Spatial variability of methane production and methanogen communities within a eutrophic reservoir: evaluating the importance of organic matter source and quantity

Megan E. Berberich[1], Jake J. Beaulieu[2], Trinity L. Hamilton[3], Sarah Waldo[2], Ishi Buffam[1]

[1] University of Cincinnati, Department of Biological Sciences

[2] National Risk Management Research Laboratory, USEPA, Office of Research and Development, Cincinnati, OH

[3] University of Minnesota, College of Biological Sciences

Freshwater CH_4 emissions (Tg C yr^{-1})

Lakes: 53.7

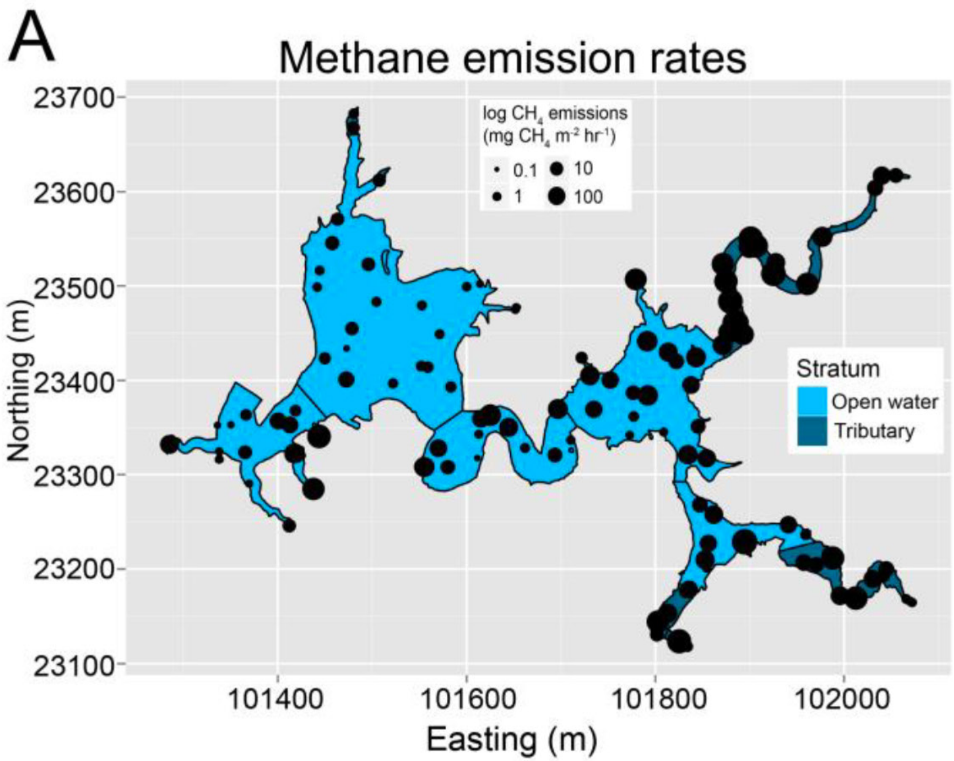
Ponds: 12

Rivers: 1.1 - 20.1

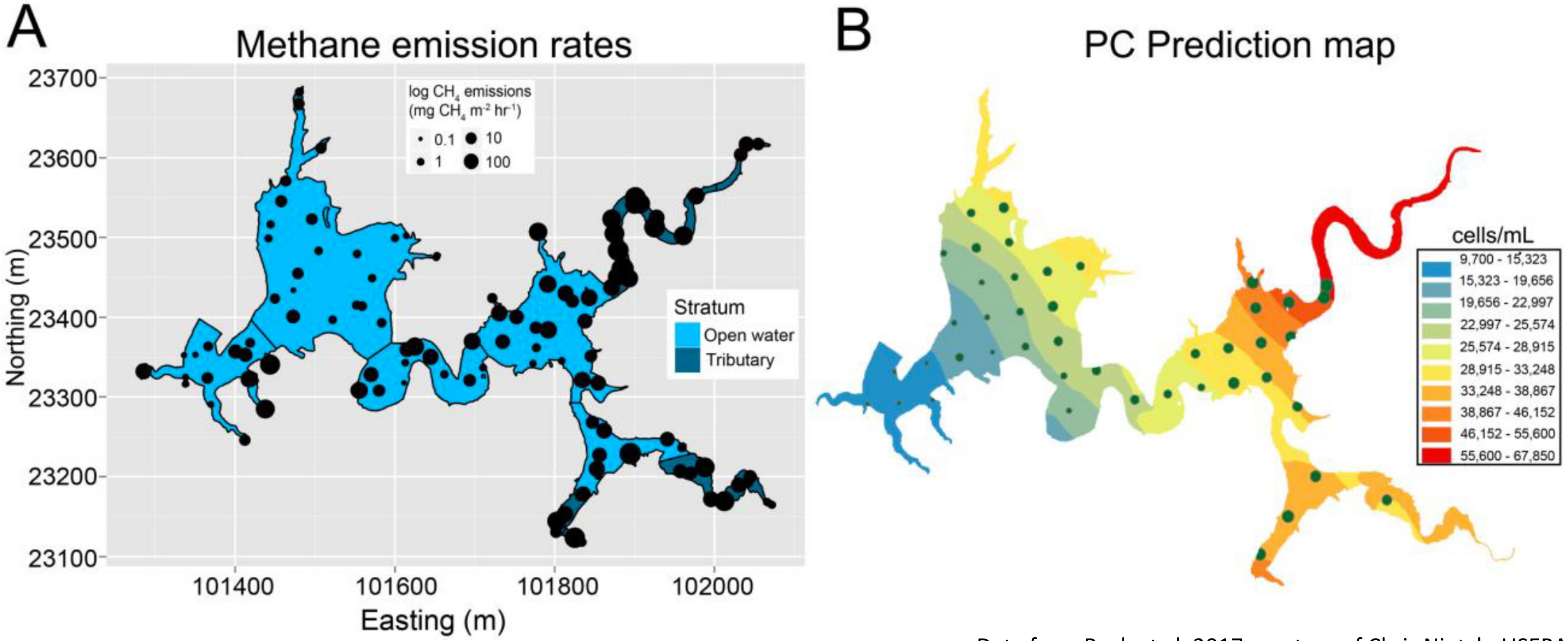
Reservoirs: 13.3 – 52.5

From:
Bastviken et al. (2011), Deemer et al. (2016), Holgerson and Raymond (2016), Stanley et al. (2016)

Surface methane emissions can be higher in tributary zones of reservoirs (Beaulieu et al. 2014).



Methane emissions (Deemer et al. 2016, DelSontro et al. 2018) and sediment methane production (Duc et al. 2010, West et al. 2015) are positively correlated with variables associated with reservoir productivity.



Data from Beck et al. 2017 courtesy of Chris Nietch, USEPA

Algal OM additions to sediment incubations stimulated greater increase in CH_4 production than terrestrial OM additions (West et al. 2012).

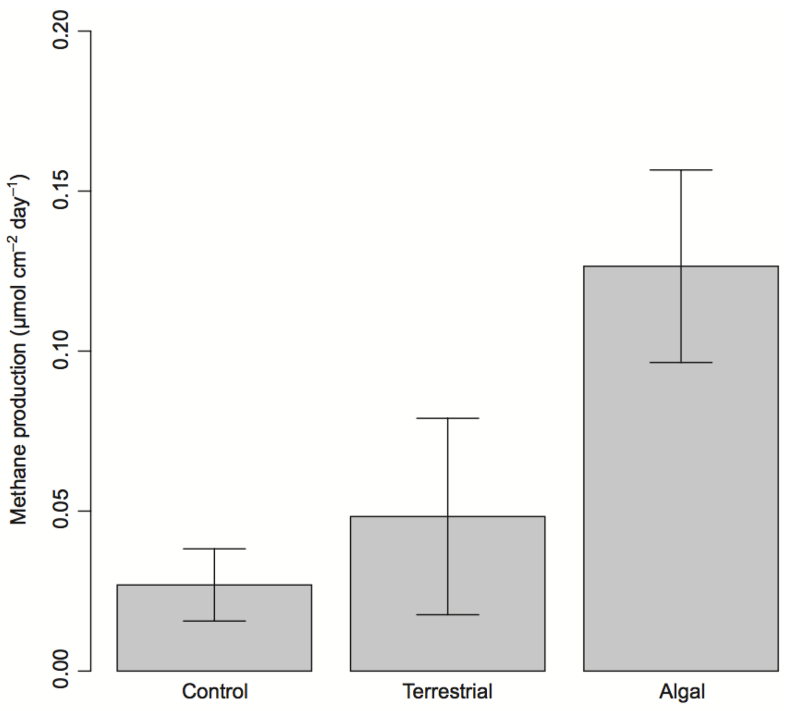
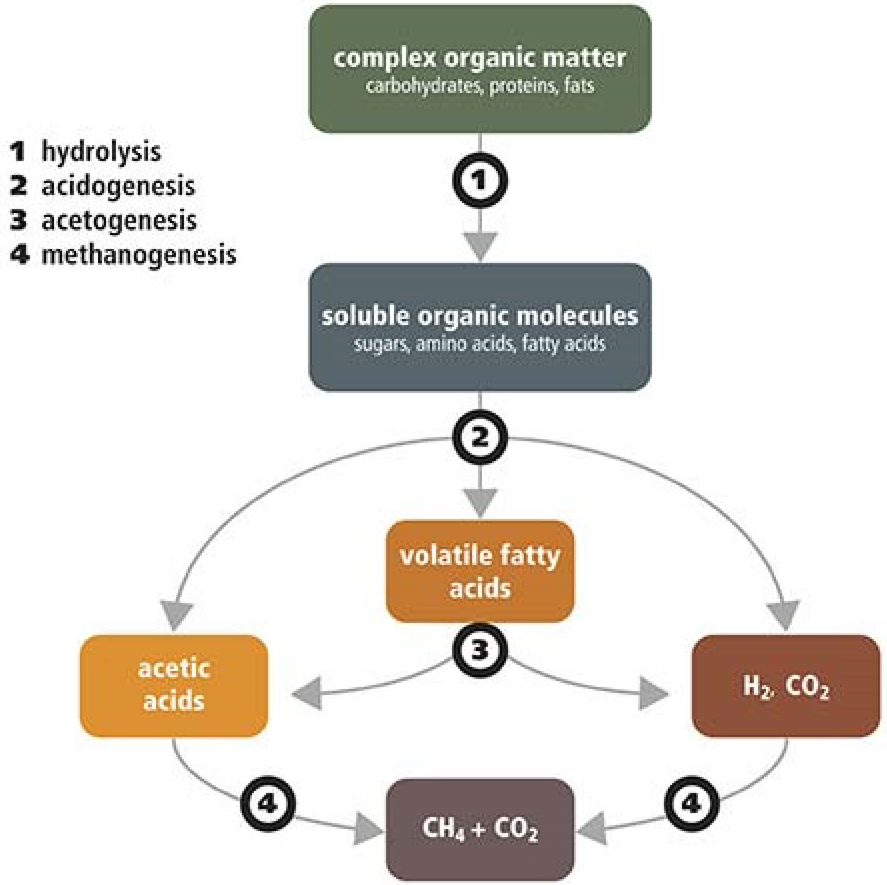


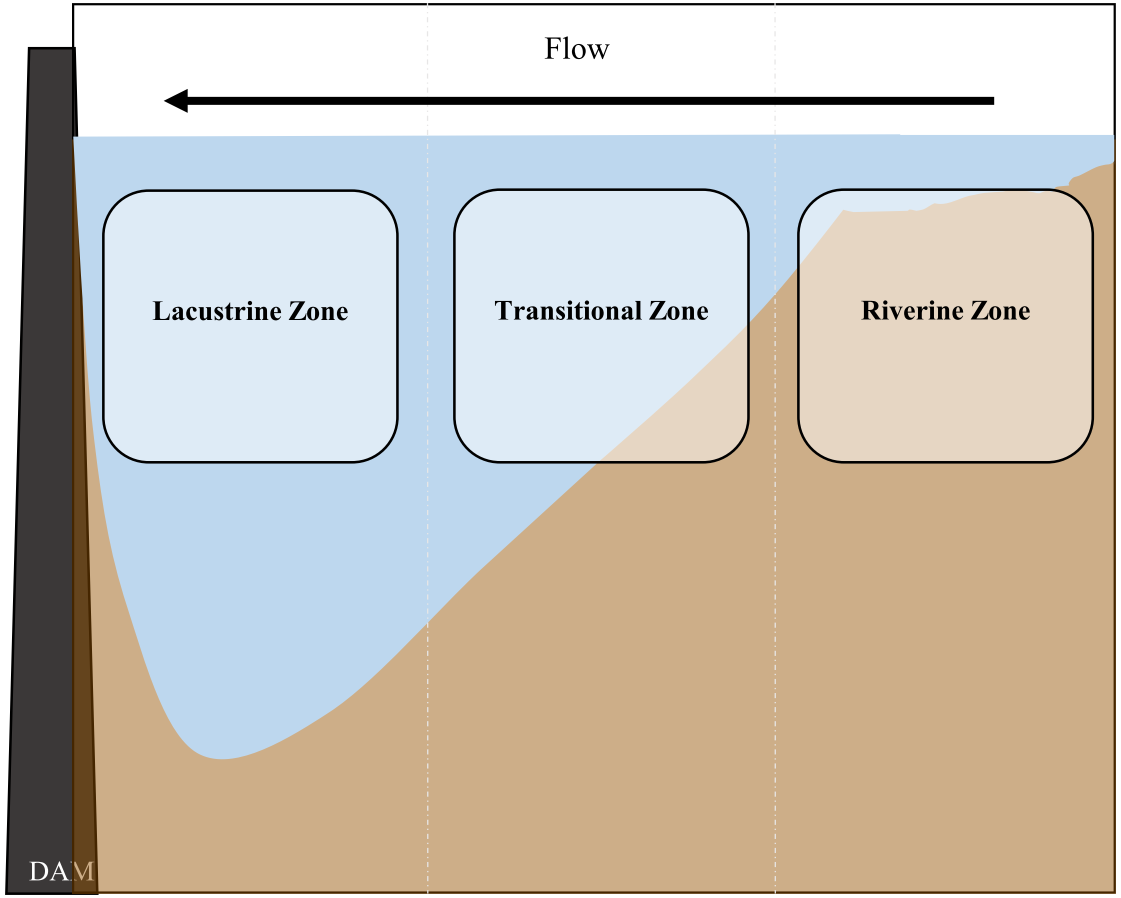
Fig. 2 Mean CH_4 production rates of Diamond Lake sediment cores with added algal biomass, added terrestrial carbon and control (one-way ANOVA, $F = 12.5$, $P = 0.007$, d.f. = 2, 6). Error bars indicate one standard deviation of the mean.

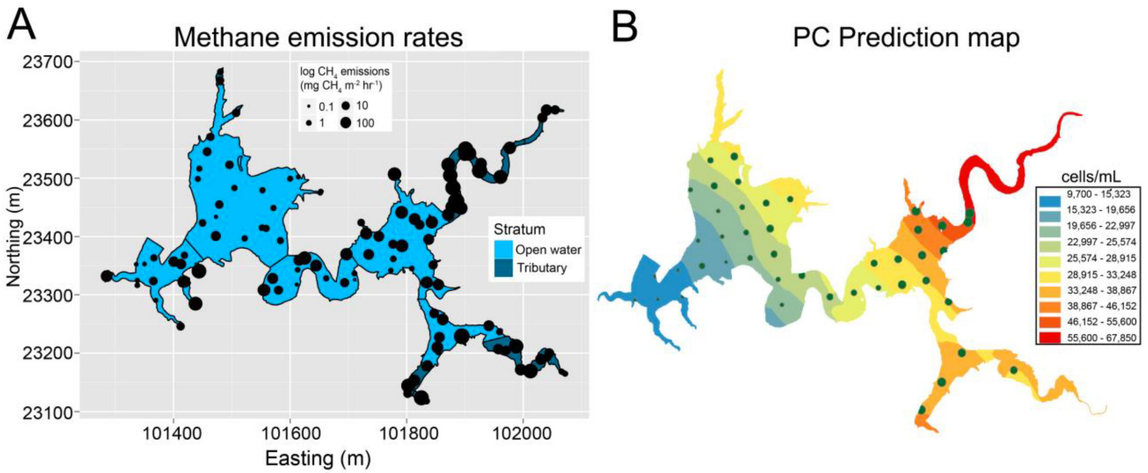
Organic matter (OM) availability is a constraint on sediment methane production.

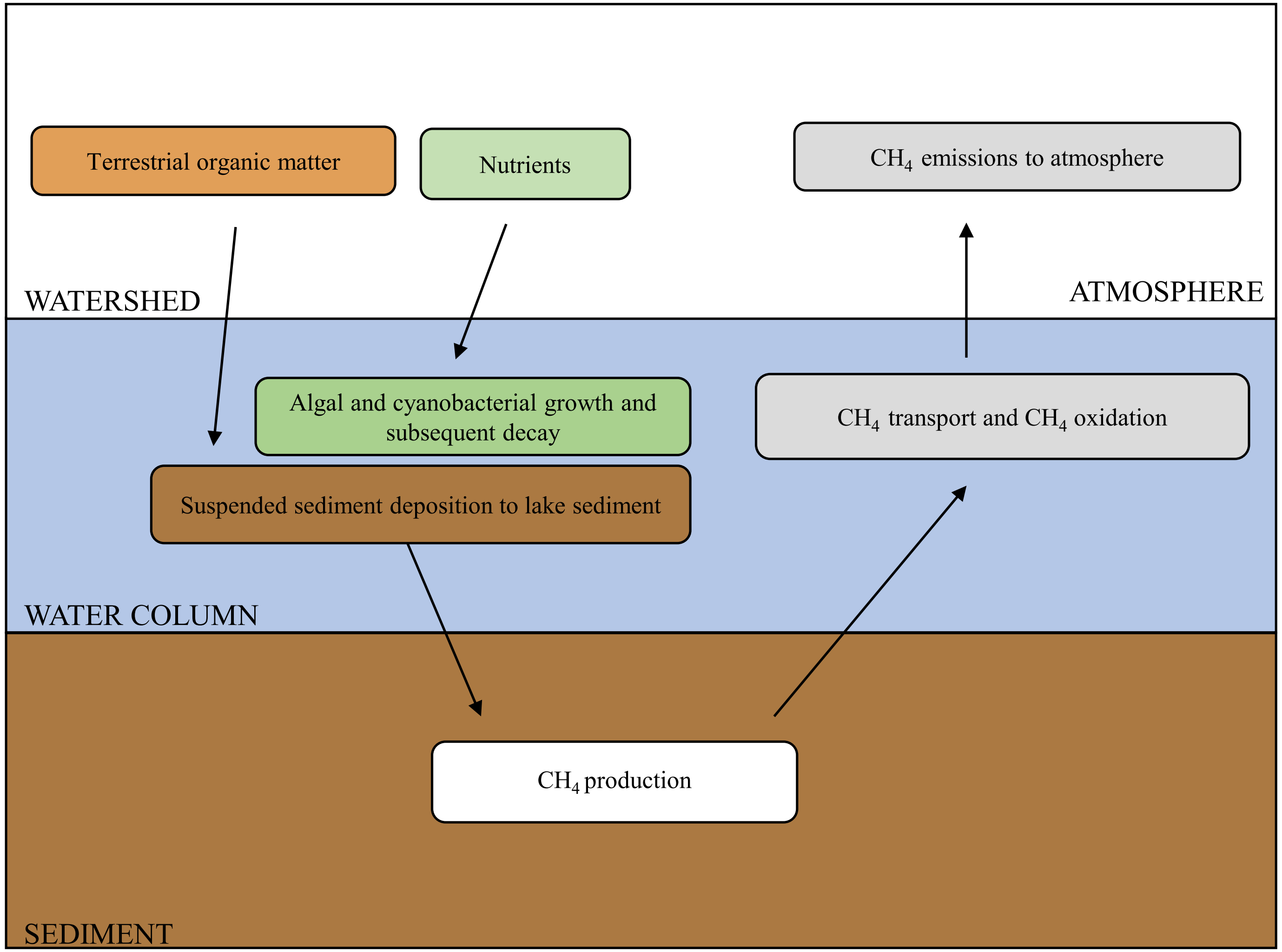


Source: http://www.harvestpower.com/clean-energy/about-anaerobic-digestion/

Reservoirs can be divided into functional zones based on spatial variability (Thornton et al. 1990).







Terrestrial organic matter
Nutrients
CH_4 emissions to atmosphere
WATERSHED
ATMOSPHERE
Algal and cyanobacterial growth and subsequent decay
CH_4 transport and CH_4 oxidation
Suspended sediment deposition to lake sediment
WATER COLUMN
CH_4 production
SEDIMENT

Objectives

1. Establish if **methane production rates** and **OM source and quantity** exhibit distinct variation among reservoir zones.

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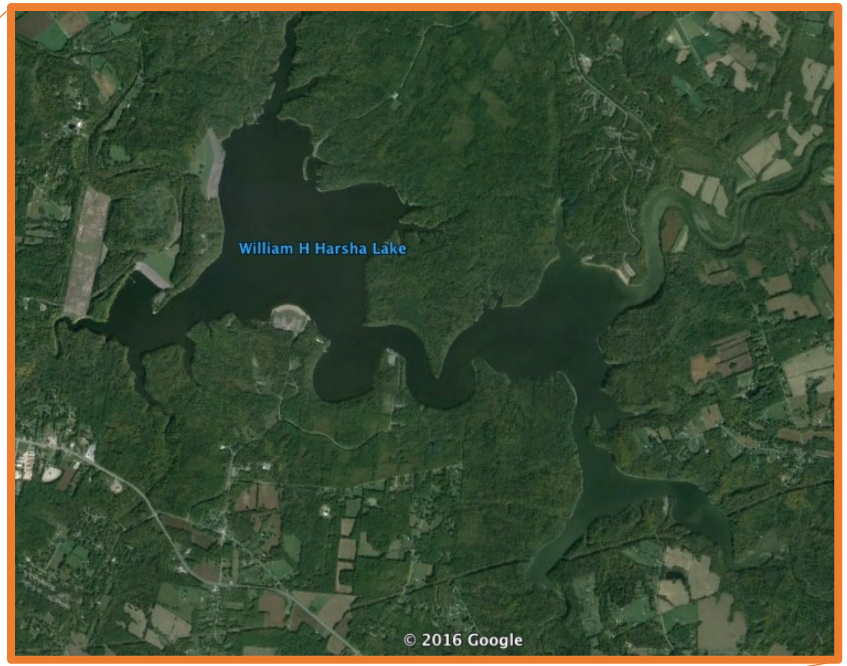
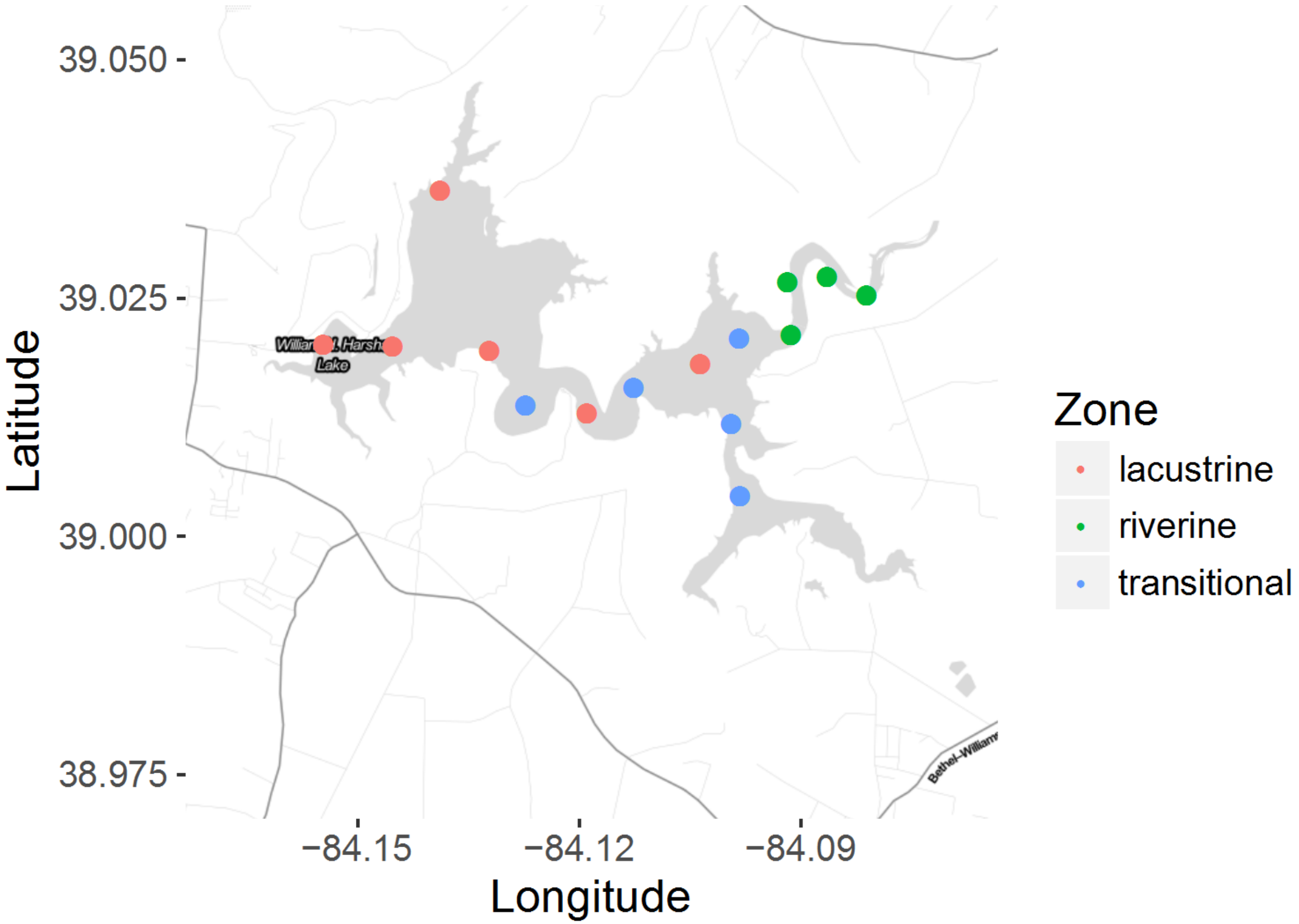
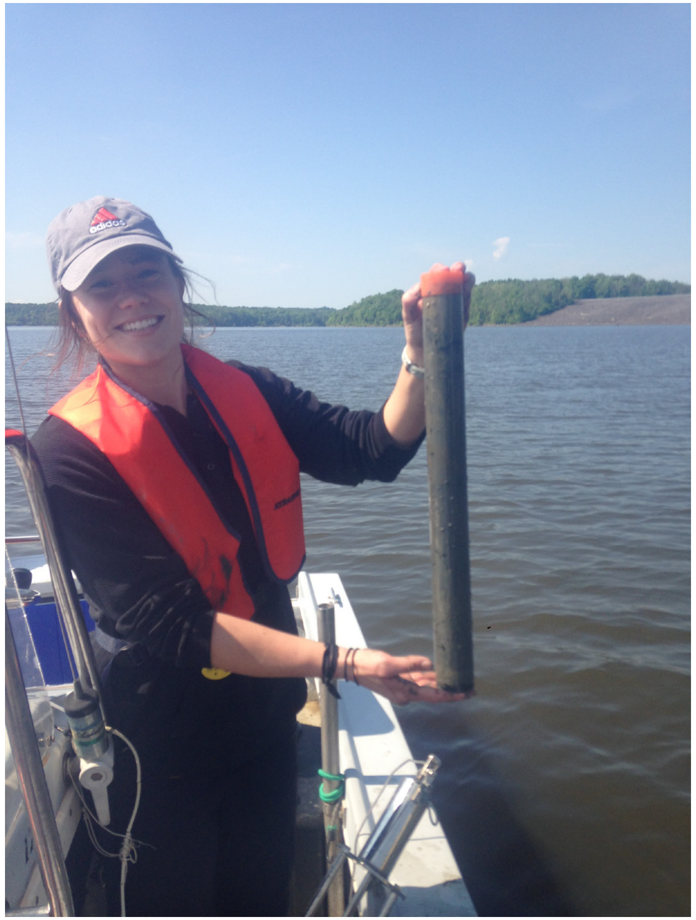
Study Site

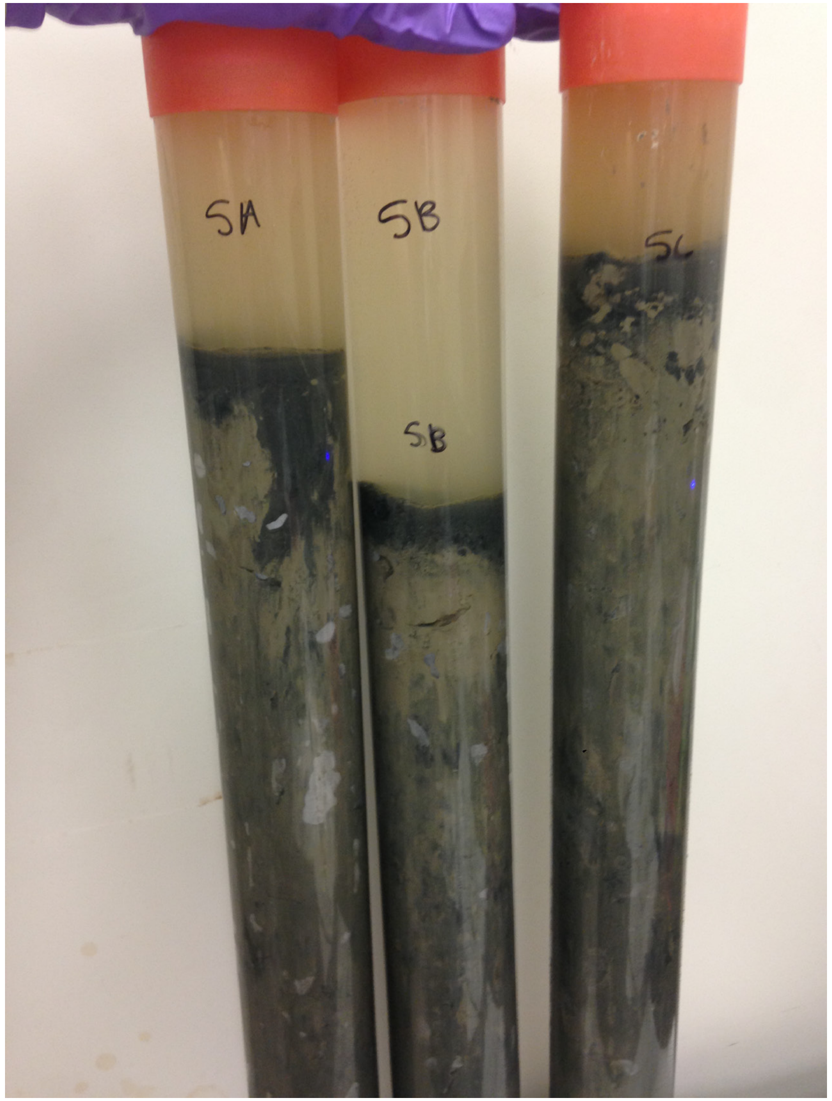
William H. Harsha ("East Fork") Lake

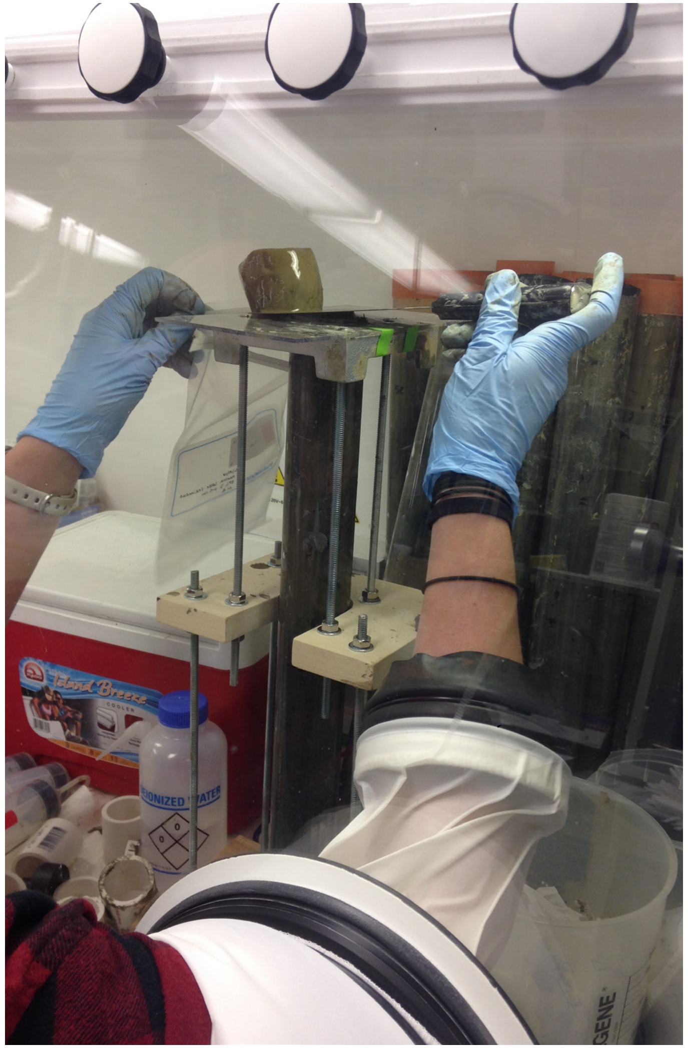


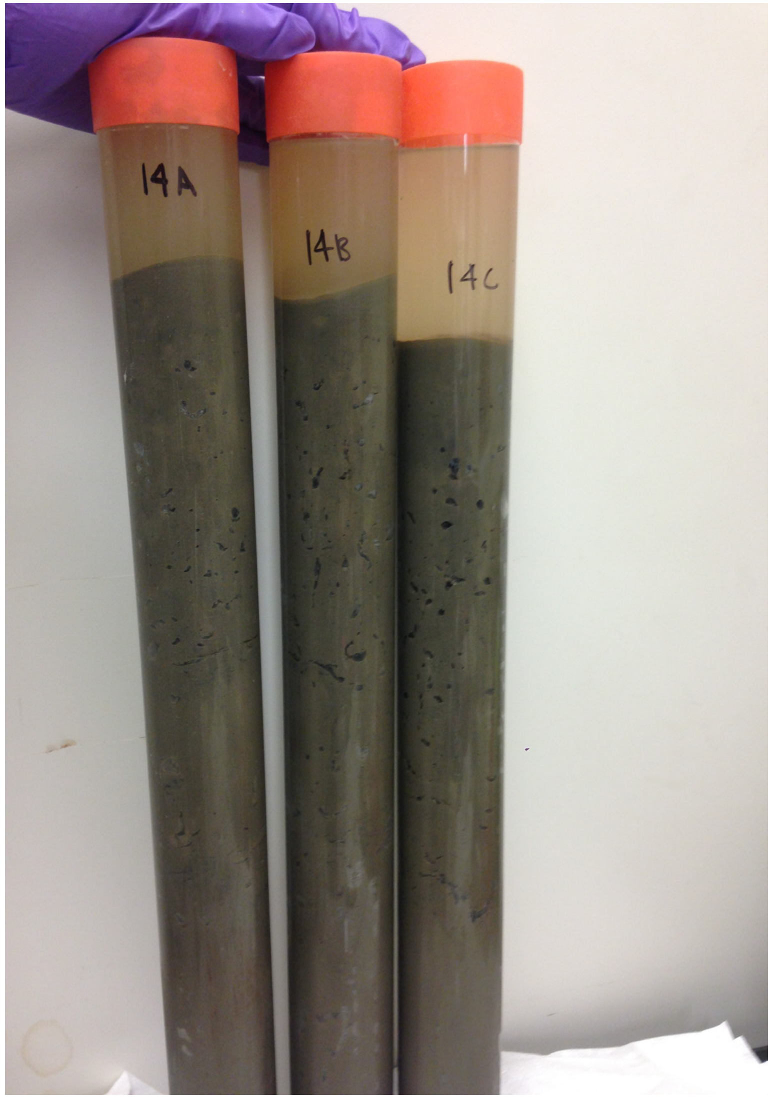


39.050
39.025
39.000
38.975
Latitude
−84.15
−84.12
−84.09
Longitude
Zone
lacustrine
riverine
transitional
Lake




5A
5B
5C
5B


Island Breeze


14A
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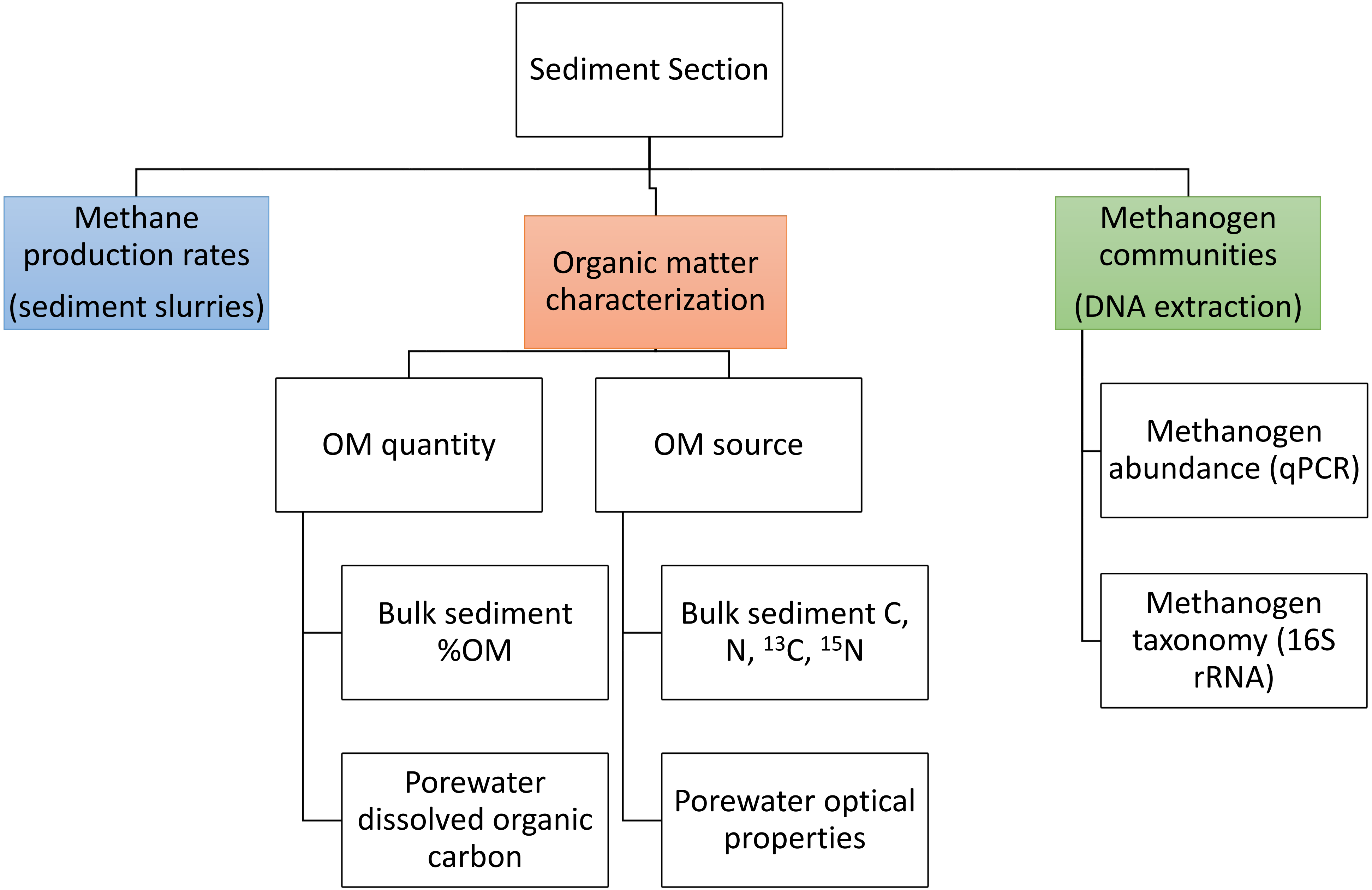
Sediment Section
Methane production rates
(sediment slurries)
Organic matter characterization
Methanogen communities
(DNA extraction)
OM quantity
OM source
Methanogen abundance (qPCR)
Methanogen taxonomy (16S rRNA)
Bulk sediment %OM
Porewater dissolved organic carbon
Bulk sediment C, N, 13C, 15N
Porewater optical properties

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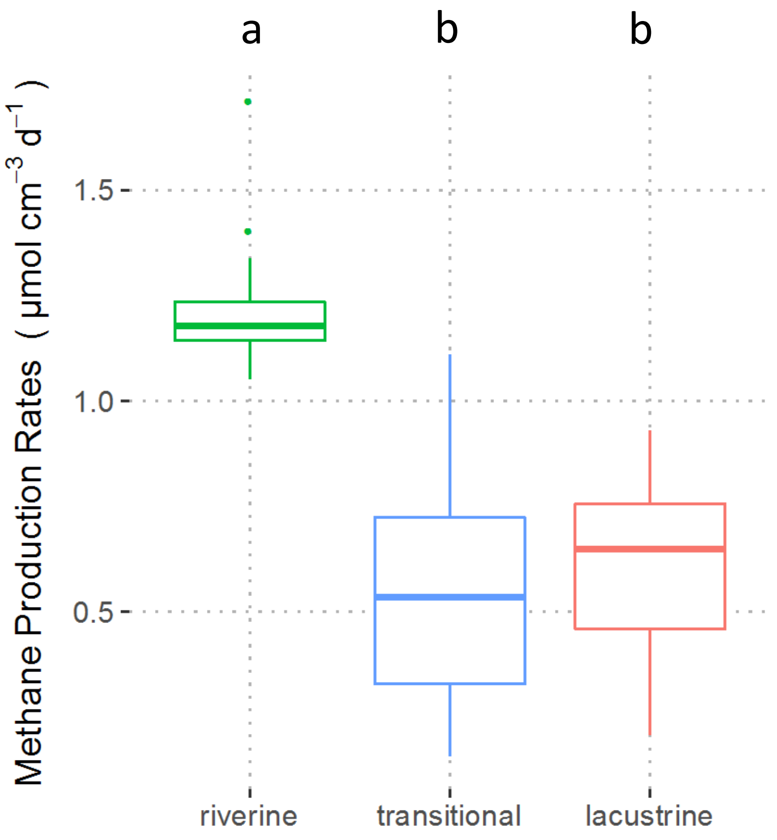
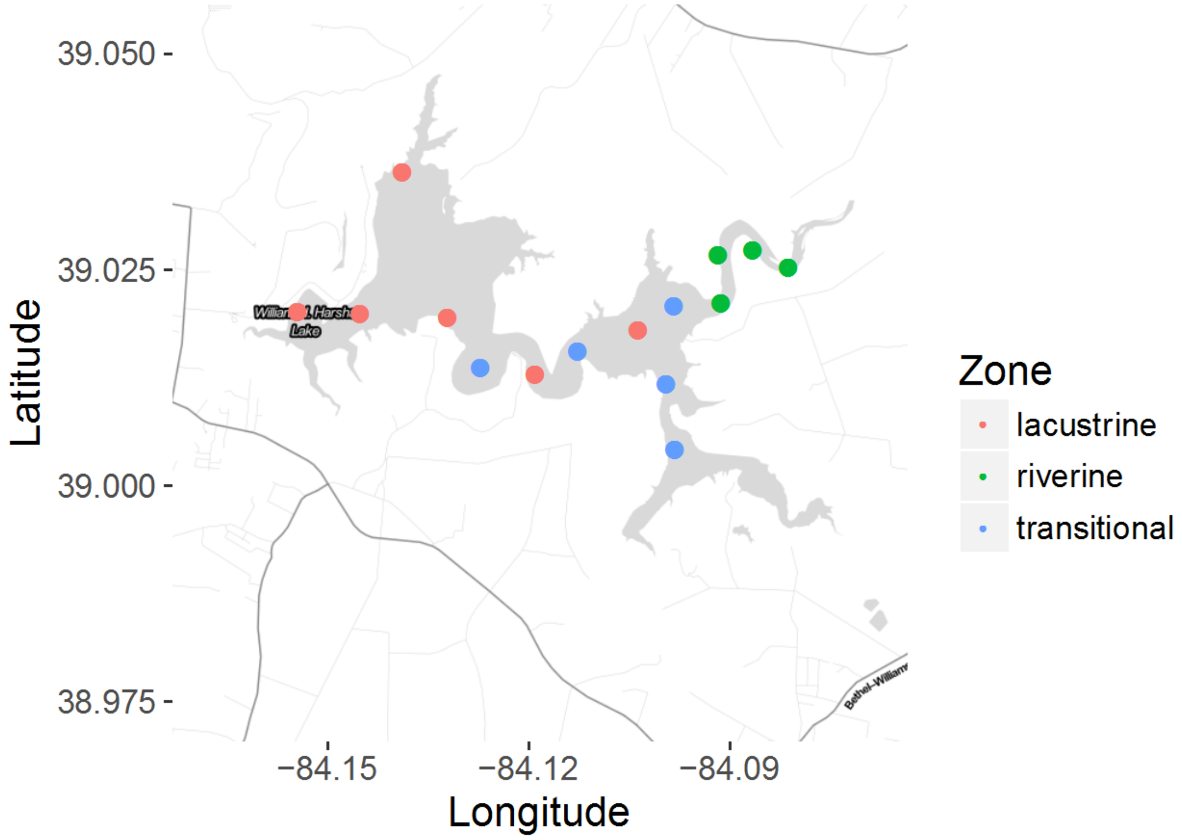
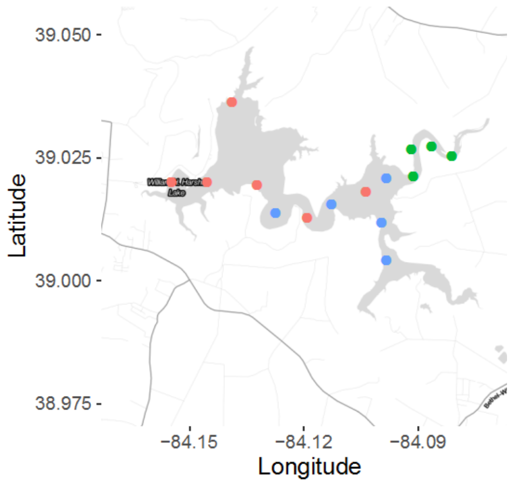
Spatial variation: Methane production rates





Spatial variation: Organic matter **quantity**



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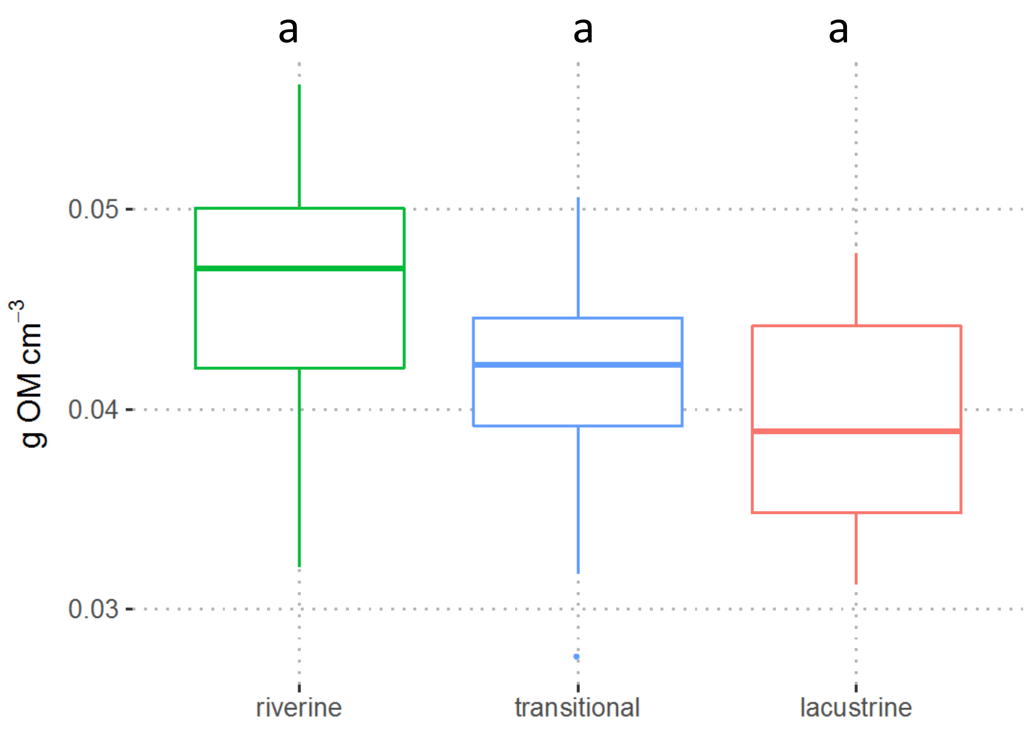
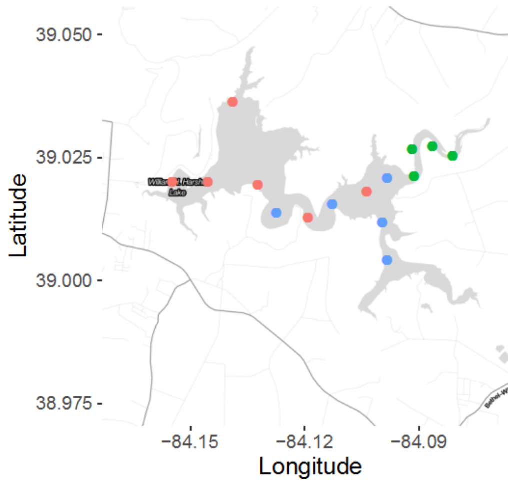
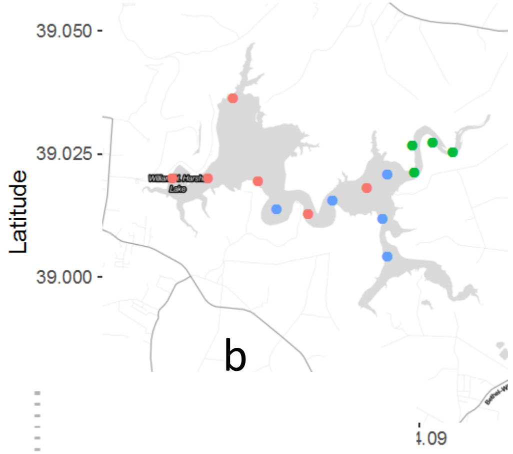




BULK SEDIMENT fraction of OM

Spatial variation: Organic matter **quantity**



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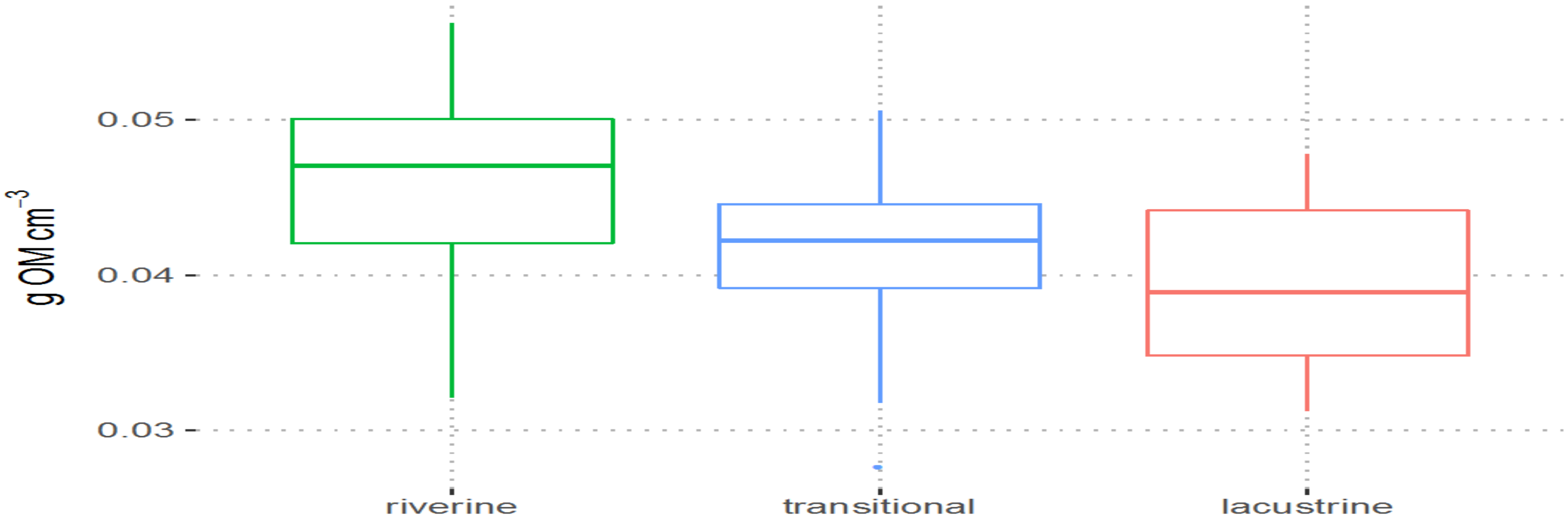
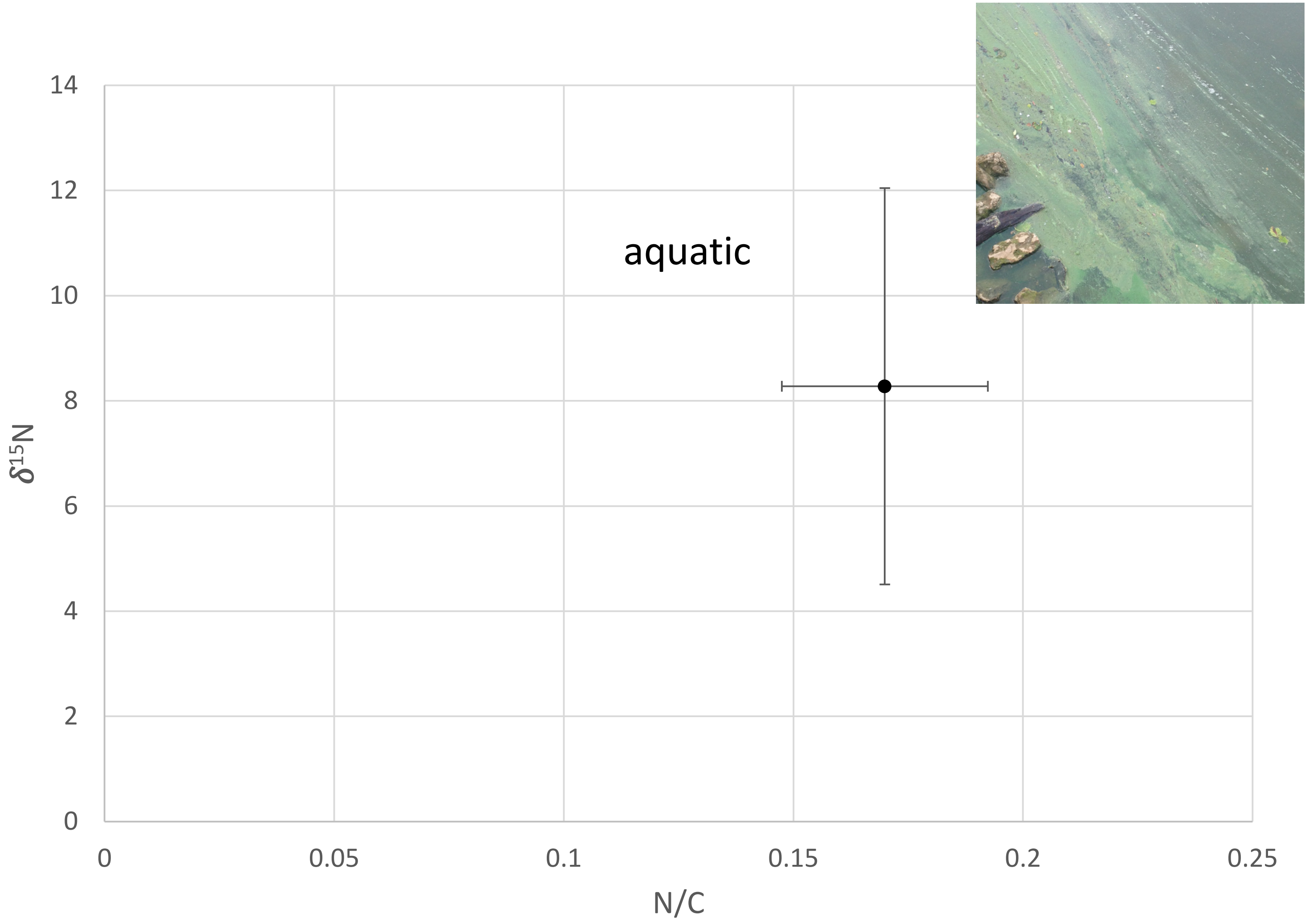


BULK SEDIMENT fraction of OM

DISSOLVED fraction of OM

Spatial variation: Organic matter **source**

Mixing model to estimate the proportion of sediment OM that is from algal-derived sources



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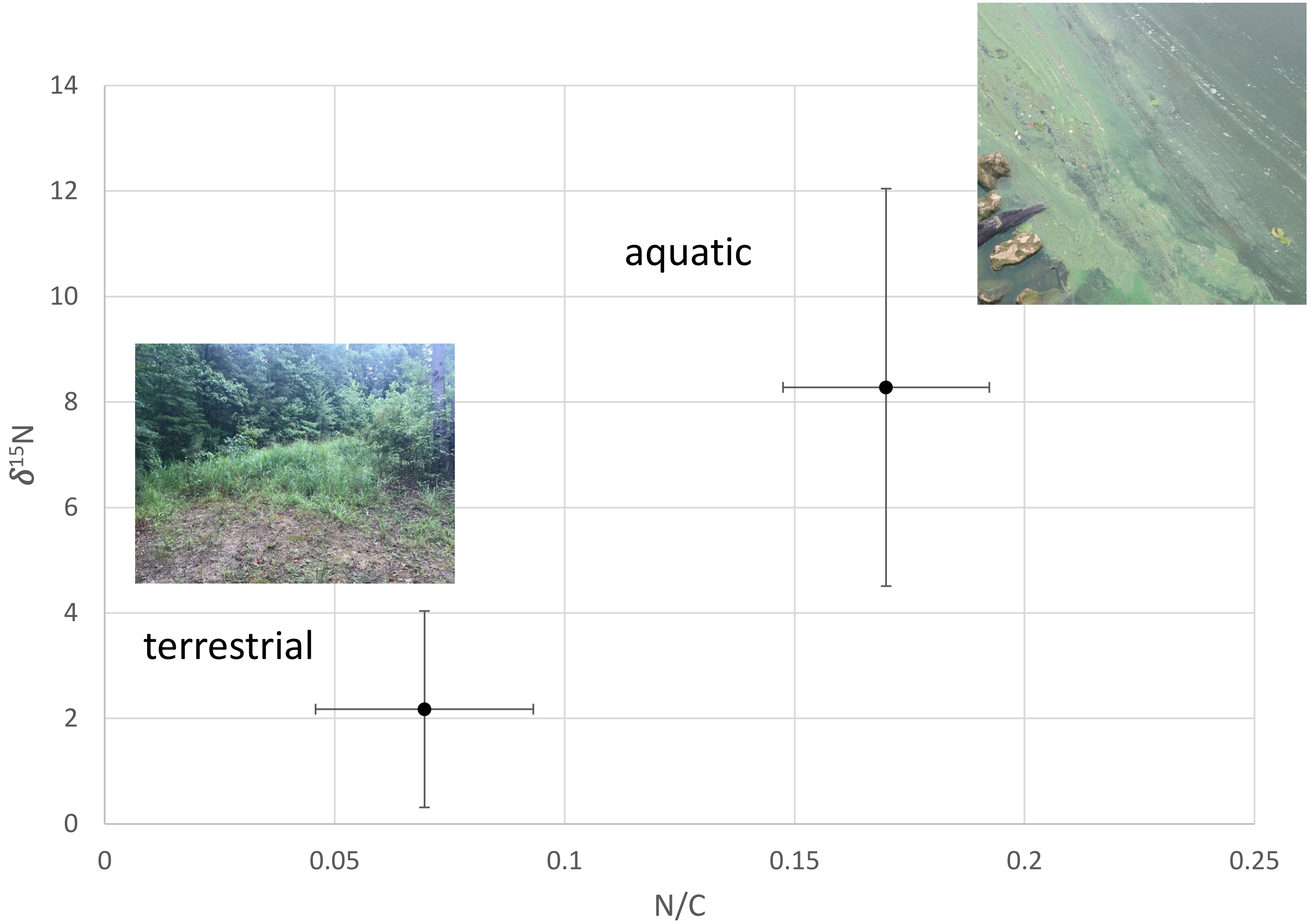

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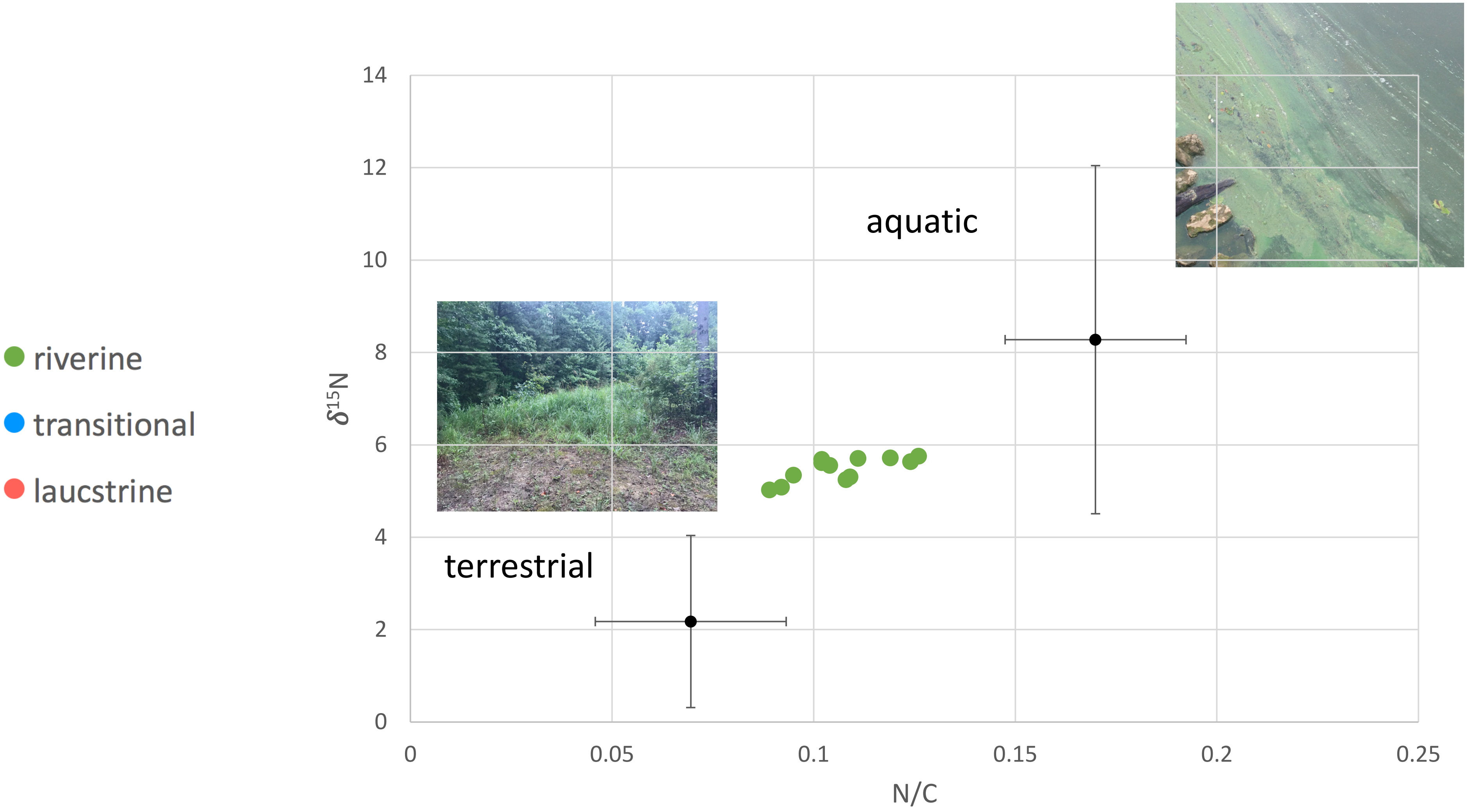

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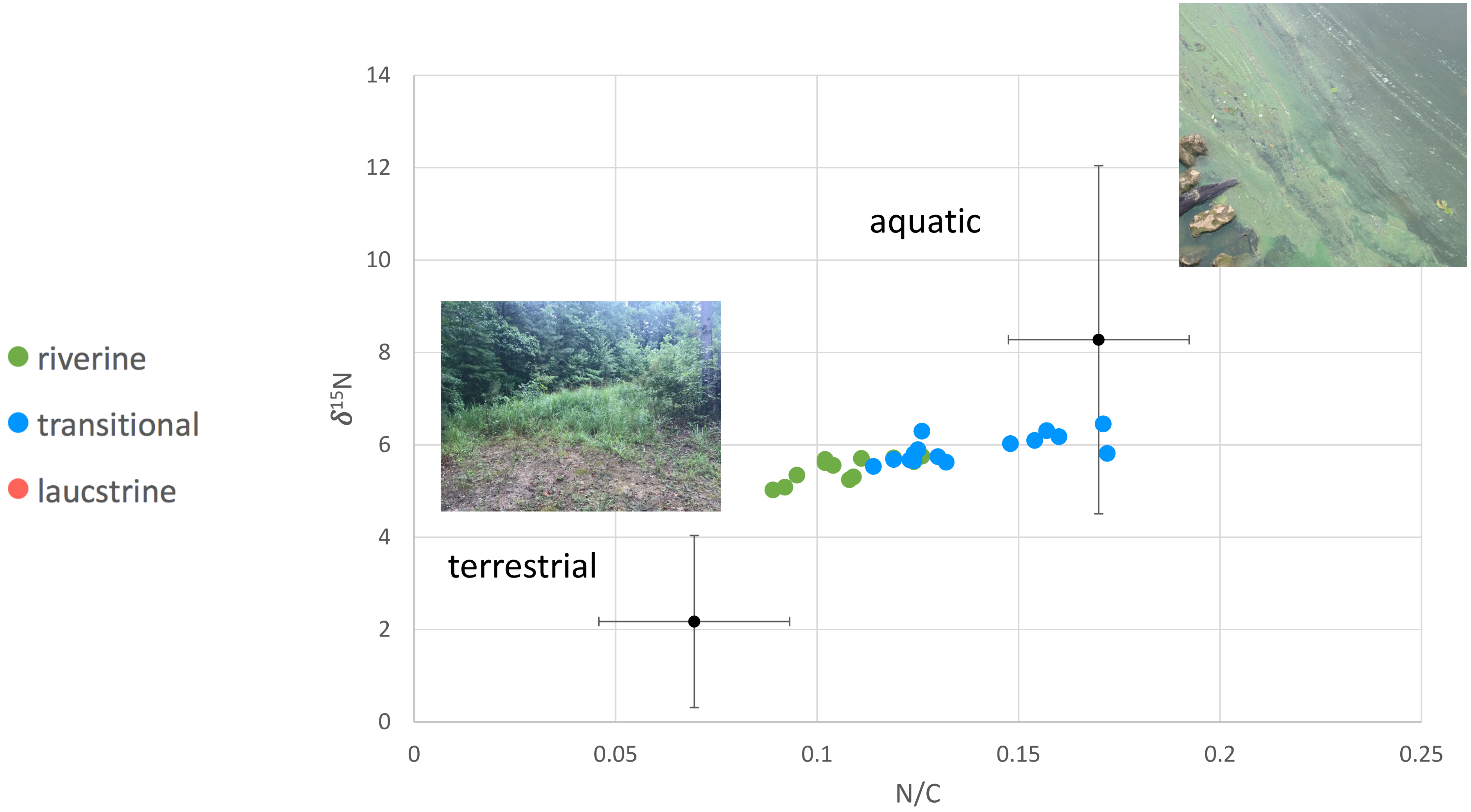

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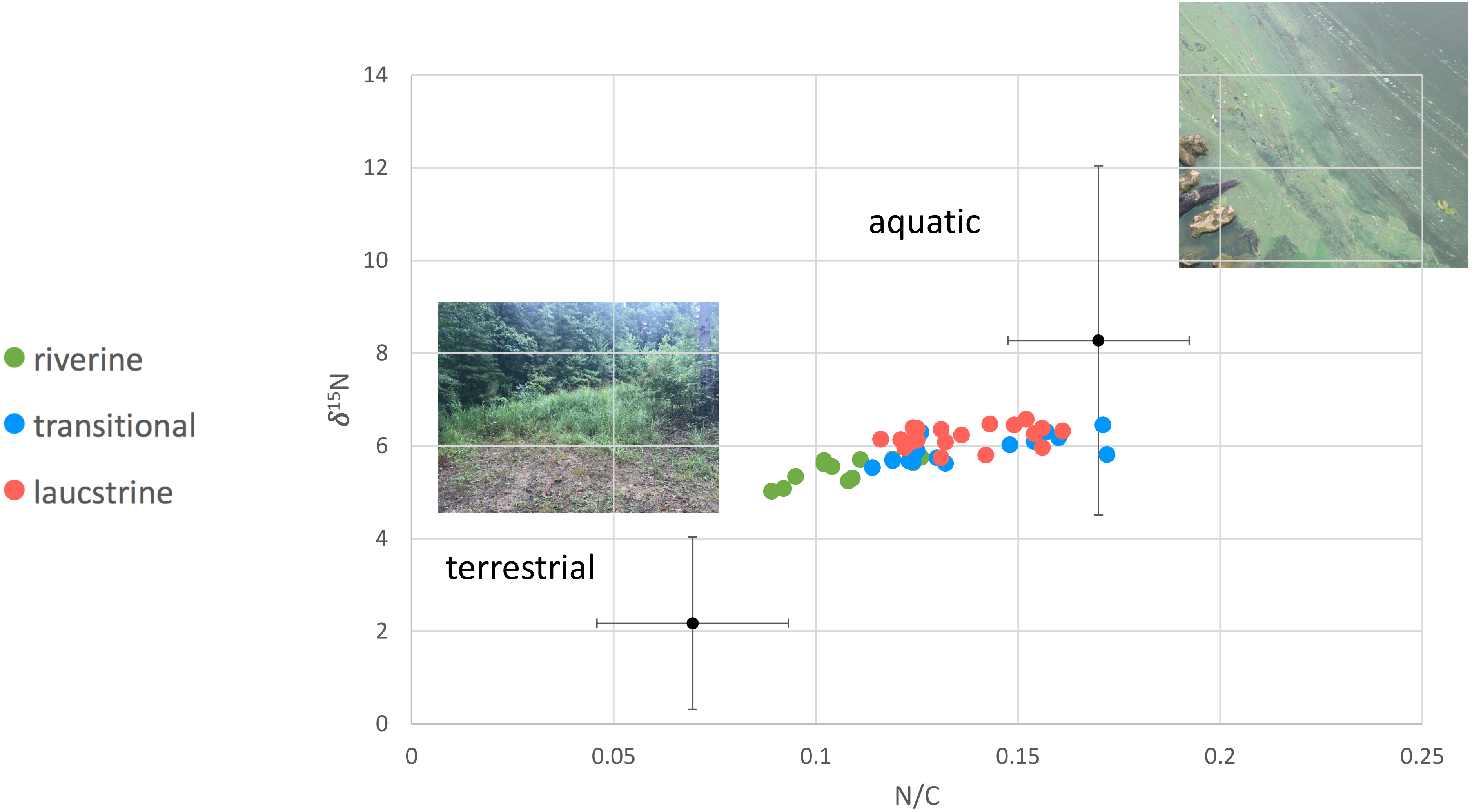

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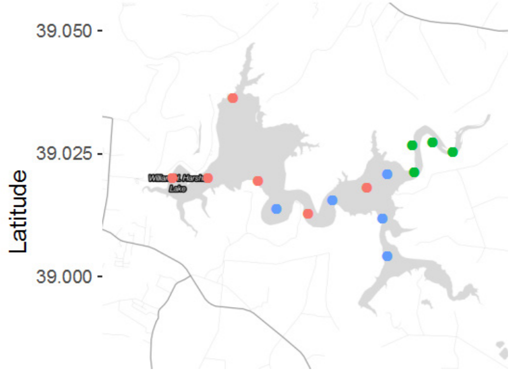

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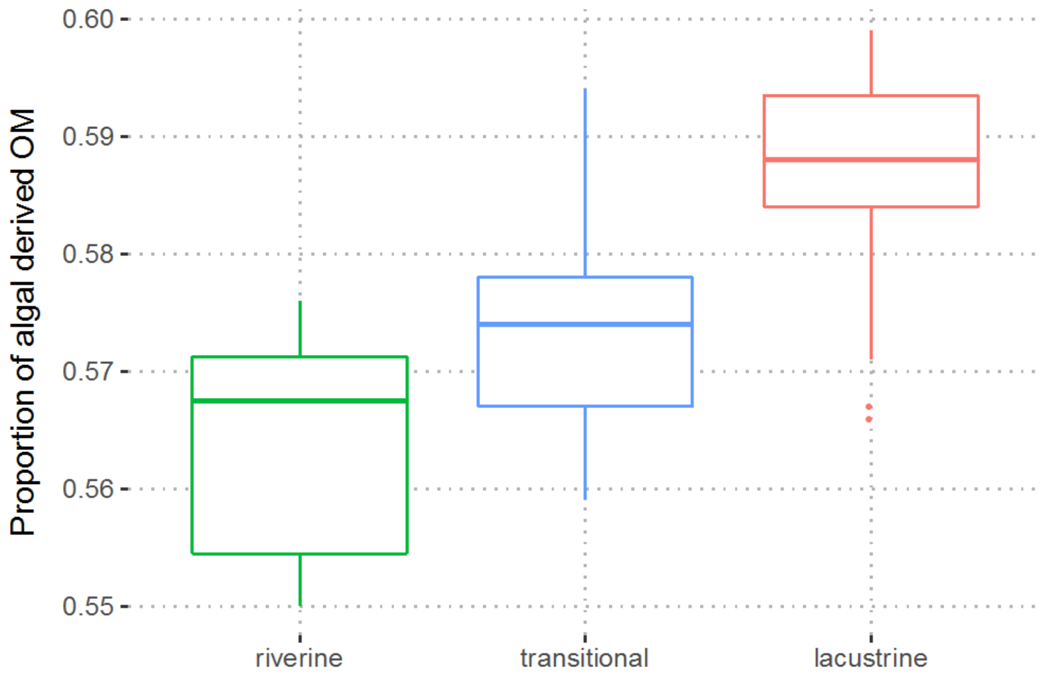

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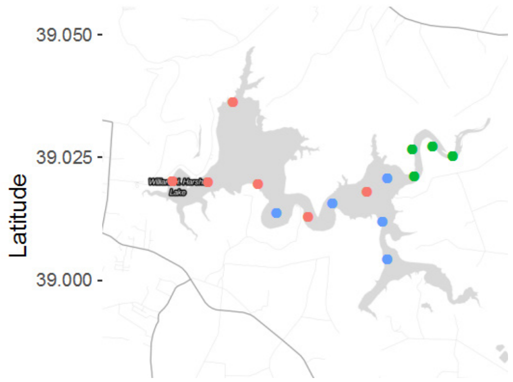

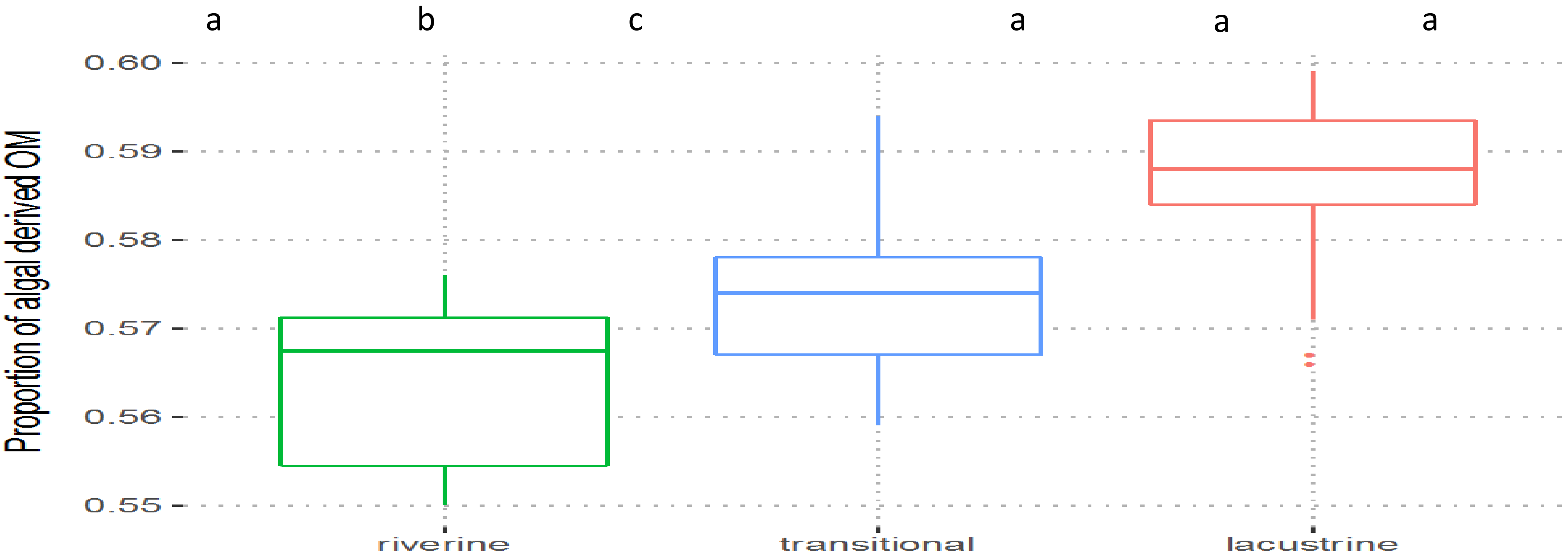

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H1: Organic matter **quantity** is the best predictor of methane production rates in Harsha Lake.

Marginal R^2	**0.48**
Conditional R^2	0.87

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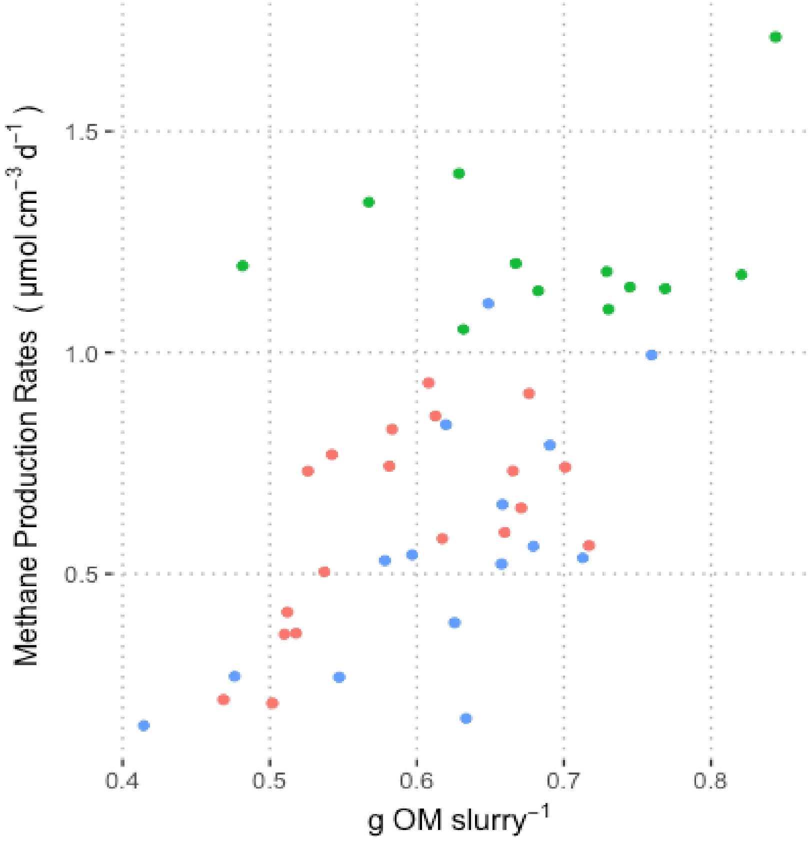

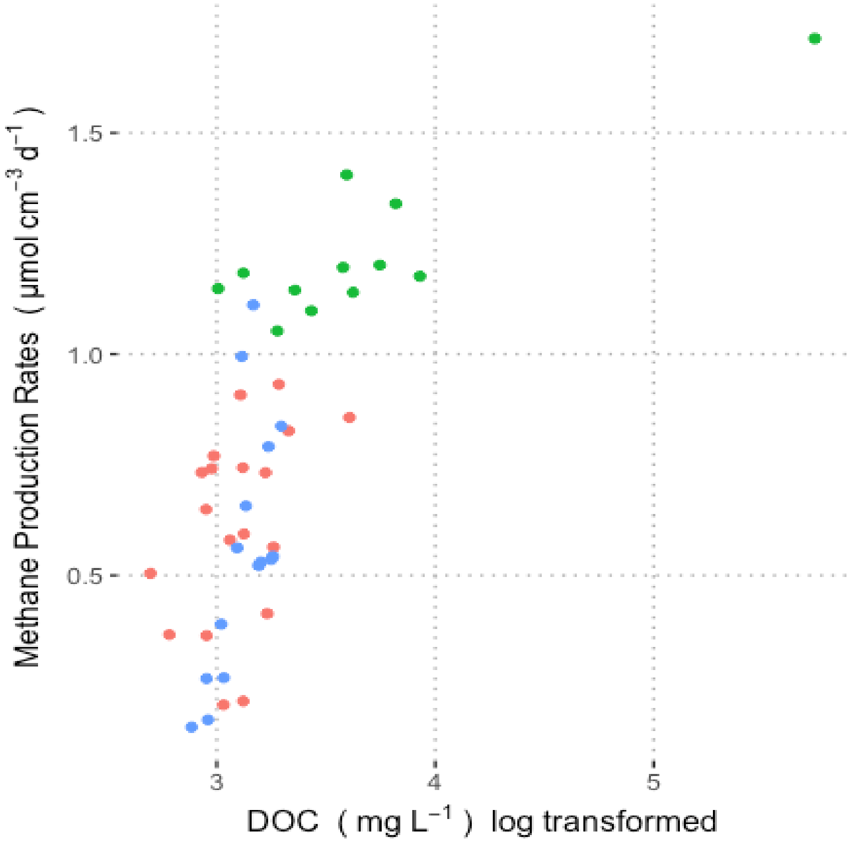

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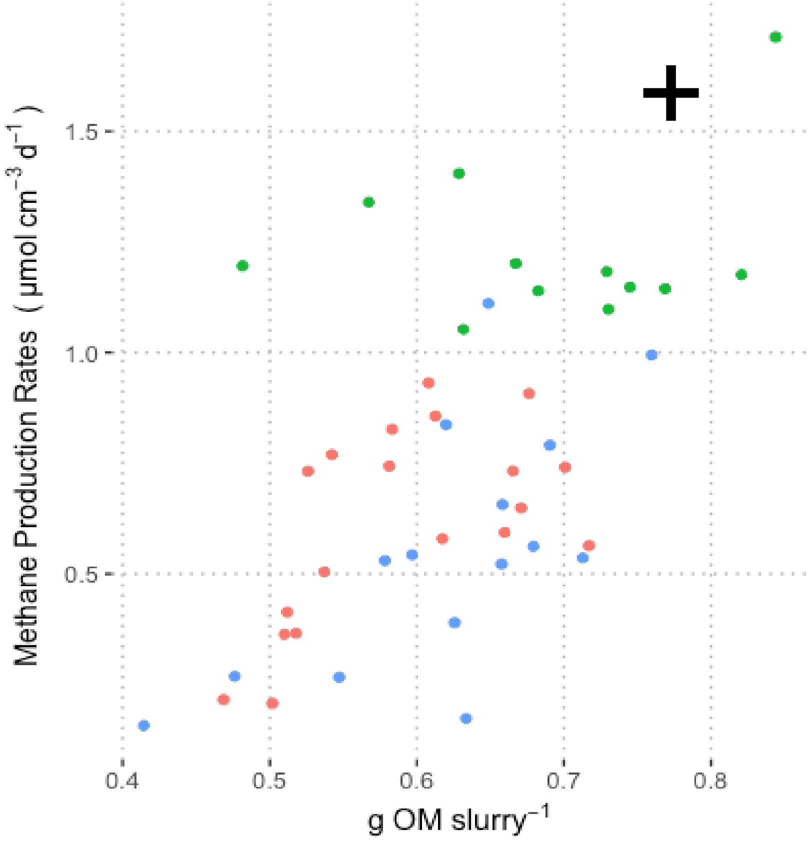

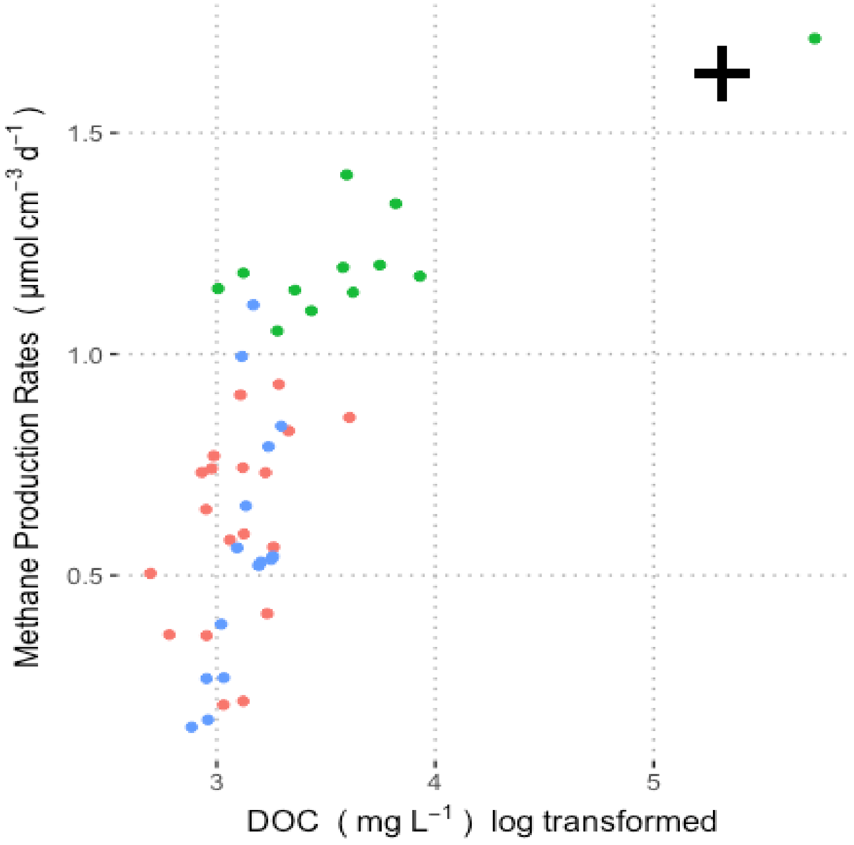

H2: Organic matter **source** is the best predictor of methane production rates in Harsha Lake.

Marginal R^2	**0.33**
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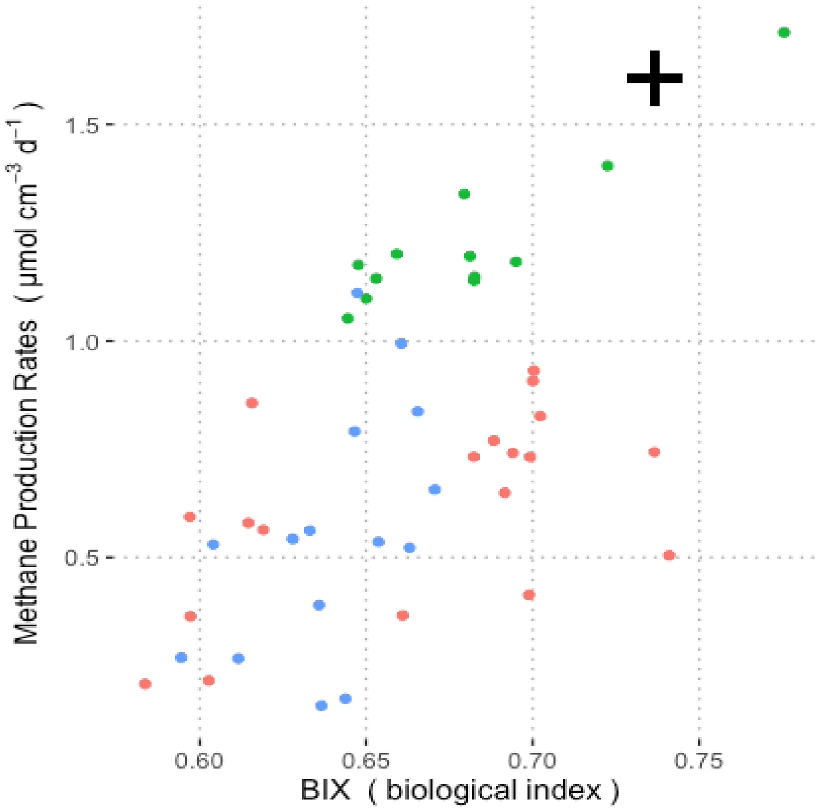

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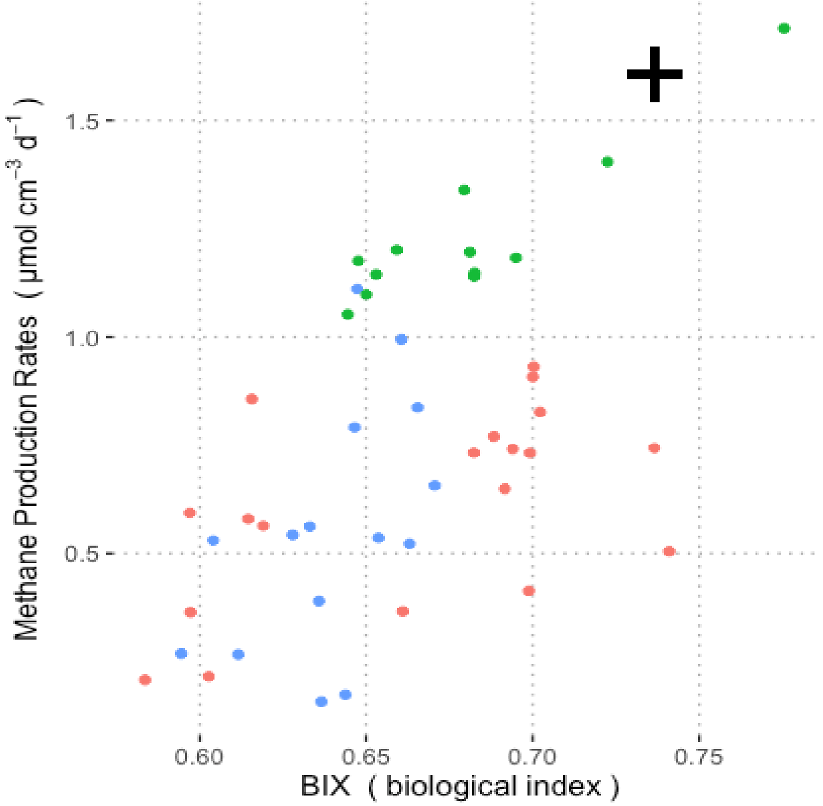

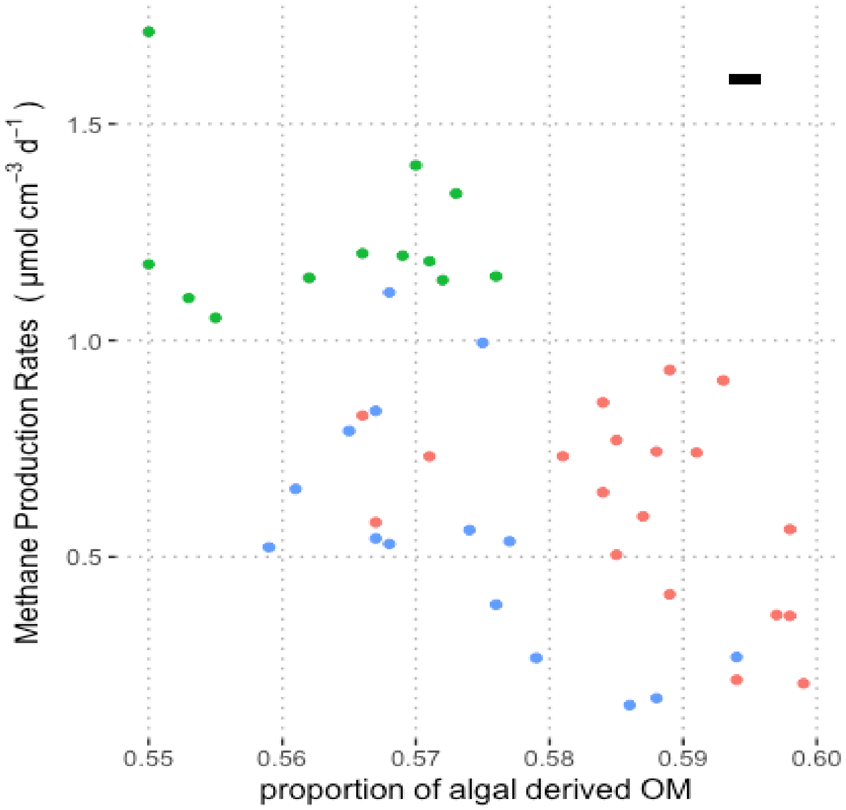

H3: The combination of OM **quantity and source** is the best predictor of methane production rates in Harsha Lake.

Marginal R^2	**0.70**
Conditional R^2	0.89

Model summaries:

Model	Hypothesis	AICc	Rank	Model probability w_i	Evidence ratio	Marginal R^2	Conditional R^2
H1	quantity	-13.4	3	0.003	370.6	0.48	0.87
H2	source	-15.6	2	0.008	123.8	0.33	0.85
H3	quantity + source	-25.2	1	0.989		0.70	0.89

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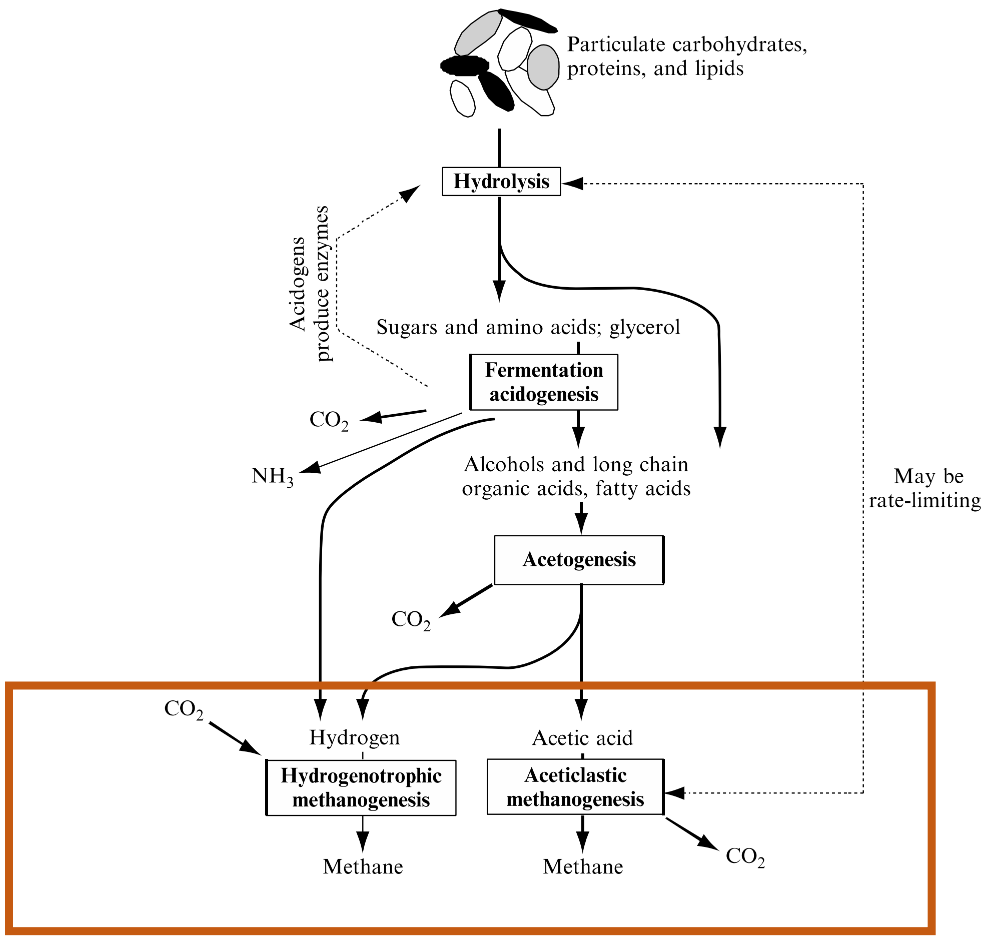
Microbial decomposition of OM

Primary fermenting bacteria

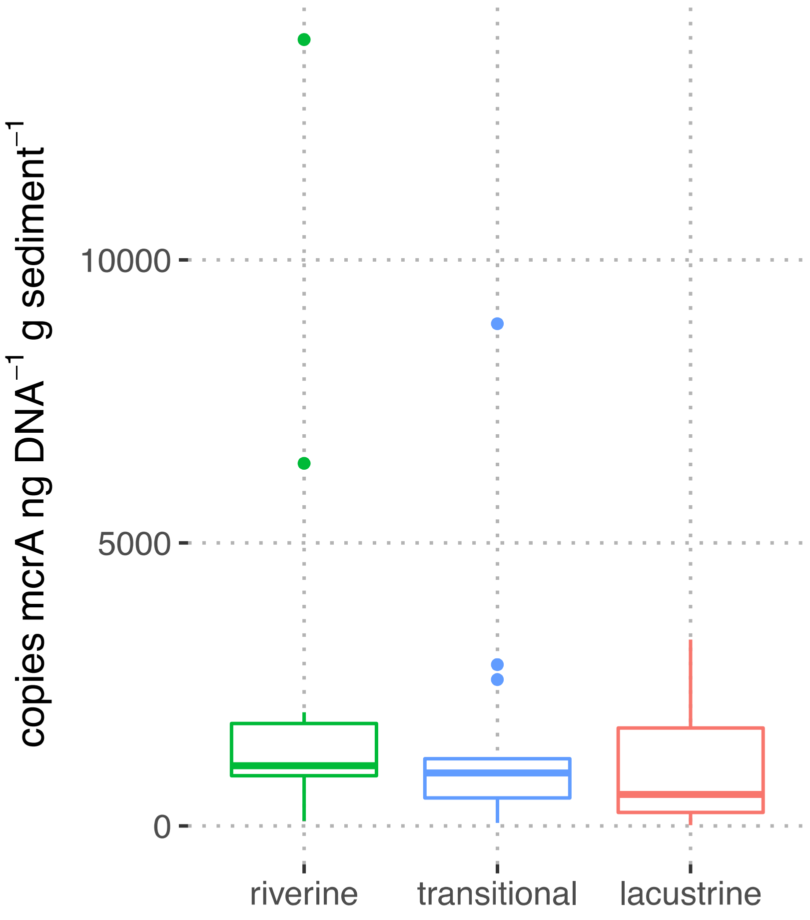
Anaerobic oxidizing bacteria

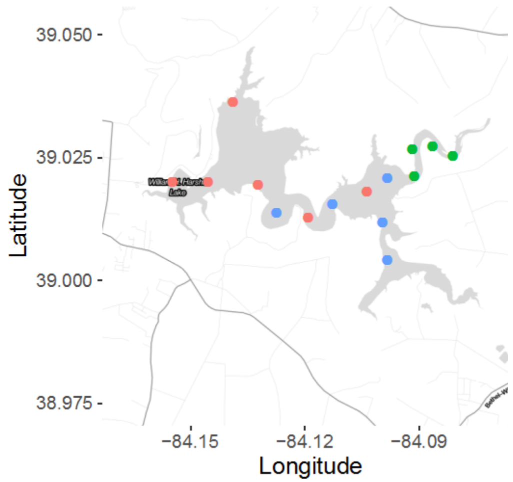
Methanogenic archaea



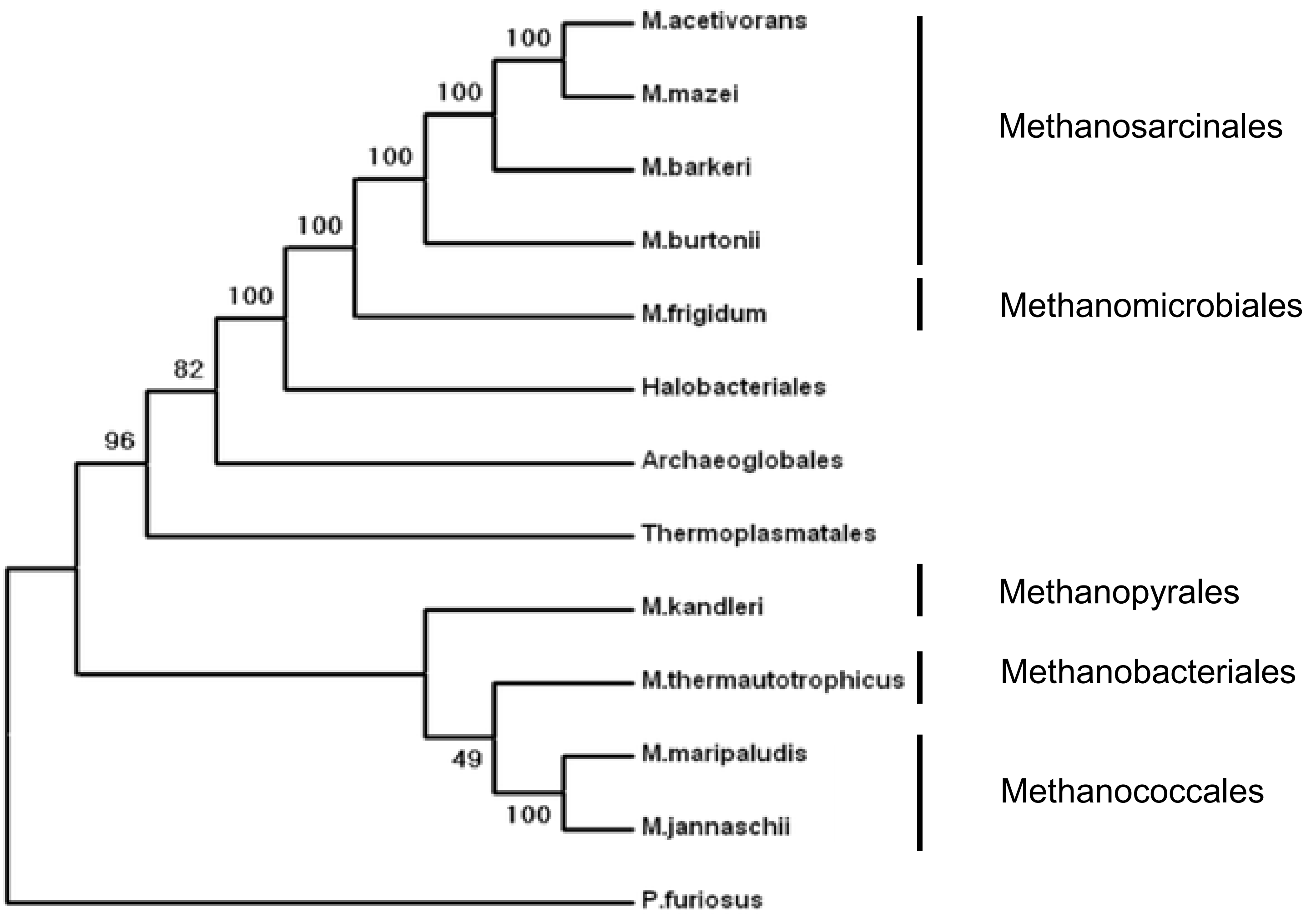
From Angelidaki et al (2011), modified from Batstone and Jensen (2010)

Spatial variation: Methanogen abundance



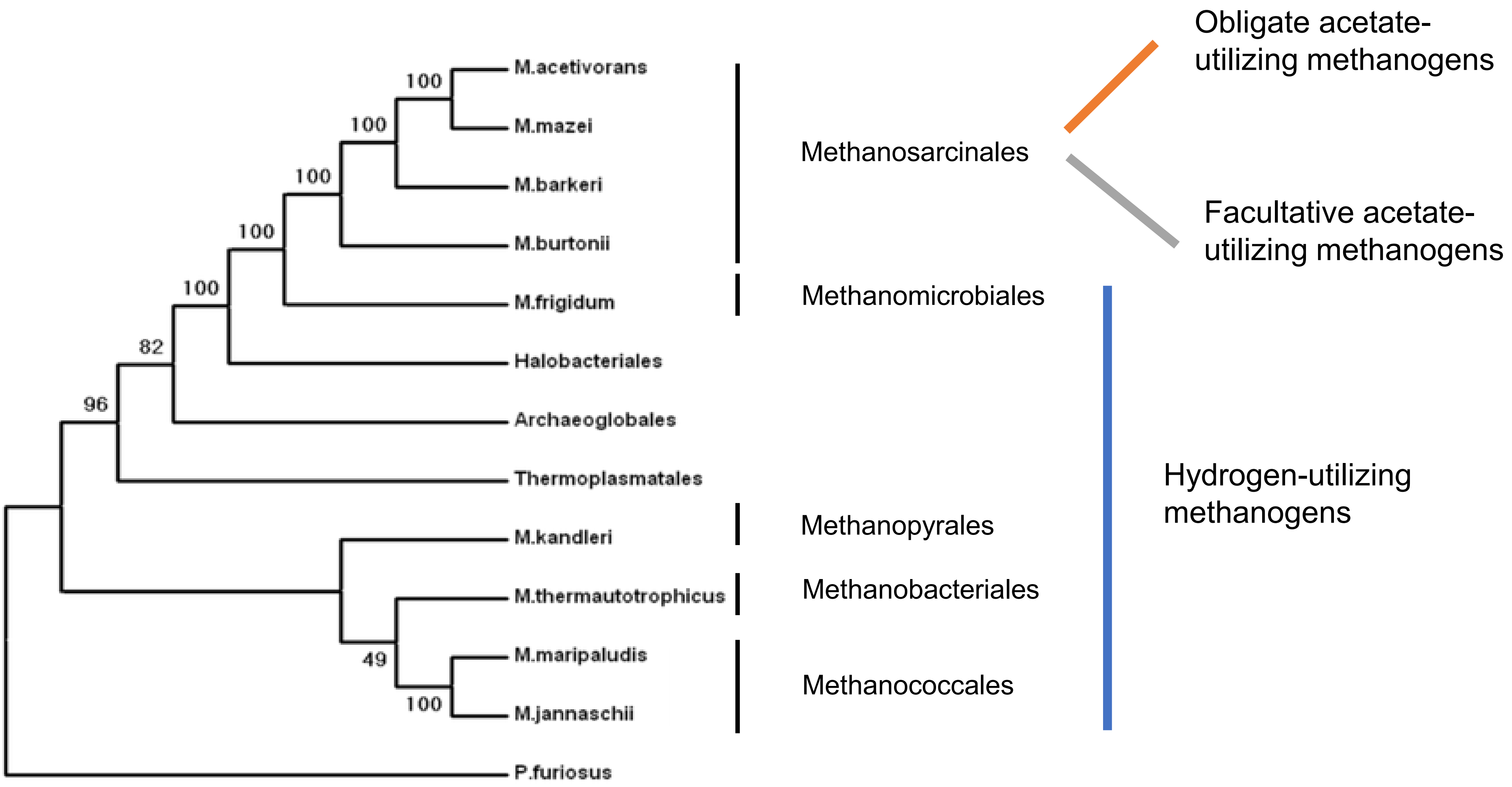


Methanogen taxonomy



Luo et al. (2009)

Methanogen taxonomy



Luo et al. (2009)

Relative abundance of methanogen genera by zone

	riverine	transitional	lacustrine
Methanomicrobiales; Methanoregula	47.7	69.5	66.9
Methanosarcinales; Methanosaeta	19.6	15.2	16.6
Methanobacteriales; Methanobacterium	15.1	9.6	7.3
Methanomicrobiales; Methanolinea	2.8	6.4	4.8
Methanosarcinales; Methanosarcina	15.4	0.5	0.4
Methanomicrobiales; Methanoline	1.4	1.7	3.6
Methanomicrobiales; Methanospirillum	4.3	0.8	1.3
Methanocellales; Rice_Cluster_I	0.9	0.1	0.3
Methanomicrobiales; SMS−sludge−7_unclassifie	0.3	0.1	0.5
Methanosarcinales; Candidatus_Methanoperedens	0.4	0.8	0
Methanomicrobiales; Methanomicrobiales_unclassifie	0	0.4	0.4
Methanosarcinales; Methanolobus	0.8	0	0
Methanomicrobiales; Methanomicrobiales_unclassified	0.4	0.1	0.2
Methanosarcinales; Methanomethylovorans	0.6	0	0
Methanobacteriales; Methanobrevibacter	0.4	0	0

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Conclusions

- The riverine zone was different in its methane production rates, sediment characteristics, and methanogen composition
- Quantity and source of OM combined better predict methane production rates than either quantity or source alone
- The proportion of algal-derived OM in the bulk sediment was negatively correlated to methane production rates.

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Kaitlin Henn
Caroline Tran

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Madison Duke
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