

Beaver ponds as potential sources of greenhouse gas emissions

Elizabeth Elmstrom¹, Julia Hyman², Kelly Addy³, Dr. Arthur Gold⁴

¹ EPSCoR Undergraduate Research Fellow, ² PhD Candidate, ³ Research Associate, ⁴ Professor, Department of Natural Resource Sciences



Introduction

Despite the recent focus on direct sources (e.g., end of pipe releases) of greenhouse gas (GHG) generation, 'indirect sources' of GHGs remain elusive. Due to rising beaver populations in North America, beaver ponds have grown of particular interest as indirect sources of GHGs. From their ability to extend water retention times and accumulate organic matter, these ponds provide anaerobic conditions perfect for methanogenesis and denitrification, processes that produce carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) – all GHGs of great concern. Methane and N₂O have global warming potentials of 25 and 298 CO₂ equivalents respectively (Forster, 2007) – meaning that they are more potent than CO₂ which generally receives the most attention. The possible formation of these potent GHGs led us to hypothesize that beaver ponds represent a hotspot for emissions that could change the net assessment of GHG flux within forested landscapes. We collected cores from three beaver ponds and used mesocosm studies to extract GHGs to understand the range of GHGs generated from beaver ponds, determine which gas dominated these emissions, and assess characteristics that control the rate and type of GHG flux.

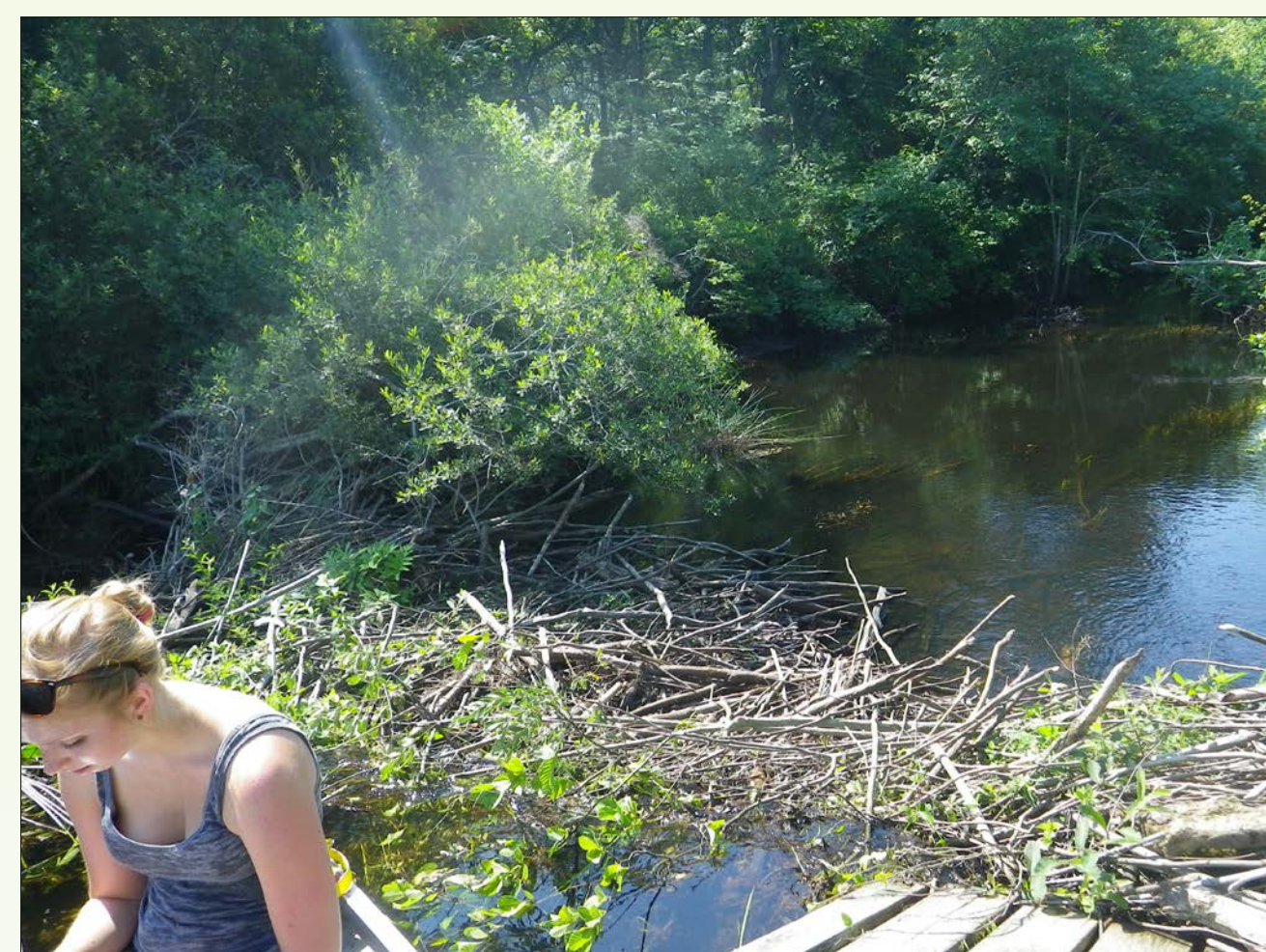


Figure 1: Beaver dam (Site 1)

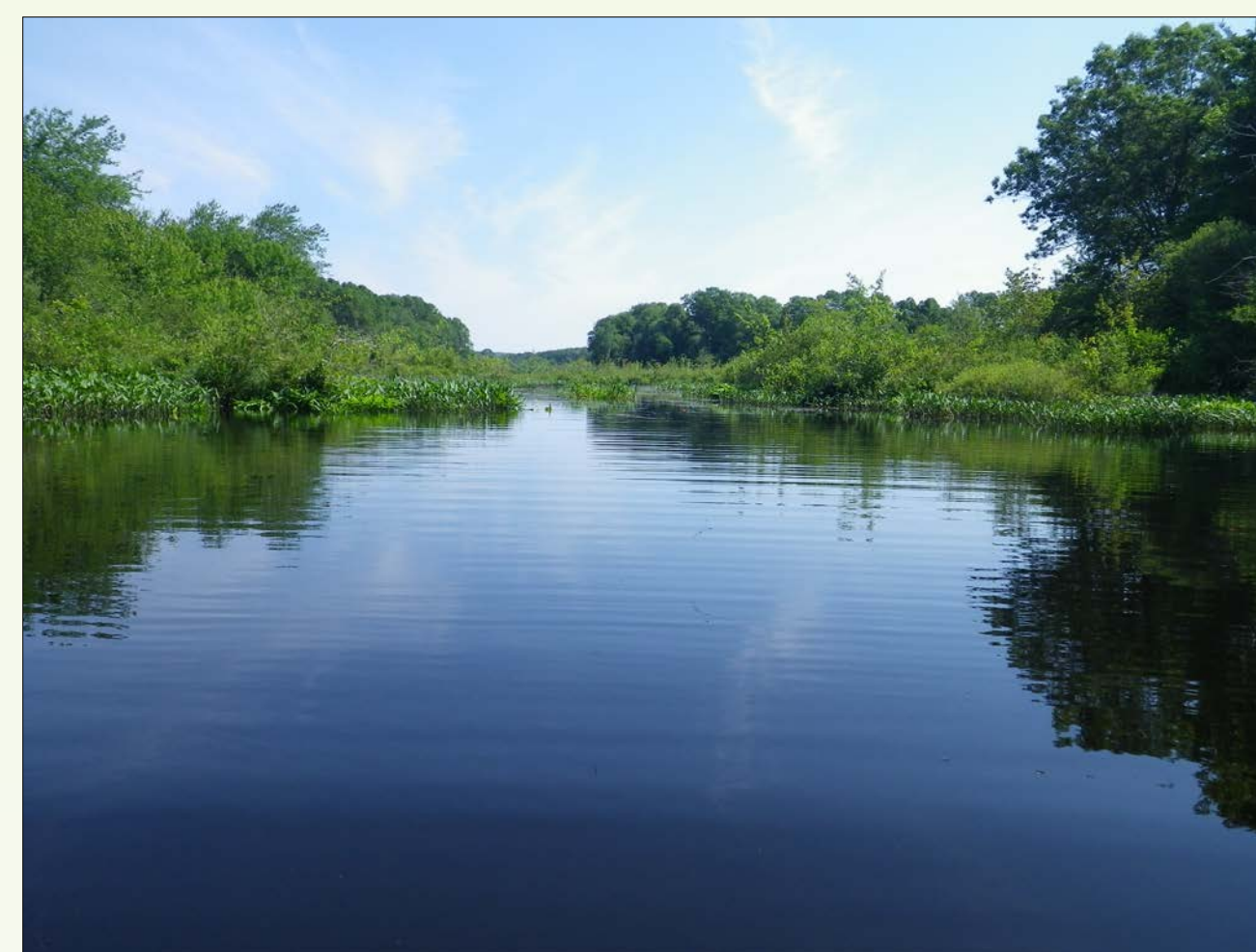


Figure 2: Area of retention (Site 1)

Biogeochemical Background

Anaerobic Biogeochemistry:

Fundamentally controls GHG generation!

•**Denitrification:** $\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$
water soluble gases

- Anaerobic, heterotrophic
- Expect high rates in wetlands
- Difficult process to measure and model
- N₂O vs. N₂ end product is extremely uncertain

•**Methanogenesis:** $\text{CO}_2 \rightarrow \text{CH}_4$

- Occurs in more reduced conditions than denitrification
- Lower energy yield, potentially inhibited by denitrification
- Natural wetlands are a large global source of CH₄

•**Carbon Dioxide Formation**

- CO₂ is a byproduct of both denitrification and decomposition of organic matter



Figure 3: North American Beaver

Methods

GHG Emission Rates (Mesocosm Method):

- Ten cores were taken from each of the beaver ponds (Fig 4.). Experiments were run at pond temperature in a climate controlled chamber.
- Cores were placed in glass mesocosms, capped and filled with pond water via peristaltic pump, leaving a 1.5 cm headspace (Fig. 5)

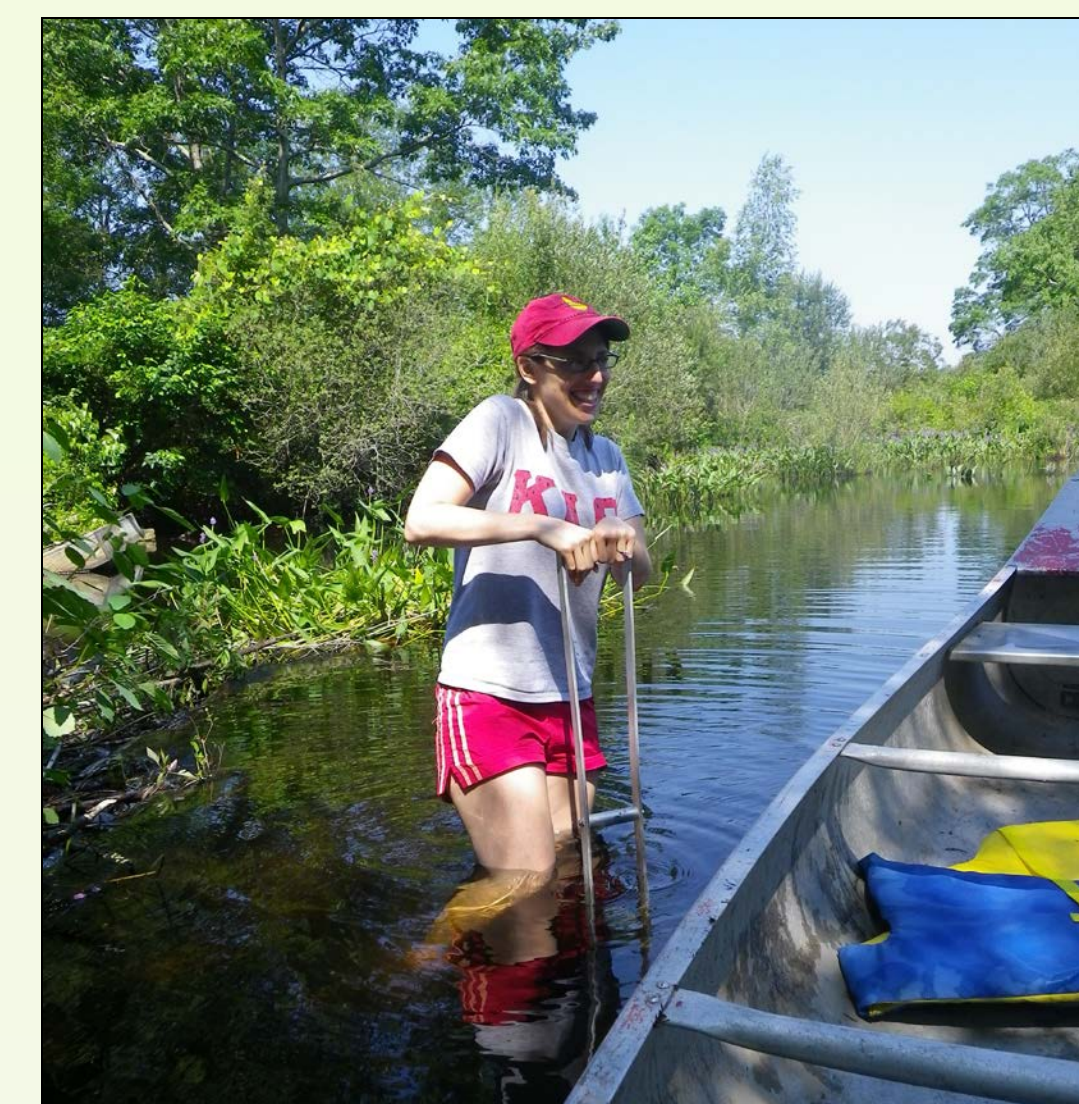


Figure 4: Collecting cores

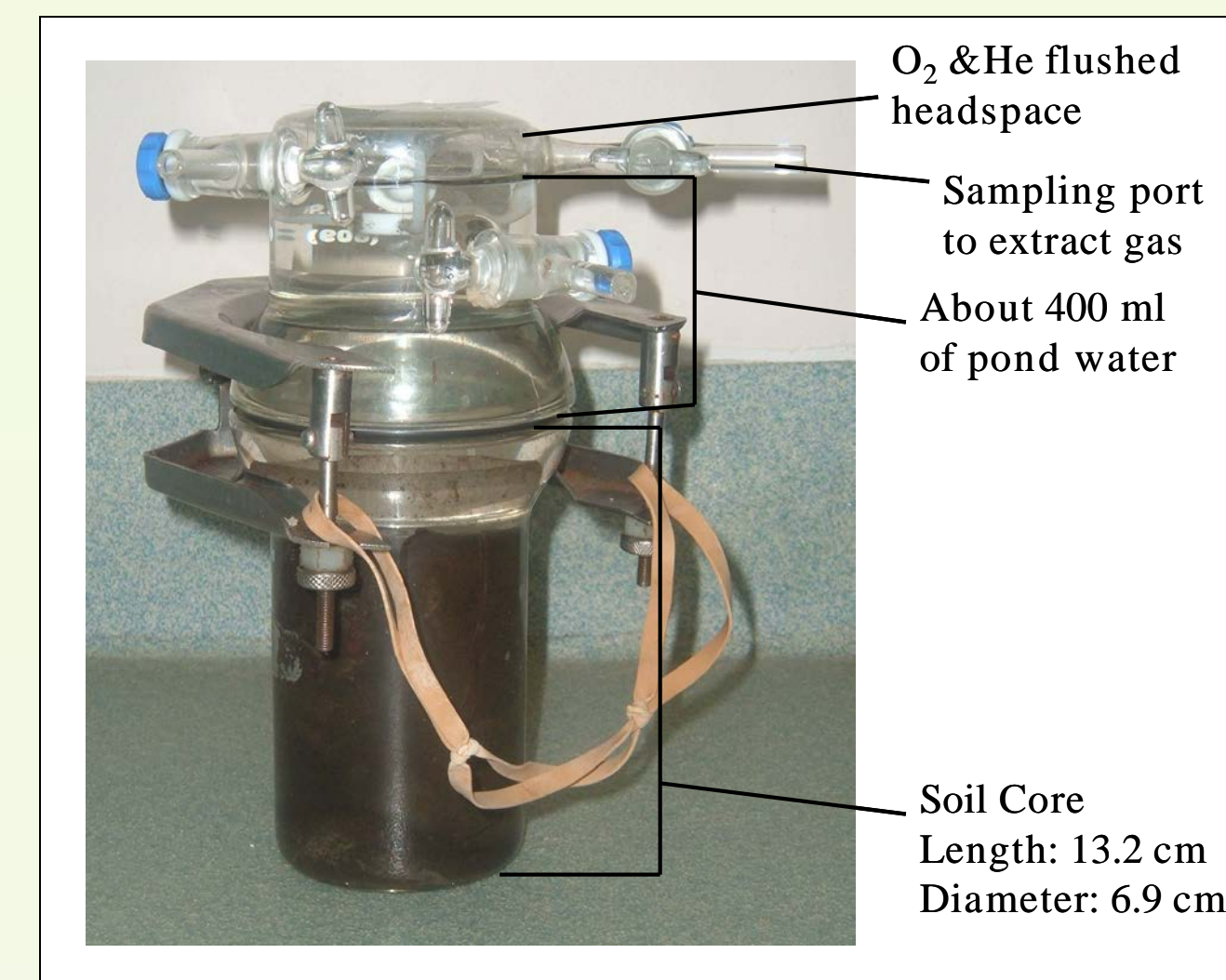


Figure 5: Mesocosm setup

- Mesocosm ports were left open overnight to allow air circulation, imitating the natural environment of pond sediments.
- The next day, gas samples were taken via gas-tight syringe with a stopcock from each mesocosm (Fig. 6). A Tedlar bag with oxygen and helium was attached to one of the sampling ports while gas was extracted from another to prevent atmospheric contamination.
- Sample ports were closed and the water was mixed using a stirrer for 1 min/hr for four hours (Fig. 7)
- Gas samples were taken from each mesocosm at the end of the incubation as above.

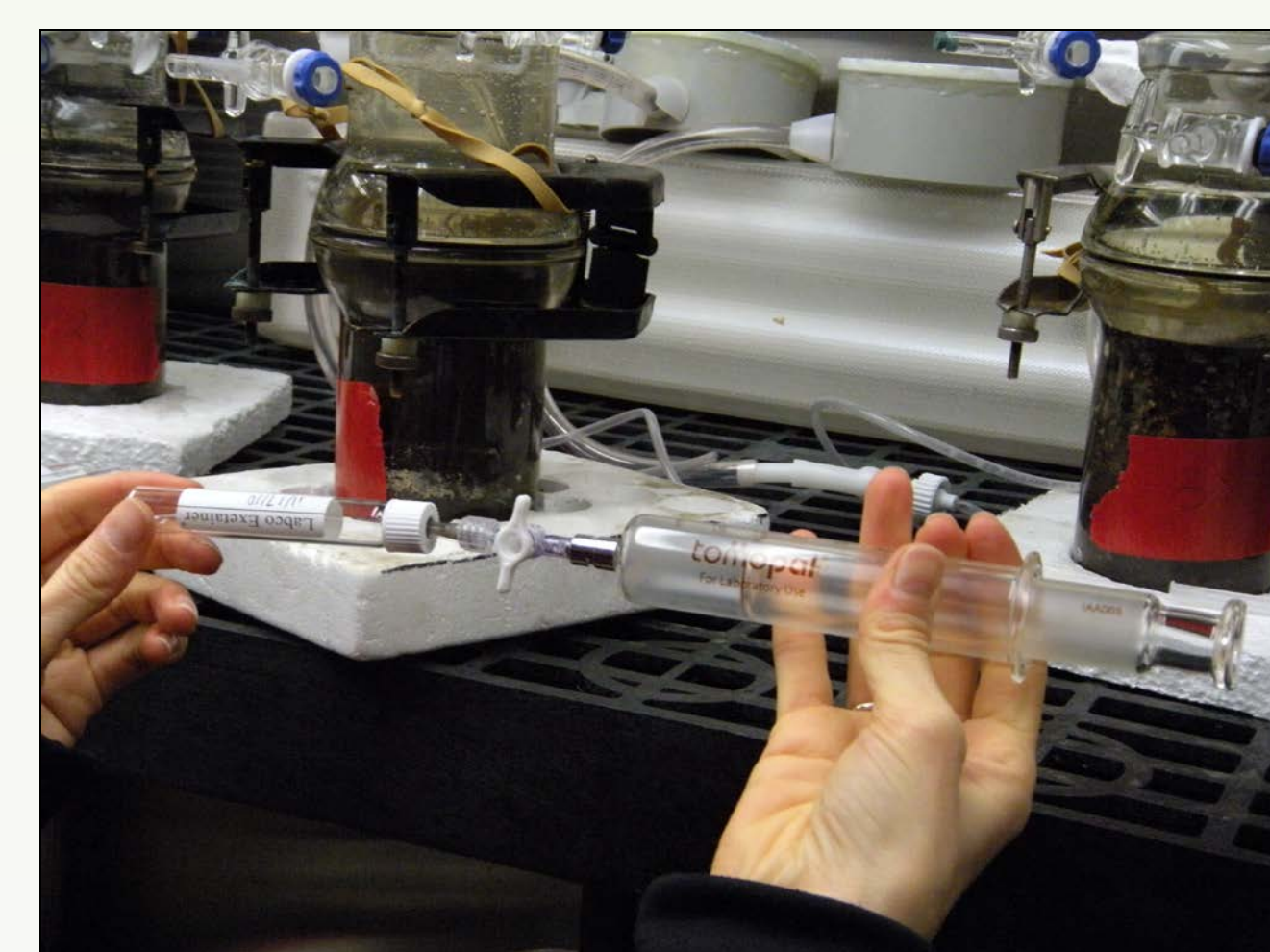


Figure 6: Injecting gas sample into vial



Figure 7: Compressed air from stirrer drives stir bar within mesocosm

- Gas samples were run for CO₂, CH₄, and N₂O on a gas chromatograph. Rates of gas generation were calculated as: $[(\text{mg of end gas}) - (\text{mg of starting gas})] / [(\text{surface area of core}) * (\text{time})]$
- CH₄ and N₂O rates were converted into CO₂ equivalents for comparison of global warming potentials.

% Organic Matter (Loss on Ignition Method):

- Each core was air-dried and sieved. A subsample of each was heated at 550° C in a muffle furnace, burning off the carbon, and was measured as described by Cuniff (1995).

Results

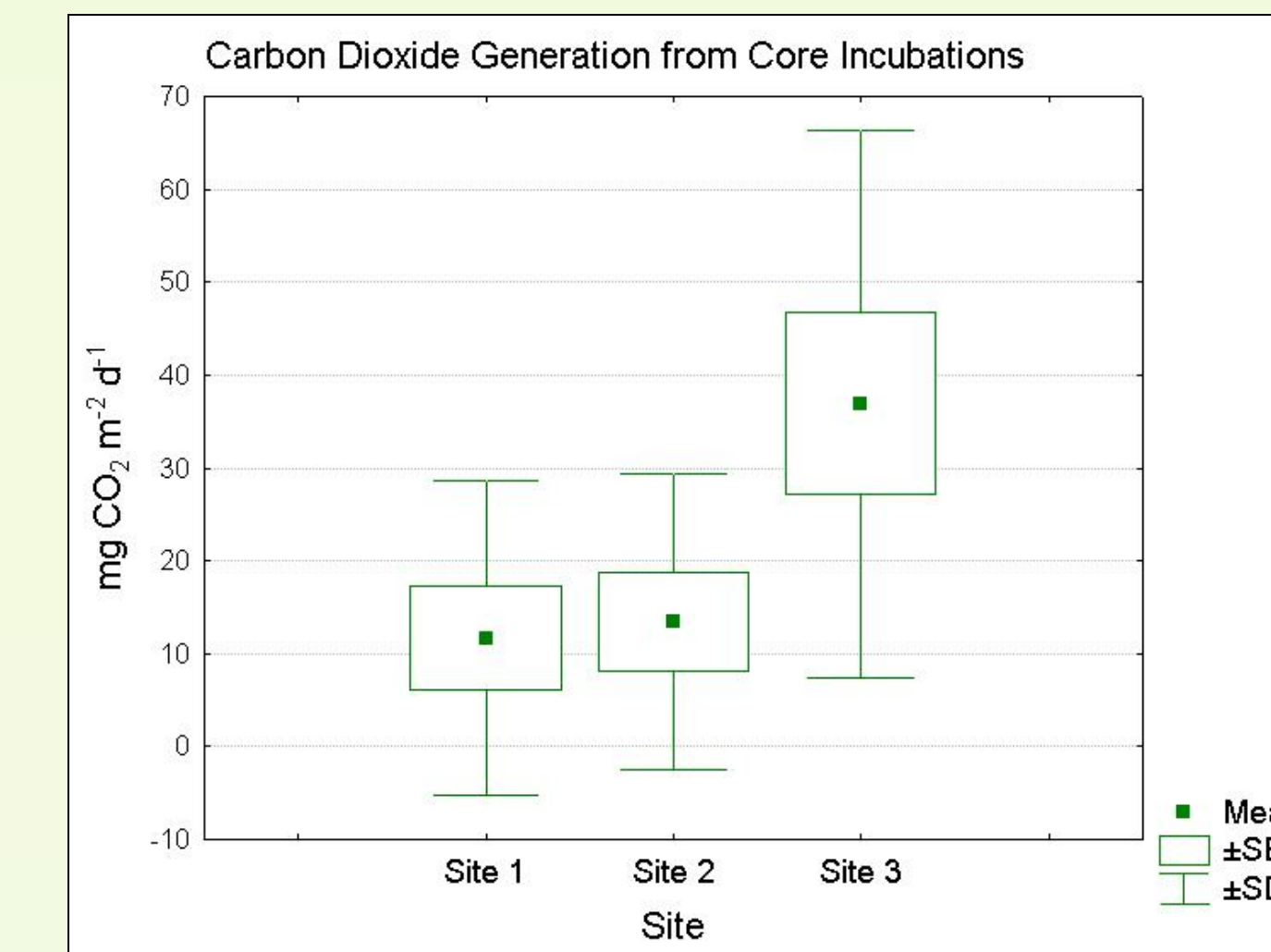


Figure 8: Rates of CO₂ emissions from the three beaver ponds

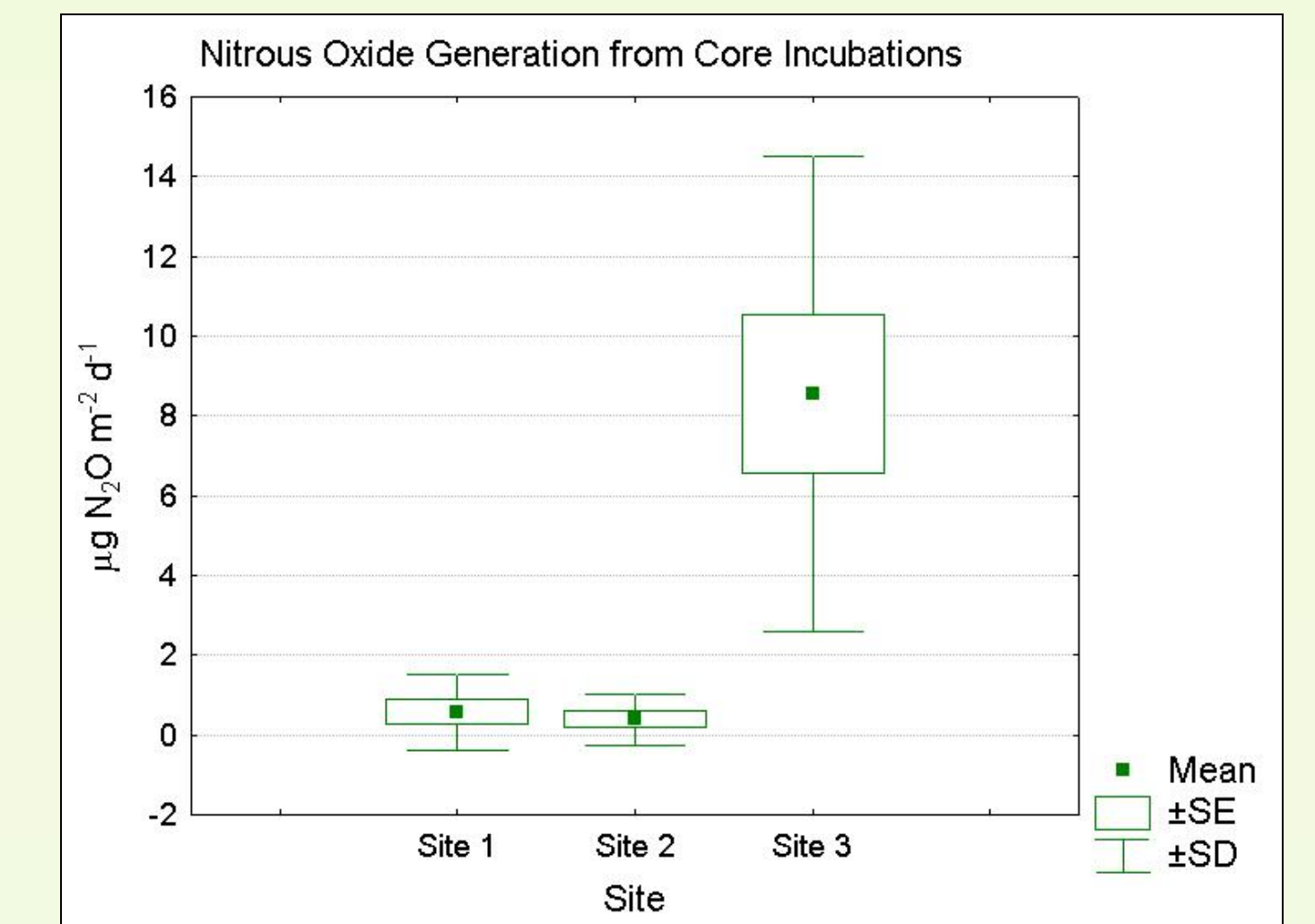


Figure 9: Rates of N₂O emissions from the three beaver ponds

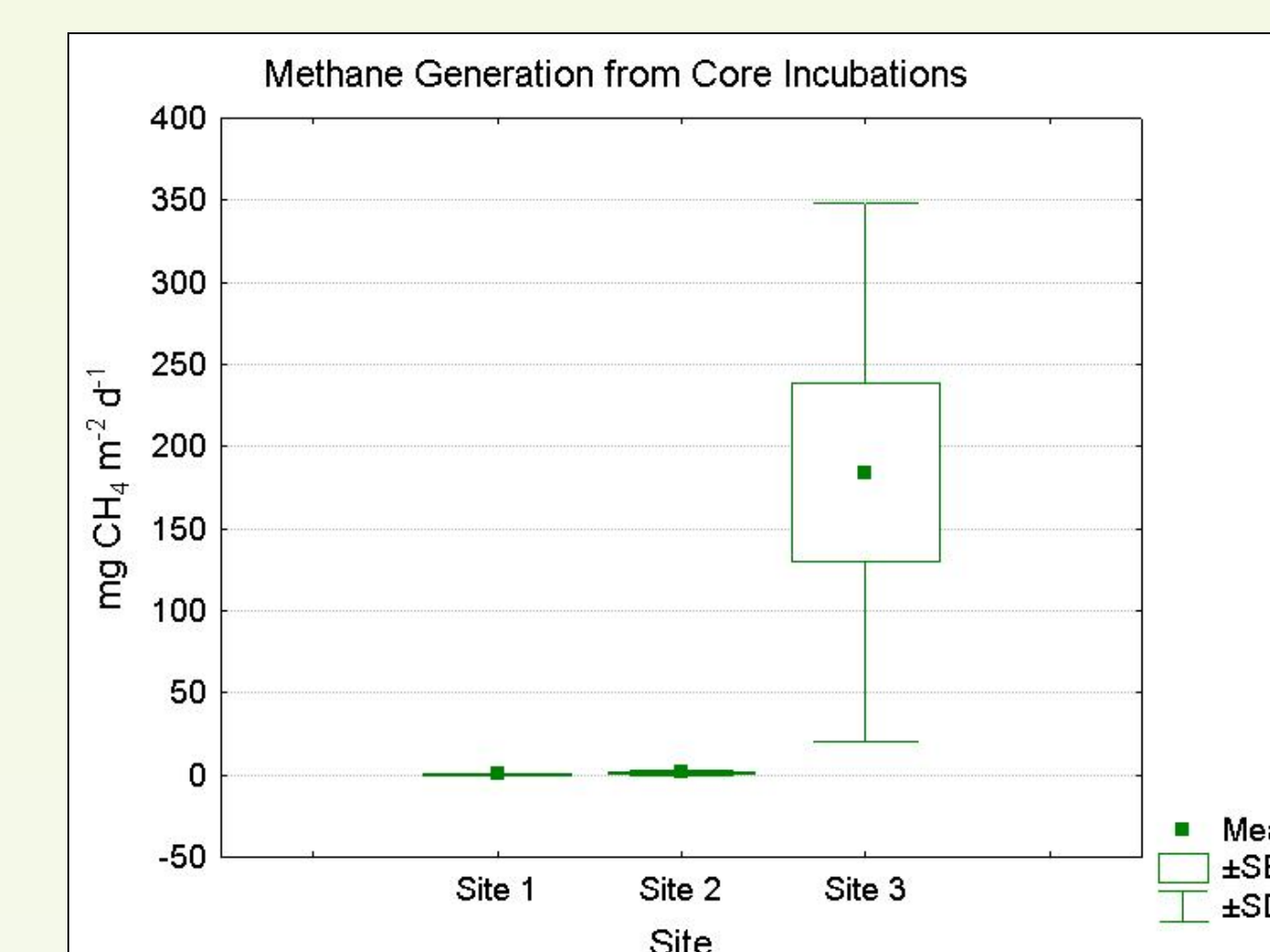


Figure 10: Rates of CH₄ emissions from the three beaver ponds

	Site 1: mg m ² day ⁻¹ in CO ₂ equiv.	% Gas Sampled	Site 2: mg m ² day ⁻¹ in CO ₂ equiv.	% Gas Sampled	Site 3: mg m ² day ⁻¹ in CO ₂ equiv.	% Gas Sampled
CO ₂	11.7	54.0	13.5	25.8	36.9	0.8
N ₂ O	0.2	0.8	0.1	0.2	2.6	0.1
CH ₄	9.8	45.3	38.6	74.0	4603.6	99.2
Total	21.7	100%	52.2	100%	4643.1	100%

	Site 1	Site 2	Site 3
Water temperature (°C)	17.2	13.9	16.8
Dissolved oxygen (mg/L)	7.6	7.9	8.1
% Organic Matter	22%	52%	26%
Organic Matter Classification	Fibric	Hemic	Sapric
Flow Regime	Flowing	Stagnant	Stagnant

- Site 3 had the highest rate of all GHG emissions (Fig. 8, 9, 10).
- Of the three gases emitted at Site 2 and 3, CH₄ was the most prevalent greenhouse gas when converted to CO₂ equivalents (Table 1). At Site 1 there also was, substantial CH₄ emissions, but CO₂ had the greatest global warming potential.

Discussion

- GHG emissions between sites showed variable results. However, high emission rates from Site 3 suggest that beaver ponds do have the potential to generate substantial GHG flux within forested landscapes. Further studies are warranted to assess beaver ponds and include in net assessments of GHG flux by groups like the IPCC.
- Throughout all sites, CH₄ emissions were substantial, dominating Site 2 by 74% and Site 3 by 99.2% (CO₂ equivalent). Such high emission rates indicate the need to study the factors controlling methanogenesis in beaver ponds.
- Site 3's high level of GHG may be related to its sapric (very mucky) organic matter, stagnant water and warm temperature which provide ideal conditions for denitrification, methanogenesis, and decomposition. The role of the quality of organic matter, flow regimes, and seasonal patterns should be explored further.

References

Cuniff, P. A. (ed). 1995. *Official Methods of Analysis of AOAC International*, 16th edition. Method 2.7.08. Chapter 2, p 37.
 Forster, P., V. Ramaswamy, P. Artaxo, T. Bernsten, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Acknowledgements

This study is based upon work supported by the National Science Foundation under EPSCoR Grant #1004057 to Rhode Island. I would like to thank my mentors Dr. Art Gold, Kelly Addy, Julia Hyman, Suzanne Cox and fellow undergraduates Molly Welsh and Mary Gutierrez for their support and guidance.

