The “Nutrient Conundrum”

Challenges and opportunities for managing eutrophication

Helen Jarvie, University of Waterloo.
How do we achieve food, water & energy security under increasing pressures from climate change - without impairing the quality and ecological status of our water resources?
Despite successes in global P distribution, profound inequalities remain:

- **Soil P surpluses** in North America, Brazil, China, Europe, linked to water quality impairment;
- **Soil P deficits** across 30% of global cropland, linked to poverty & food insecurity.
An increasingly fragmented P cycle

Mixed livestock and crop farming (where P was recycled locally) has given way to industrial-scale farming, dependent on large-scale P transfers from mineral reserves, to geographically distinct areas of grain and livestock production & cities.
A ‘conundrum’ of simultaneous P deficiencies and P excesses...

- Large transfer distances preclude P recycling
- Breakdown in the P cycle
- Increased dependence on cheap inorganic P fertilizers (non-renewable rock P reserves)

...Poor P use efficiency, which impairs water quality, limits water use, and threatens water & P security.

Jarvie et al. (2015) JEQ.
Continued chronic release of legacy P may mean a long wait for downstream water-quality improvements...

Indicative legacy P storage timescales

Soil/hill slope (c.5-30 yr)
In-channel (<1 yr)
Riparian/floodplain (<1-1000 yr)
Groundwater (<1-50 yr)
Lakes (c.5-30 yr)

Journal of Environmental Quality

Water Quality Remediation Faces Unprecedented “Legacy Phosphorus”
Helen P. Jarvie, Andrew N. Sharples, Bryan Spears, Anthony Buda, Linda May, and Peter J. A. Kleinman

Phosphorus Legacy: Overcoming the Effects of Past Management Practices to Mitigate Future Water Quality Impairment
Andrew Sharples, Helen P. Jarvie, Anthony Buda, Linda May, Bryan Spears, and Peter Kleinman
River Thames: 80-year P record

Total-P

Population increases:
Increasing sewage effluent discharges

1991: Urban Wastewater Treatment Directive:
upgrades to sewage treatment
Accumulation and drawdown of Legacy P in our watersheds is directly linked to food production & consumption - imports & exports of P as fertilizer, feed, crop and livestock products - and urbanization.
In-stream ‘Legacy’ P retention & source apportionment

By not accounting for in-stream P retention & remobilisation,

Illinois River at the state line between Arkansas & Oklahoma
Nutrient cycling along the aquatic continuum

'Taking the lab. into the field': Application of high-frequency *in-situ* hydrochemical monitoring technologies to explore nutrient cycling processes
Biogeochemical & climate drivers of legacy nutrient release at the land-water interface

Wetland-pond at the University of Oxford’s Wytham field station, S. England.

Part of the U.K.’s Environmental Change Network monitoring network.

Long-term behavior of wetlands and ponds as ‘nature-based solutions’ for flood management and soil and water conservation.
‘Memory’ effects of antecedent climate drivers: accumulated legacies of organic matter from previous years’ biomass production

Jarvie et al. (in press), J. Environ. Qual.
High-resolution (hourly) *in-situ* monitoring of wetland nutrient release processes

Temperature drives short-term (day-to-day) variability in P release

...but subdaily (diurnal) variability in P release is driven by water-body metabolism (the balance between primary production & respiration)
Implications for nutrient legacies & stream eutrophication risk

- Water-quality tradeoffs: climate and biogeochemical drivers mobilize legacy P & N, causing water-quality impairment & accelerating stream eutrophication risk;
- Climate change has potential to increase the magnitude & frequency of wetland nutrient release events.
Coupling biological processes, nutrient cycling, and eutrophication along the land-river continuum

- Macronutrients:
  - Phosphorus (P),
  - Nitrogen (N)
  - Carbon (C)
- Light
- Water temperature
- Flow conditions

Redfield ratio (106C:16N:1P)

Gross Primary Production: Grand River, ON

- P-depleted relative to N and/or C
- N-depleted relative to P and/or C
- C-depleted relative to N and/or P
- P and N co-depleted relative to C
- N and C co-depleted relative to P
- P and C co-depleted relative to N

Redfield Zone (approaching optimal C:N:P ratios for primary production)
‘Fingerprints’ of eutrophication: the role of P

UK headwater streams

UK rivers

Phosphorus and nitrogen limitation and impairment of headwater streams relative to rivers in Great Britain: A national perspective on eutrophication

Helen P. Jarvie a*, Douglas R. Smith b, Lisa R. Norton c, Francois K. Edwards a, Michael J. Bowes a, Stephen M. King a, Peter Scarlett b, Sian Davies c, Rachael M. Dils c, Nuria Bachiller-Jareno a
Changing fingerprints of eutrophication in Japan

~250 Japanese rivers & streams, sampled in the 1940s, 1950s & 1970s
The Nutrient Conundrum: Challenges....

- Simultaneous excesses & deficiencies;
- Build up of nutrient legacies along the land-water continuum.

- Chronic P release from legacy stores is a continuing source of water-quality impairment;
- Climate change has potential to accelerate legacy nutrient release.
Opportunities: Forging Societal Solutions...

Addressing the ‘nutrient conundrum’ requires collaboration across all sectors of society to increase nutrient use efficiency & secure synergies across food, bioenergy & water security sectors.

- Integrated soil, land and water management; legacy nutrient drawdown;
- P recovery and recycling to “reconnect our broken P cycle”;
- Wider nutrient governance across the entire food system.
Thank you

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