Greenhouse gas emissions from a human-impacted estuary

Identifying mechanisms their drivers and stability

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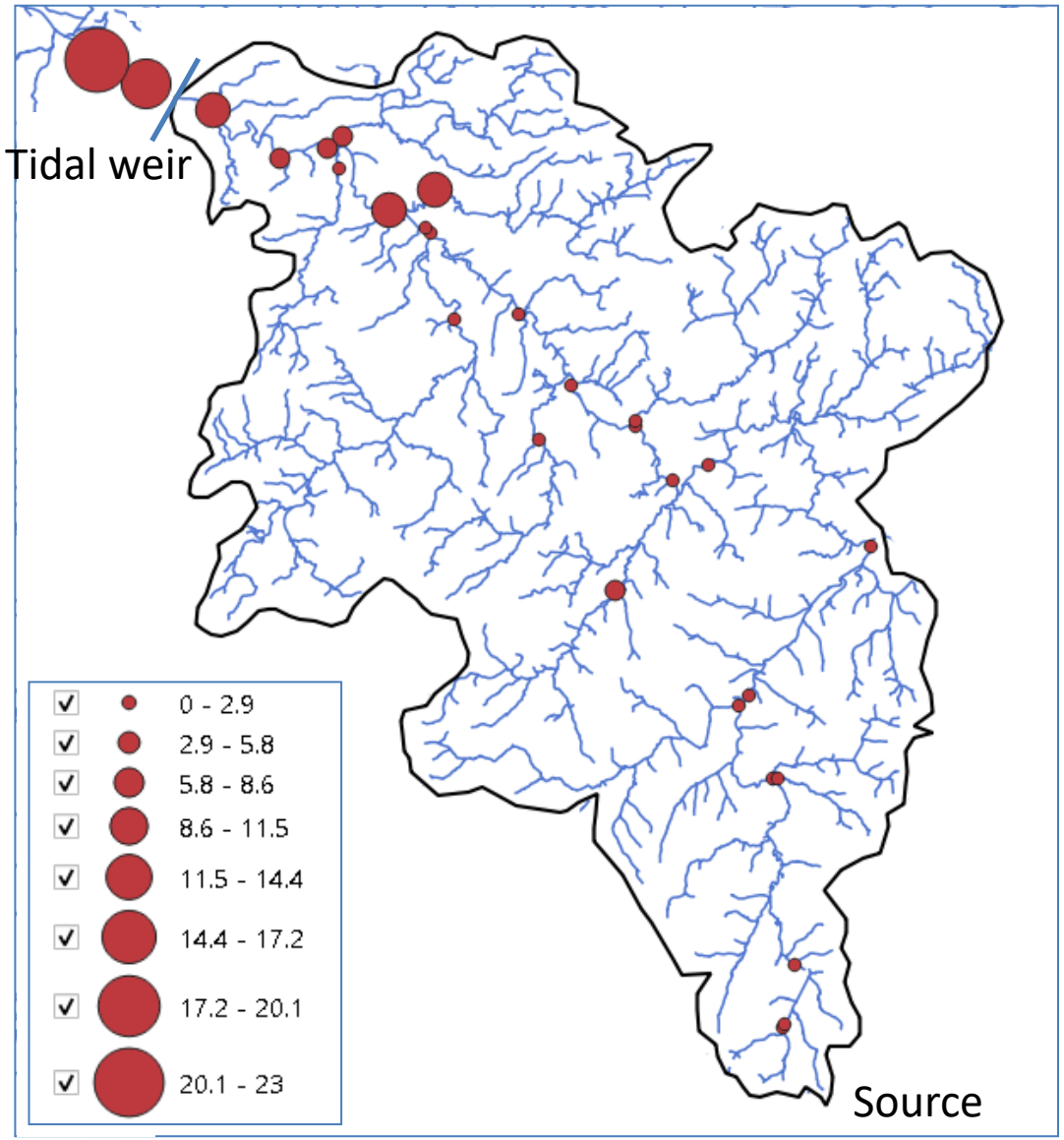
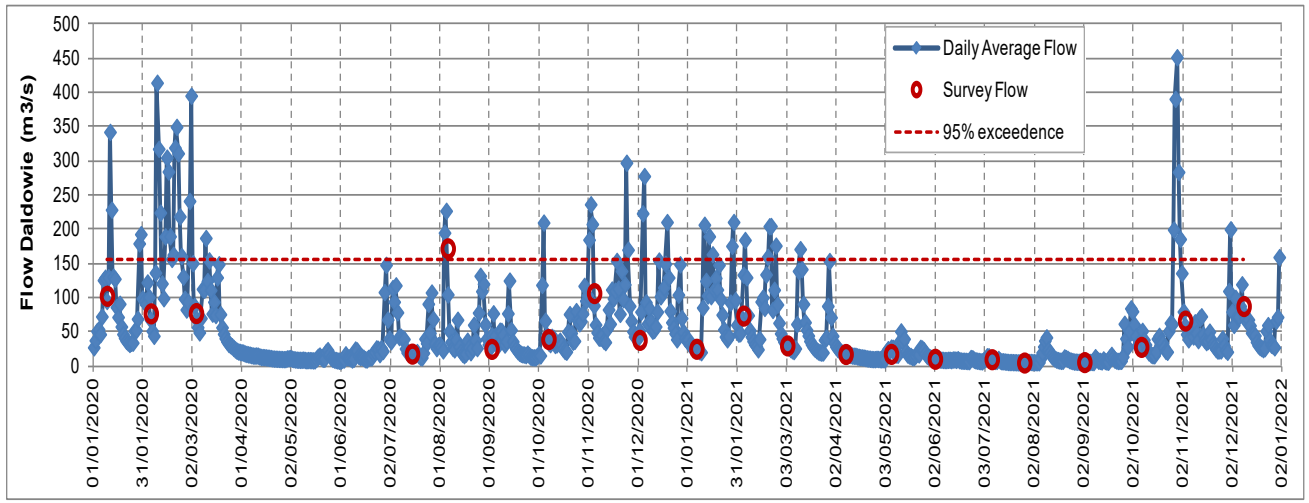
Impact of river / catchment on estuary - Methane



- Estuary CH_4 – 2.8 - 68µg/l (Surface)
- Estuary N_2O – 0.5 - 2.8µg/l
- Estuary CO_2 – 0.5 - 2.3mg/l
- Low river flow in summer 2021 resulted in a significant semi-permanent saline intrusion



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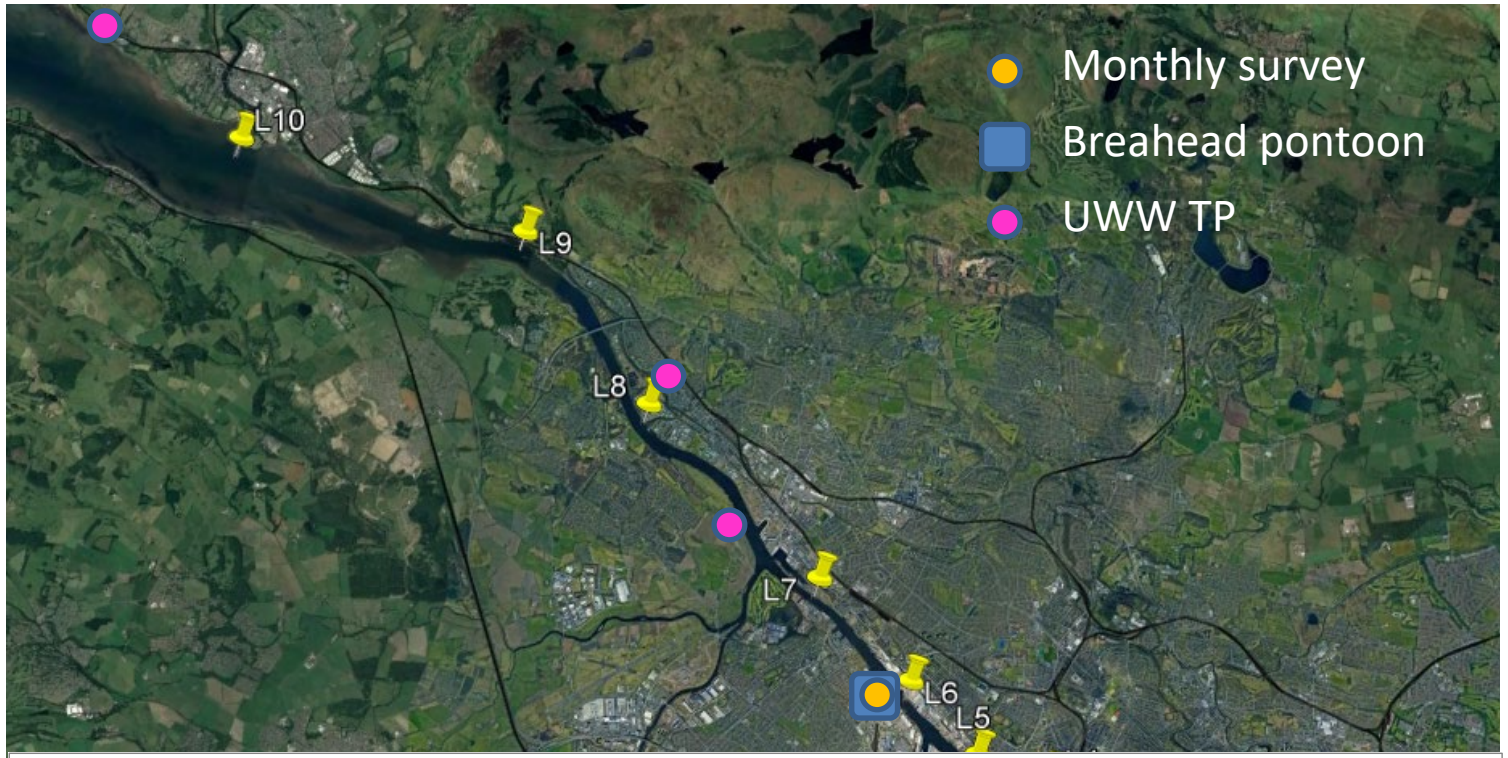
Area of Study

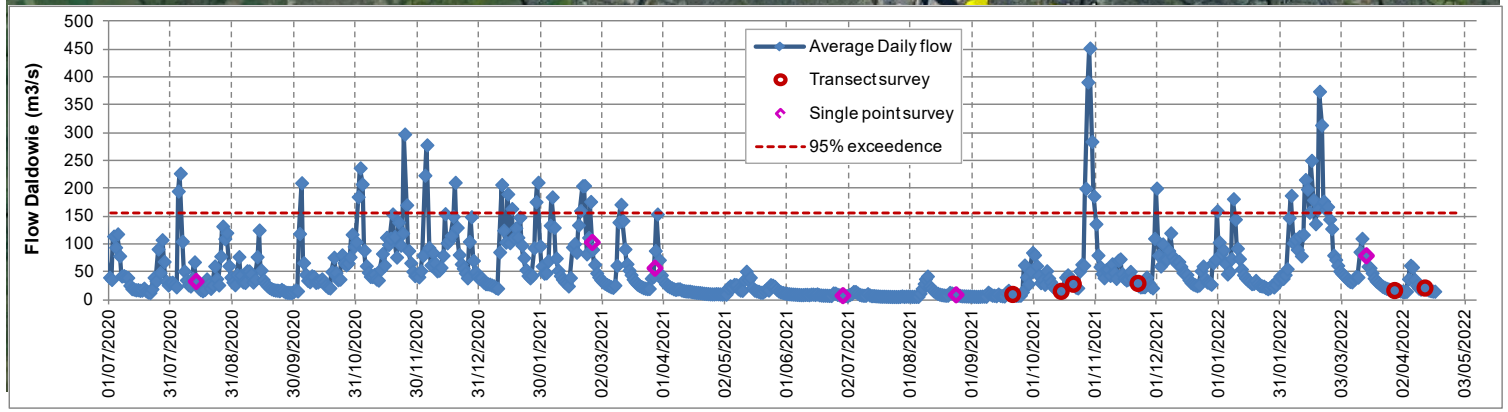
10 point Longitudinal

No	Date	Temp (deg C)	Tidal range (m)	River flow (m3/s)
1	21-Sep -21	16.1	3.53	10.6
2	15-Oct -21	11.3	2.00	16.1
3	21-Oct -21	11.5	3.71	29.0
4	22-Nov -21	9.2	3.73	30.4
5	29-Mar-22	9.9	3.09	17.6
6	13-Apr-22	9.7	2.51	22.1

Single point tidal cycle

No	Date	Temp (deg C)	Tidal range (m)	River flow (m3/s)
1	13-Aug-20	18.1	2.52	33.8
2	25-Feb-21	7.3	2.70	104.0
3	28-Mar-21	8.2	3.65	57.7
4	29-Jun-21	19.0	3.77	8.4
5	24-Aug-21	17.9	3.99	9.9
6	15-Mar-21	7.7	2.13	80.1





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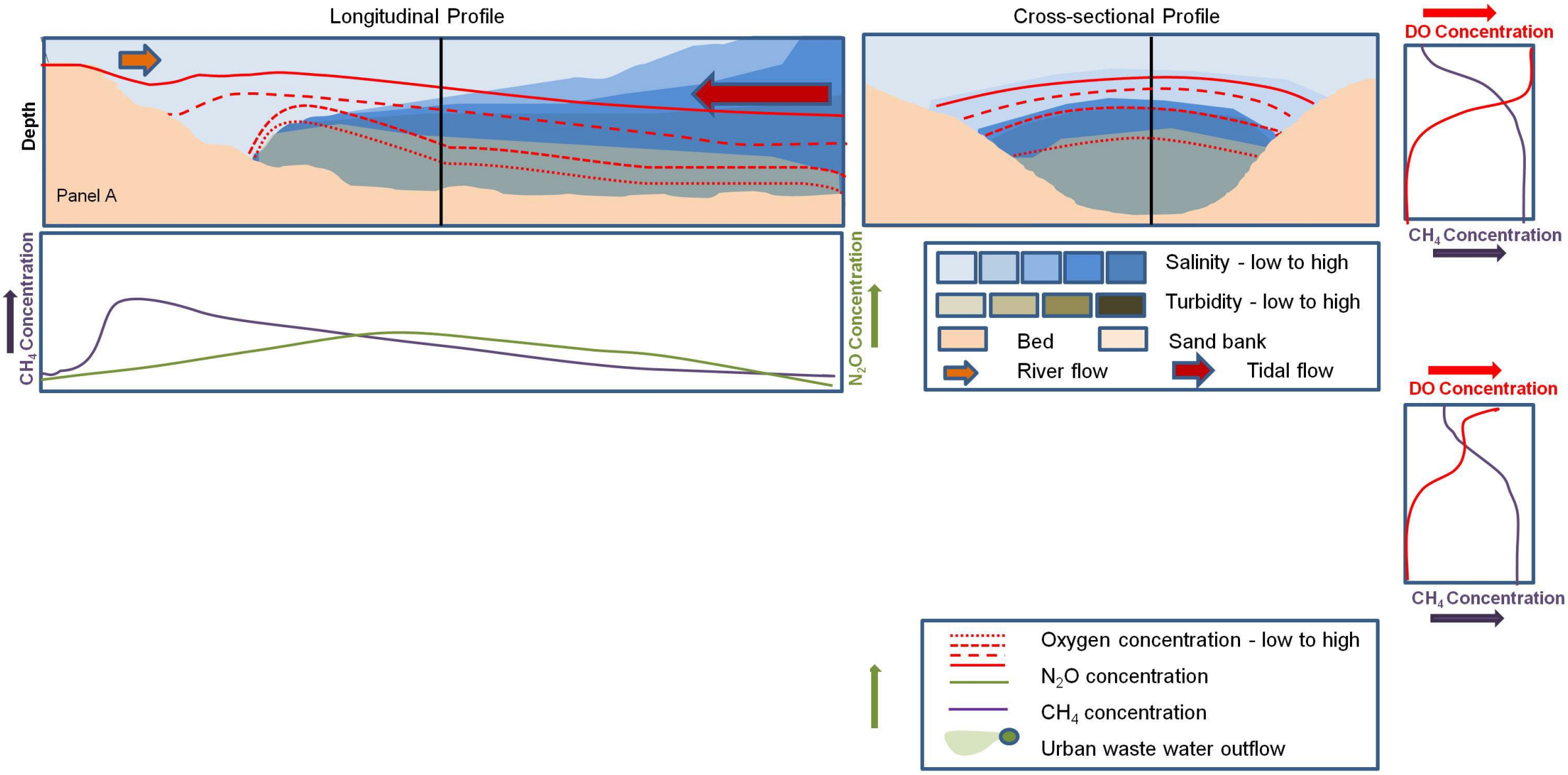
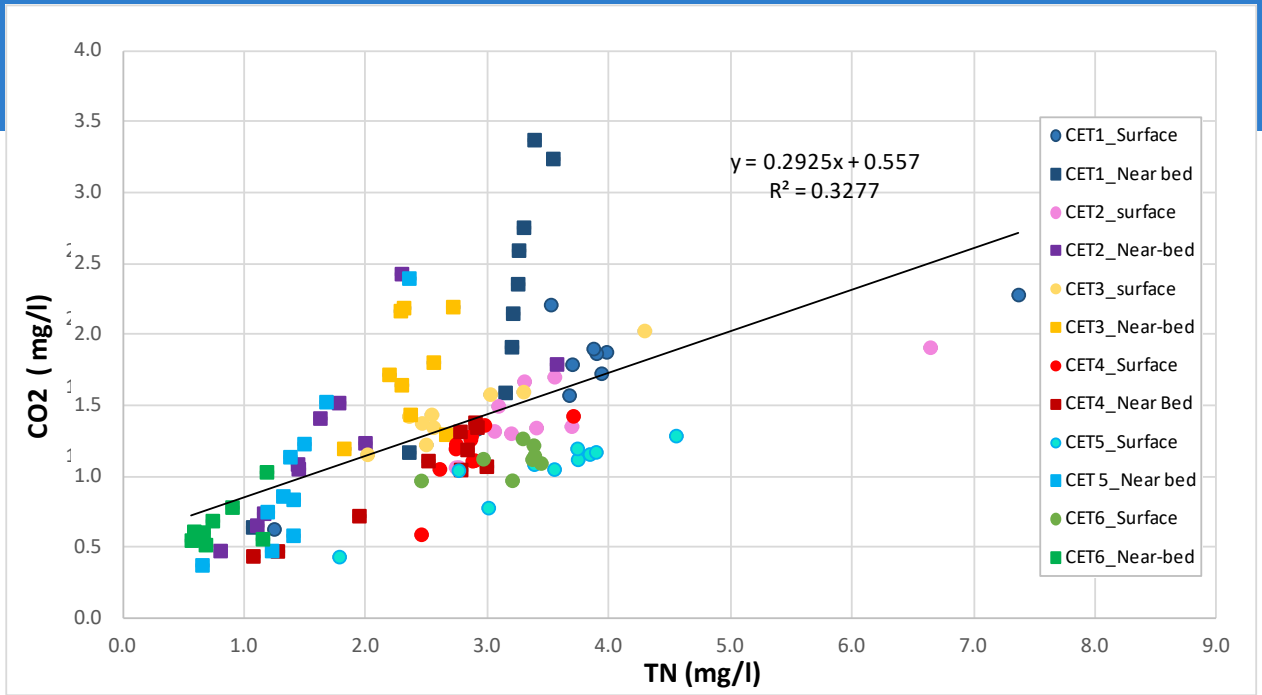
Clyde estuary - Salt wedge estuary

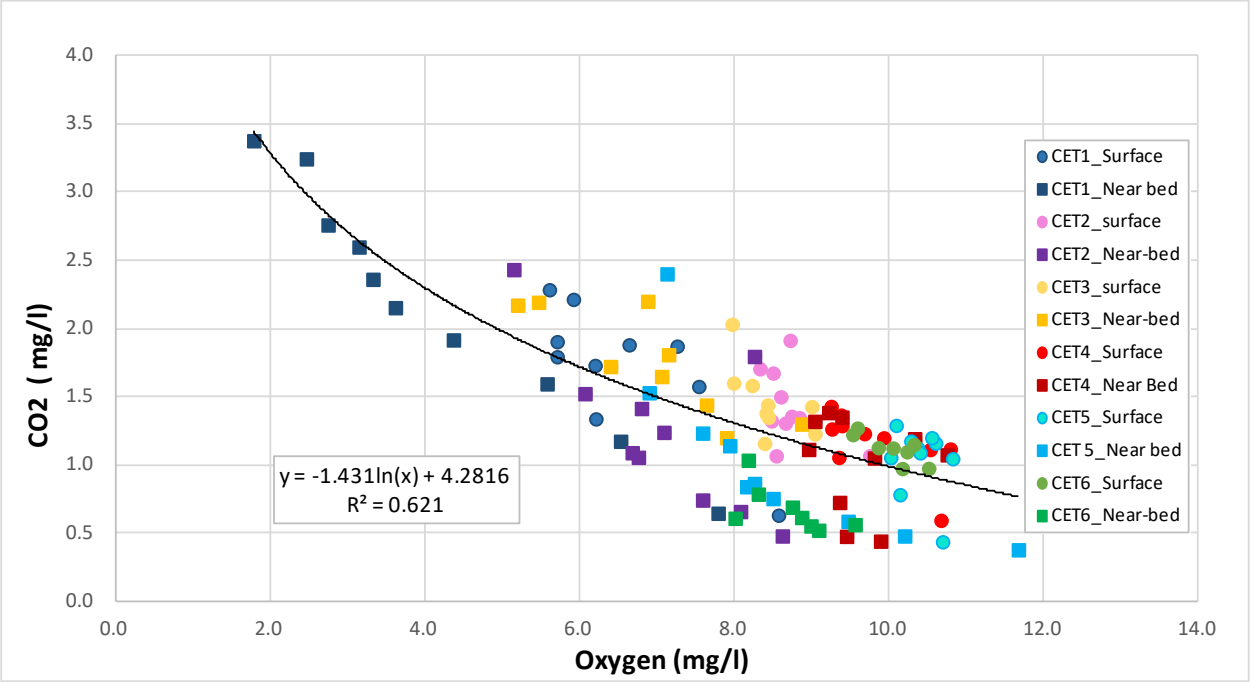


CO_2 concentrations

Correlations
- Dissolved oxygen
- Total dissolved nitrogen

Independent of :
- Layer (surface or bed)
- Location within estuary





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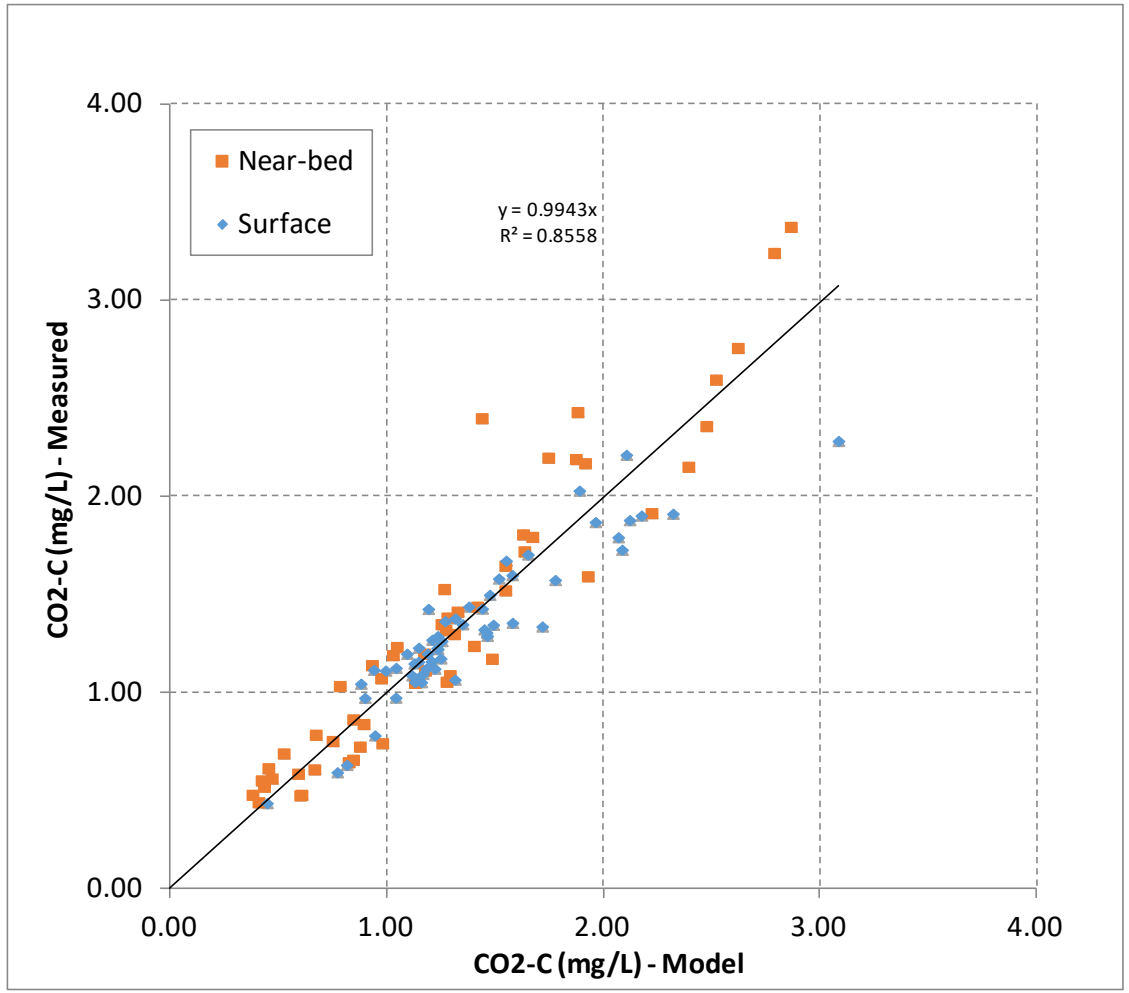
CO_2 concentration

Causes of variability
- 59 % - Dissolved oxygen
- 24 % - Total dissolved nitrogen
- 3% - Conductivity

Impacts
- CO_2 production removes O_2
- Weak mixing - limits oxygen replacement
- Respiration / decomposition higher than primary production
- Surface (fresh) and near-bed (saline) fit same model



CO_2-C(mg/l) = (-0.2235*DO(mg/l) + 3.1636) + (0.2475*TN(mg/l) - 0.6501)

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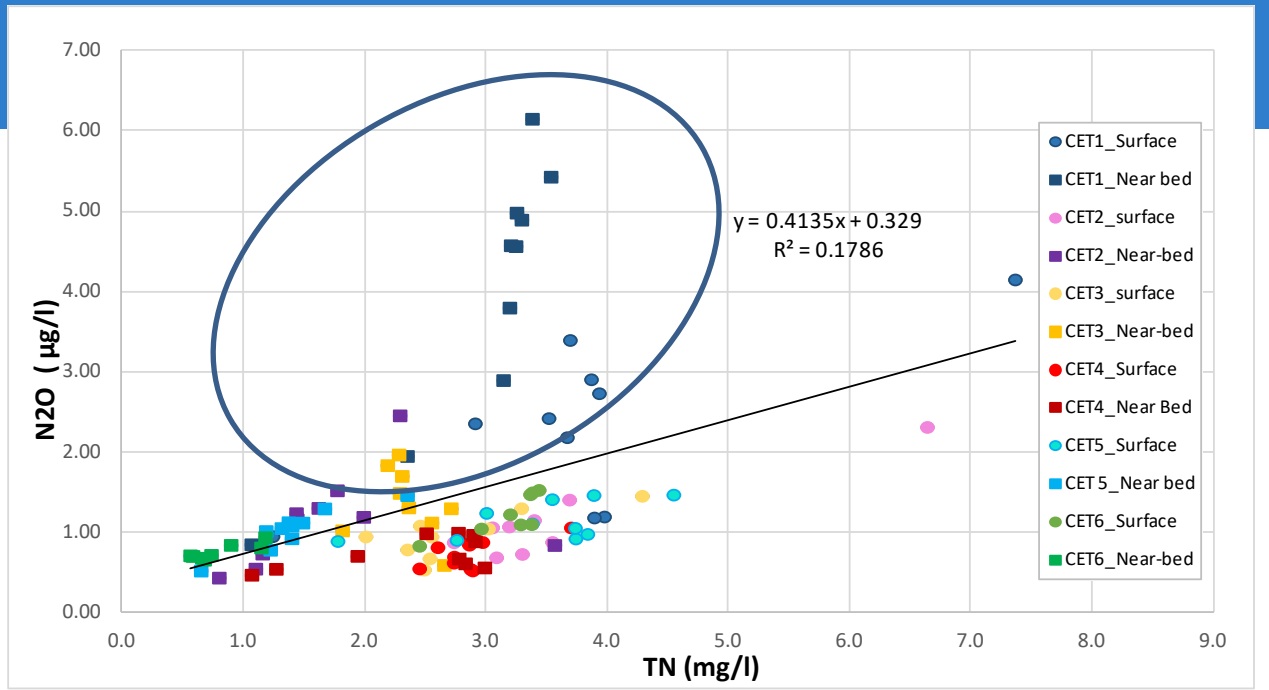
N_2O concentrations

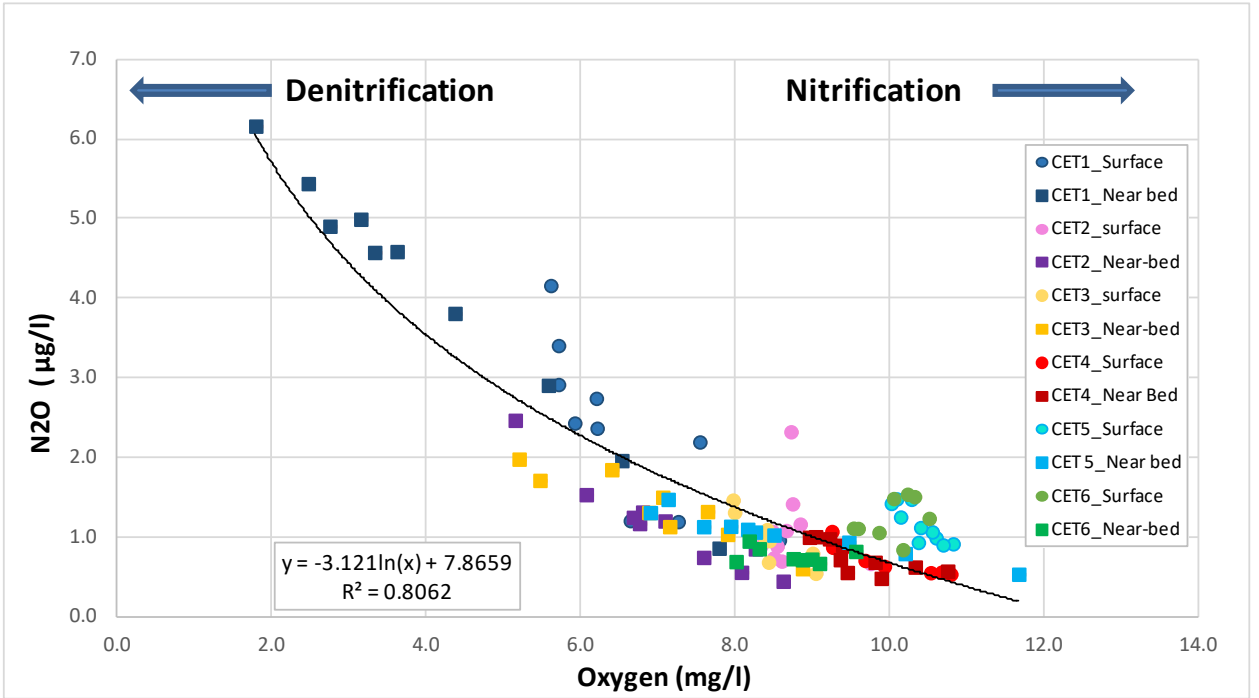
Correlations

- Dissolved oxygen - selection of nitrification or de-nitrification
- Total dissolved nitrogen

Independent of :

- Layer (surface or bed)
- Location within estuary





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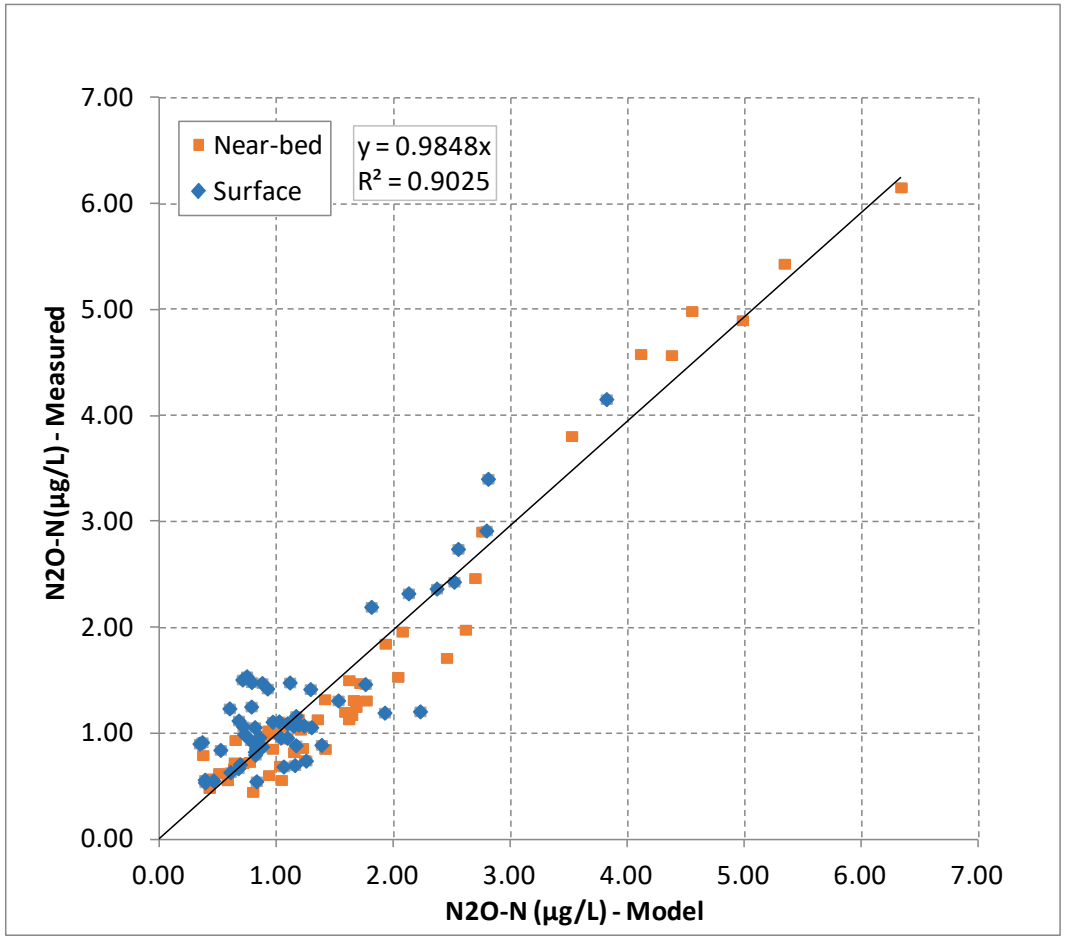
N_2O Concentrations

Causes of variability

- 80 % - Dissolved oxygen
- 3 % - Total dissolved nitrogen
- 6% - Conductivity

Impacts

- Low oxygen saturation increases % of N converted to N_2O
- Surface has higher N and DO%
- Weak mixing - limits oxygen replacement
- Surface (fresh) and near-bed (saline) fit same model



$N_2O\text{-}N(mg/l) = (3.121*\ln(DO(mg/l) + 7.8659) + (0.2844*TN(mg/l) - 0.7476)$

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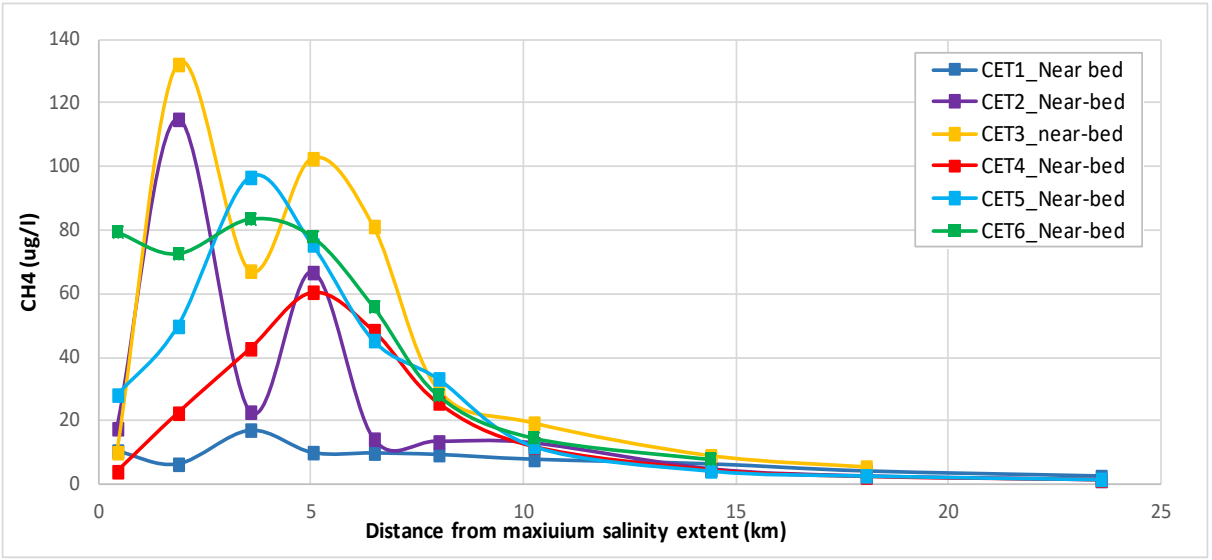
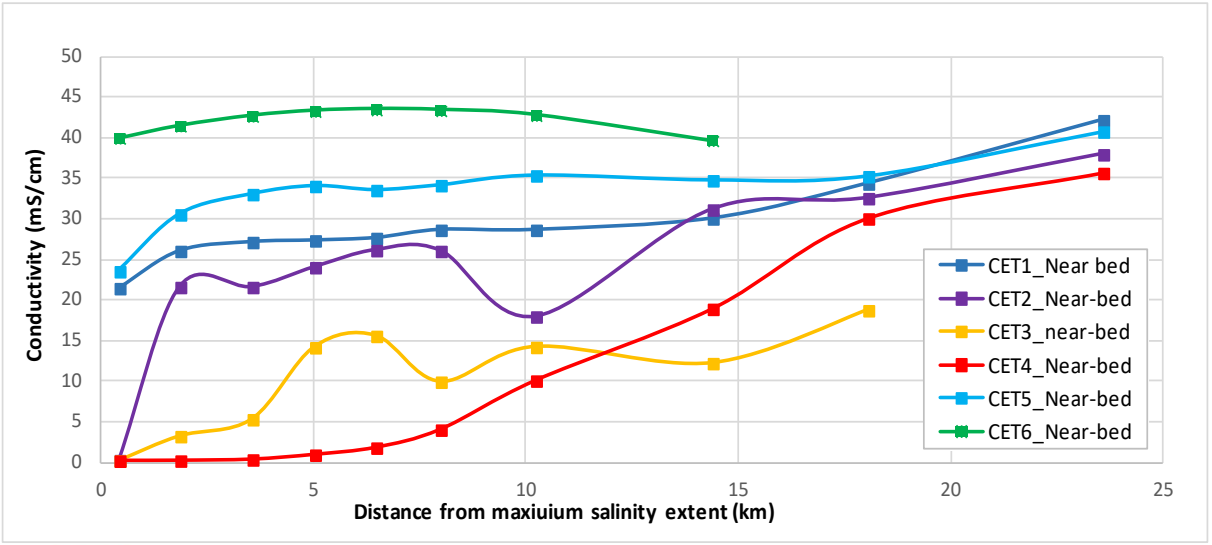
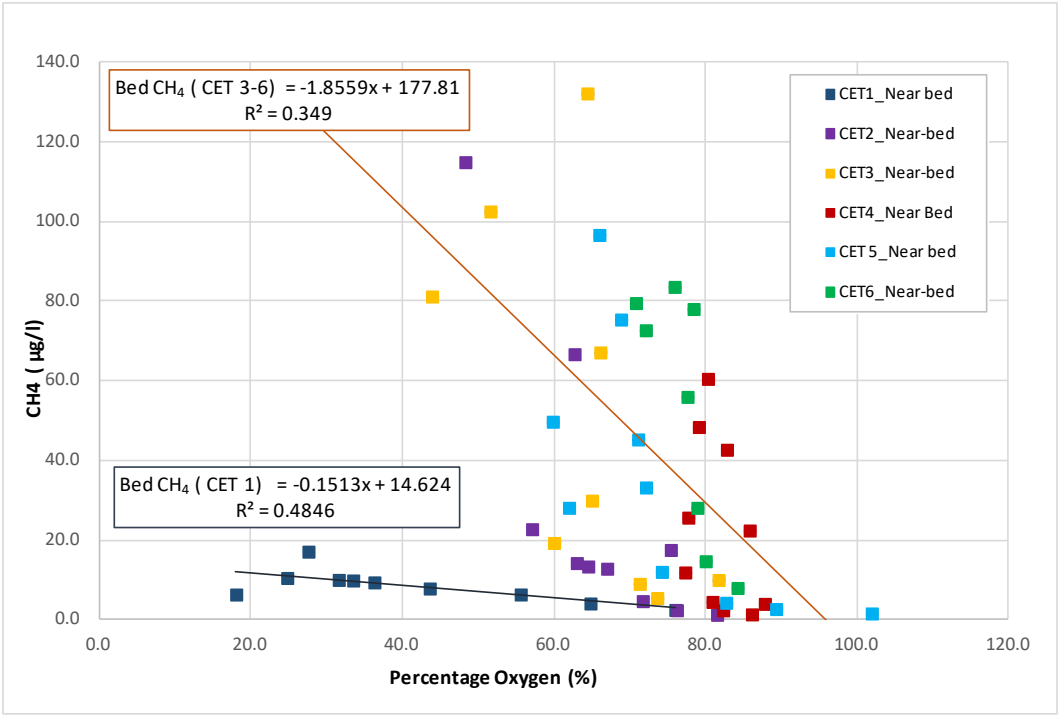
CH_4 Concentration – Near-bed





- Freshwater no bed production
- Permanent saline water switches of bed production (Sulphate-reducing bacteria outcompete methanogens)
- Increases with anoxic conditions



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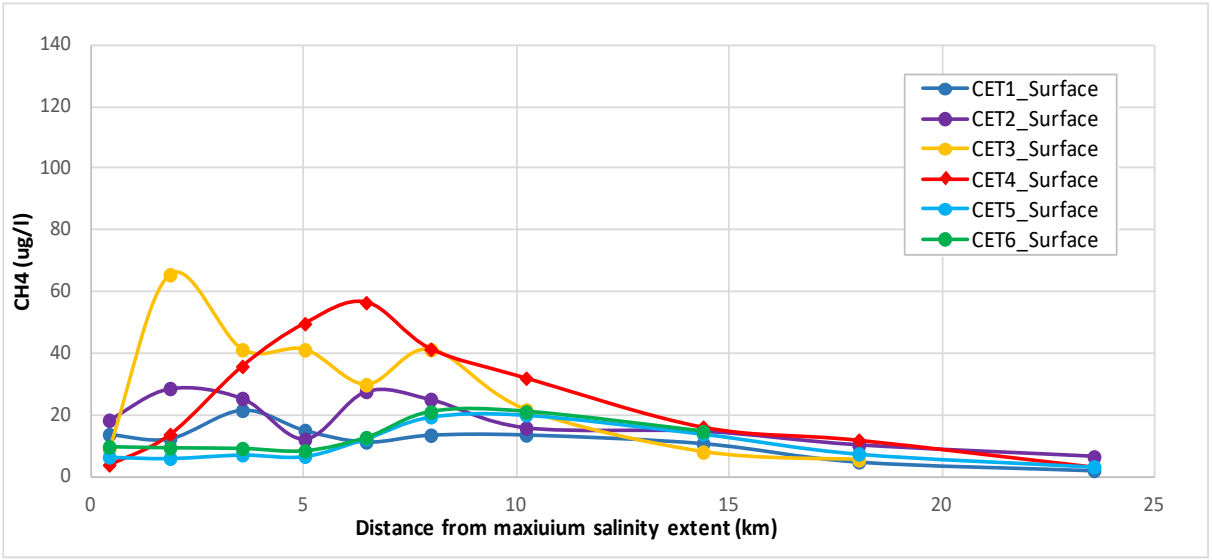
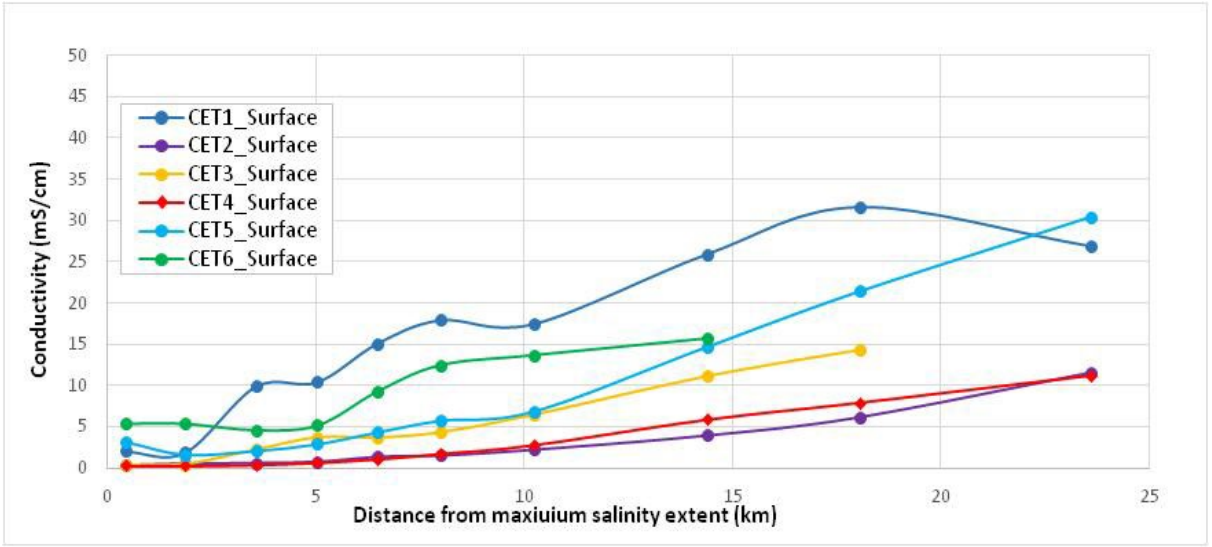
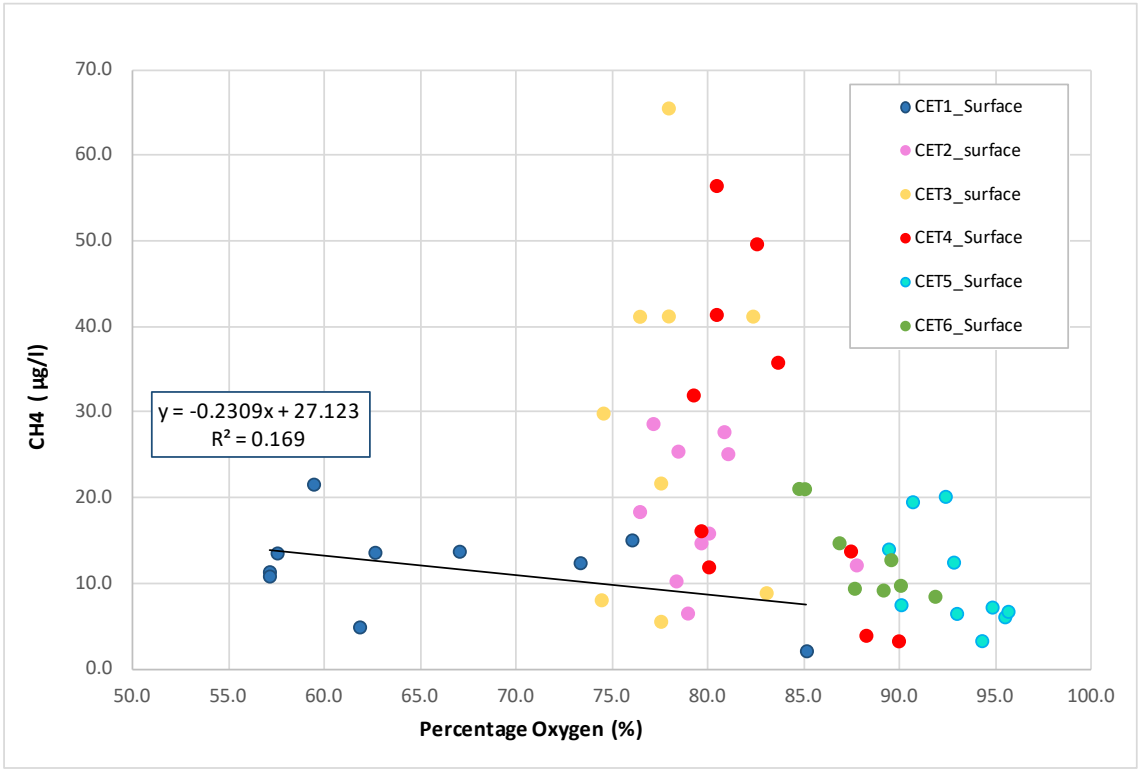
CH_4 Concentration - surface





- Triggered by increase in salinity
- Decreased by conservative mixing
- Weak correlation turbidity
- Weak correlation TN/TP ratio



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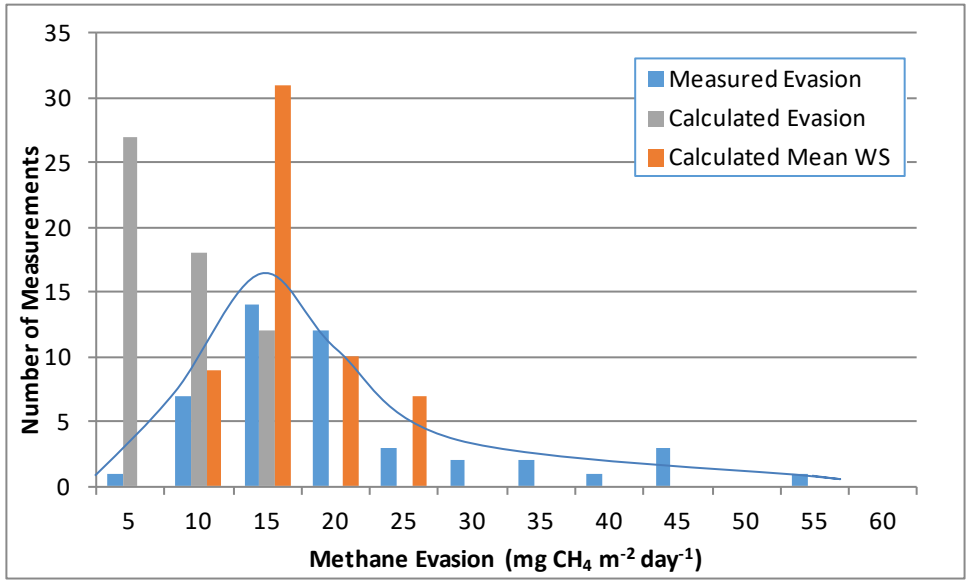
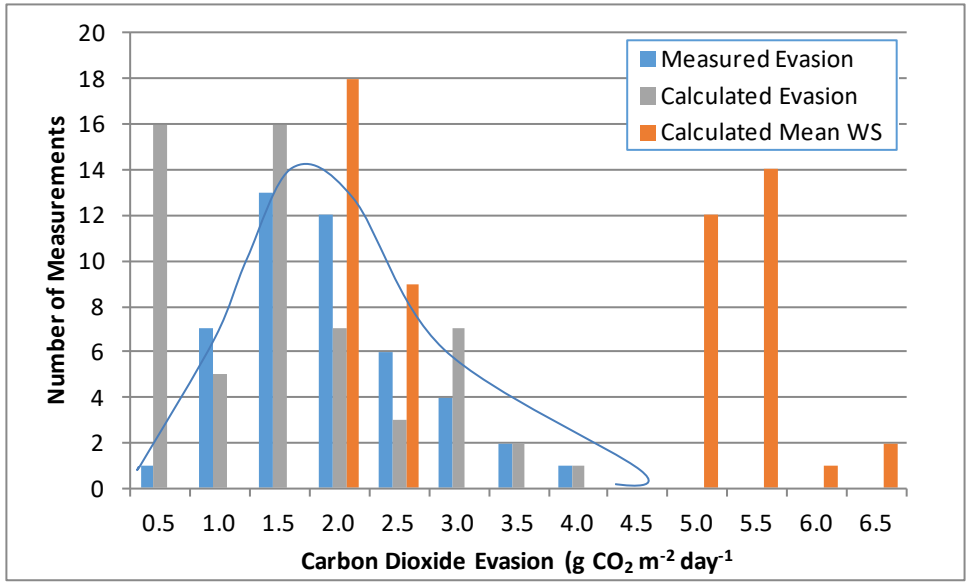
Methane and Carbon dioxide evasion





Measured average evasion (U_{mean} = 2.5m/s)

- Methane Evasion 20 mg m^{-2} d^{-1}
- Carbon dioxide Evasion 2 g m^{-2} d^{-1}

- CH_4 - Calculated evasion low compared to measurements

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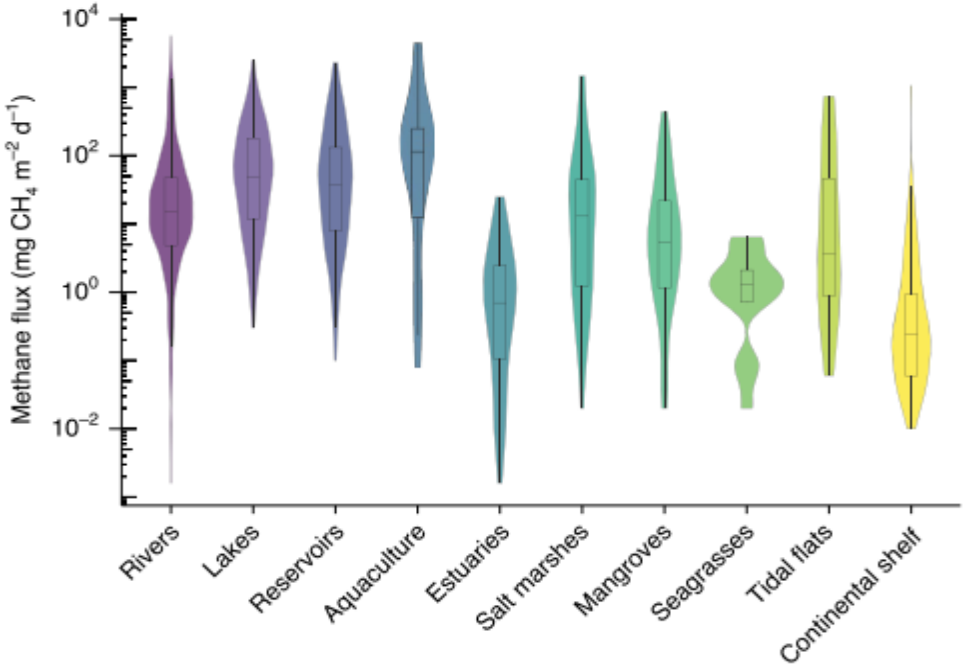
Wanninkhof, R.: Relationship between wind speed and gas exchange over the ocean revisited, Limnol. Oceanogr. Methods, 12(JUN), 351–362, doi:10.4319/lom.2014.12.351, 2014.

Summary

- Clyde estuary is highly stratified with low mixing and high nutrient levels
- Excess nutrients (from UWW and agriculture) result higher CO_2 and lower oxygen
- Low oxygen is exacerbated by: stratification, low mixing, low tidal range
- Low oxygen conditions promote higher nitrous oxide (denitrification) and methane (anoxic production / reduced methane oxidation).

The bigger picture

- Nutrient loads in UK estuaries are small compared to reported figures for European and North African estuaries
- 22 of the 32 largest cities in the world are located on estuaries
- Global estuaries are not well studied
- **Are estuaries a hidden source of GHG globally**?



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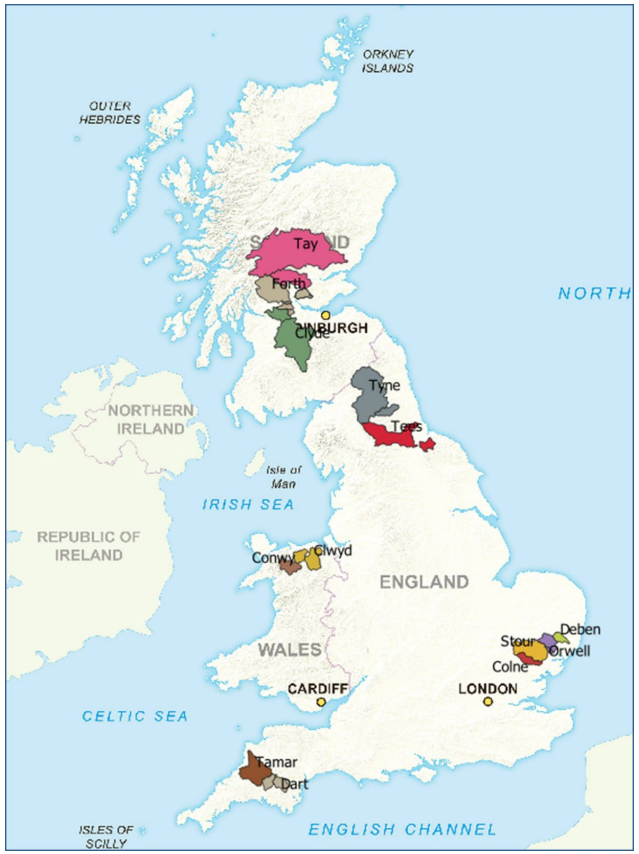
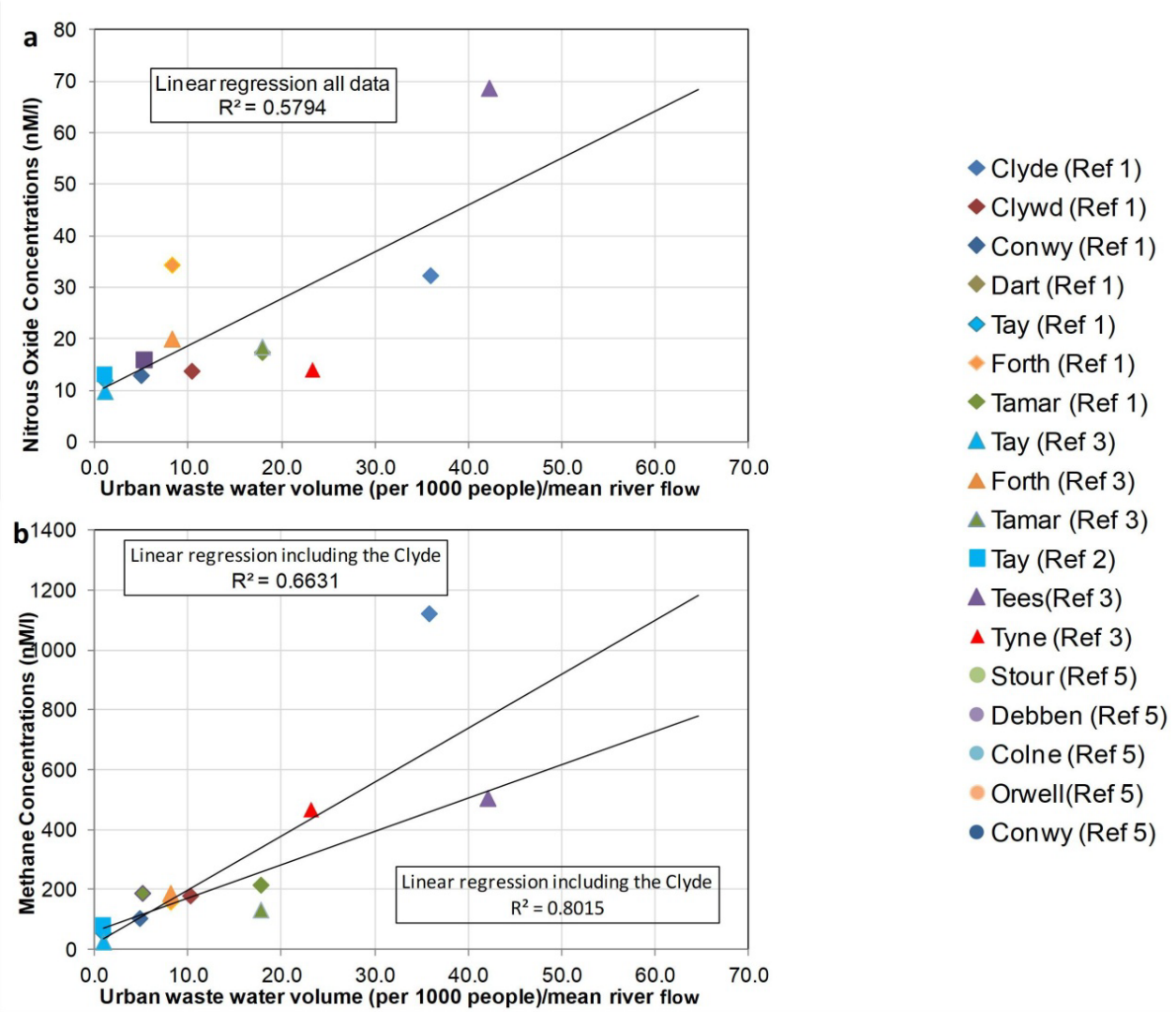
Rosentreter, J. A., Borges, A. V., Deemer, B. R., Holgerson, M. A., Liu, S., Song, C., Melack, J., Raymond, P. A., Duarte, C. M., Allen, G. H., Olefeldt, D., Poulter, B., Battin, T. I. and Eyre, B. D.: Half of global methane emissions come from highly variable aquatic ecosystem sources, Nat. Geosci., 14(4), 225–230


Greenhouse gas emissions from a human-impacted estuary
Thank you

CH_4 and N_2O concentrations

- Considerations of the estuary environments suggests strong link with urban waste water





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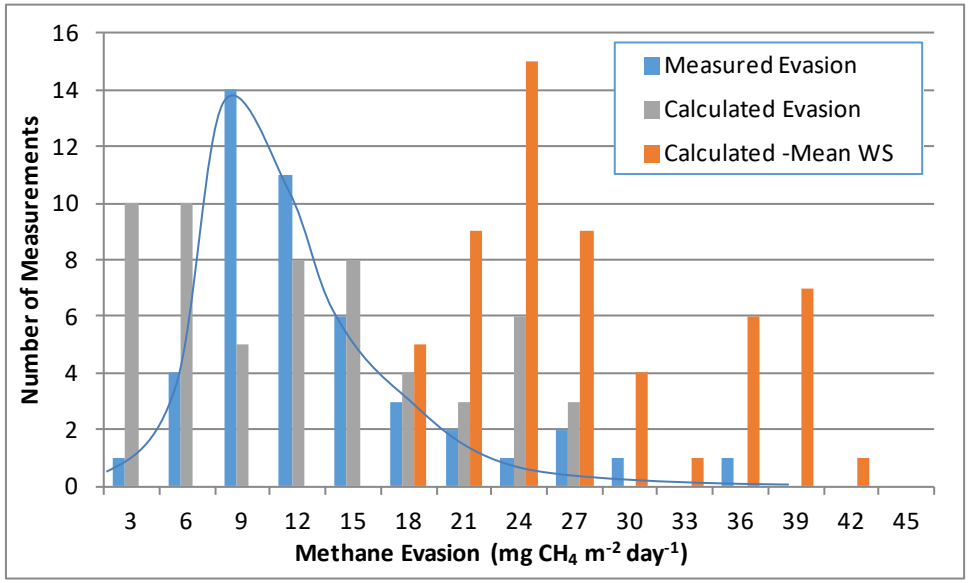
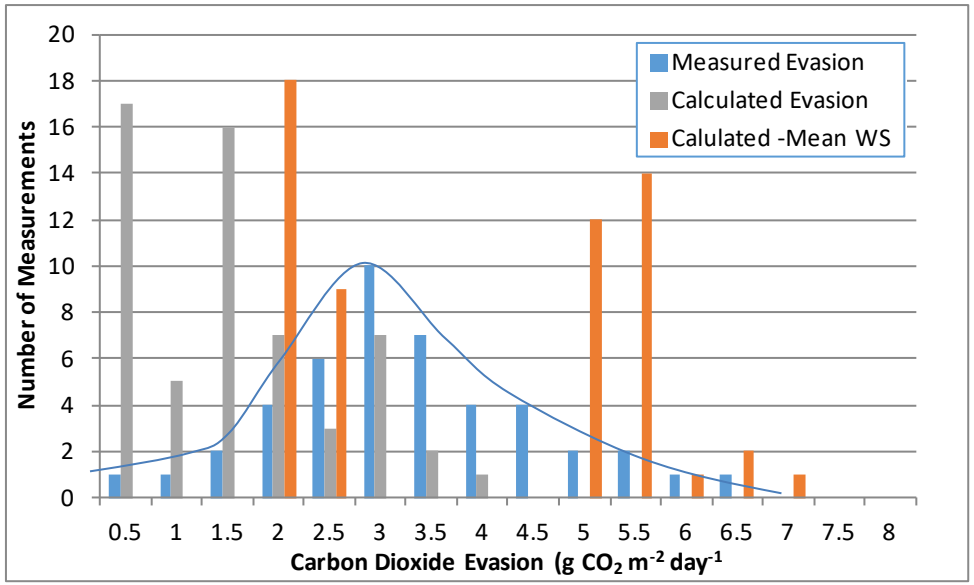
Brown, A. M., Bass, A. M. and Pickard, A. E.: Anthropogenic-estuarine interactions cause disproportionate greenhouse gas production: A review of the evidence base, Mar. Pollut. Bull., 174(July 2021), 113240, doi:10.1016/j.marpolbul.2021.113240, 2022.

Methane and Carbon dioxide evasion





Combining surface concentrations and average wind speed

- Methane Evasion 35 mg m^{-2} d^{-1}
- Carbon dioxide Evasion 3.1 mg m^{-2} d^{-1}

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