Challenges and Opportunities for Urban Seas in the Face of Global Change

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Photo credit: Marinas.com

A Challenge

- Many Urban Seas contain legacies of pollution that persist despite improvements in “water quality”
- Climate pressures may prevent restoration actions from being fully realized
- There are engineering solutions to these challenges, but we know little about their **scalability,** **unintended consequences**, and **resilience/durability**

A Global Challenge

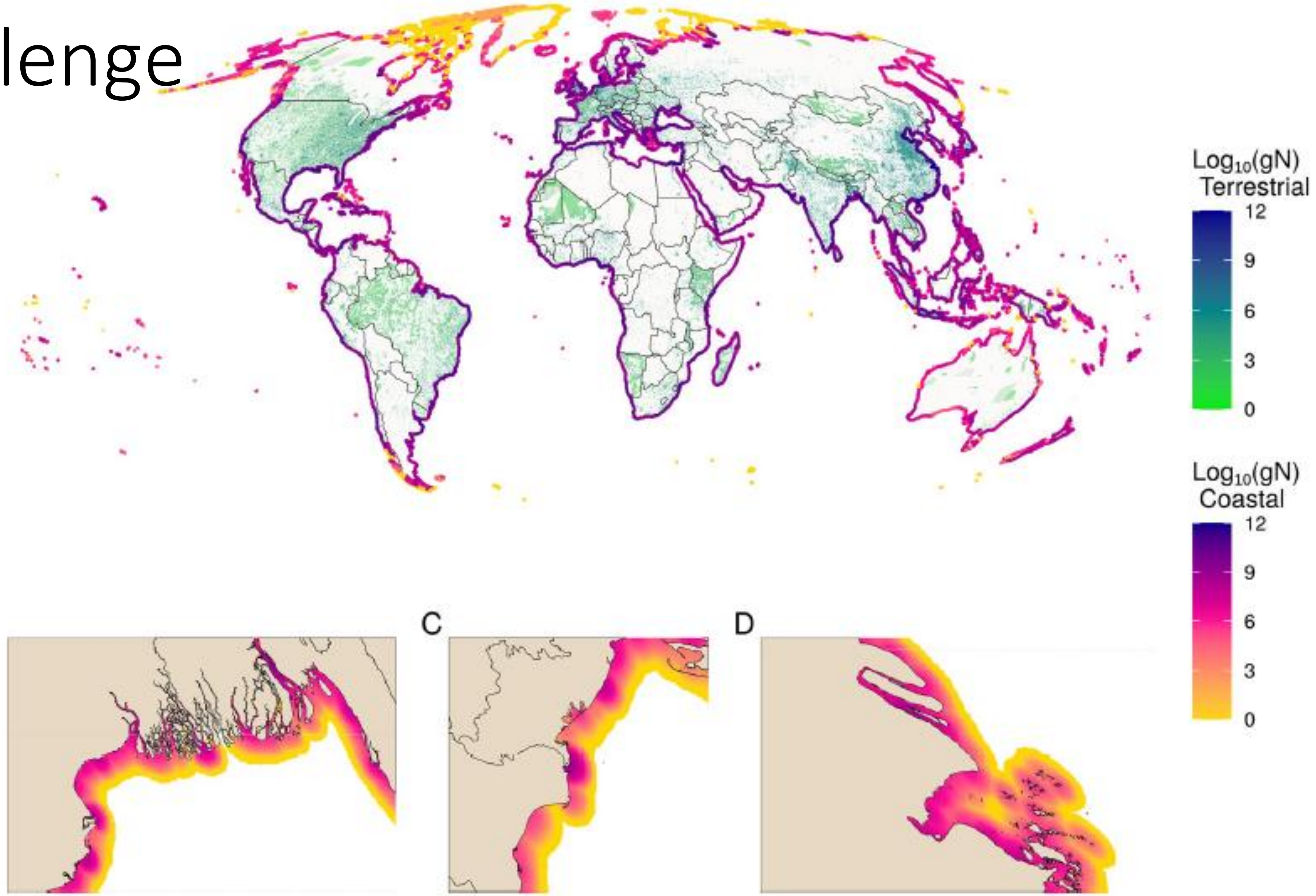
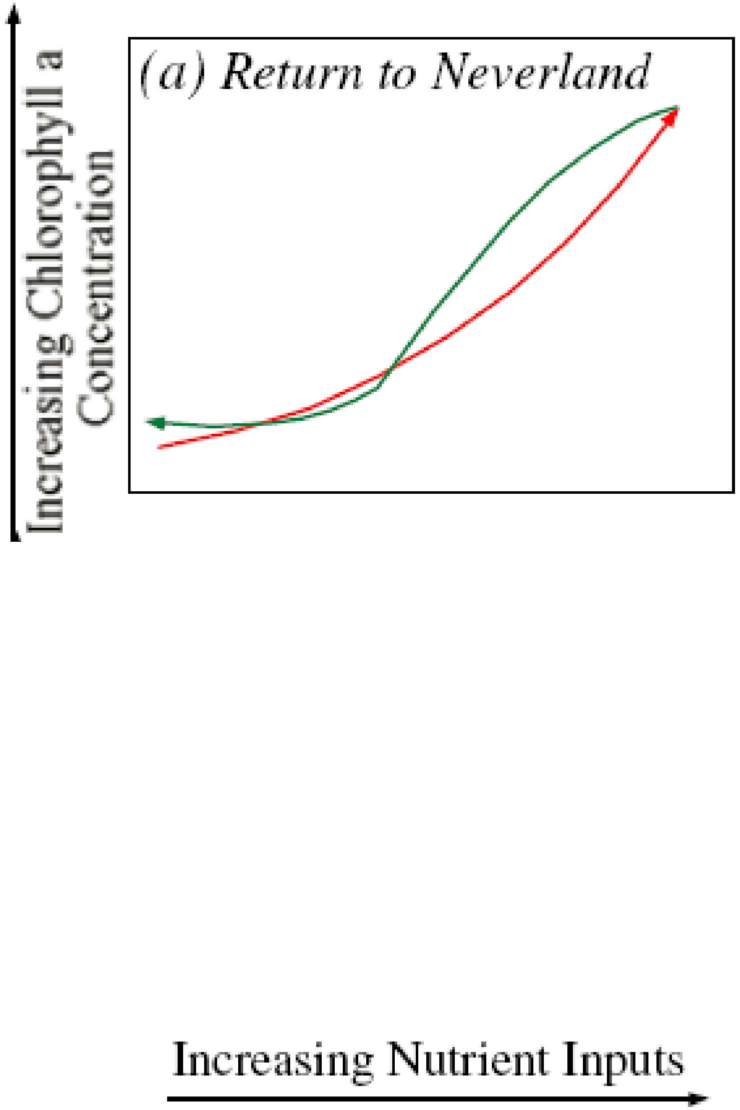


Fig 1. Global distribution of total wastewater N. A) Global map of the terrestrial sources (green to blue) and coastal diffusion of inputs (yellow to purple) of total wastewater N, measured in log10(gN) in both. Coastal plumes have been buffered to line segments to exaggerate patterns to be visible at the global scale. Insets show zoomed-in views of the B) Ganges, C) Danube, and D) Chang Jiang (Yangtze) Rivers, showing wastewater plumes at high resolution.

Tuholske et al. 2021

Ecosystem Recovery Trajectories

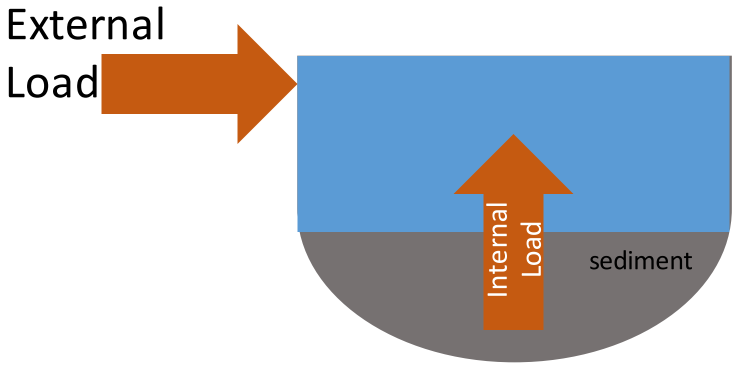


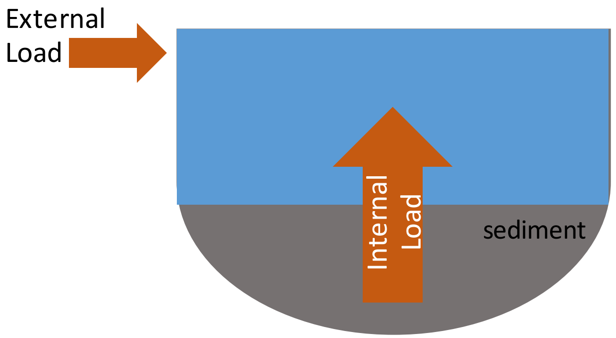
Duarte et al. 2009

- As we seek to 'restore' ecosystems, we envision an overly pathway to recovery back to some previous condition
- But physical, chemical, and biological processes in the system have been disrupted, and climate is changing
- Why? Warming, altered landscapes, legacy pollutants, etc.

How Do We *Unlock* Urban Seas From Degradation?

Are there lags in ecosystem recovery due to legacy nutrient inputs from sediments?





Endless summer: internal loading processes dominate nutrient cycling in tropical lakes

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Internal Phosphorus Loading in Shallow Lakes: Importance and Control

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DELAY IN LAKE RECOVERY CAUSED BY INTERNAL LOADING

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The Eutrophication of the Baltic Sea has been Boosted and Perpetuated by a Major Internal Phosphorus Source

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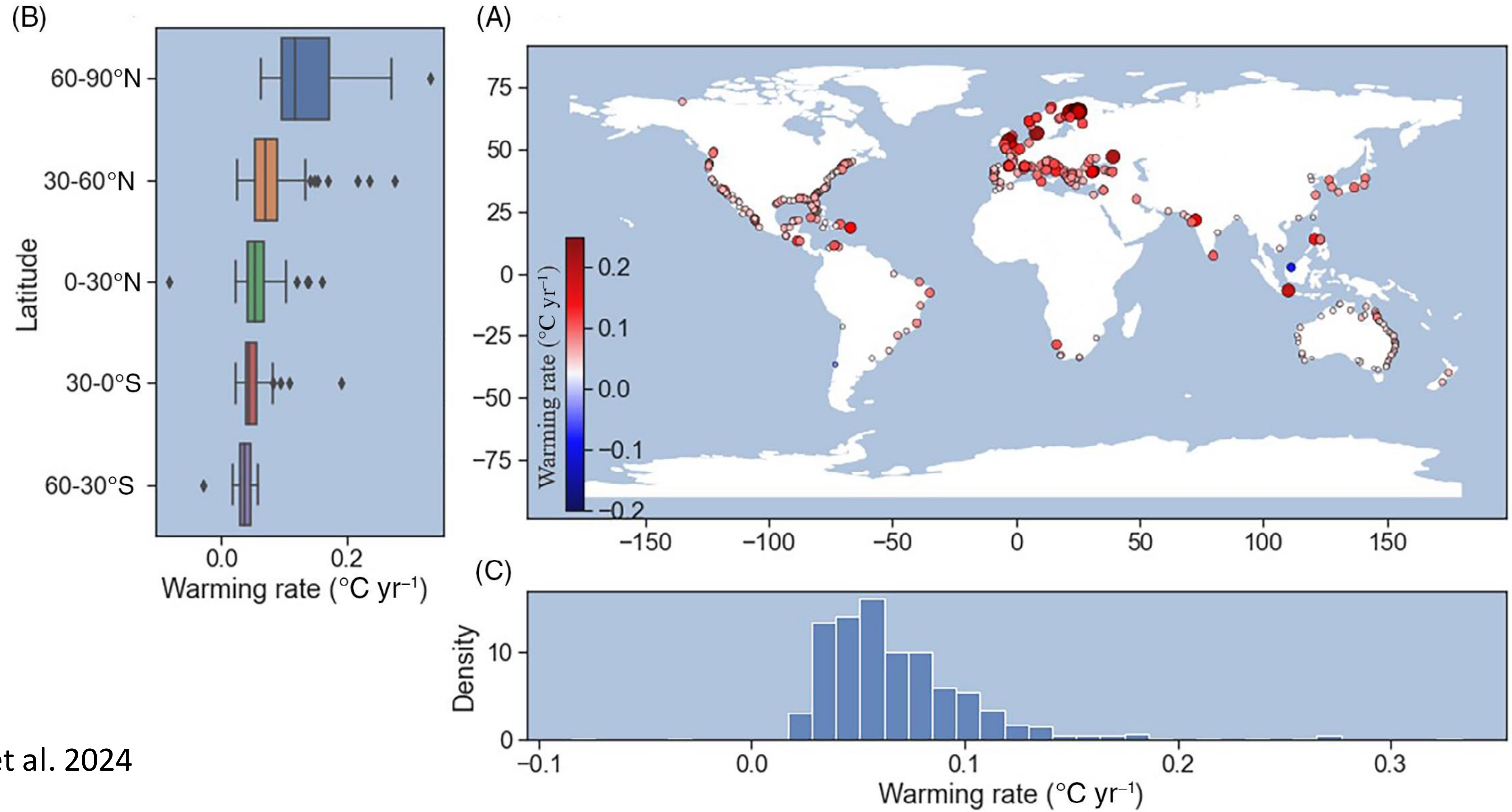
How Do We *Compensate* for Altered Climate?



Prum et al. 2024

Engineering the Sea?

We already engineer land. All of the time. We are comfortable engineering the land because we do it in our daily lives.

In the face of increasingly expensive nutrient reductions and climate, what other tools do we have to super-charge restoration?

There are limits to engineering, unintended consequences, requires scientific study

Many of these activities are already occurring. In some ways, the train has left the station. How can the scientific community keep up?

Engineering the Sea Example 1: Floating Wetlands

WHY?

- Traditionally used in storm water retention ponds
- Tissue nutrient uptake, potential for denitrification
- Provide habitat, shoreline protection, aesthetic value

Problems?

- How well do they work?
- Do they last?
- Can they be scaled up reasonably

Liverpool; www.biomatrixwater.com

Lake Washington, Seattle; https://www.portseattle.org/projects/floating-wetland

Boston Harbor, https://emerald-tutu.com/about

Baltimore, MD Inner Harbor

Engineering the Sea Example 2: Oxygenation

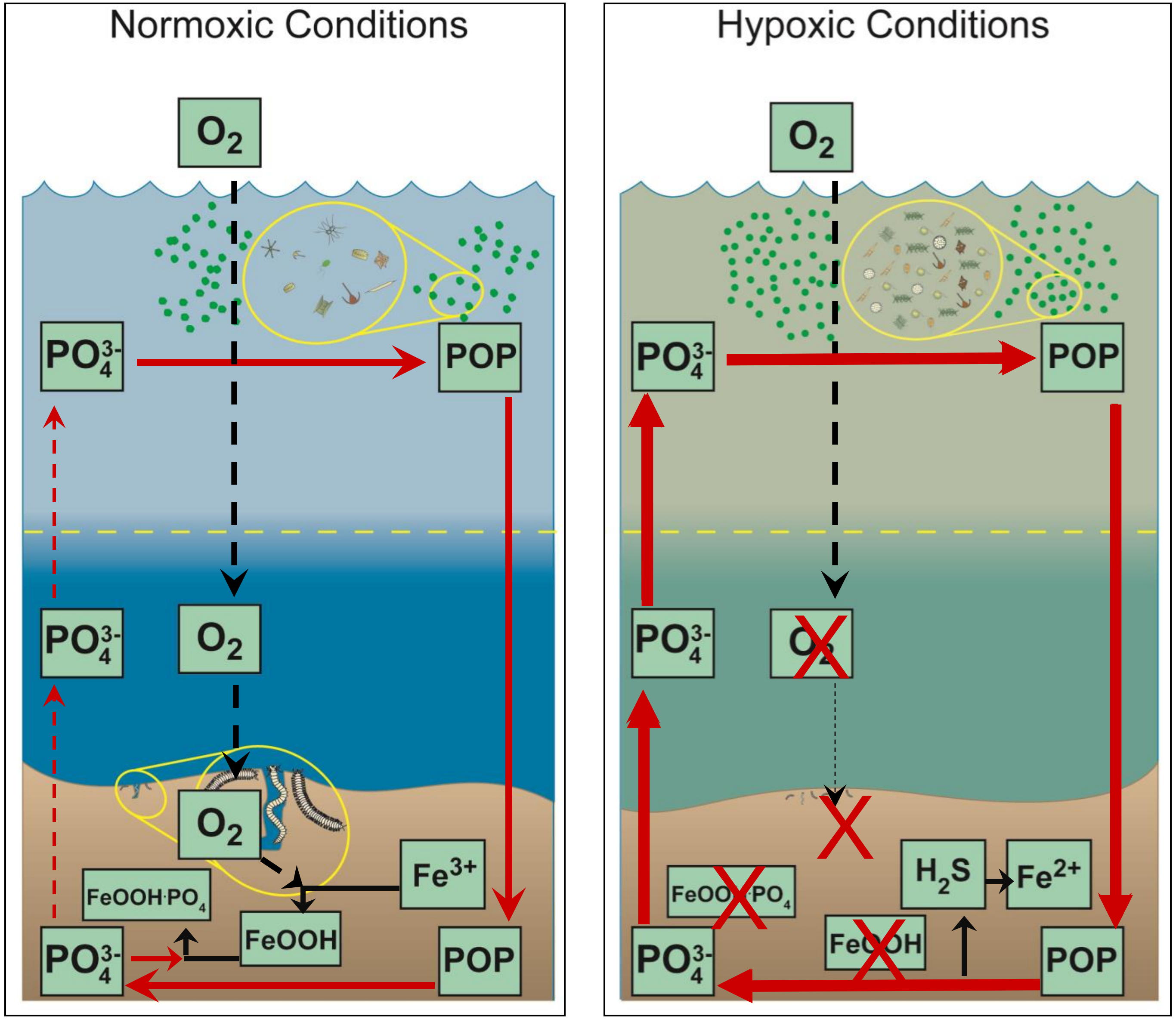
WHY?

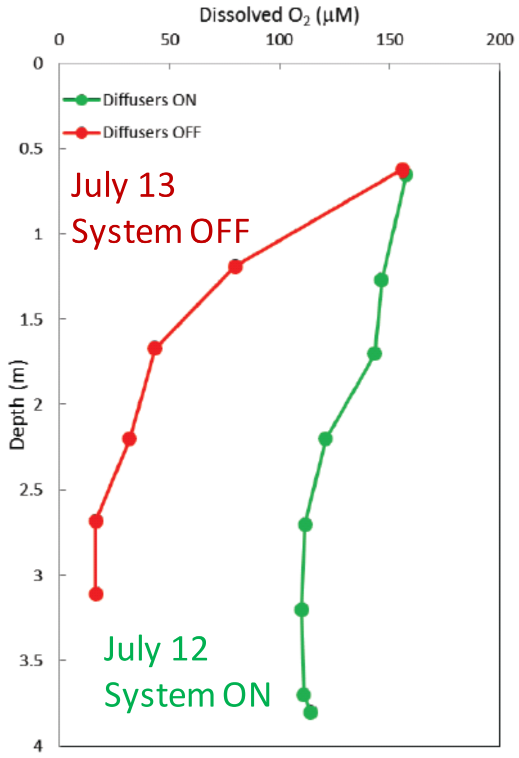
- Oxygen depletion can enhance nutrient recycling
- Highly polluted areas difficult to restore
- Warming will push oxygen lower

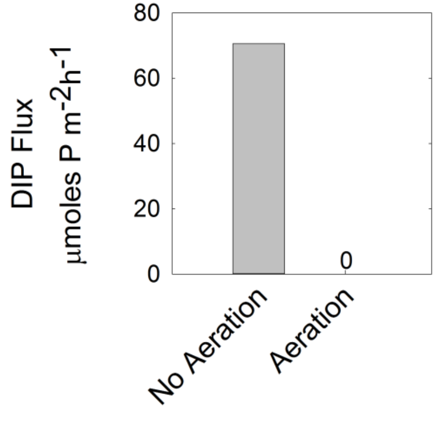
Problems?

- How well do they work?
- Do they last?
- Can they be scaled up reasonably?
- Do they have unintended consequences?

The So-Called “Viscous Cycle”







The technology is already being applied at scale, can we better understand it in the coastal zone?

What Works

Aeration and Oxygenation Methods for Stratified Lakes and Reservoirs

Barry Moore, Mark Mobley, John Little, Bob Kortmann, and Paul Gantzer

Introduction – *Barry Moore*

"The earth is like a spaceship that didn't come with an operating manual."

~ *R. Buckminster Fuller*

Buckminster Fuller was a great visionary thinker, architect, mathematician, and inventor. He is probably best known for the geodesic

intended, which summarizes collective efforts of lake scientists, at least up to 2005, to provide operating guidance for lakes. But for both in-lake and watershed management technologies, we are far from a standardized "cook book," with prescriptions for lake and reservoir design, operation, and maintenance.

Hypolimnetic Aeration and Oxygenation – *Barry Moore*

oxygenation (HO). However, both HA and HO project numbers are far short of the situations where these technologies may be appropriate. Economics undoubtedly plays a role in this disparity, but the situation is starting to change, with more economical means for oxygen delivery, and because we are learning to better match system design with individual lake requirements. While oxygenation systems still do not come with an operating

Evaluating hypoxia alleviation through induced downwelling

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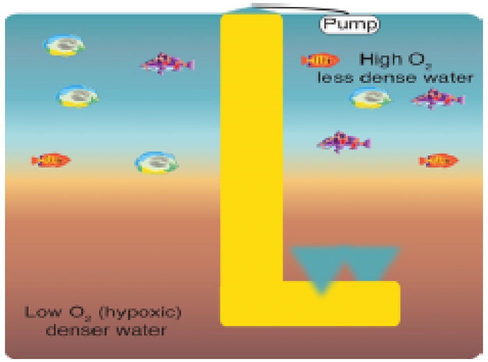
HIGHLIGHTS

- Downwelling may be up to 10^2 times more efficient than aeration at adding oxygen to hypoxic water bodies
- A field experiment showed some success at localized hypoxia mitigation and areas for improvement
- 0.4 to 4 MW per cubic kilometer of water, or 50 to 500 US dollars per cubic kilometer per hour, could avert regional hypoxia
- Capital costs, operating costs, and potential side effects may decrease the value of downwelling

GRAPHICAL ABSTRACT



Recommendations

- There are opportunities to advance the science, engineering, and application of technology to restore urban tidal waters
- Given that the private sector is advancing, the scientific community needs to keep up. We are in the midst of this for carbon dioxide removal
- Of course, social science questions abound with these solutions, given the trade-offs that will need to be made and the potential impacts