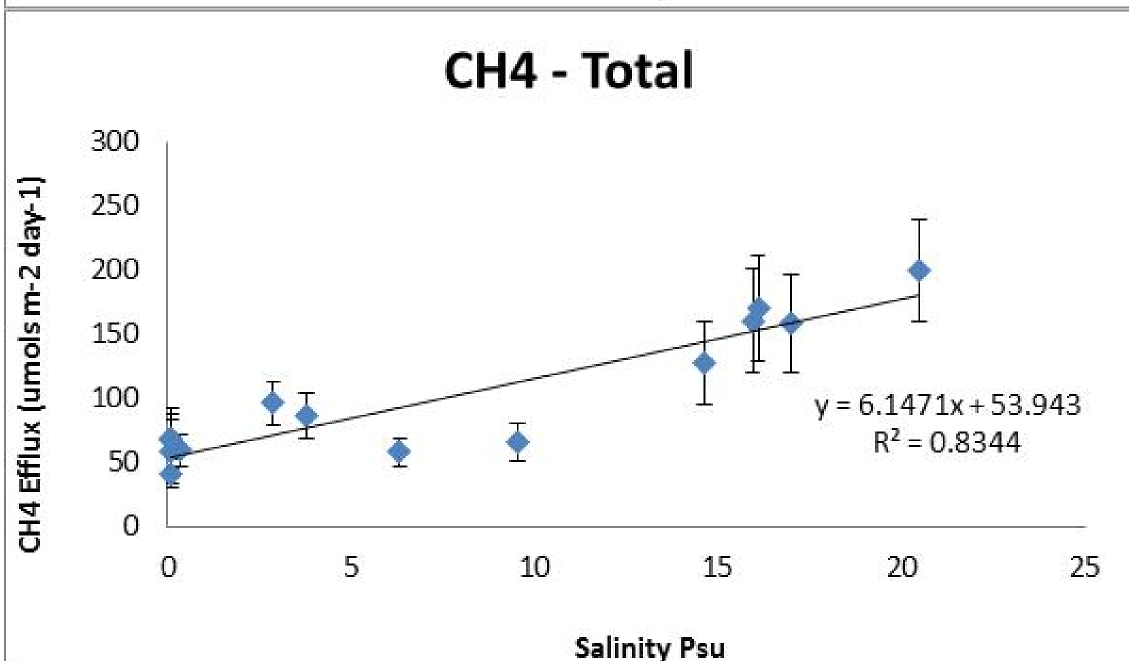

Anaerobic
N-Additions
Plants
C-Additions
Water
Soil
?
?
Soil Organic Matter (Low C:N)
?
?
Microbial Activity
?
?
CH_4
H_2S
Fe^{2+}
CO_2
Altered microbial community
Increased activity
Aerobic
N-Additions
Plants
C-Additions
Soil
Soil Organic Matter (High C:N)
+
Decomposition
Microbial Activity
CO_2
Altered microbial community
Increased activity

Potential CH_4

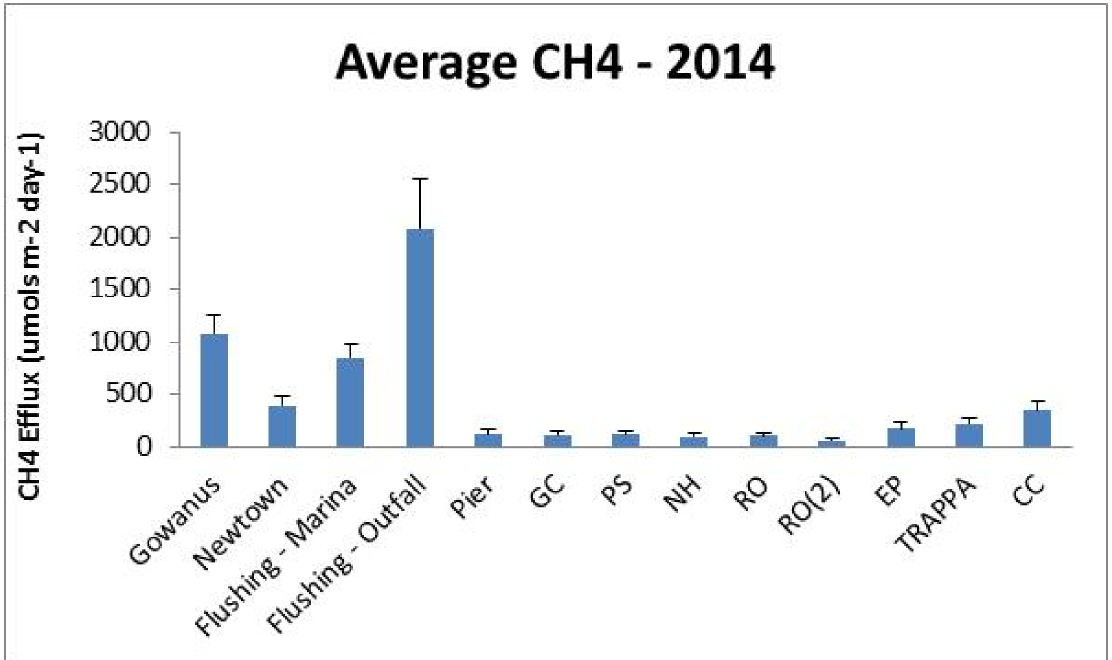




All data points



Urban "Albany" areas removed


Average CH4 - 2014
CH4 Efflux (umols m-2 day-1)
3000
2500
2000
1500
1000
500
0
Gowanus
Newtown
Flushing - Marina
Flushing - Outfall
Pier
GC
PS
NH
RO
RO(2)
EP
TRAPPA
CC

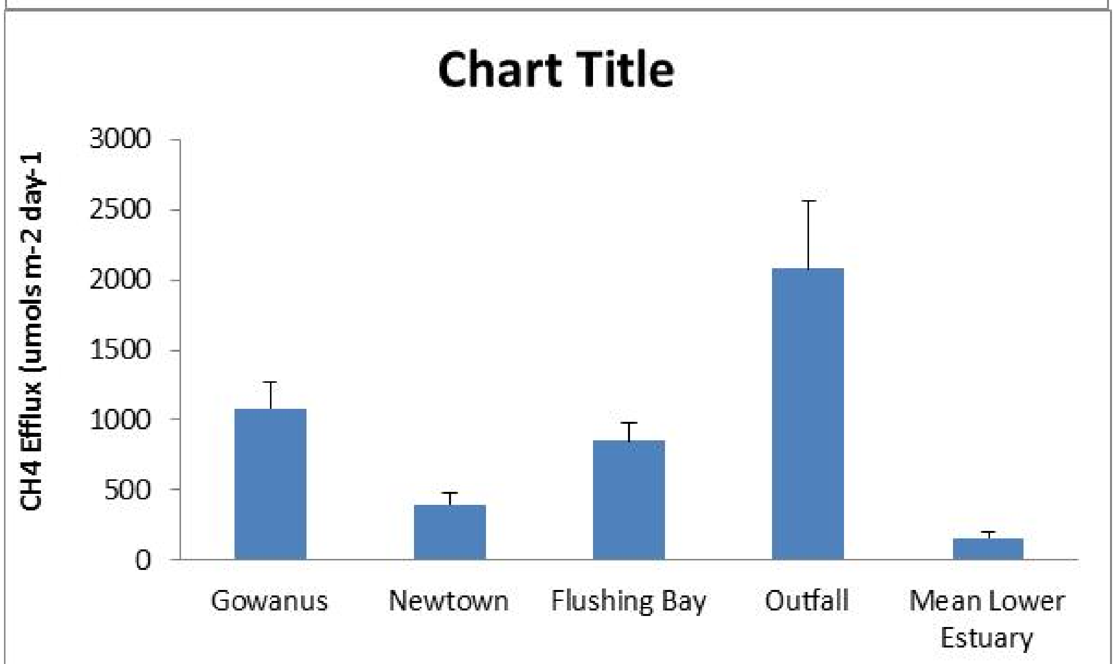
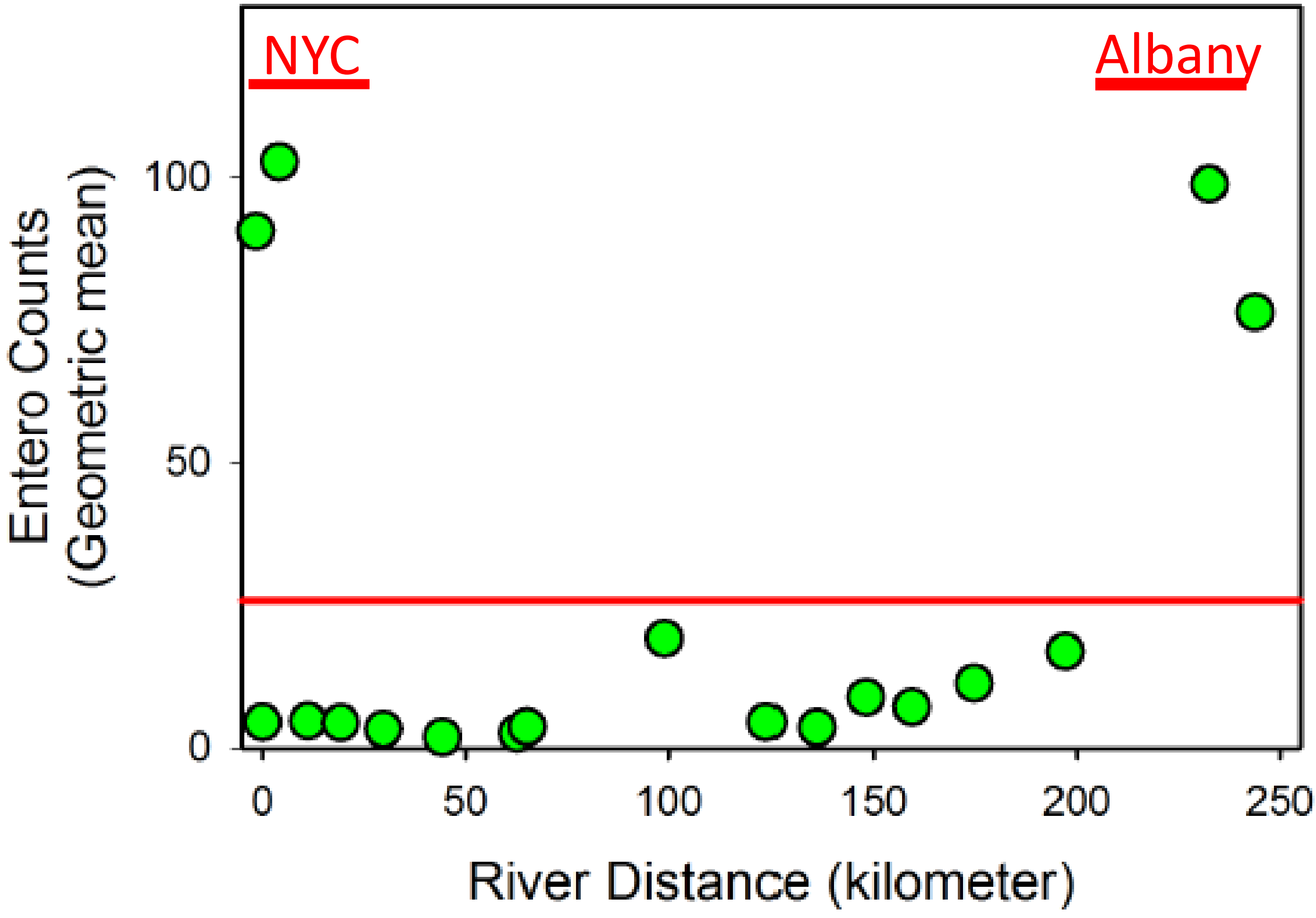
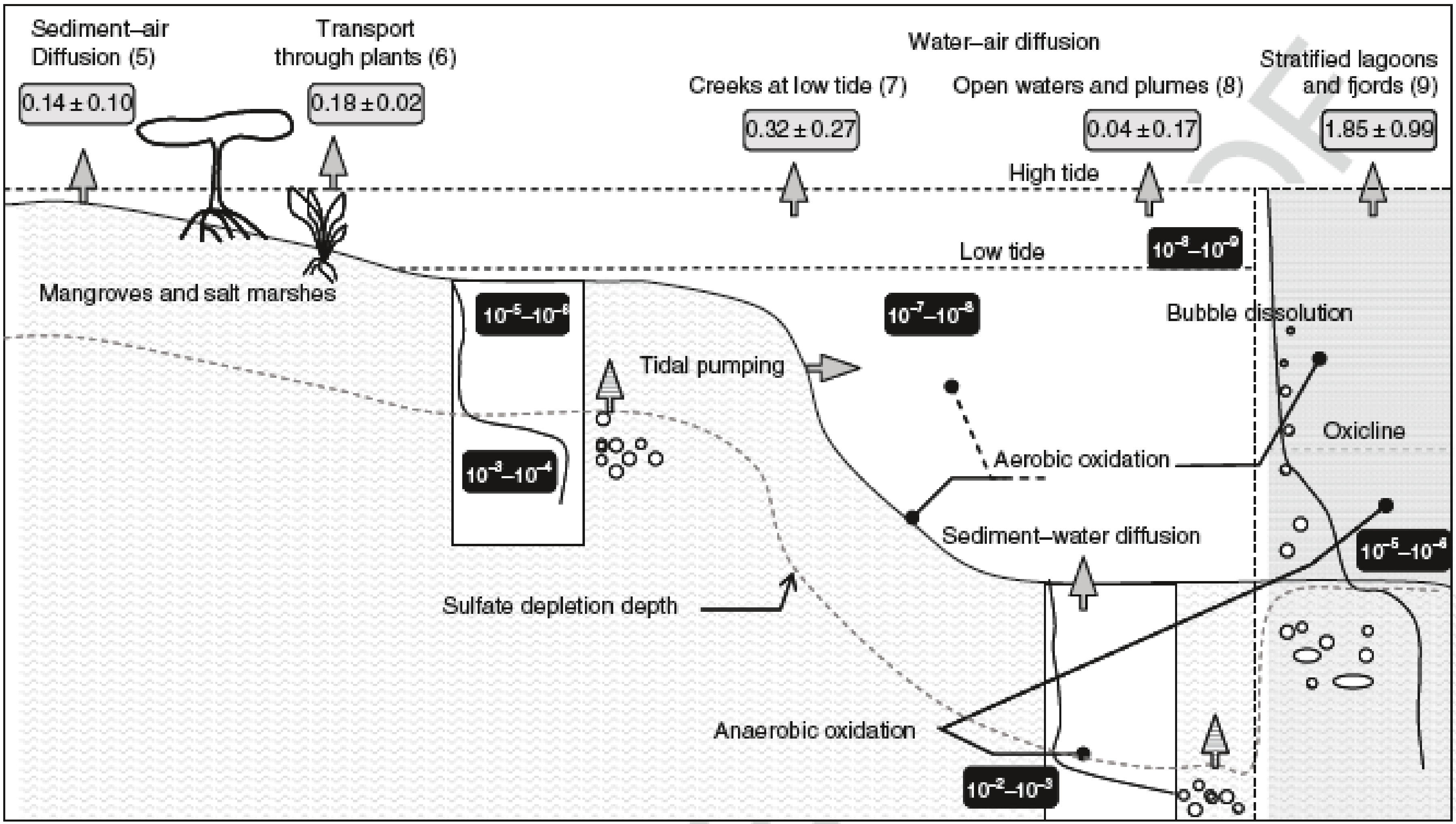


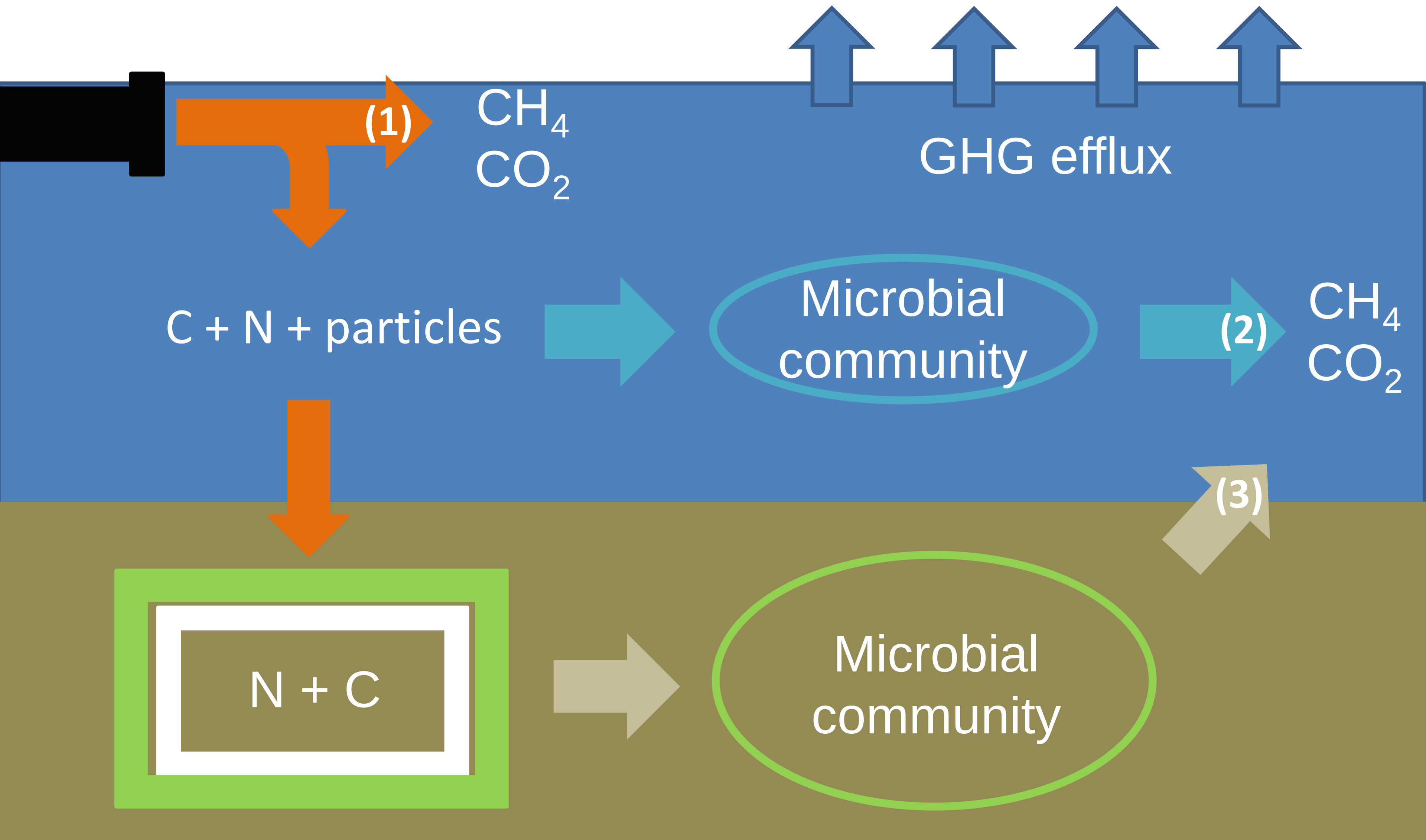
Chart Title
CH4 Efflux (umols m-2 day-1
3000
2500
2000
1500
1000
500
0
Gowanus
Newtown
Flushing Bay
Outfall
Mean Lower Estuary



NYC
Albany
Entero Counts
(Geometric mean)
100
50
0
0
50
100
150
200
250
River Distance (kilometer)

(b) High-salinity regions





(1)
CH4
CO2
GHG efflux
C + N + particles
Microbial community
(2)
CH4
CO2
(3)
N + C
Microbial community

Part III: Wetland soil response

Potential CH_4 sources