The influence of lake productivity on methane production and ebullition from temperate and arctic lake sediments

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Importance

- Methane (CH_4) is a potent greenhouse gas with a global warming potential that is 32x greater than CO_2 over 100 years.[1]
- Ebullition (bubbling) is a major source of CH_4 emission from northern (>40°N) lakes and ponds in littoral (shallow, lake edge) sediments. [2,3]
- Classes of lake productivity: oligotrophic (low), mesotrophic (medium), eutrophic (high). Chlorophyll α (chla) is often used as proxy.[4,5]
- Few studies have investigated lake productivity in relation to both sediment potential CH_4 production and ebullition from littoral sediments across a trophic gradient and between ecoregions.

Study Sites

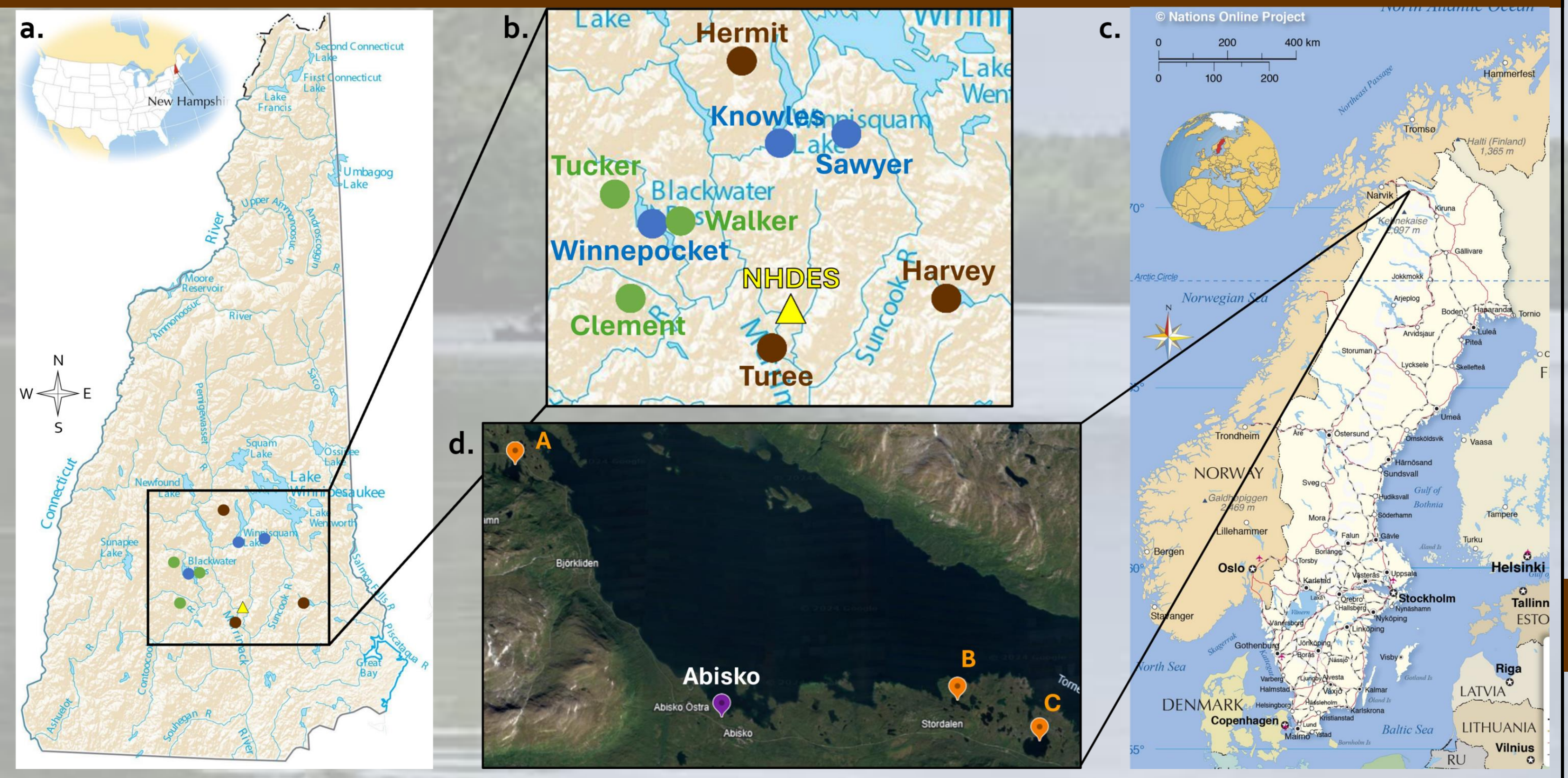

Fig. 1. NH study sites (**a.**) with close-up of oligotrophic (blue dots), mesotrophic (green dots), eutrophic (brown dots), and NH Dept. of Environmental Services (NHDES) lab (yellow triangle) (**b.**). Sweden study sites (**c.**) with close-up of selected lakes (orange pins) and Abisko Scientific Research Station (purple pin) (**d.**). Small (30-200 acre), shallow (<20m) lakes with safe access were chosen.

Research Question

How does lake productivity influence sediment potential CH_4 production and ebullition rates across a trophic gradient and between temperate and arctic ecosystems?

Methods

Water quality: Chlα, total nitrogen (TN) & phosphorus (TP), chloride, pH, conductivity, turbidity (**Fig. 2.**) & dissolved organic carbon (DOC), water temp. & bottom dissolved oxygen (D.O.)

Sediment CH_4 production rates: 0-10cm sediment core (**Fig. 3.**) incubations for each lake and determined rate using slope of linear regression.

- Measured sediment carbon and nitrogen content from core

Ebullition: 3 bubble traps (~5m apart in 1.5-4m depth) at each lake (**Fig. 4. & 5.**)

NH: 4 weeks in June; Sweden: 4 weeks in July

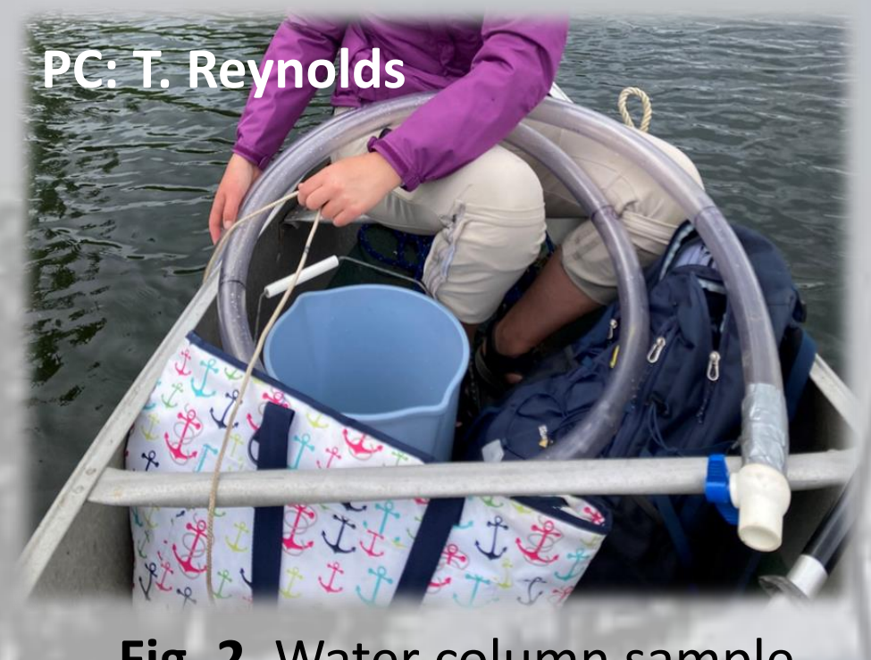
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Fig. 2. Water column sample collection.


PC: P. Tansey

Fig. 3. Sediment core (0 - 10cm).

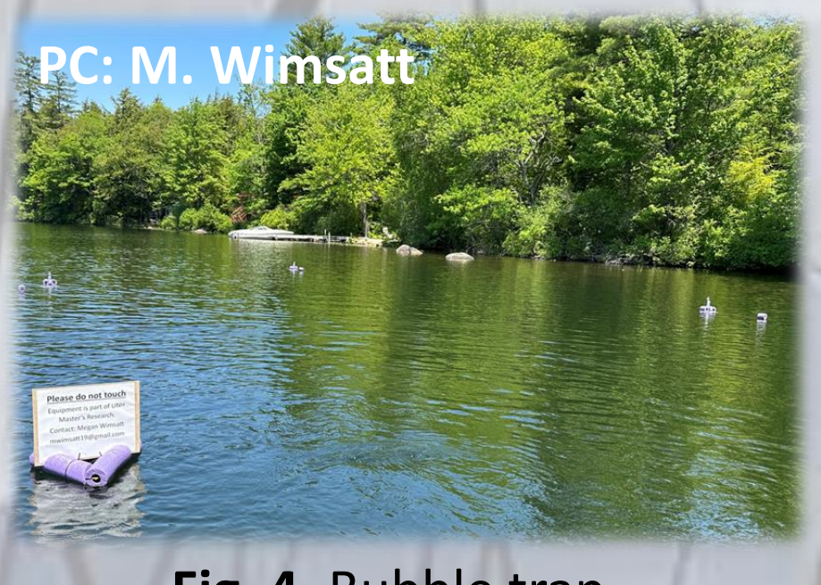
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Fig. 4. Bubble trap deployment with sign.


PC: D. Darling

Fig 5. Collecting CH_4 gas from bubble trap.

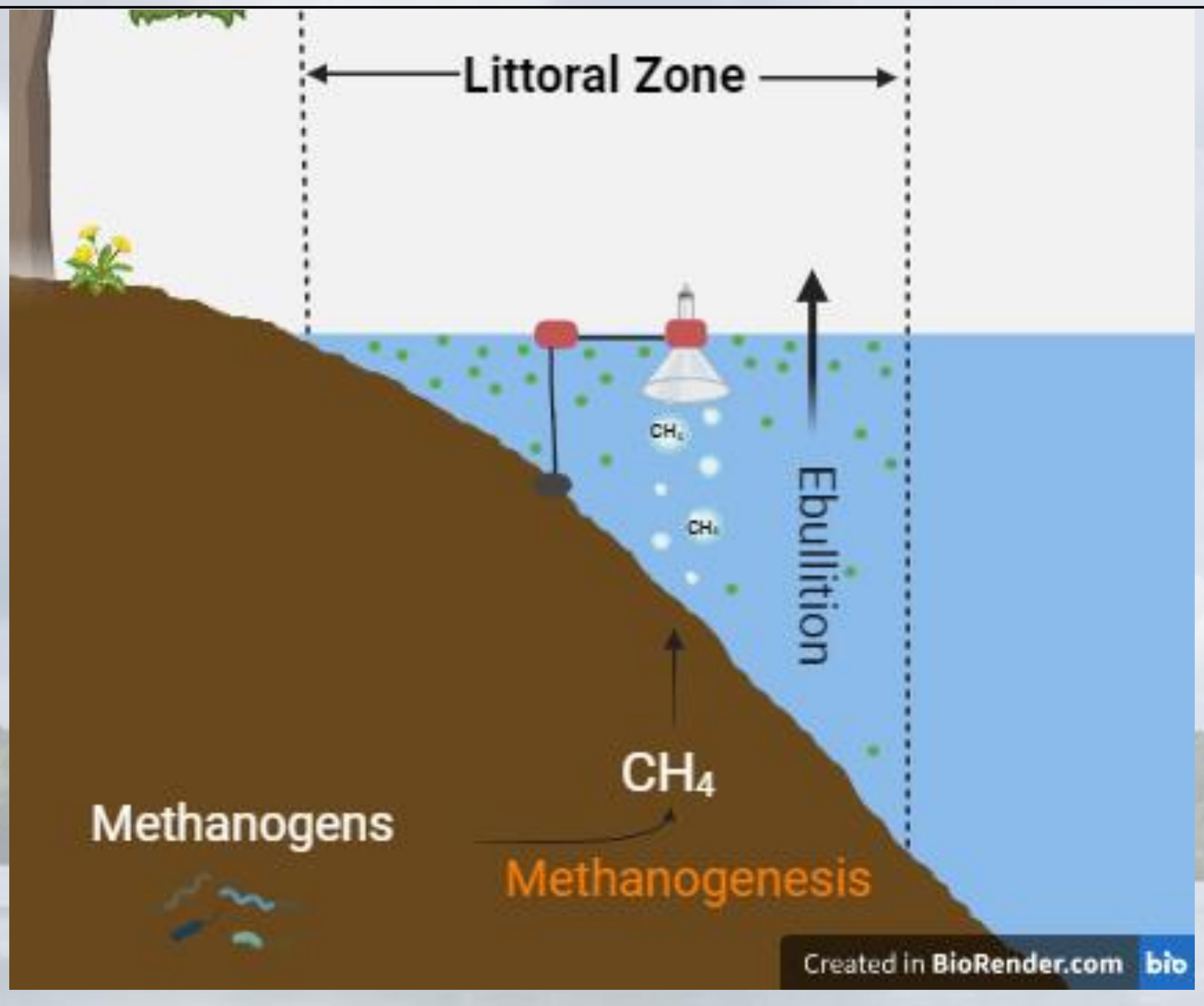

Fig. 6. Methane production (via methanogenesis) and ebullitive flux (captured for measurement by bubble trap) from littoral sediments in a lake ecosystem. Chlα is indicated by small green dots in water column and is more abundant near the surface.

Groupings of Significant Chemical Variables

⬆Chlα ⬆TN ⬆DOC ⬆Cond. ⬆Chloride ⬇Bottom D.O.

⬇pH ⬆Cond. ⬆Chloride ⬆Sed. C. ⬆Sed. N. ⬇Bottom D.O.

⬆Turbidity ⬆Sed. CH₄ Prod. Rate ⬇Water Temp.

Fig. 7. Three groupings of chemical variables that were significantly related with one another within each group @ alpha 0.05.

Drivers of Sediment Potential CH_4 Production Rates

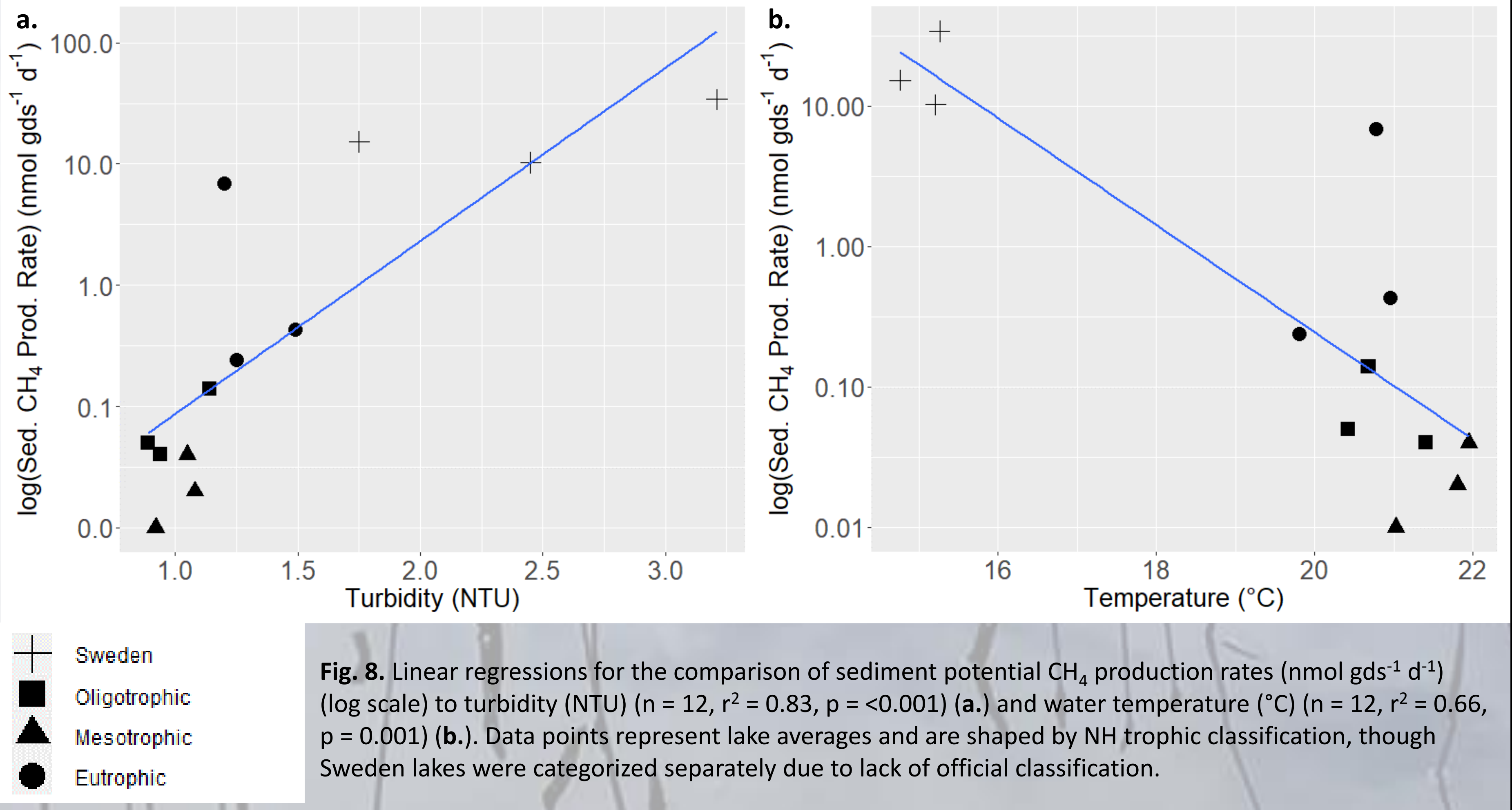

Fig. 8. Linear regressions for the comparison of sediment potential CH_4 production rates (nmol gds^{-1} d^{-1}) (log scale) to turbidity (NTU) (n = 12, $r^2 = 0.83$, p = <0.001) (**a.**) and water temperature (°C) (n = 12, $r^2 = 0.66$, p = 0.001) (**b.**). Data points represent lake averages and are shaped by NH trophic classification, though Sweden lakes were categorized separately due to lack of official classification.

Drivers of Ebullition

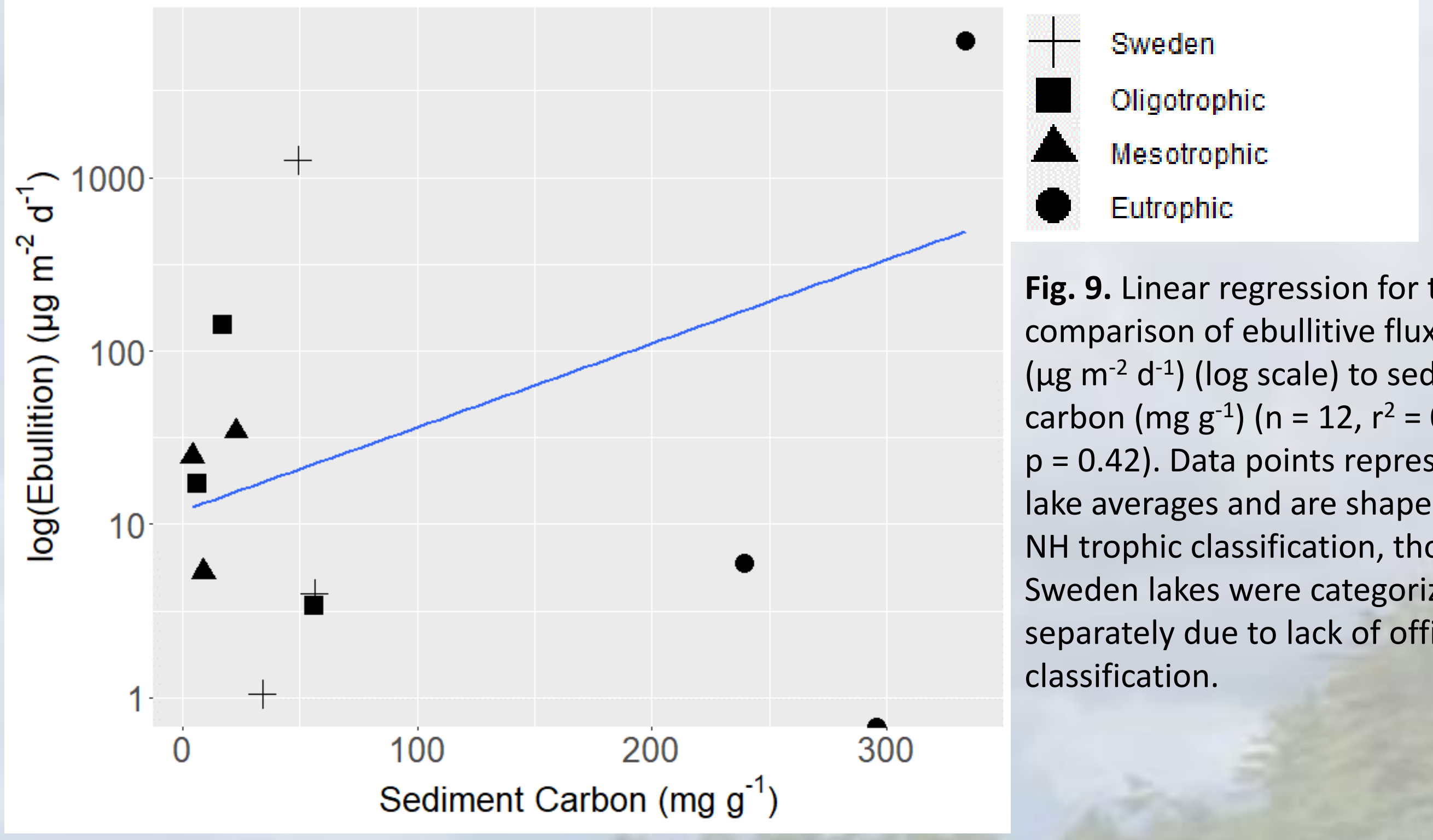

Fig. 9. Linear regression for the comparison of ebullitive flux rate (μg m^{-2} d^{-1}) (log scale) to sediment carbon (mg g^{-1}) (n = 12, $r^2 = 0.35$, p = 0.42). Data points represent lake averages and are shaped by NH trophic classification, though Sweden lakes were categorized separately due to lack of official classification.

Summary & Implications

- Assessment by trophic gradient was not ideal due to limited sample size per class (n = 3). Understanding lake chemistry provided a better understanding of limnological CH_4 cycling.
- Sediment potential CH_4 production rates were driven by increased turbidity and decreased water temperature.
- Ebullition was driven by increased sediment carbon.
- Sediment potential CH_4 production and ebullition rates were reduced by lake productivity in eutrophic NH lakes.
- Sediment potential CH_4 production and ebullition rates were low relative to similar studies.[5,6]

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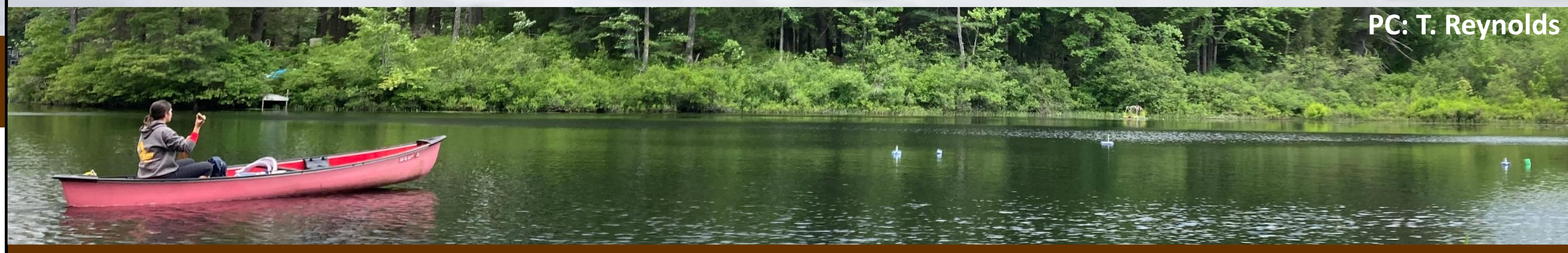
Our snapshot early summer sampling likely coincided with an expected seasonal decline in chlα following spring turnover[7,8], thus reducing CH_4 cycling rates and potentially explaining its inverse correlation to lake productivity. Future climate warming implications could not be determined due to limited sample duration.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