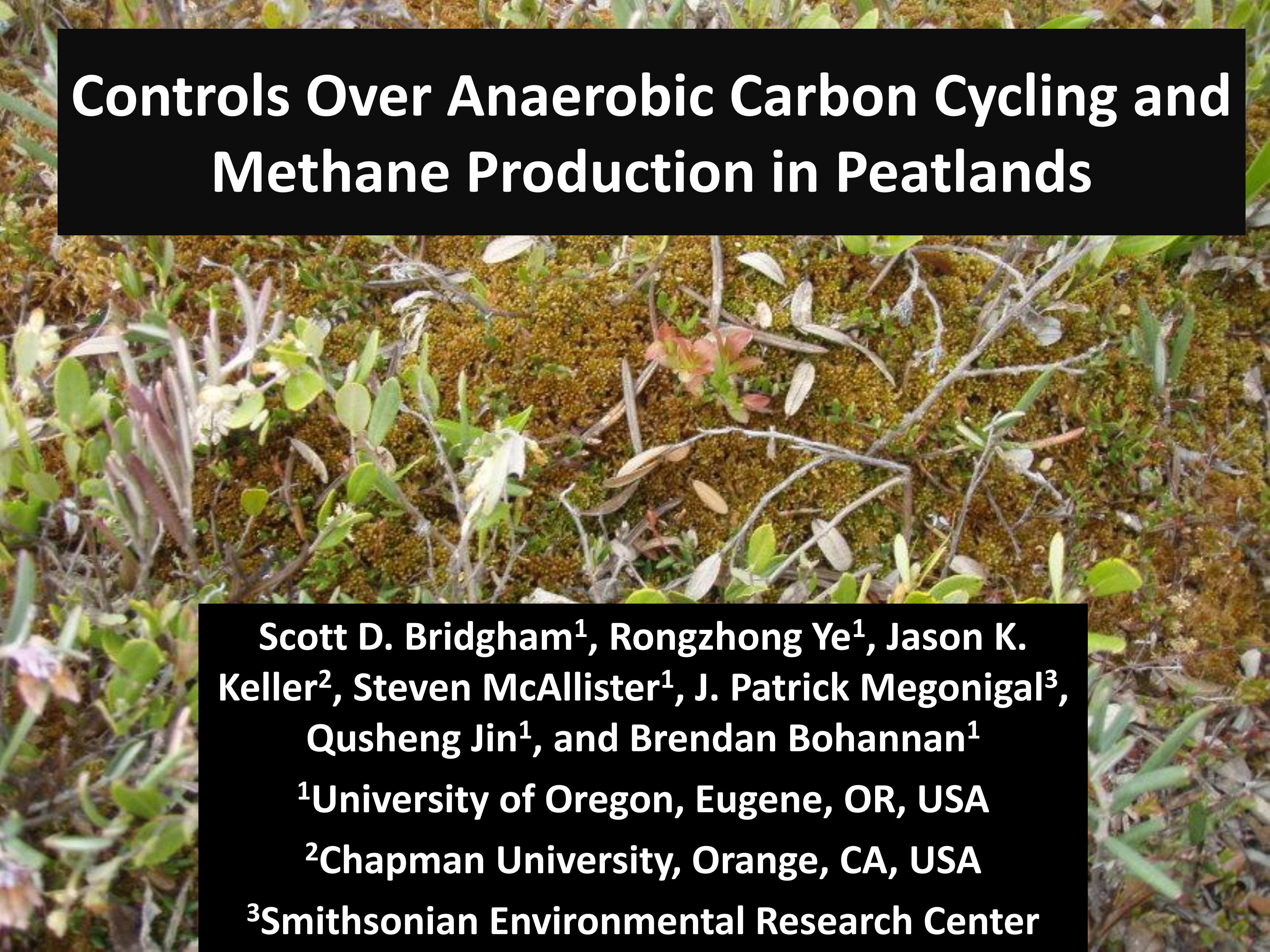


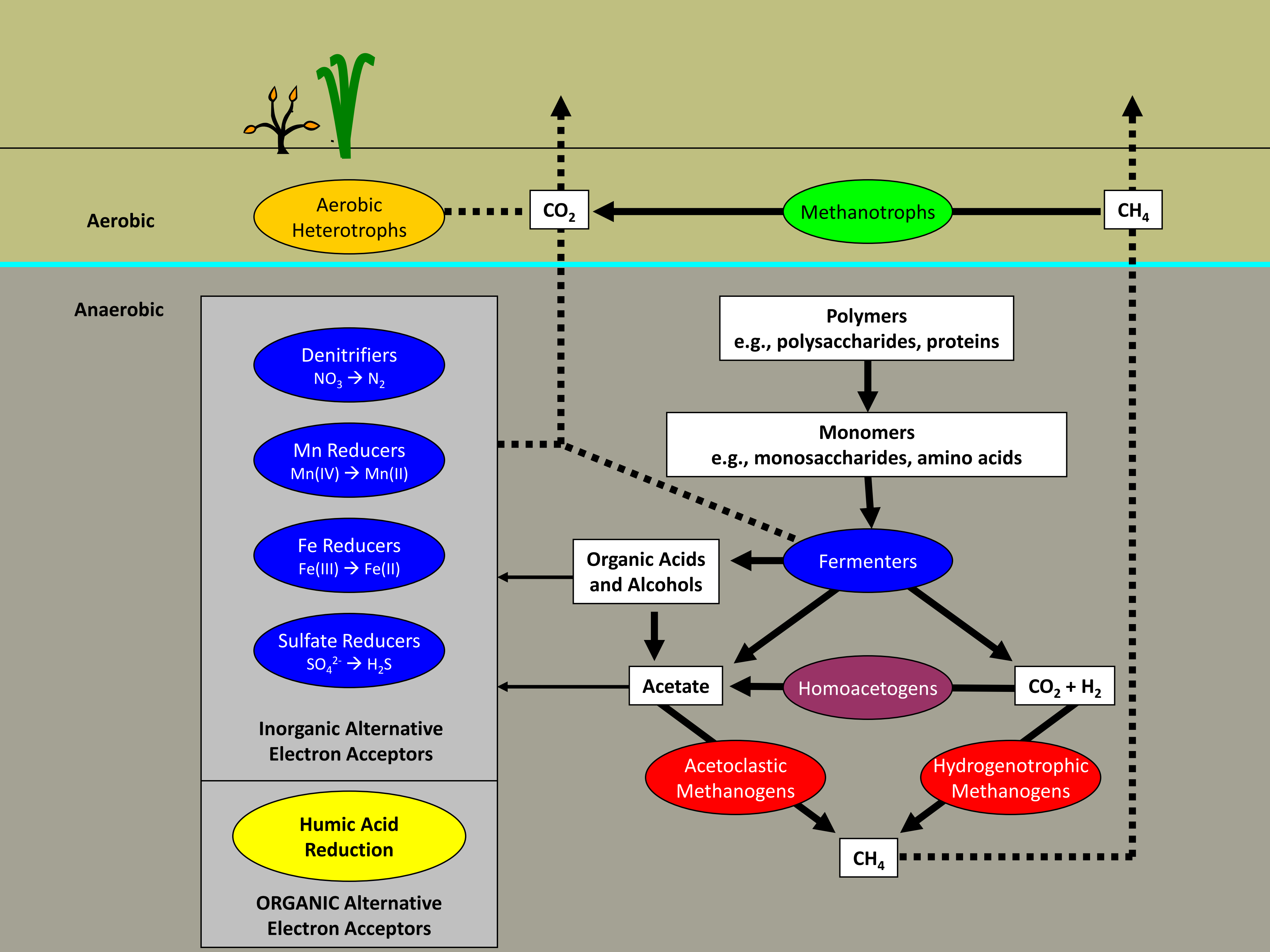
Controls Over Anaerobic Carbon Cycling and Methane Production in Peatlands

Scott D. Bridgham[1], Rongzhong Ye[1], Jason K. Keller[2], Steven McAllister[1], J. Patrick Megonigal[3], Qusheng Jin[1], and Brendan Bohannan[1]

[1]University of Oregon, Eugene, OR, USA

[2]Chapman University, Orange, CA, USA

[3]Smithsonian Environmental Research Center

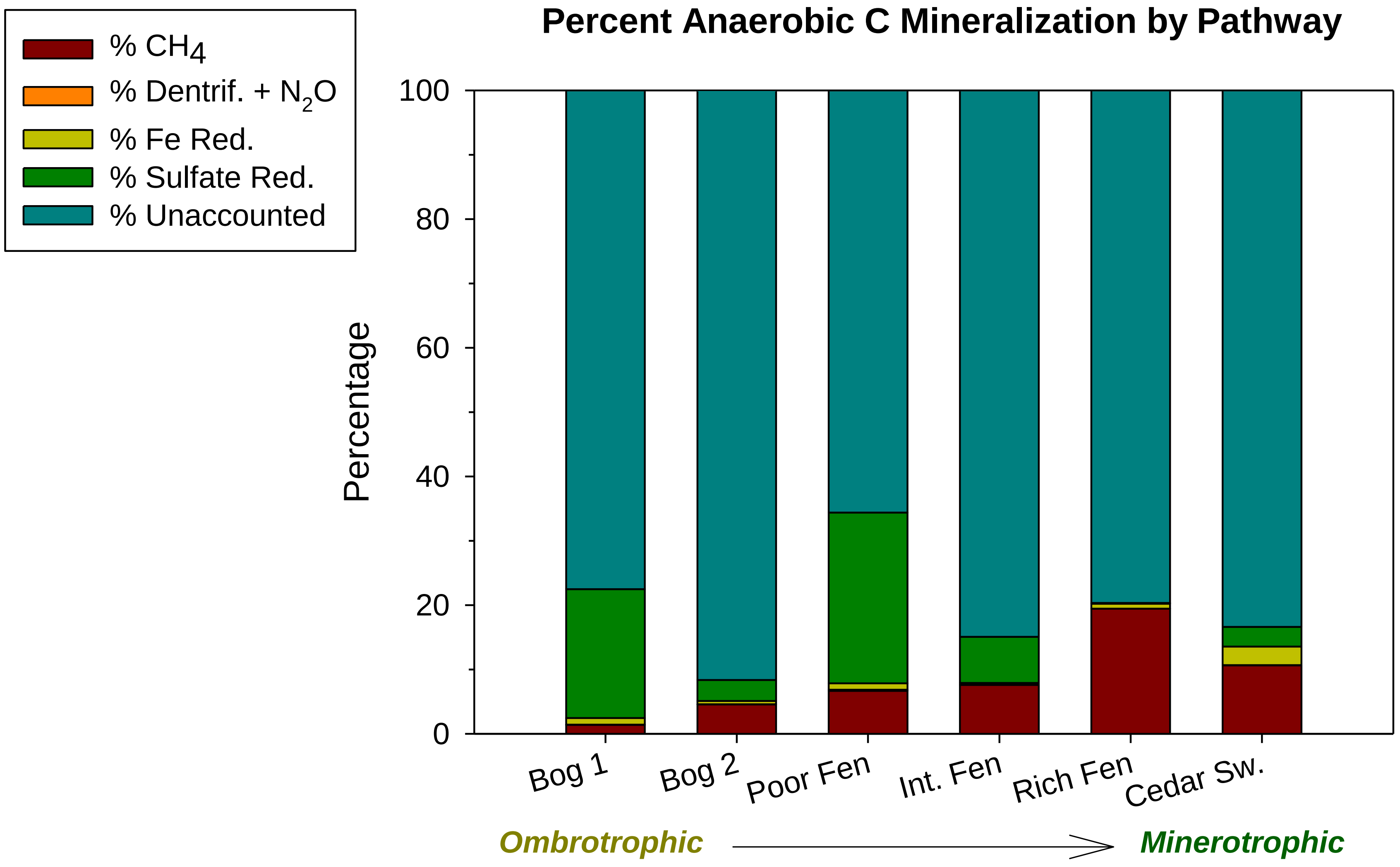

Aerobic
Aerobic Heterotrophs
CO_2
Methanotrophs
CH_4
Anaerobic
Denitrifiers
$NO_3 \rightarrow N_2$
Mn Reducers
Mn(IV) → Mn(II)
Fe Reducers
Fe(III) → Fe(II)
Sulfate Reducers
$SO_4^{2-} \rightarrow H_2S$
Inorganic Alternative Electron Acceptors
Humic Acid Reduction
ORGANIC Alternative Electron Acceptors
Polymers
e.g., polysaccharides, proteins
Monomers
e.g., monosaccharides, amino acids
Fermenters
Organic Acids and Alcohols
Acetate
Homoacetogens
$CO_2 + H_2$
Acetoclastic Methanogens
Hydrogenotrophic Methanogens
CH_4

Northern Michigan Study Sites

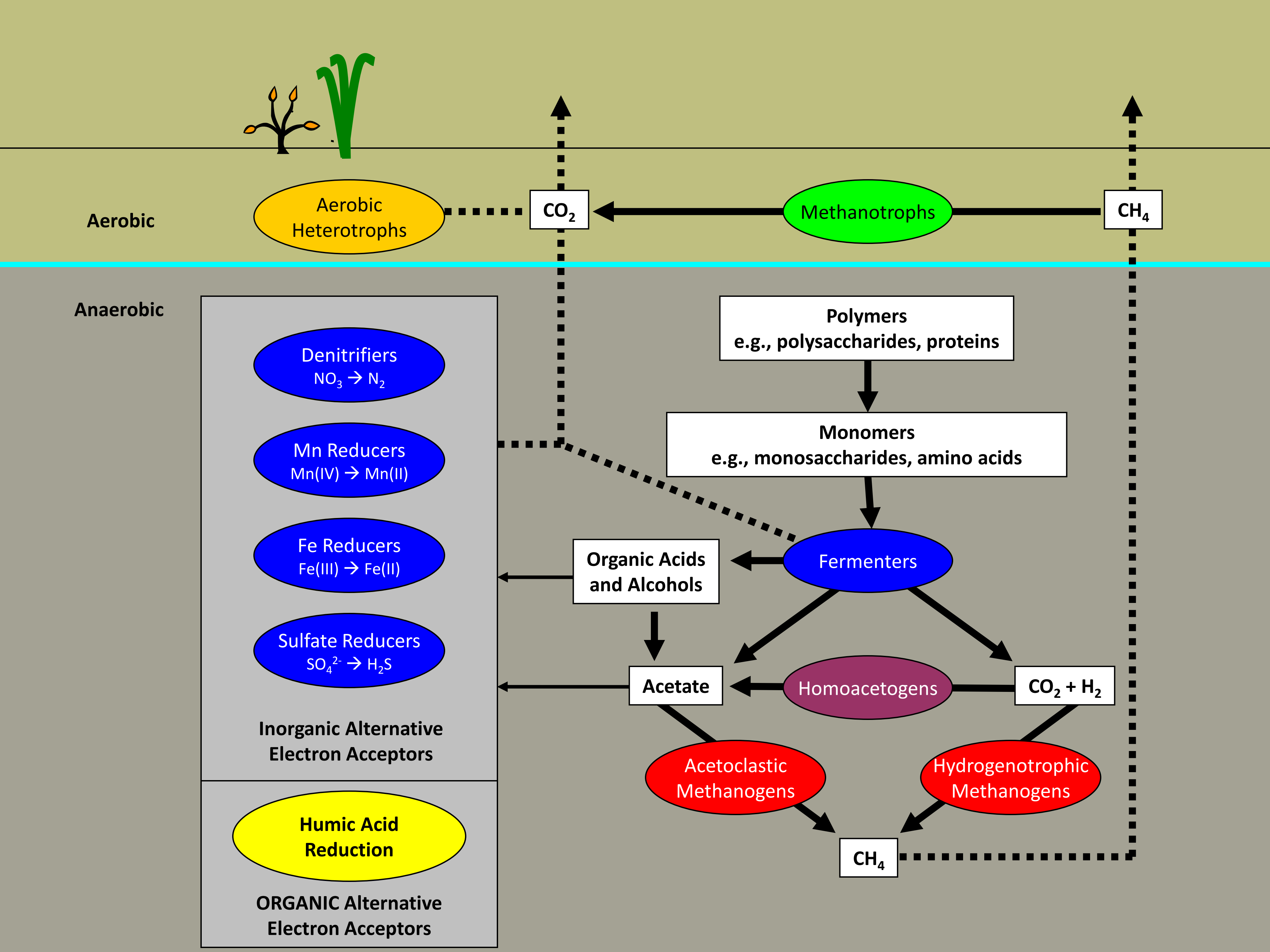
ombrotrophic

- Bog 1 (B1)
- Bog 2 (B2)
- Poor Fen (PF)
- Intermediate Fen (IF)
- Rich Fen (RF)
- Cedar Swamp (CS)

minerotrophic


% CH4
% Dentrif. + N2O
% Fe Red.
% Sulfate Red.
% Unaccounted
Percent Anaerobic C Mineralization by Pathway
Percentage
0
20
40
60
80
100
Bog 1
Bog 2
Poor Fen
Int. Fen
Rich Fen
Cedar Sw.
Ombrotrophic
Minerotrophic

Why are peatlands, and particularly ombrotrophic peatlands, so non-methanogenic?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pH Manipulative Experiment

Questions:

What is the mechanism of pH control over methanogenesis (through substrate availability or directly)?

Are differences in pH sufficient to explain the large differences in CH_4 production efficiency in peatlands along the ombrotrophic – minerotrophic gradient?

Ye et al. *In press*. Soil Biology and Biochemistry.

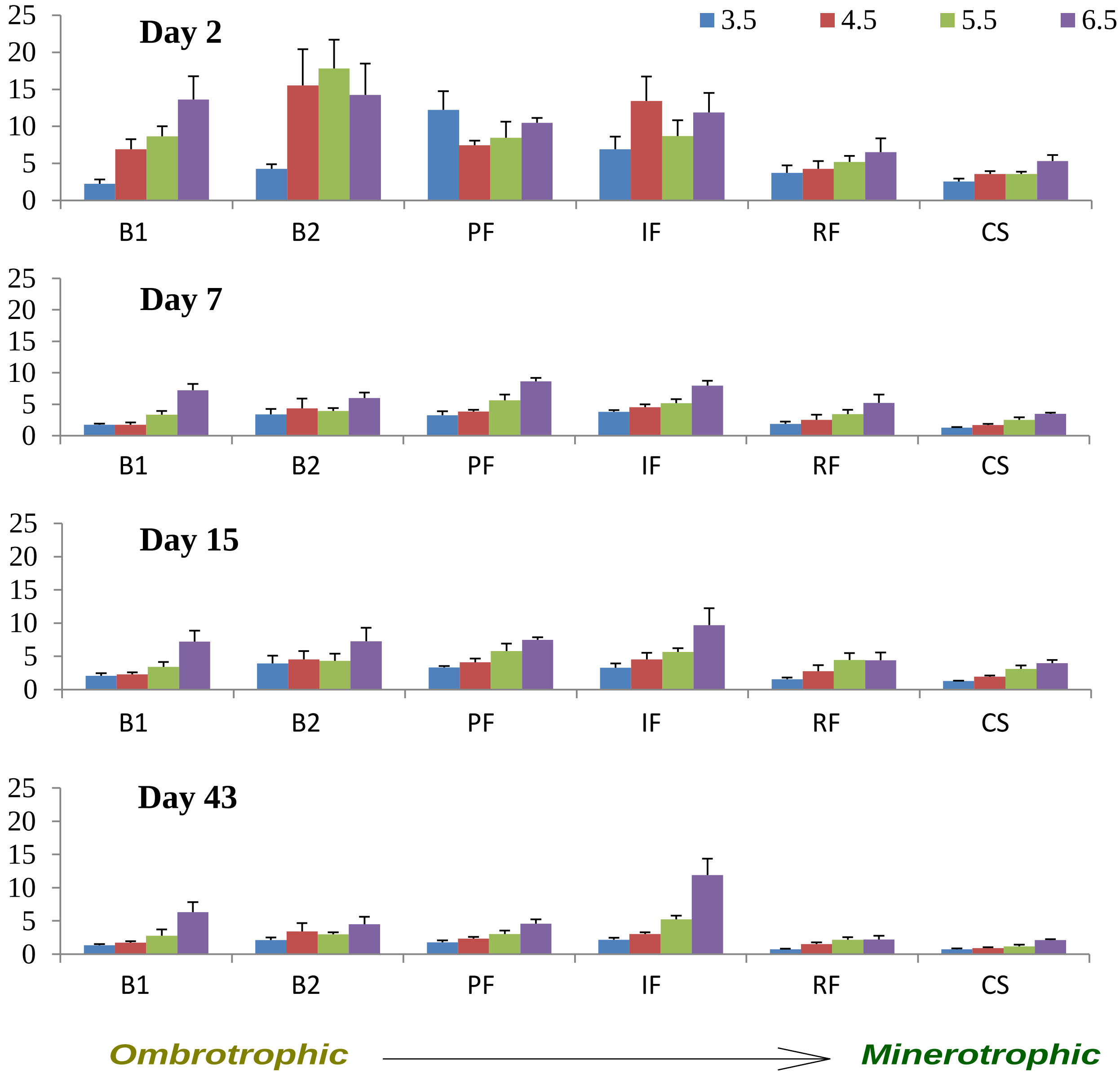
pH Manipulative Experiment

Experimental Protocol:

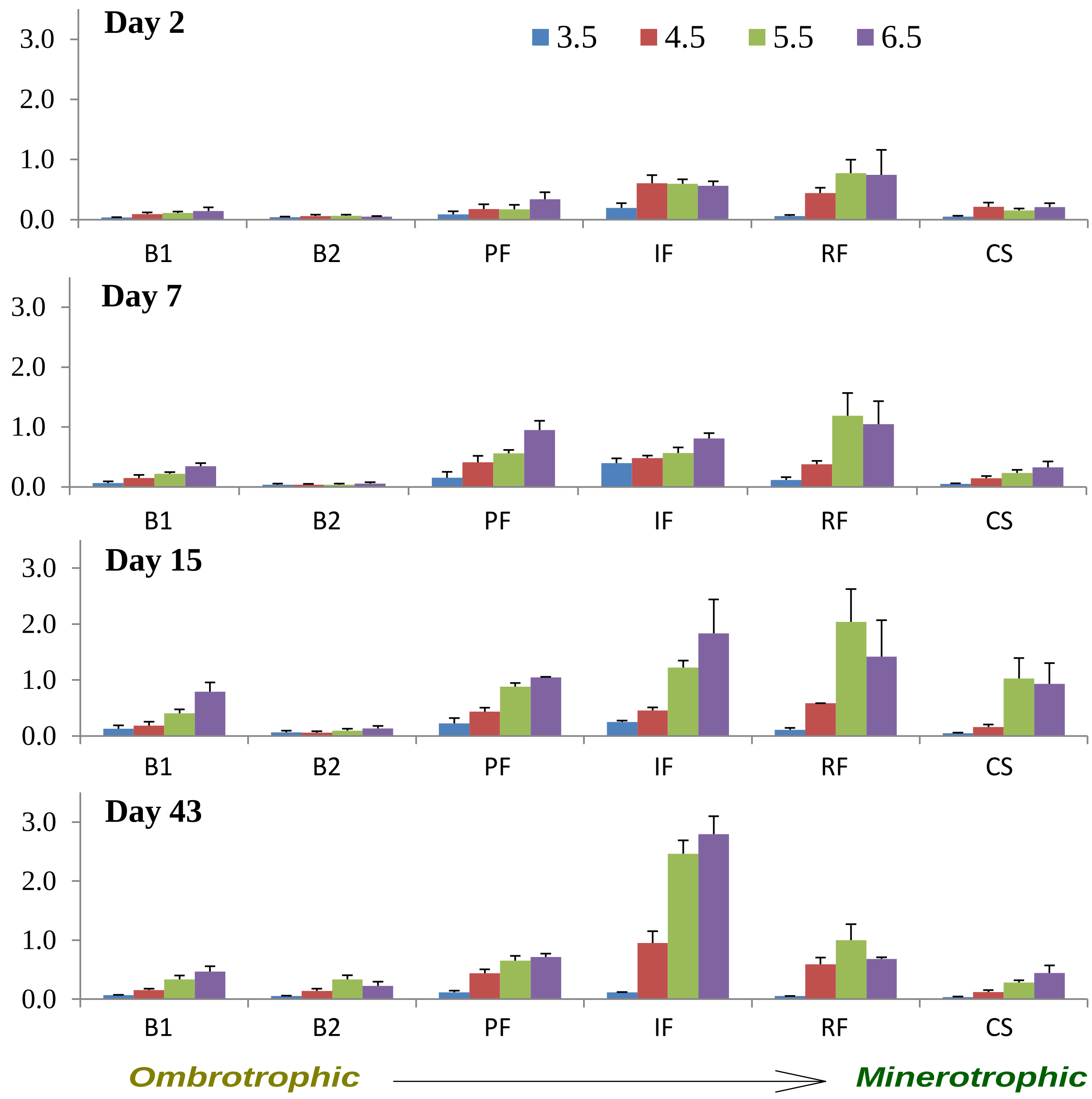
Took peat from all six peatlands along the MI gradient and subjected all peats to pHs of 3.5, 4.5, 5.5, and 6.5 for 43 days under strict anaerobic conditions.

Measured a suite of response variables to understand relative pH effects on various components of anaerobic C cycle.

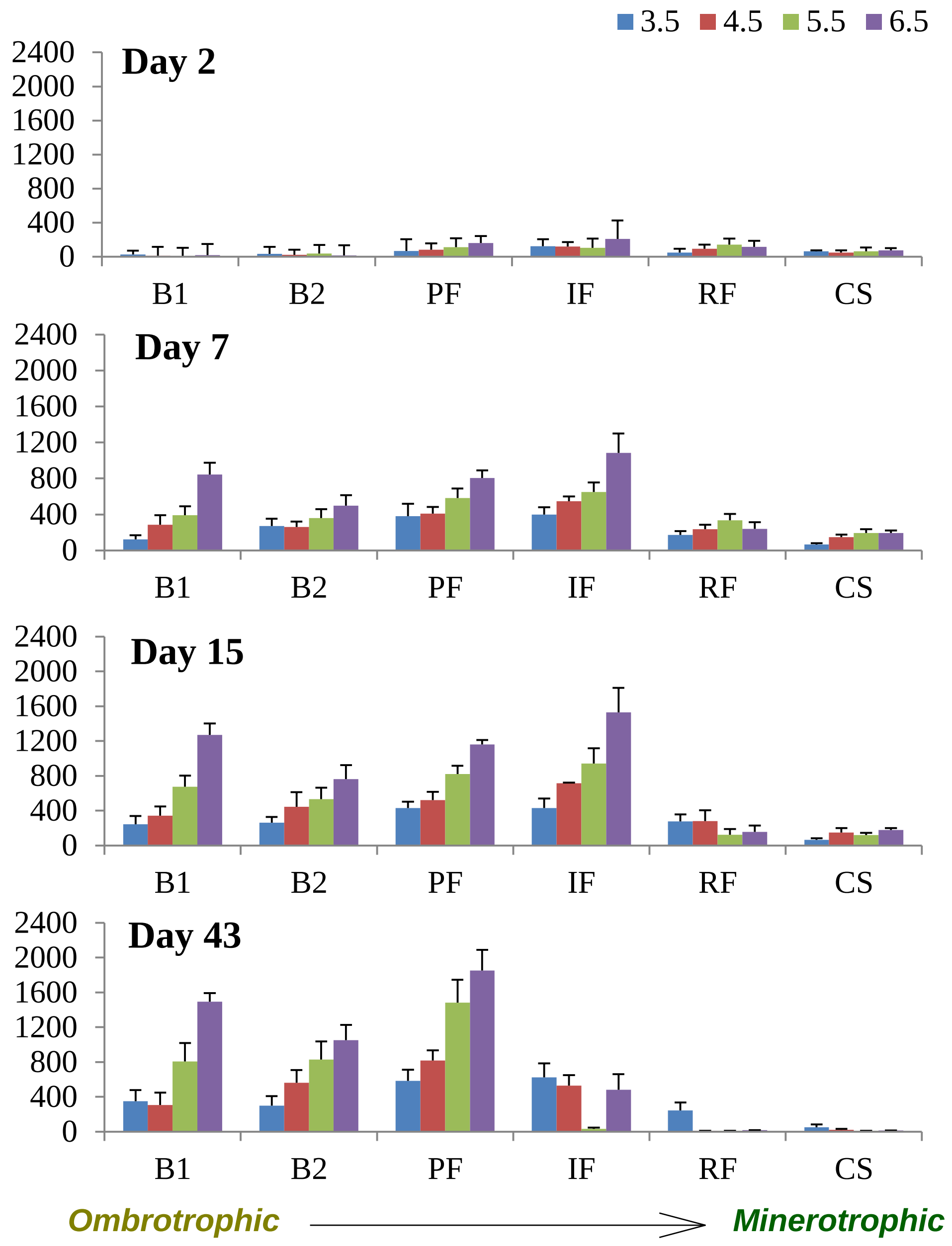
CO_2 Production (µmol C g^{-1} d^{-1})



Methane Production (μmol C g^{-1} d^{-1})



Acetate Concentrations (μM)



So what is causing the very low CH_4 production efficiency in ombrotrophic peatlands?

- Jason Keller did an experiment that showed that trace metals do not constrain CH_4 production in these peatlands.

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- The previous research of ourselves and others strongly suggest that nutrient availability cannot explain this.

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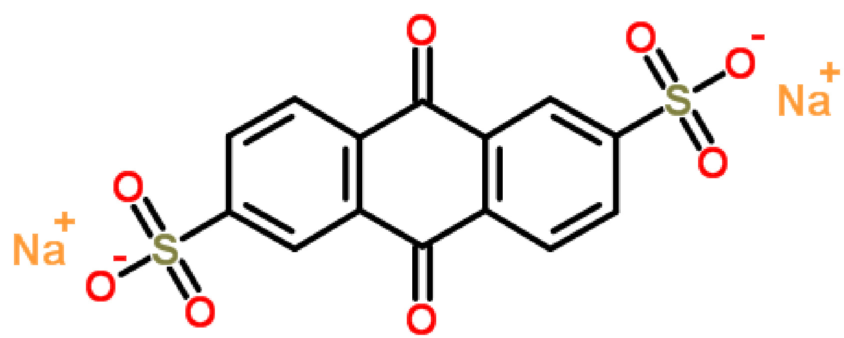
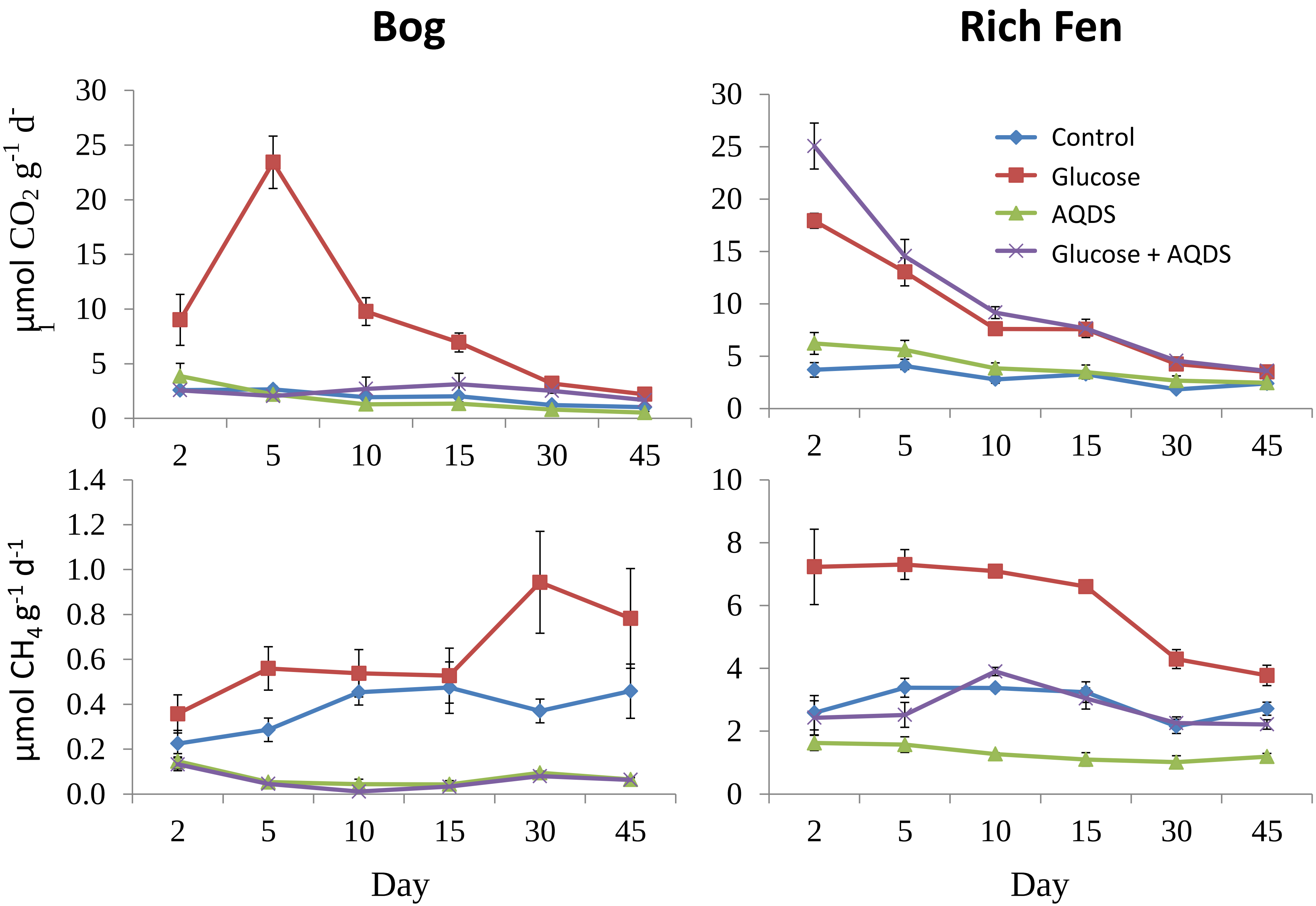
- Jason Keller did an experiment that showed that heavy metals do not constrain CH_4 production in these peatlands.
- The previous research of ourselves and others strongly suggest that nutrient availability cannot explain this.
- We hypothesize that humic substances or other phenolic-containing compounds in bogs are highly inhibitory to methanogenesis beyond their potential effects as electron acceptors.

To attempt to address this hypothesis, we added a humic substance analog, with and without glucose, to peat from a bog and a rich fen.



anthraquinone-2,6-disulfonate (AQDS)



Bog
Rich Fen
μmol CO2 g-1 d-1
μmol CH4 g-1 d-1
Control
Glucose
AQDS
Glucose + AQDS
Day
Day

Why are there such large differences in CH_4 along the peatland gradient?

- pH largely appears to explain differences in rates of fermentation.

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- pH largely appears to explain differences in rates of fermentation.
- Differences in pH, substrate quality, etc. are inadequate to explain differences in CH_4 production.
- We suggest that humic substances or other phenolic cmpds. may play an essential role in limiting CH_4 production in ombrotrophic peatlands.

What are these inhibitory compounds?

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What is the implication of this for climate change impacts on peatlands?

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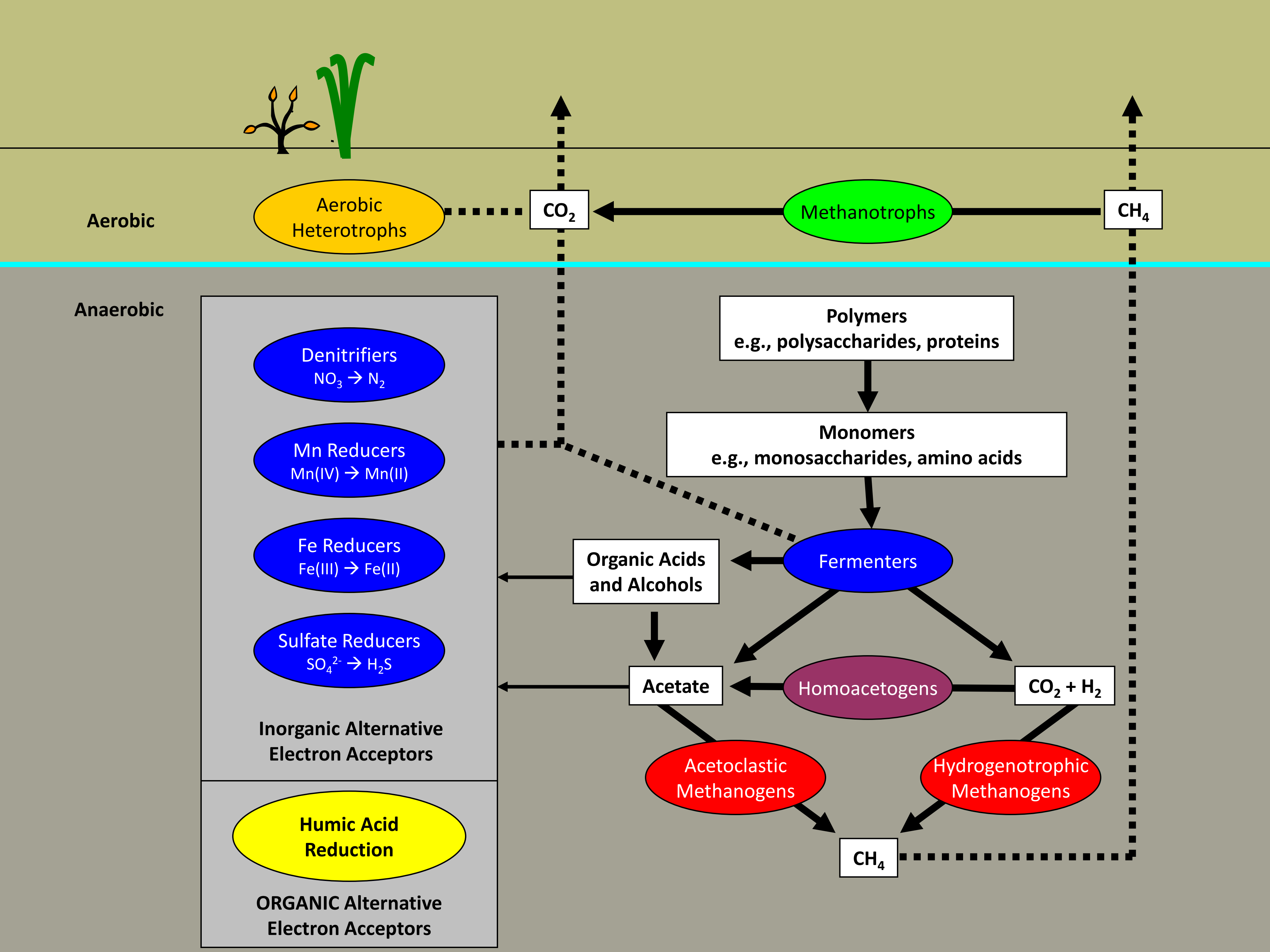
Are bogs incapable of producing large amounts of CH_4, irrespective of warmer temperatures?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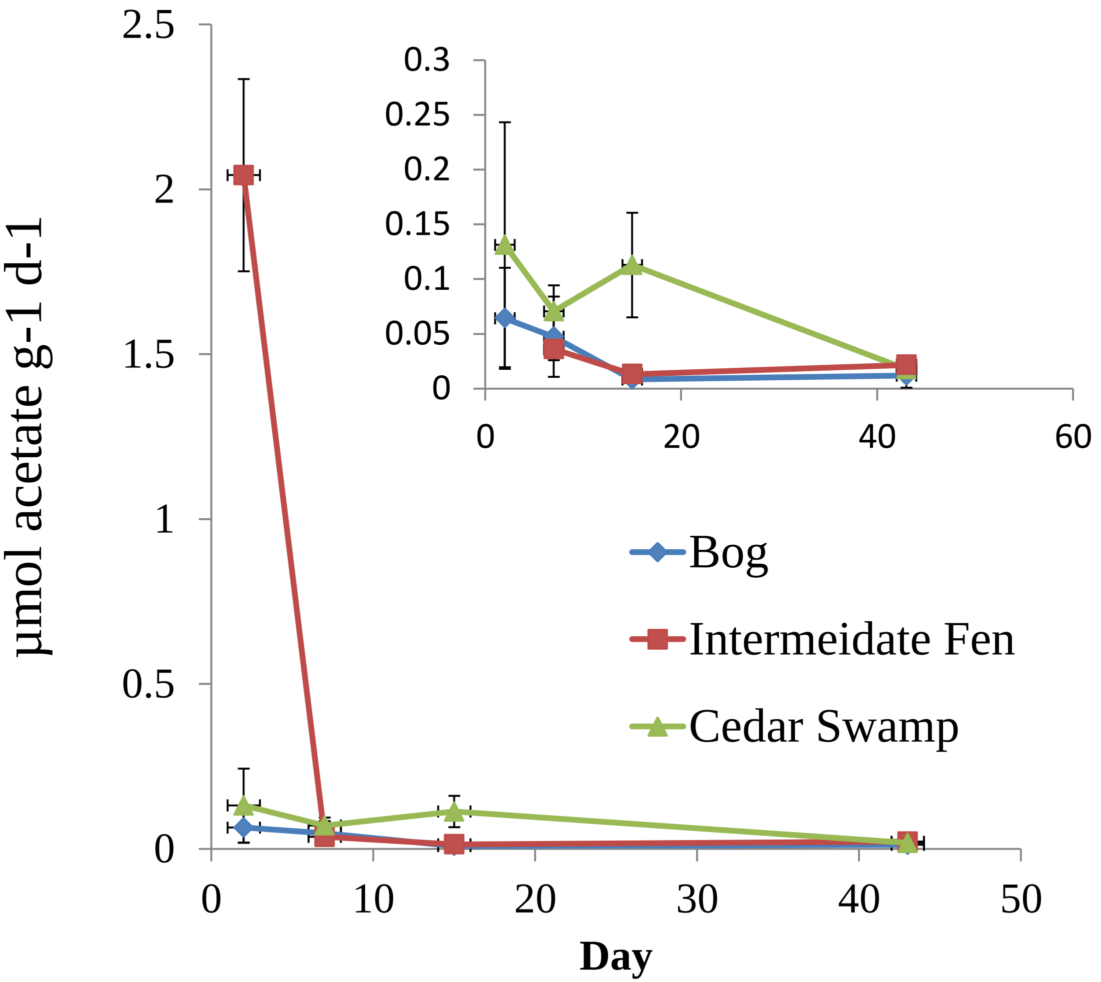
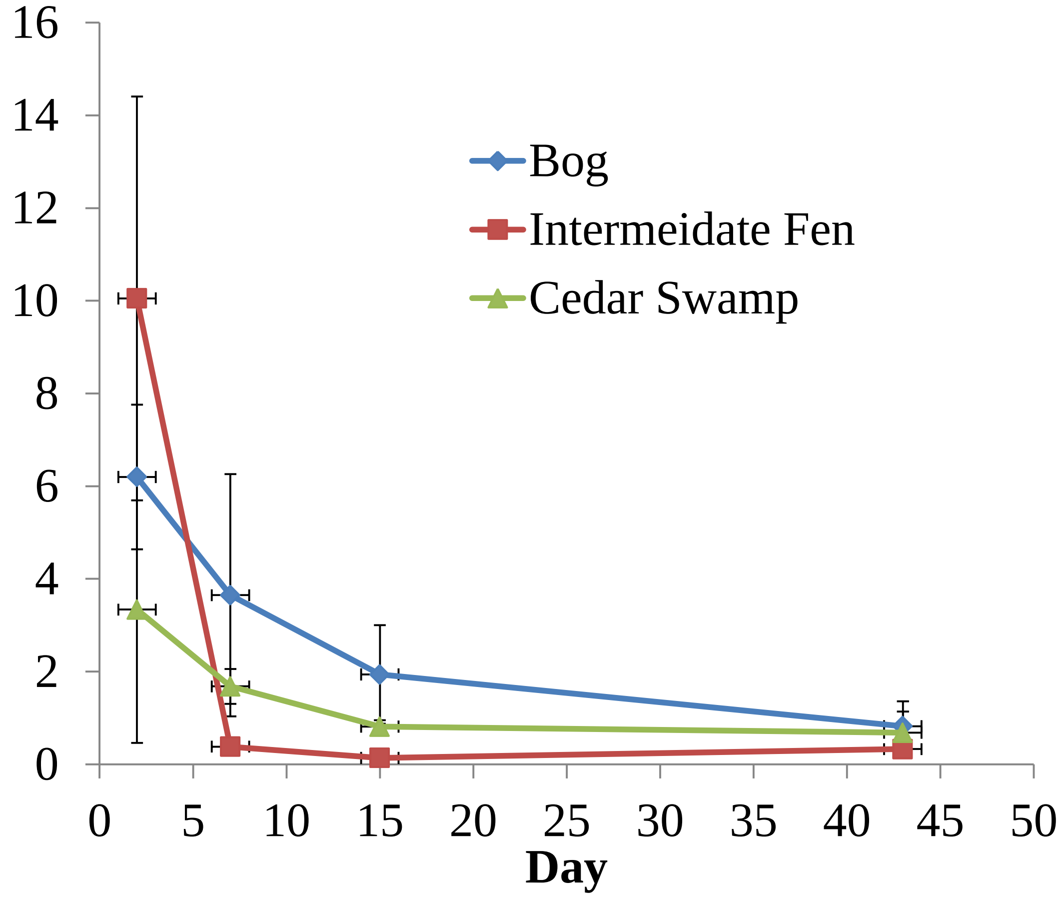
CH_4

Rates of Homoacetogenesis



Ratio of Homoacetogenesis to Hydrogenotrophic Methanogenesis



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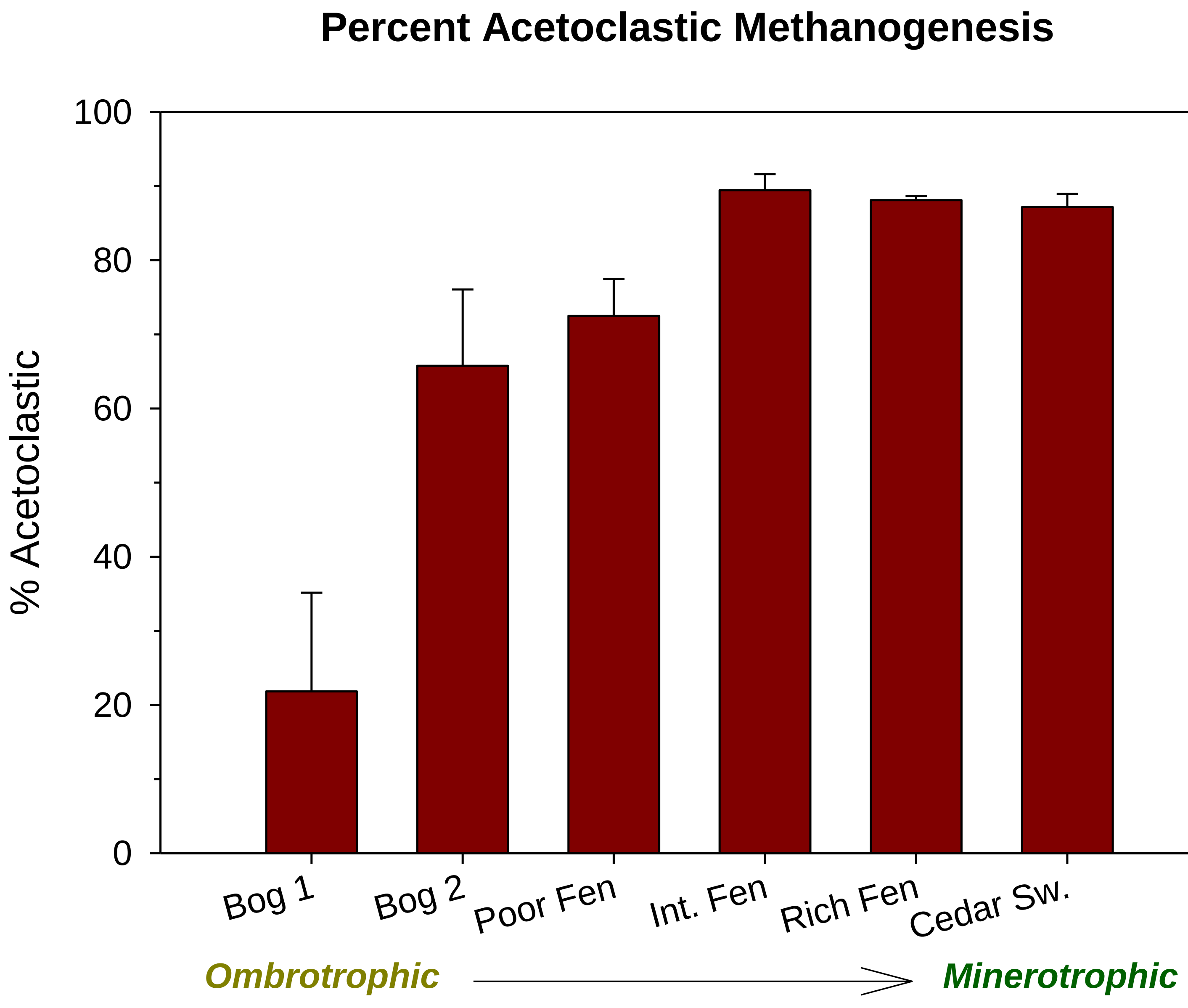
Cameron Stewart
Bharat Narang

University of Notre Dame Environmental Research Center
University of Oregon SPUR Program


Percent Acetoclastic Methanogenesis
% Acetoclastic
100
80
60
40
20
0
Bog 1
Bog 2
Poor Fen
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Cedar Sw.
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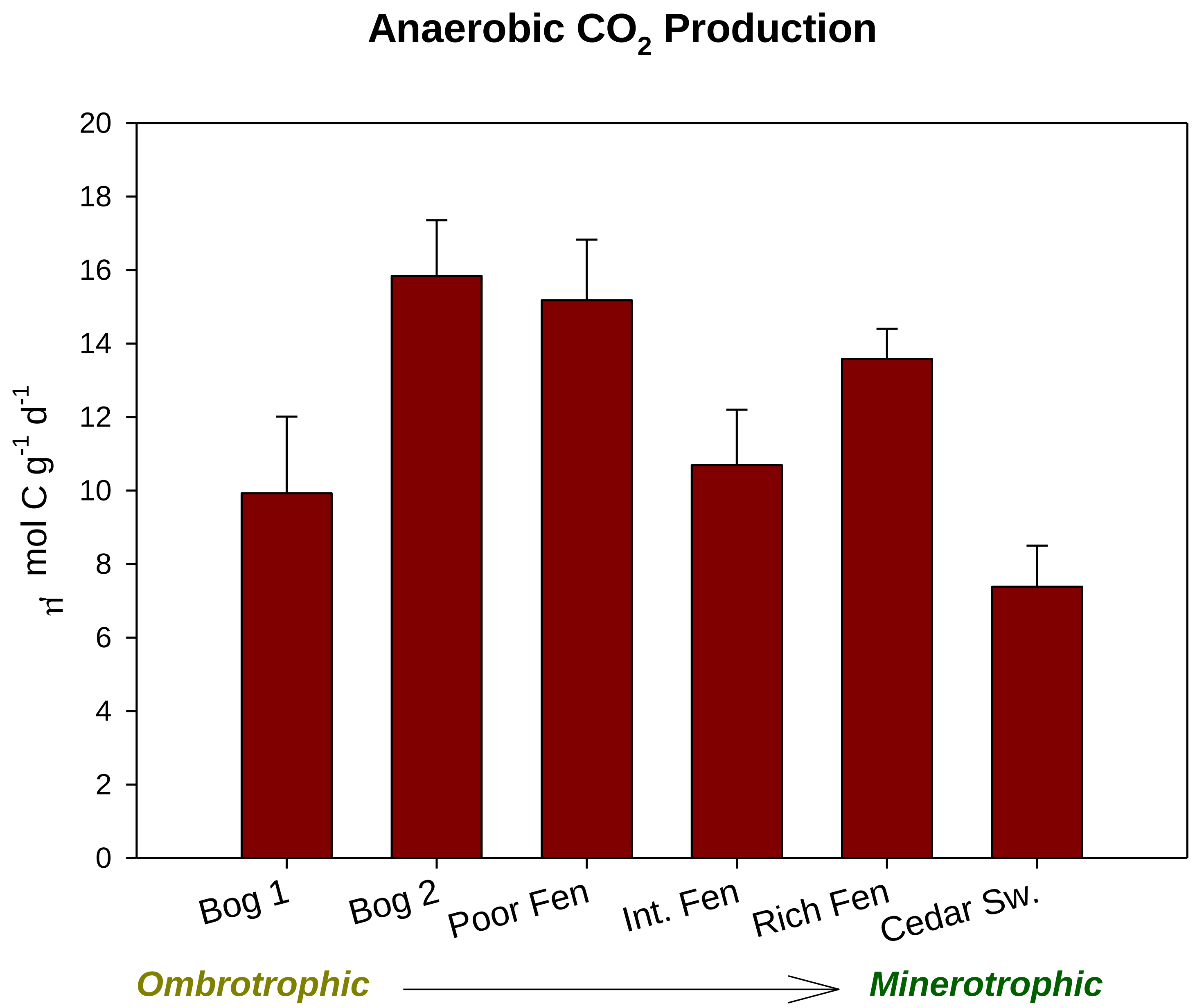
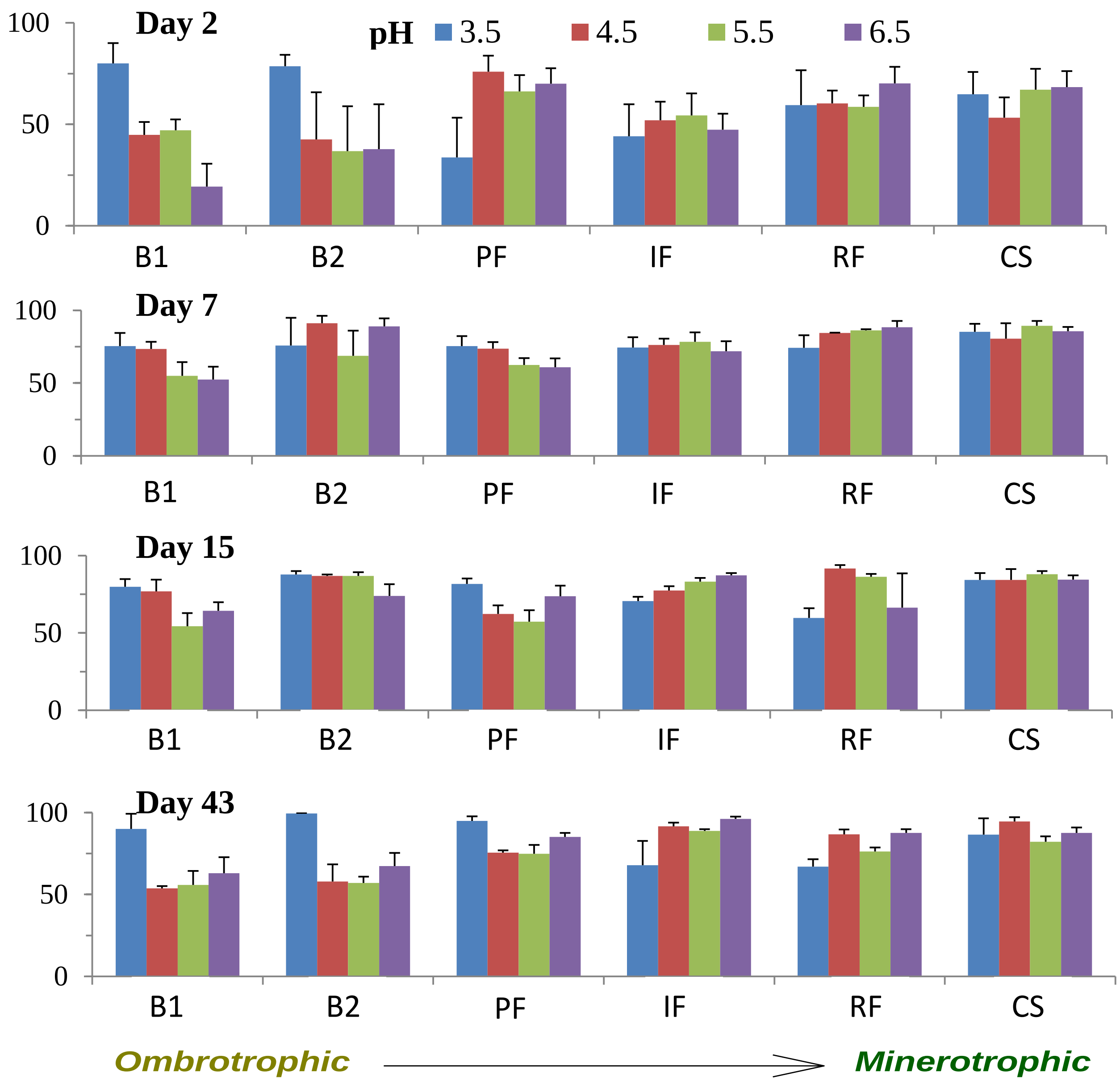
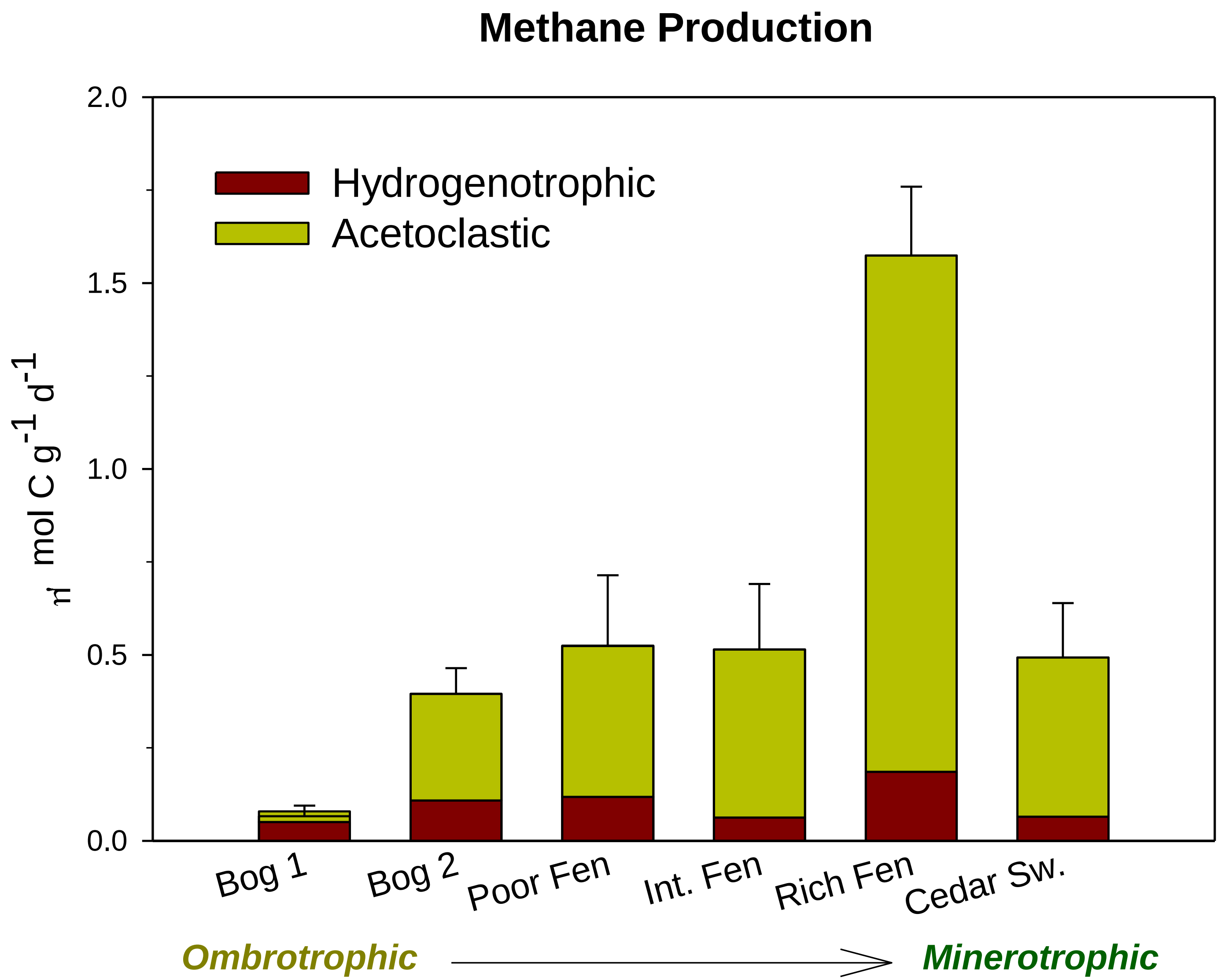

Anaerobic CO_2 Production
µmol C g⁻¹ d⁻¹
0
2
4
6
8
10
12
14
16
18
20
Bog 1
Bog 2
Poor Fen
Int. Fen
Rich Fen
Cedar Sw.
Ombrotrophic
Minerotrophic

Percent Acetoclastic CH_4 of Total CH_4





Methane Production
Hydrogenotrophic
Acetoclastic
µ mol C g-1 d-1
2.0
1.5
1.0
0.5
0.0
Bog 1
Bog 2
Poor Fen
Int. Fen
Rich Fen
Cedar Sw.
Ombrotrophic
Minerotrophic

Experimental Design

- Two Peats: Bog and Rich Fen

— Treatments:

1) Control (C)
2) 3.21 mM anthraquinone-2,6-disulfonate, AQDS (A)
3) 2.7 mg Glucose (G)
4) 2.7 mg Glucose + 3.21 mM AQDS (GA)

* Treatments were imposed after a 15-day pre-incubation at room temperature

— Temperature: 7 °C, 15 °C, 25 °C

Increasing ground-water and/or surface water inputs

→

Increasing pH and basic cation concentrations

Ombrotrophic Bog

All water inputs via precipitation

Minerotrophic Rich Fen

Significant groundwater or surface water inputs