REMTEC & EMERGING CONTAMINANTS SUMMIT

OCTOBER 3-5, 2023

Combined removal of recalcitrant pharmaceuticals and greenhouse gas using constructed wetlands

J.O. Sharp, Colorado School of Mines

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The village: co-authors & collaborators

Colorado School of Mines


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Gary Vanzin


Lily Bosworth

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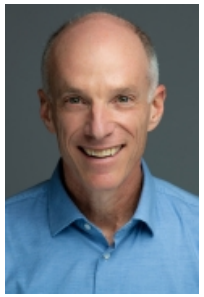
David Sedlak

Colorado State University


Reb Daly


Adrienne Narrowe


Kelly Wrighton

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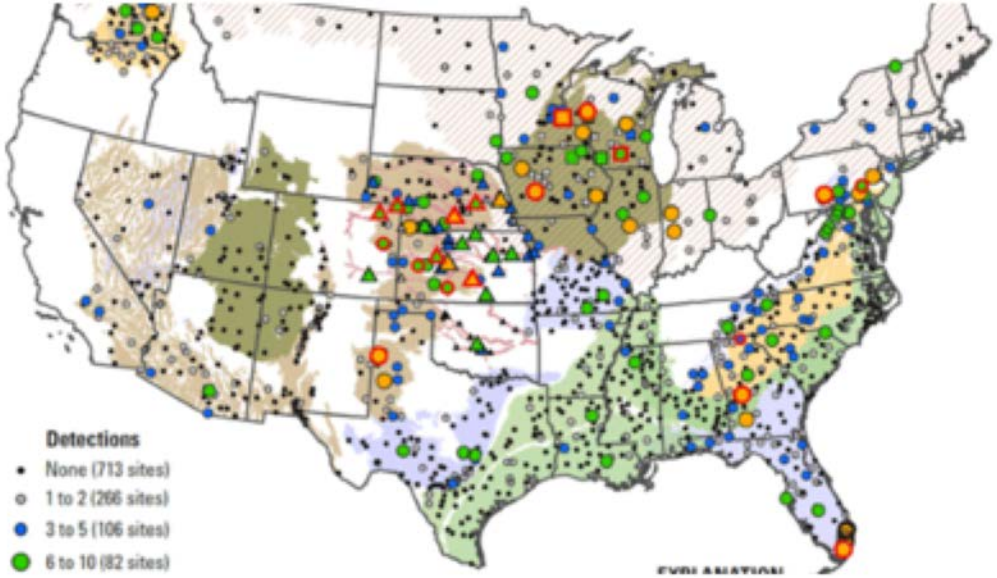
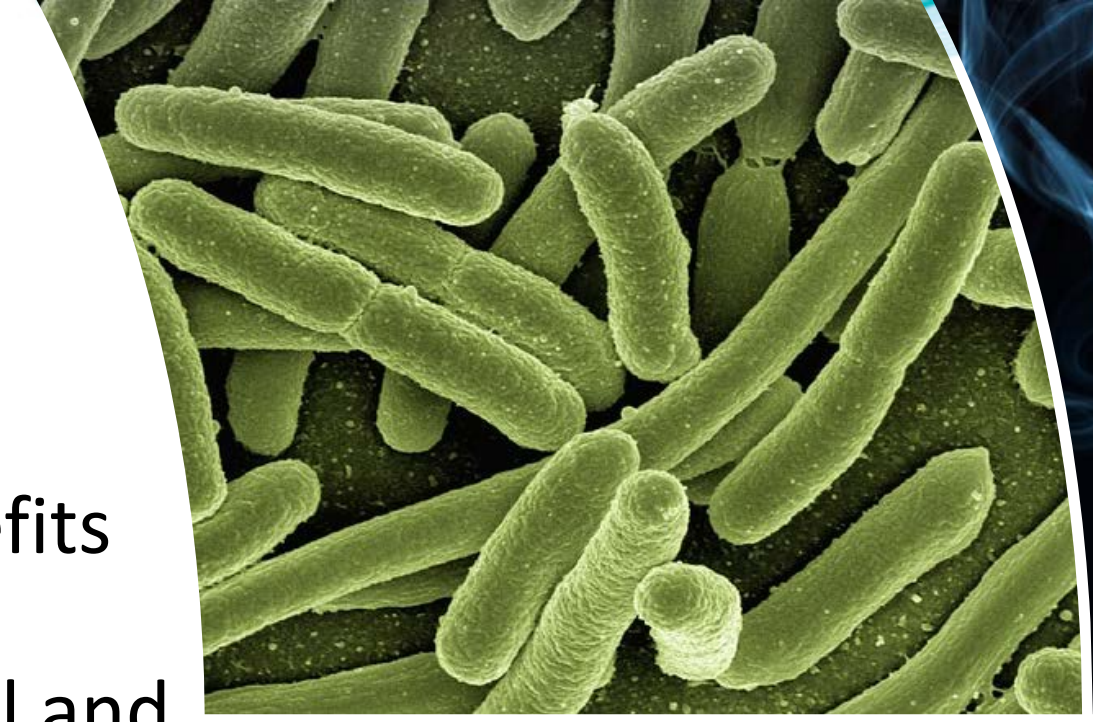


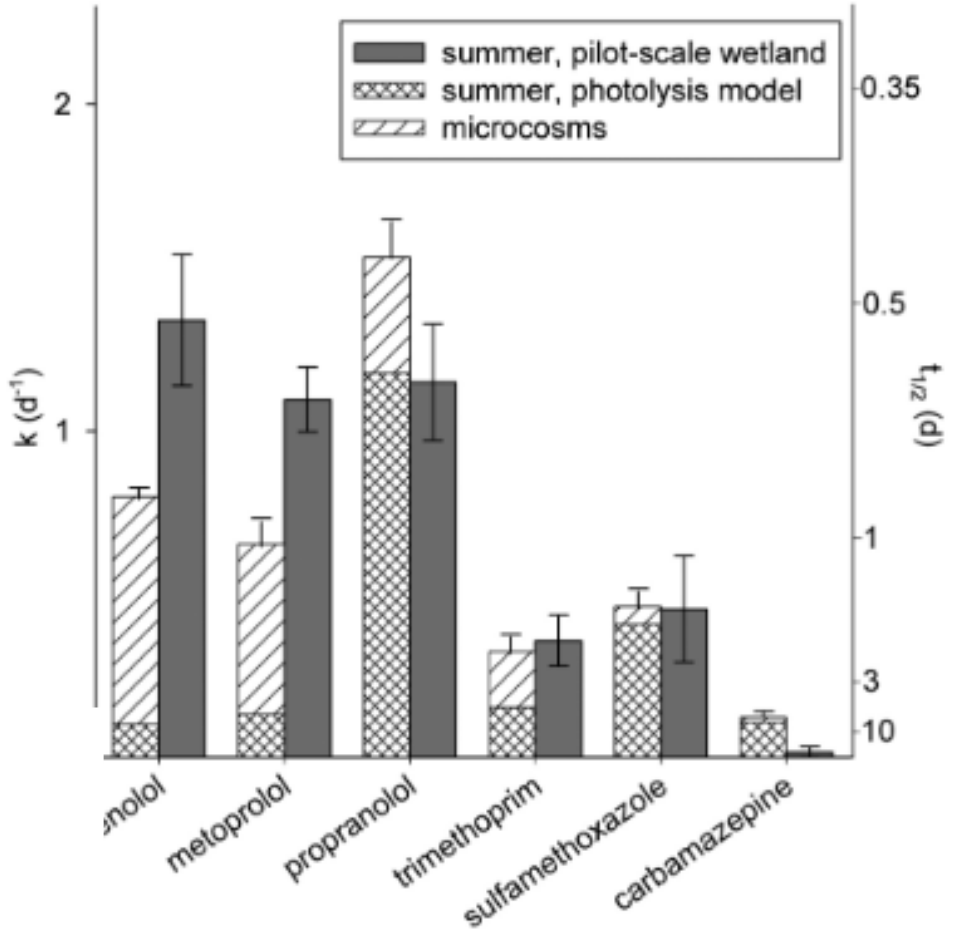
Bexfield et al., 2020 ES&T

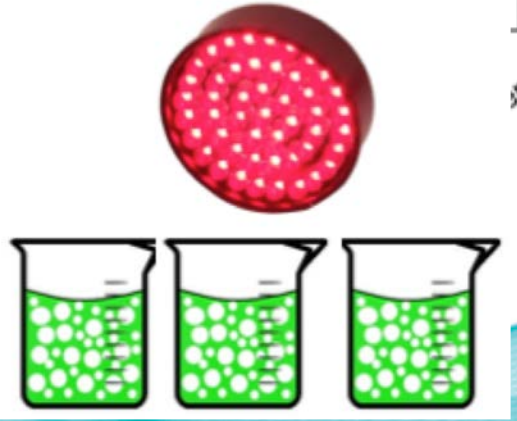
Kolpin et al., 2002 ES&T

Attenuation benefits from synergies in physical, chemical and biological mechanisms



Purification of Water Is Achieved by a Combination of Sunlight (UV) and Biodegradation



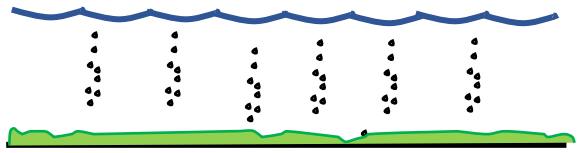


Jasper et al (2014a). ES&T **48**: 5136.

- Attenuation rates are 10-100 times faster than in vegetated systems
- Complementary attenuation by photolysis and microbial processes

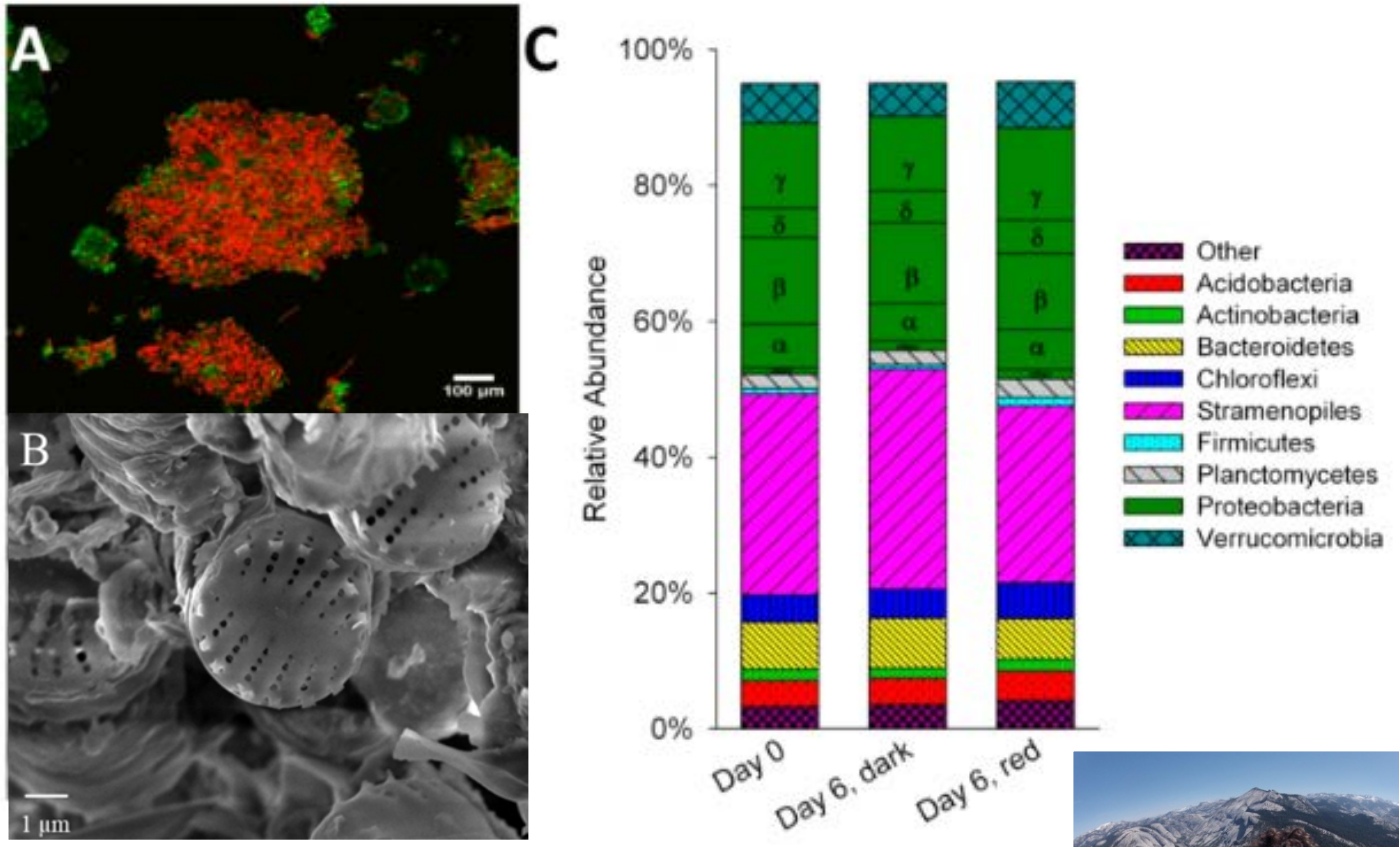
Justin Jasper, UCB

Unexpected role of microbiology in treatment



Photosynthetic “periphyton”
Microbial mat (4-15cm thick)

Diatoms = primary producers / limited diversity
Bacteria = heterotrophic and autotrophic guilds



Jasper et al (2014a). ES&T **48**: 5136.

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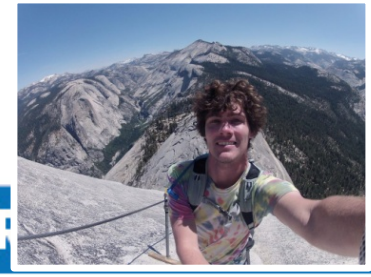


Zack Jones

Prado Constructed Wetlands: Corona, CA

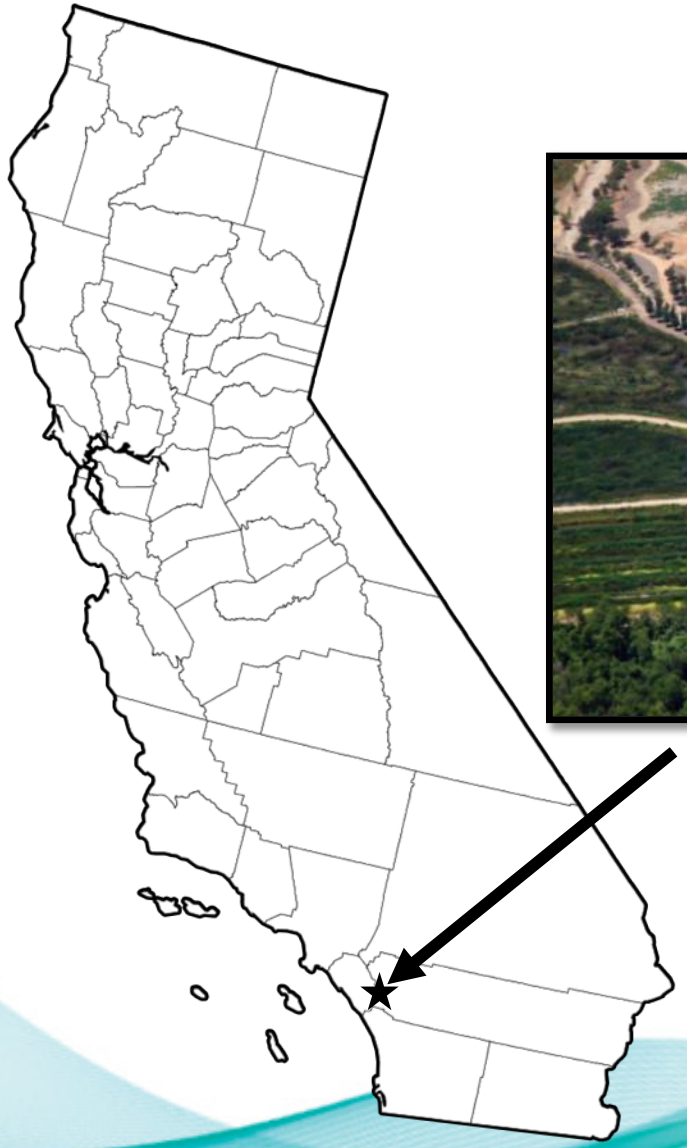
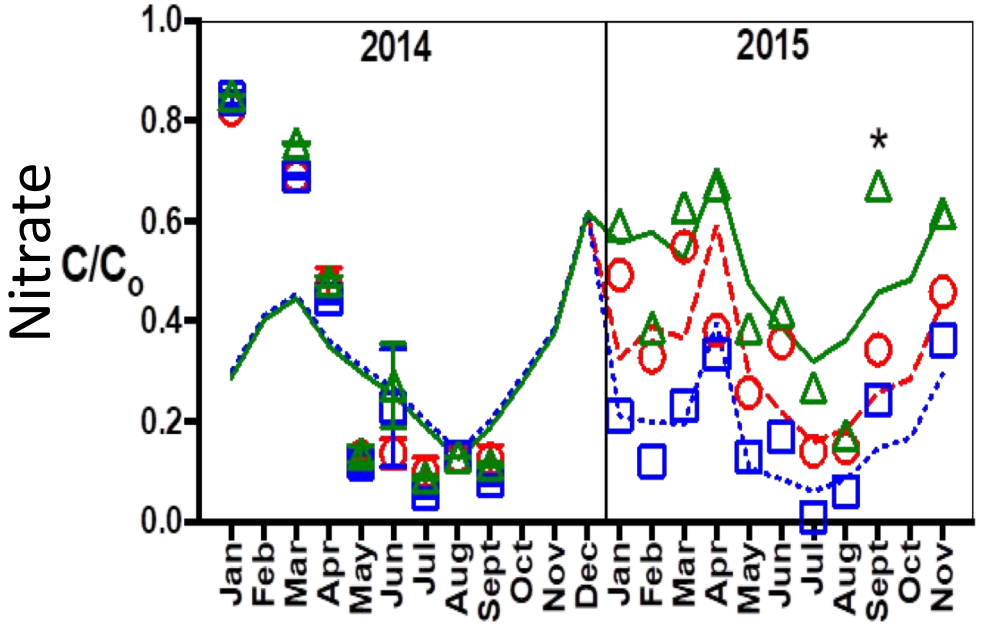


Photo Credit: OCWD

- Influent = Santa Ana River, impaired by nitrified wastewater effluent
- Managed by Orange County Water District (OCWD)
- Research cells designed/studied by NSF ERC ReNUWIt

Reproducibly and Rapidly Implemented in Different Locations

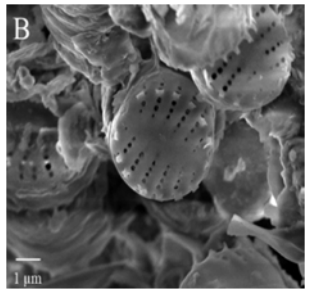


Sam Bear, UCB

Bear et. al. 2018
Ecol Eng 109:76

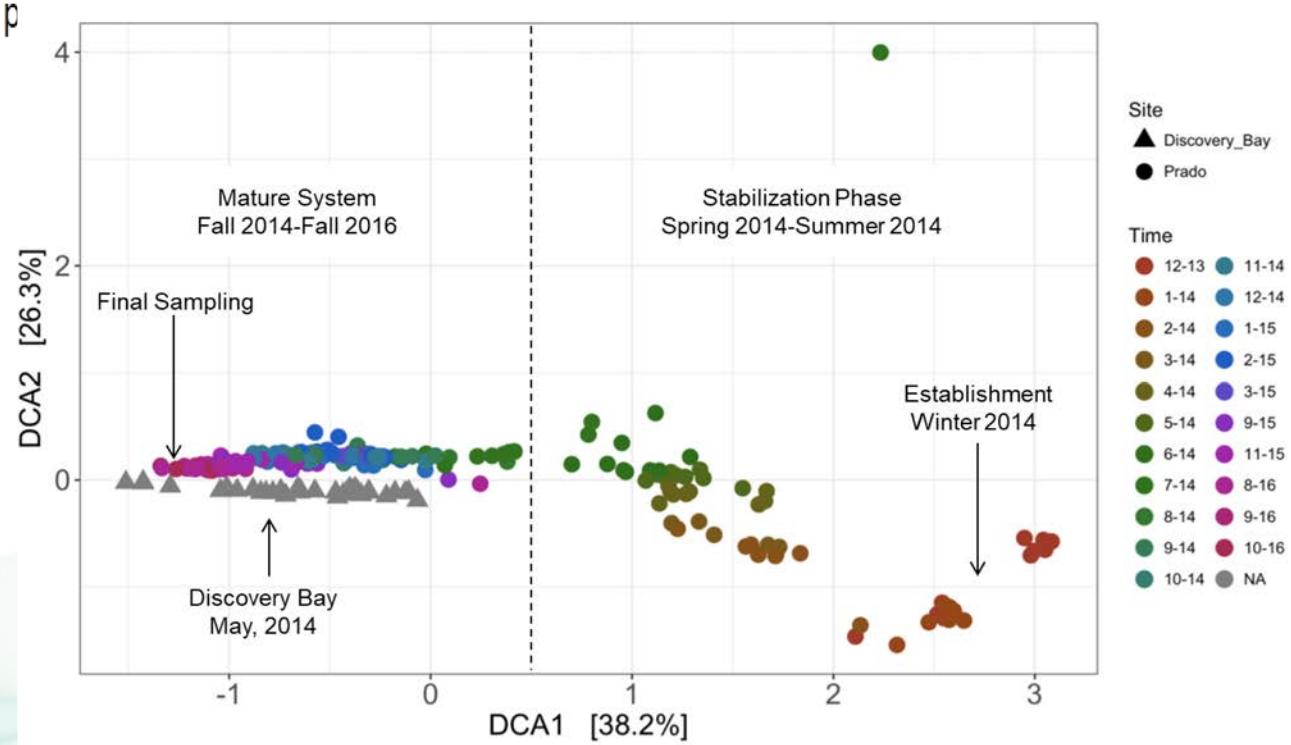
Kristin Mikkelson

Zack Jones



Diatoms

Jones et. al. 2018. W*ater Research* 133

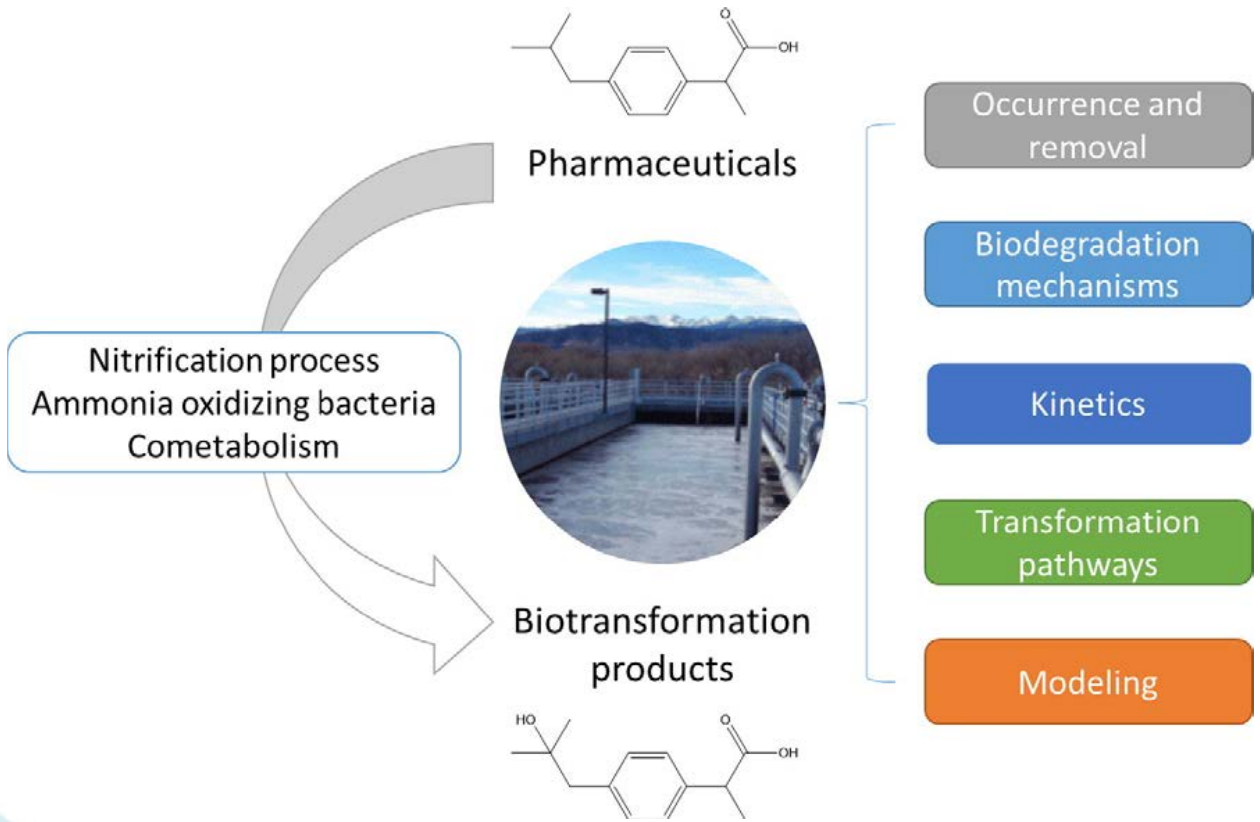


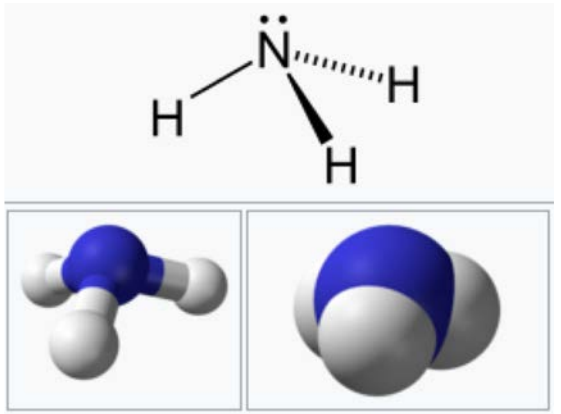
Trace quantities of contaminants are unlikely to select for desirable metabolic processes; can we go beyond black box treatment?

1ppt = ng/L = 1 x 10^{-12}
There are 5 x 10^{10} drops of water in an Olympic size swimming pool

Growth is supported by mg/L or more: How can we select for desirable attributes?

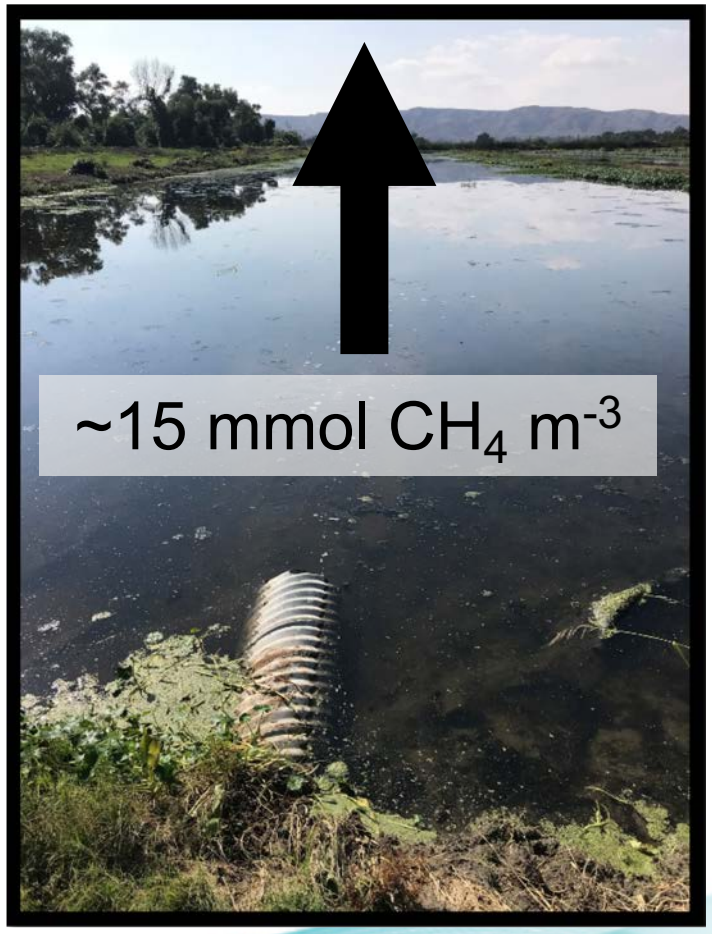
Ammonia monooxygenase activity enhances pharmaceutical biodegradation in WWT.

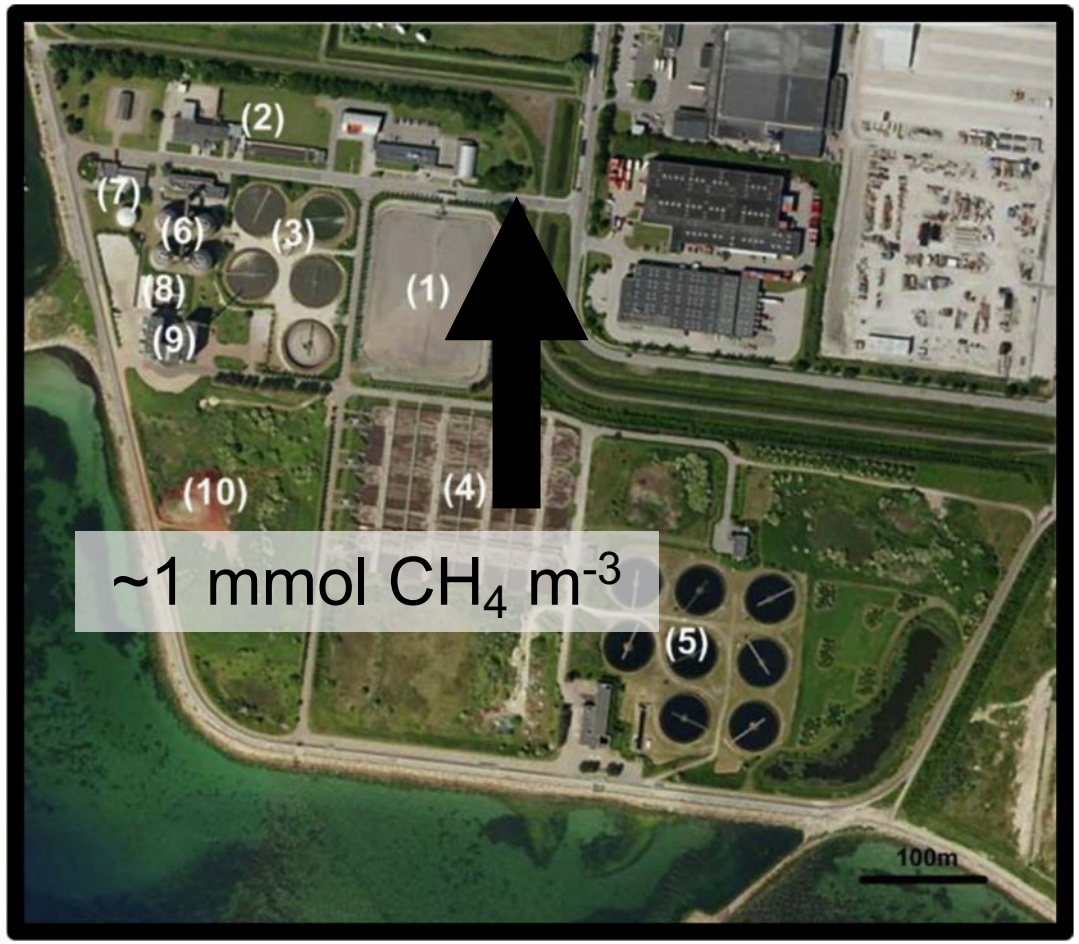




Xu et al (2016) STOTEN 566:796

Ammonia is toxic to fish; wetlands produce methane

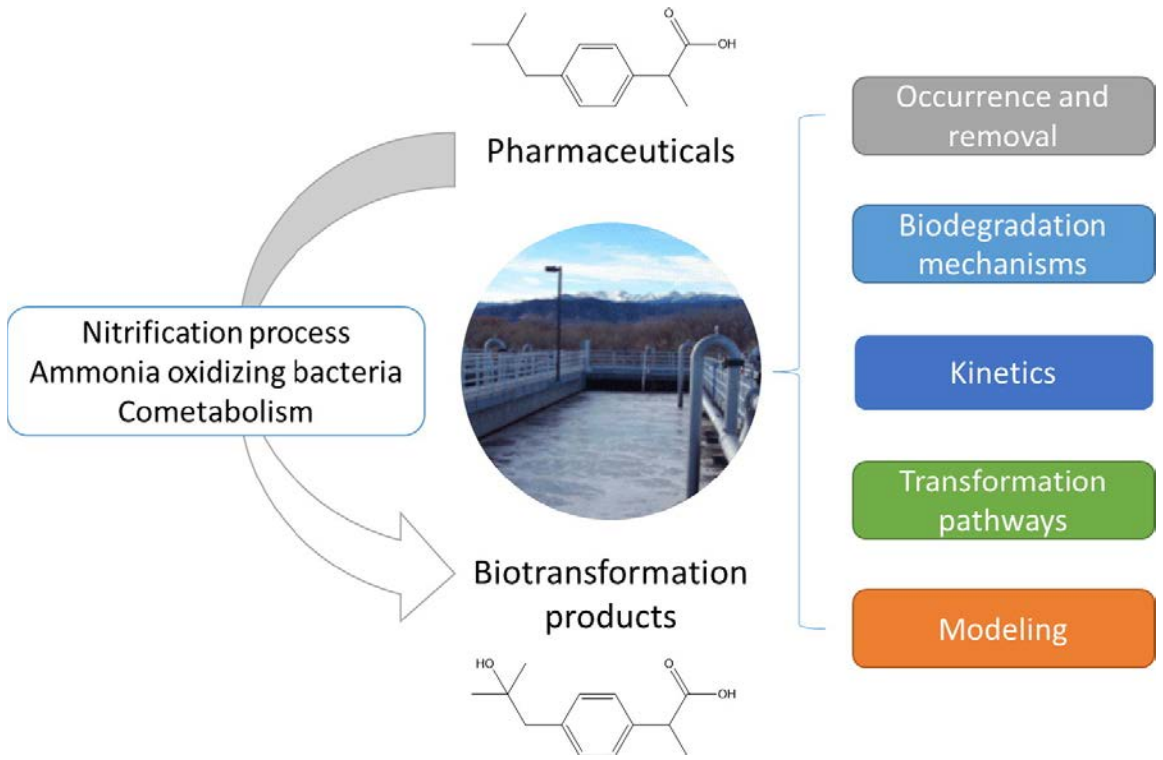


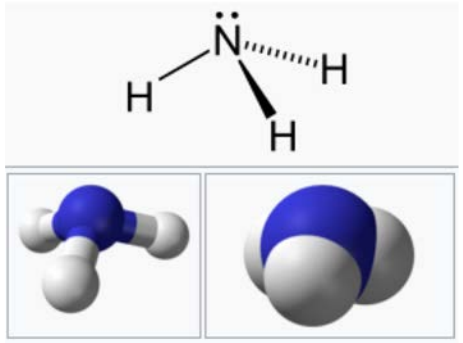


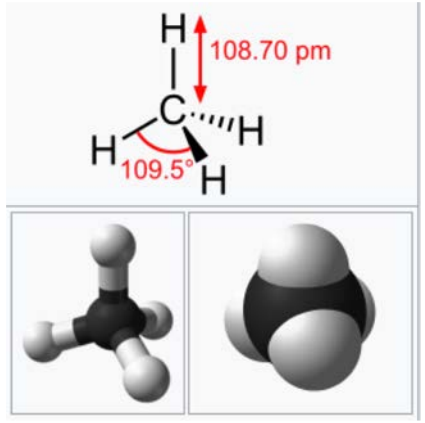
Vega *et al.* (2023) [ES&T]

Yoshida *et al.* (2014) [*Wat. Res.*]

Given analogies between AMO and MMO, could methane oxidation also enhance pharmaceutical attenuation in this wetland?



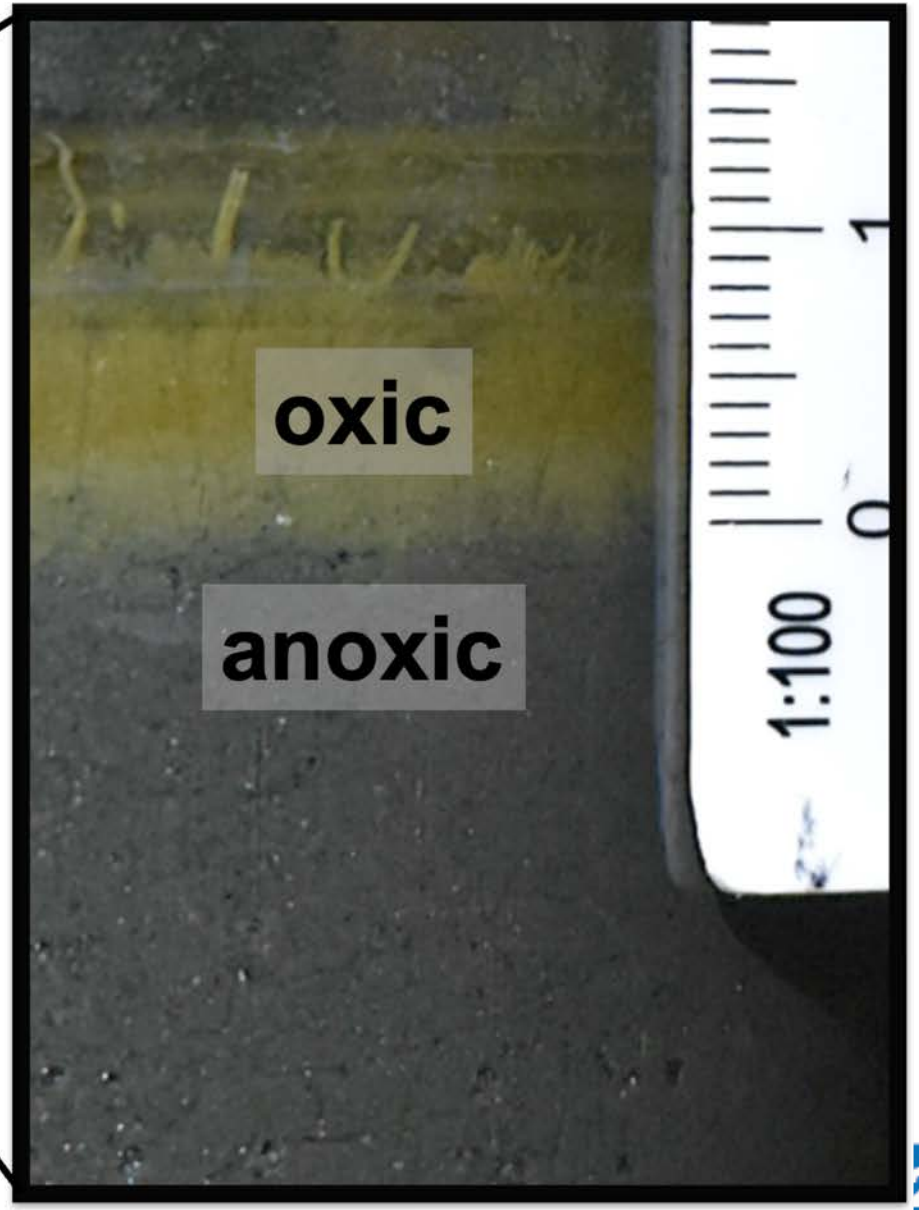




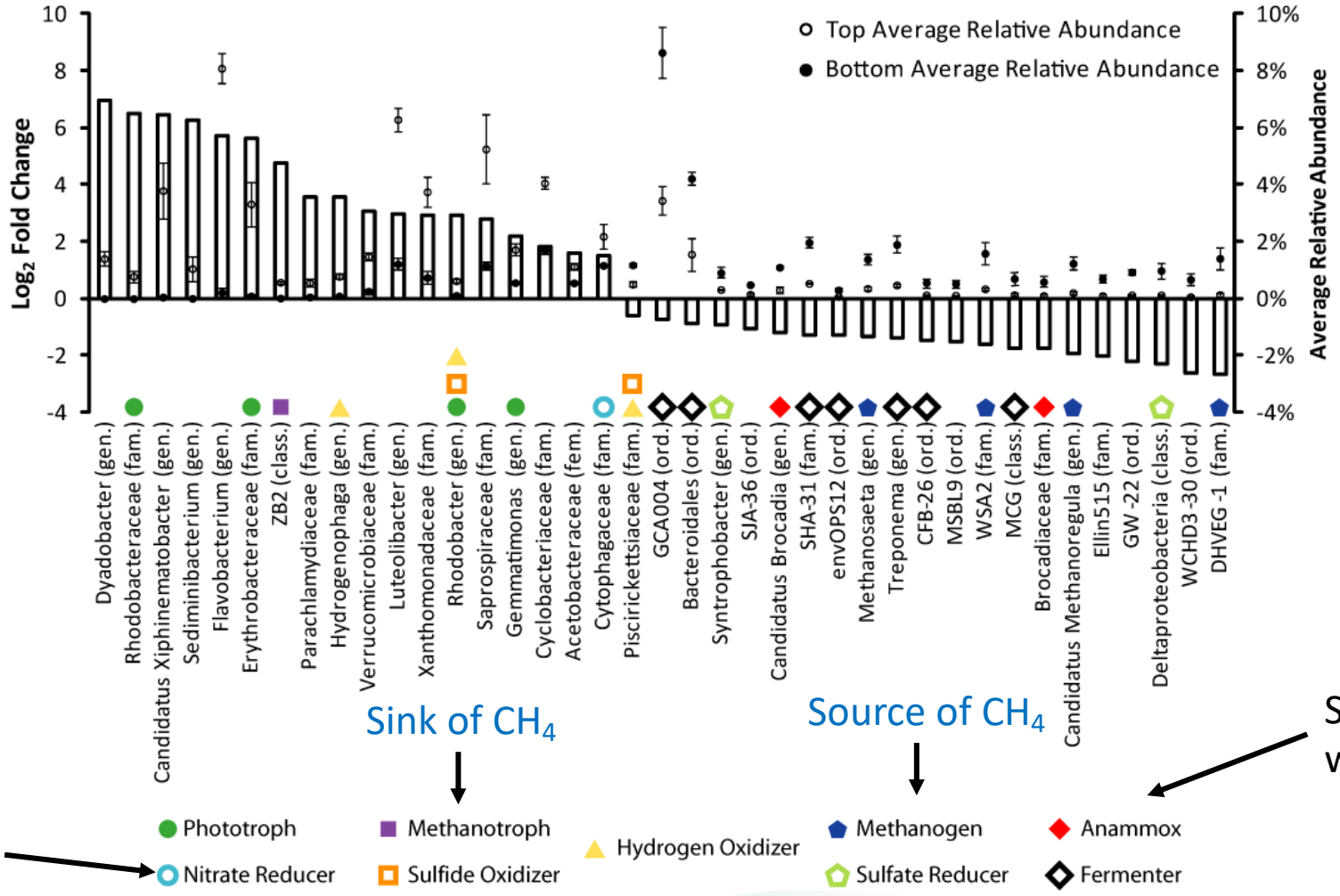
Xu et al (2016) STOTEN 566:796

Open-Water Wetland

Biomat Depth-Profile



Biogeochemical Depth Gradient



Sink of CH_4

Source of CH_4

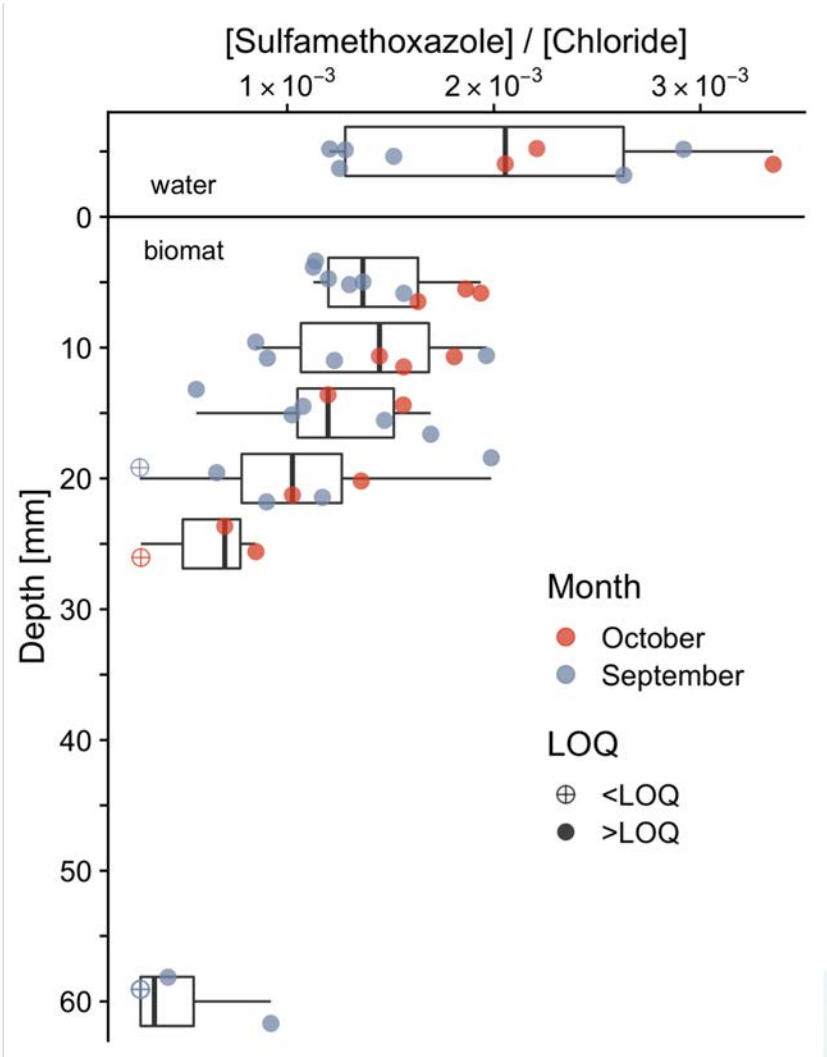
Source of N_2 w/o N_2O

Source of CO_2, N_2O, N_2

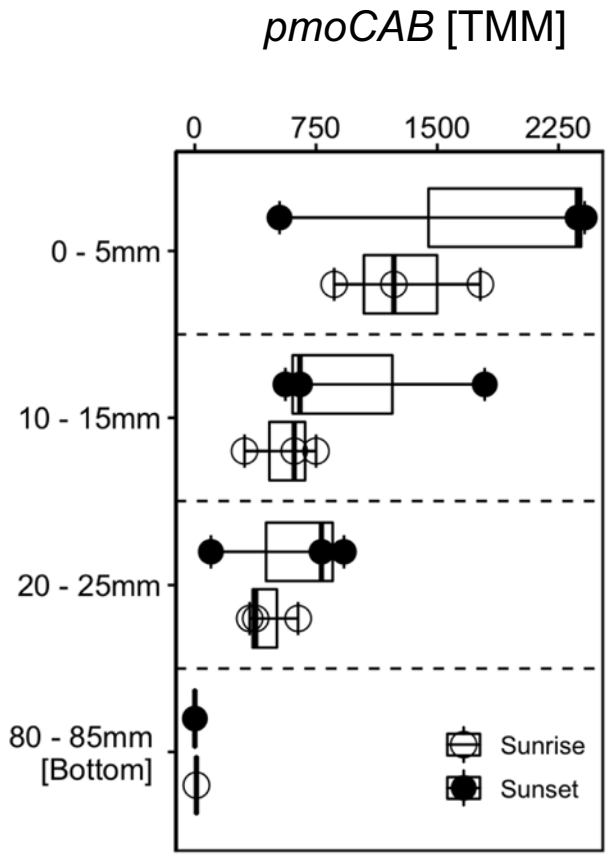
Zack Jones

Jones et. al. 2017. *AEM*

Correlation between sulfamethoxazole concentration and abundance of methane-oxidizing gene

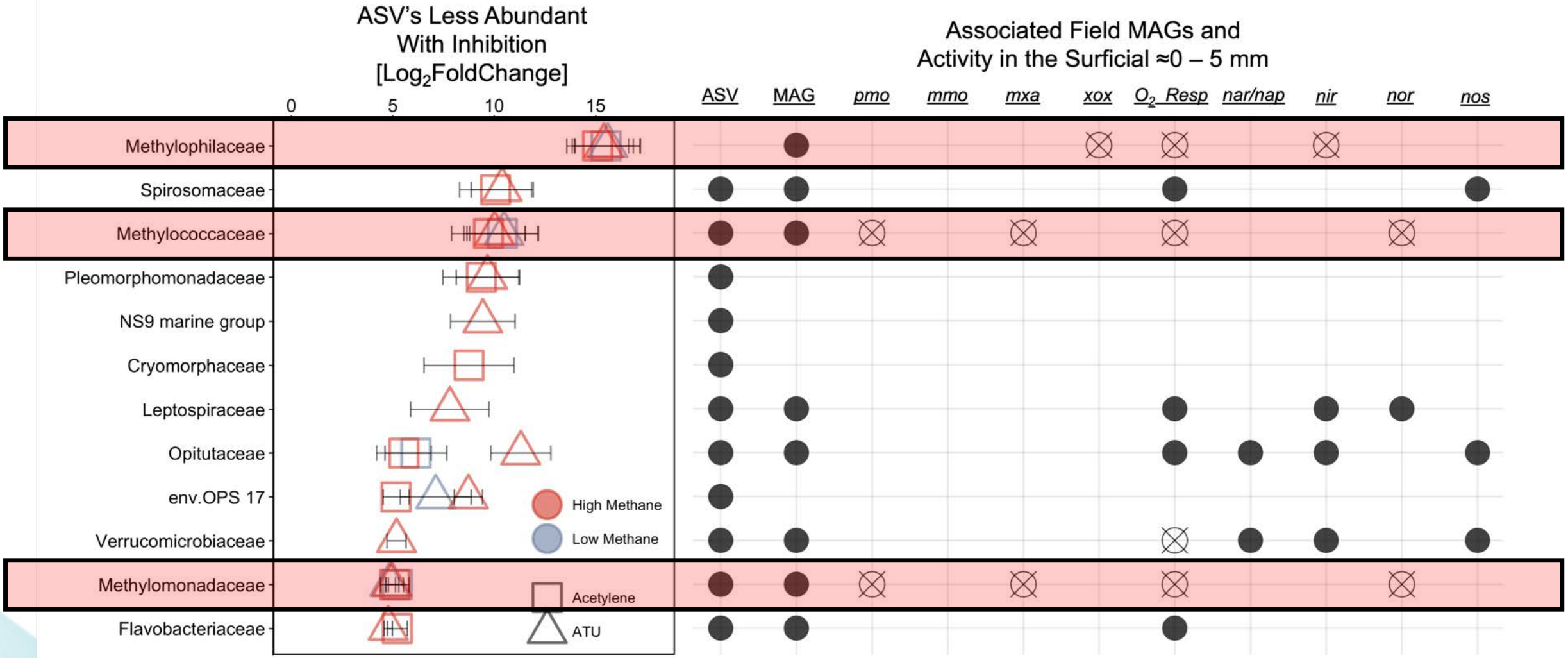


Vega *et al.* (2023) [ES&T]



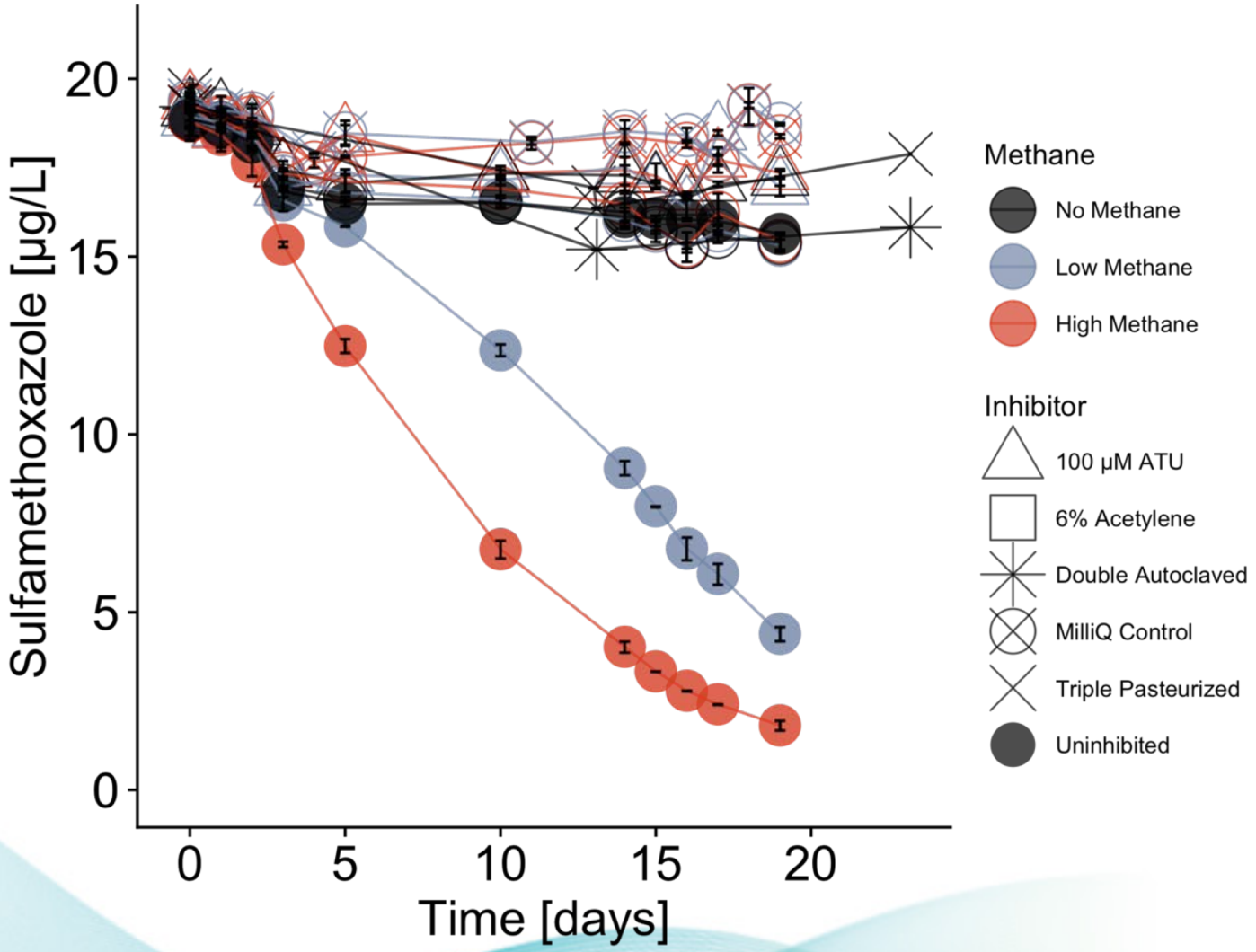
Note: *mmoXYZ* transcripts not detected

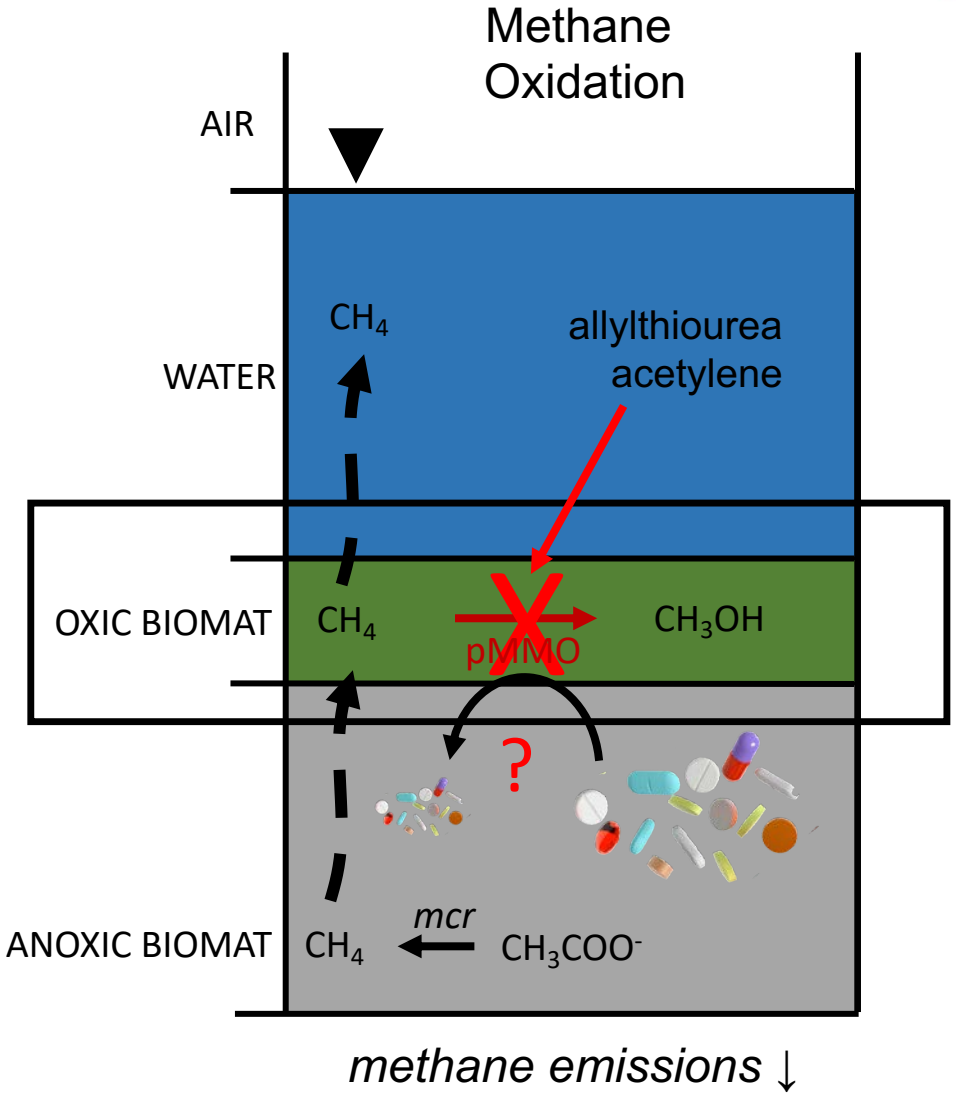
Methanotrophs and Methylotrophs are More Abundant Under Methane-Oxidizing Conditions



Vega *et al.* (2023) [ES&T]

Methane oxidation (pMMO) promotes SMX biotransformation

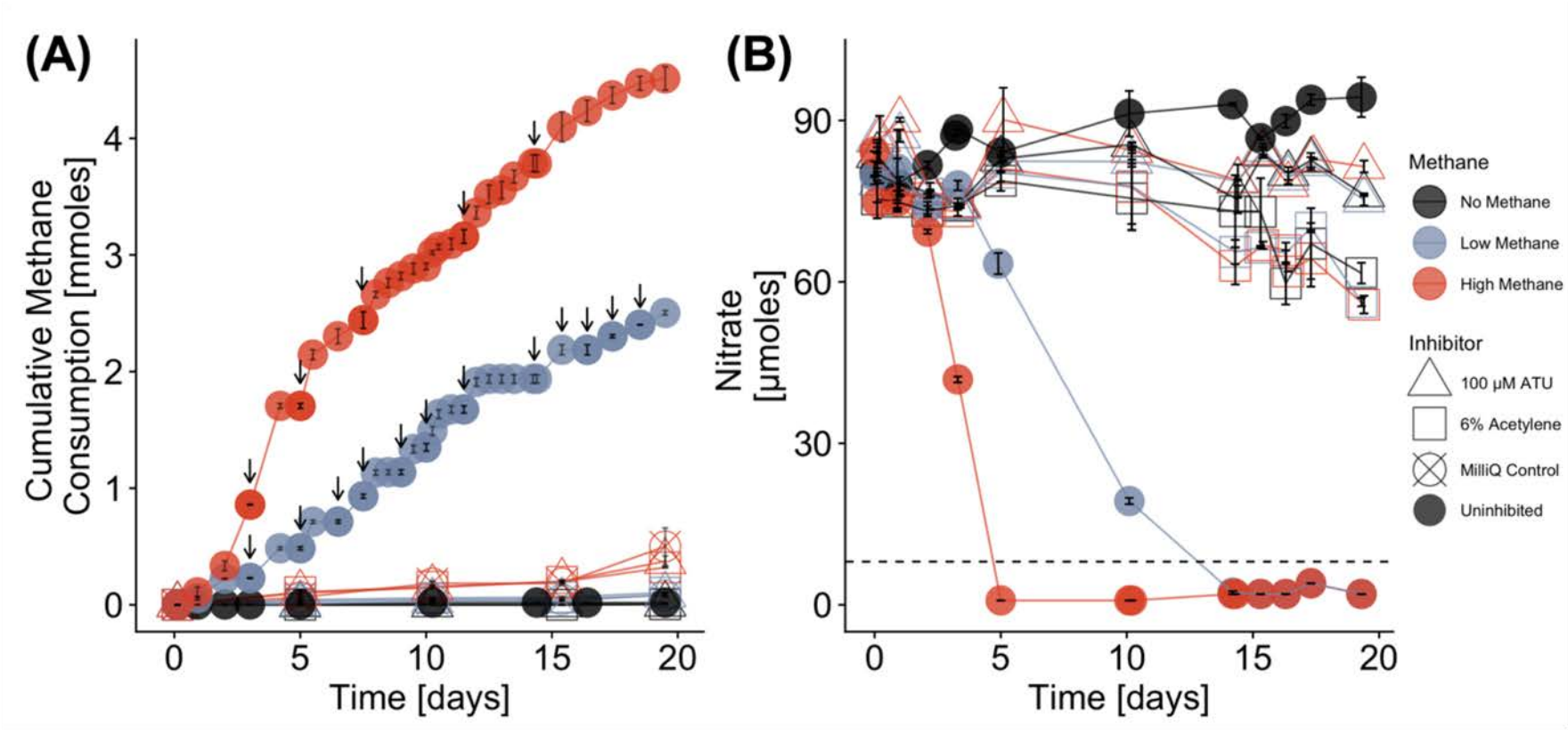




methane emissions ↓

Vega *et al.* (2023) [ES&T]

Methanotrophic activity also increases nitrate removal: consistent with assimilation (or methylotrophic denitrification)

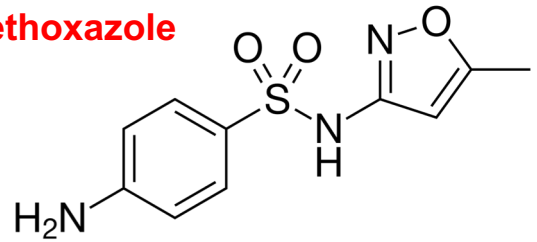


Vega et al. (2023) *ES&T.*

$NO_3^- + 17CH_4 + H^+ + 26O_2 \rightarrow C_5H_7O_2N + 30H_2O + 12CO_2$

Conceptual model: Microbial biogeochemical cycling promotes SMX attenuation

sulfamethoxazole



Transformation pathway unresolved: Detected N-acetyl-SMX but not 4-nitro-SMX, 4-nitroso-SMX, hydroxy-nitro-SMX, or 4-hydroxy-SMX

oxic

CO_2

NO_3^-

CH_4

Methanotroph (pMMO)

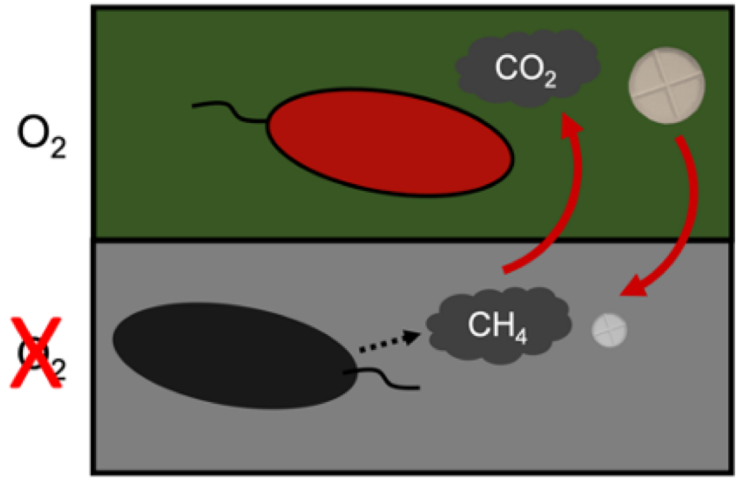
anoxic

mcr

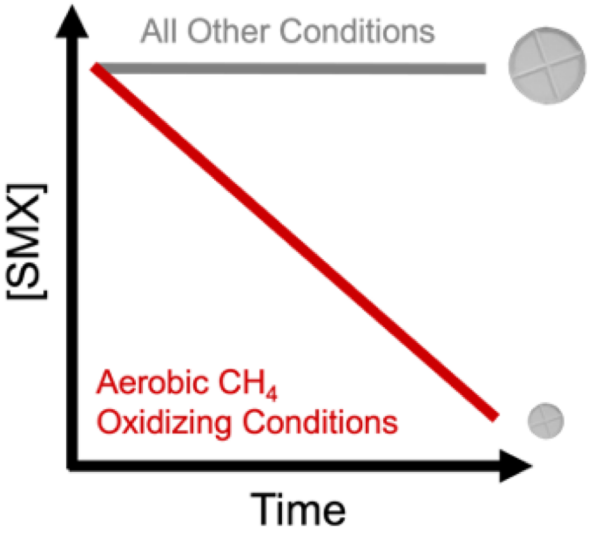
CH_4

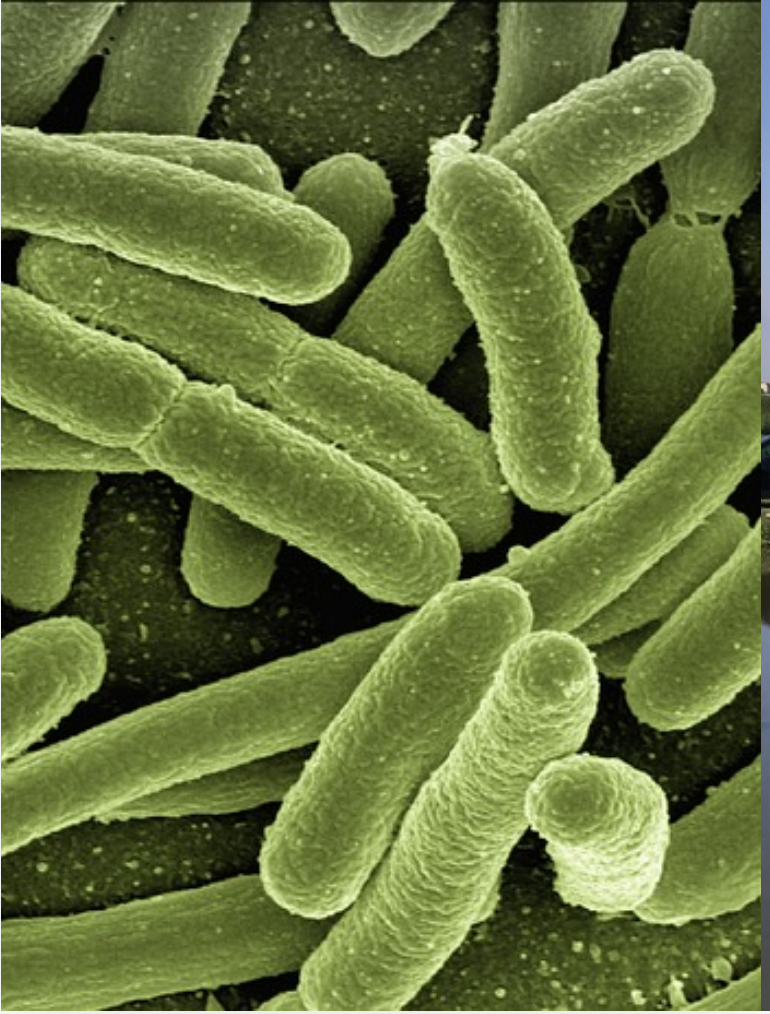
Methanogen

Field Associations

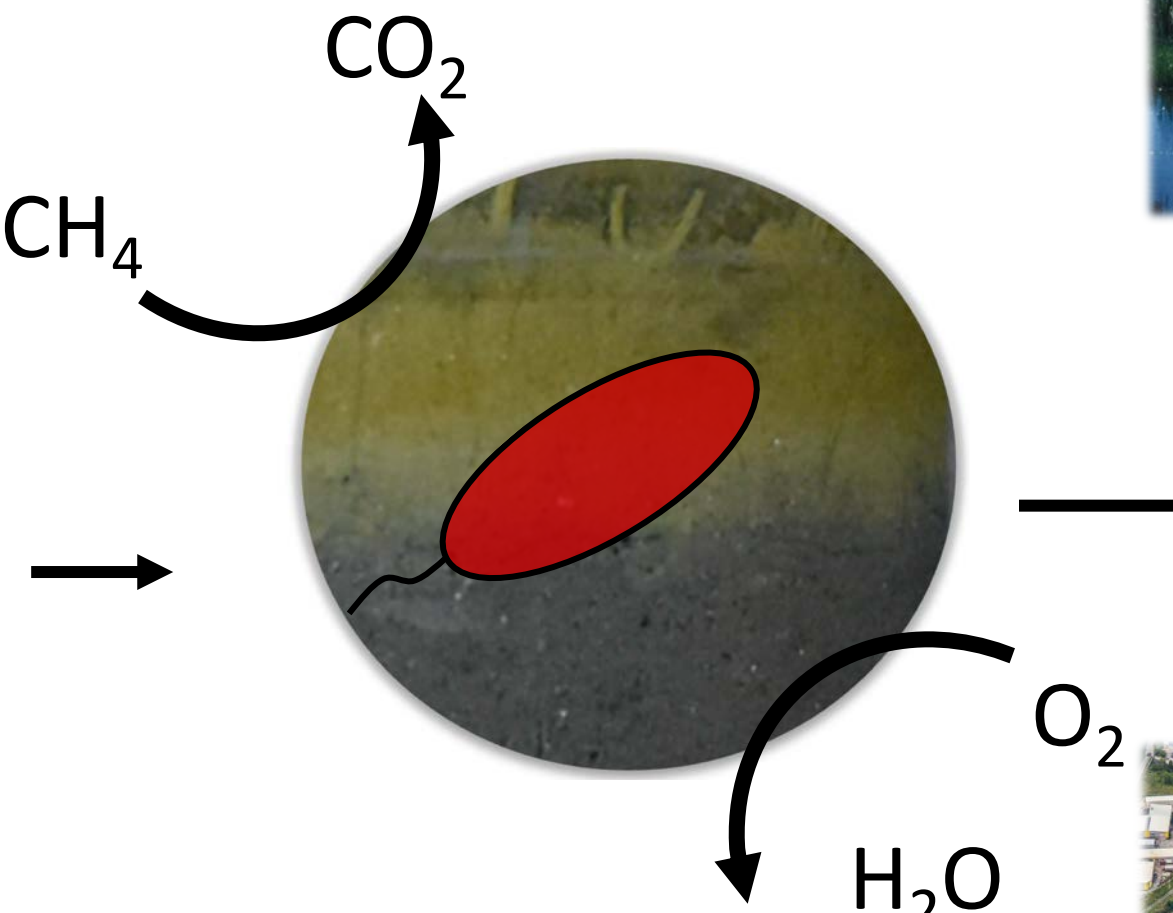


Microcosms





Can we use this approach to more effectively construct and/or manage metabolically rich and diverse systems for desirable biodegradation processes (e.g. GHG, nutrients and recalcitrant organics)



Could methane-oxidation accelerate pharmaceutical attenuation in other natural and engineered systems?

Acknowledgements

- ReNUWIt NSF ERC
- Orange County Water District
- The Joint Genome Institute
- The National Institutes For Water Resources
- United States Geological Survey
- Collaborators

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THE NATIONAL INSTITUTES FOR WATER RESOURCES

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science for a changing world

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ORANGE COUNTY WATER DISTRICT
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Methane-Oxidizing Activity Enhances Sulfamethoxazole Biotransformation in a Benthic Constructed Wetland Biomat

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Article

Pharmaceutical Biotransformation is Influenced by Photosynthesis and Microbial Nitrogen Cycling in a Benthic Wetland Biomat

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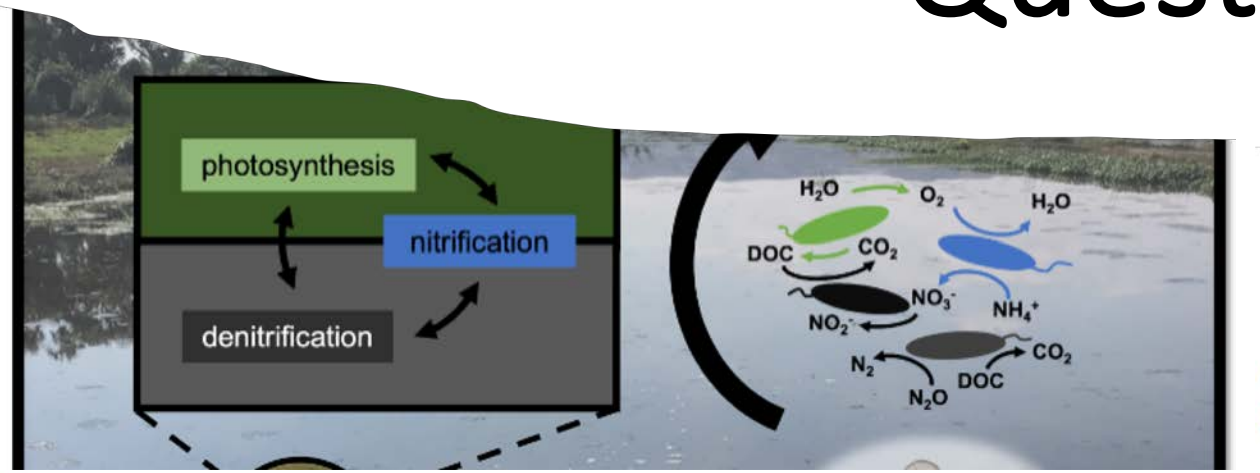
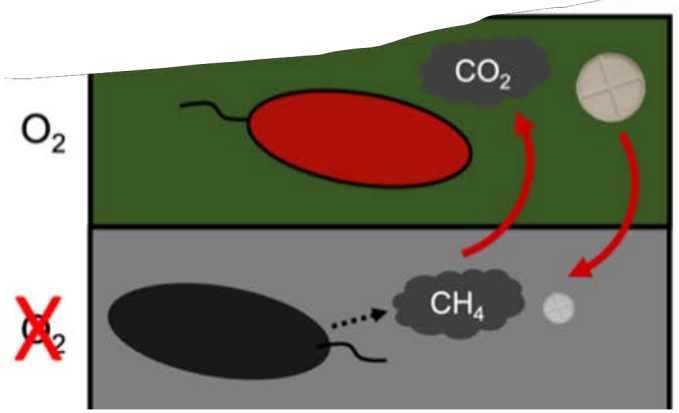
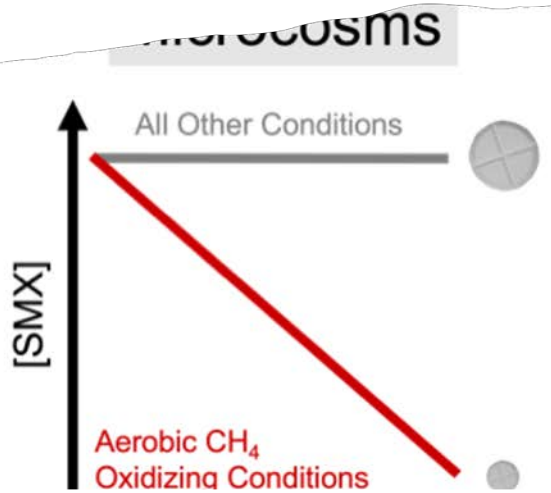
Questions?







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