2017 Estuary Research Workshop-
Limiting Factors Beyond Nitrogen

New England Interstate Water Pollution Control Commission
Estuarine Phosphorus Limitation: Examples, Impacts, and Trends

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How did this workshop come about?

• NEIWPCC started an annual Estuary Research Workshop in 2016.

• The afternoon session included an “Open Space” format where individuals could suggest discussion topics.

• For the third and last round, I, being slightly provocative, suggested the topic “Should We Worry About Phosphorus (P) in Estuaries?” (Or, can phosphorus be the limiting nutrient?) This generated an interesting discussion among the participants.

• To my surprise, when the topic for the NEIWPCC 2017 Estuary Research Workshop was announced, it was a broader version of the same theme, or “Limiting Factors Beyond Nitrogen (N)”.

• However (spoiler alert), if this discussion of P limitation makes any of you nervous, the importance of both N and P in many environments will be emphasized.
Accelerating the Global Nitrogen (N) and Phosphorus (P) Cycles

Planetary Boundaries
(Stockholm Resilience Center)

1909 Haber-Bosch
Synthetic N fixation

N and P Fertilizer Use
Tilman et al., 2001
Coastal Hypoxia and HABs
(Harmful Algal Blooms)

Number of Global Hypoxic Zones
(Diaz and Rosenberg, 2008)

PSP Distribution
(WHOI, Redtide)
The 2017 Gulf of Mexico "Dead Zone" has an area of 8,776 square miles, equal to the area of New Jersey. This is the largest since measurements started in 1985, approximately 4-5 times the goal set by Rabalais and Turner (LUMCON/LSU). The graph shows the bottom-water area of hypoxia (D.O. ≤ 2 mg/L) from 1985 to 2017, indicating a persistent and significant issue in water quality.
Other current or historic impairments in New England Estuaries: Hypoxia, fish kills, loss of seagrass, HABs (PSP and others), benthic metabolism changes.
Early US Lake Remediation

1. Lakes Erie and Washington (Seattle) showed major cyanobacterial blooms by the 1960s. The original 1971 edition of Dr. Seuss’ *The Lorax*, contained the memorable lines:

“They’ll (the fish) walk on their fins and get woefully weary in search of some water that isn’t so smeary.” “I hear things are just as bad up in Lake Erie.”

2. Decreasing phosphorus (P) by upgrading treatment plants, banning P in detergents, or diverting outfalls improved water quality in the 1970s and 1980s. (The Lake Erie line was removed from the 1986 edition of *The Lorax.*)

3. But by the late 1990’s Lake Erie was showing signs of re-eutrophication despite declines in total P, bioavailable P was increasing.
Short History of N. American Nutrient Limitation Studies

1. In 1934, Alfred Redfield first enumerated what we now call the “Redfield Ratio” the consistent N:P molar ratio of 16:1 in many ocean waters and aquatic organisms. Nutrient ratios greatly different than 16 may be considered one indicator of nutrient limitation.

2. In the 1960s and 1970s David Schindler first conducted whole-lake fertilization experiments in the Experimental Lakes Area of Canada. His studies and many others have led to the idea that P is the limiting nutrient in lakes.

3. In 1971, Ryther and Dunstan, working on the South Shore of Long Island, showed that N was the major limiting nutrient. Many other studies in coastal regions have confirmed this, though Schindler criticizes such studies because they do not involve whole systems but instead rely on bottle incubations.
The N vs. P Debate

Though the P (freshwater) and N (marine) concepts of the major limiting nutrient are widely accepted, there are exceptions which we will discuss today. In many cases both are important. However, Schindler has recently doubled down and the debate continues!

Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment


PNAS, 2008

Controlling Eutrophication: Nitrogen and Phosphorus

Daniel J. Conley,1* Hans W. Paeli,2 Robert W. Howarth,3 Donald F. Boesch,4 Sybil P. Seitzinger,5 Karl E. Havens,6 Christiane Lancelot,7 Gene E. Likens8

Science, 2009

The authors of this Science rebuttal have been referred to as “Schindler’s List” and include our next two speakers.
Our speakers on “Schindler’s List”

Hans Paerl – The freshwater connection to estuaries

Bob Howarth – The coastal ocean connection to estuaries
Where are the coastal seasonally P-limited systems which have hypoxia and/or HABs? (Laurent and Fennel, 2017)
So What is a Northeast Estuary Manager to Do? (Should she or he worry about P?)

1. In many Northeast Estuaries N is declining or stable. As N declines, the possibility of P-limitation becomes less likely.

2. The manager should probably worry about P if they manage estuaries or embayments where N is increasing and may push the system into P-limitation, or if they also manage freshwaters, especially where cyanobacterial blooms are increasing with nutrients and warming.
3. Should they heed the EPA National Coastal Condition Assessment (NCCA) which suggests that P is more of a problem than N in Northeast coastal regions? Probably not as the current NCCA thresholds may need adjustment according to EPA. The P threshold appears too high, the present thresholds yield a molar ratio of 22:1 N:P.

4. In fact, both the EPA and European Union have recently advocated for dual nutrient control of both N and P.
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5. Perhaps the best approach is Integrated Watershed Management (IWM) as Paul Stacey will address in the last talk. “One size does NOT fit all!”
Finally, I would be remiss if I did not acknowledge the contributions to both this field and this institution by the late Scott Nixon:
Questions?