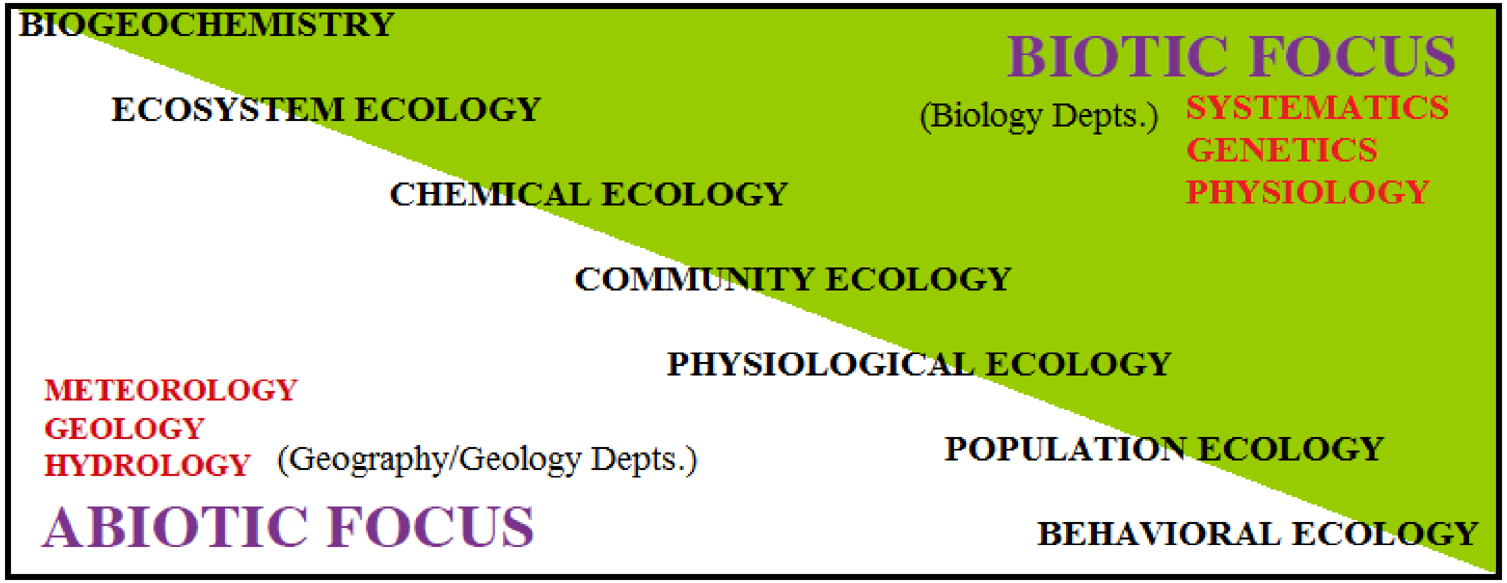
Phosphorus Legacy:
Overcoming the Effects of Past Management Practices to Mitigate Future Water Quality Impairment

Andrew Sharpley, et al. 2014

Presented by Eric Moore

Sub-disciplines in Ecology



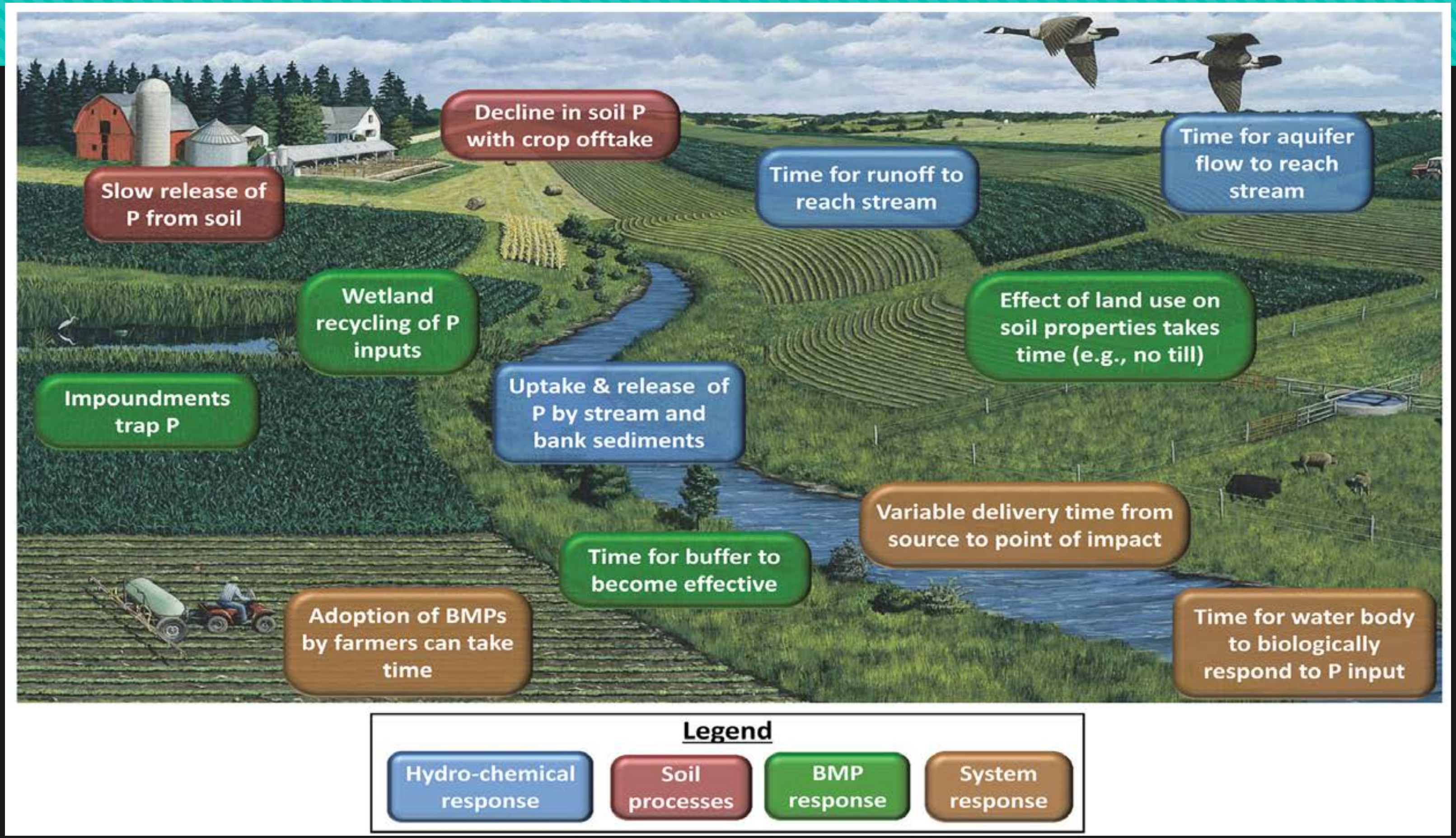
TAKEN FROM IDEAS DISCUSSED AT THE INSTITUTE OF ECOSYSTEM STUDIES, MILLBROOK, NY 1991

Three Types of Legacy Phosphorus

- Terrestrial – effect of land and nutrient management on the buildup of soil P beyond crop needs. Includes land use changes that affect connectivity of sources to rivers/streams
  - Controlled mostly by adsorption/desorption, precipitation/dissolution, mineralization/immobilization
- River – retention and remobilization of P through cascades and spirals, in drainage channels from the edge of fields to receiving standing water. Account for 10-80% of annual P flux
  - Deposition of *particulate P* as sediments, sorption of *dissolved P* onto sediments, uptake from water column by plants and microbes
- Standing water – (in lakes and reservoirs) deposition and remobilization of inorganic and organic P as functions of ecosystem drivers (residence time, water depth, extreme climate events)
  - Over the long term, sediment storage capacity can diminish, converting from sink to source

Lag time influenced by various processes

~1/2 year to many centuries



Approaches to Tracing Legacy P

- *cascade* (transport) of P from soil, to rivers/streams, then to oceans/coastal zones
  - occurs as a result of erosion, with soils losing P mostly as particulate (solid) P
  - Hotspots of Legacy P often found downslope, where water velocity slows and sedimentation increases

- biogeochemical *spiraling* (i.e., cycling during cascade) as water and sediment move “downslope and downstream”
  - Retention of dissolved P in wetlands, riparian/hyporheic zones, lakes, groundwater

Background

- Monitoring of water quality began decades ago in certain regions
- Some watershed management practices **20-30 years old**
- **$24 billion** invested in conservation measures in the between 2005-2010
- No “instant gratification” – **eutrophication** and **water quality worsened**
- Why?

Background

- **Legacy Phosphorus!**
  - Early land managers did not consider the importance of dissolved P transport via runoff/subsurface flow
- Sorption potential of P and amount of total P in most soils is much greater than dissolved P
- As saturation increases, P is then released

The Effect of Macronutrient Decoupling

Increased Carbon inputs

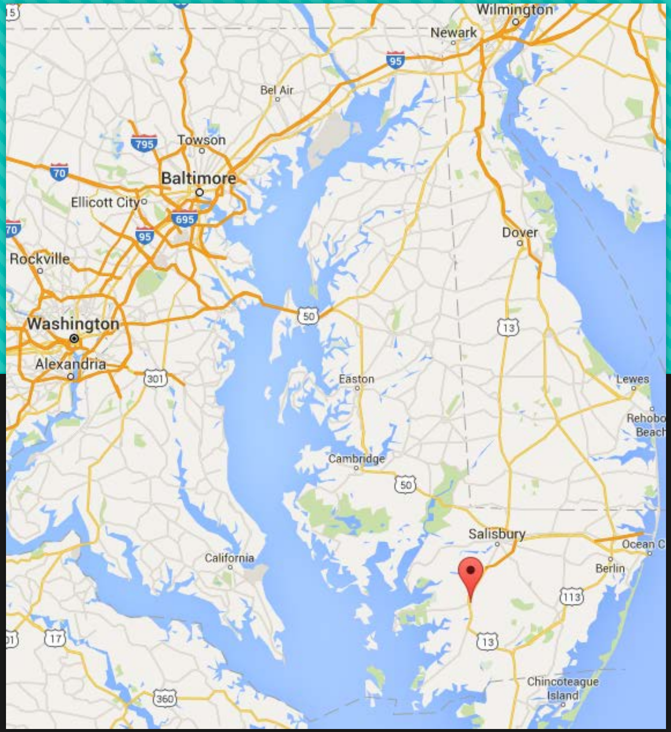
Higher rate of Microbial Respiration

Degradation of organic matter releases P, depletes O_2

Dissolution of Fe oxyhydroxides, releasing sorbed P

Case Study 1 - Terrestrial

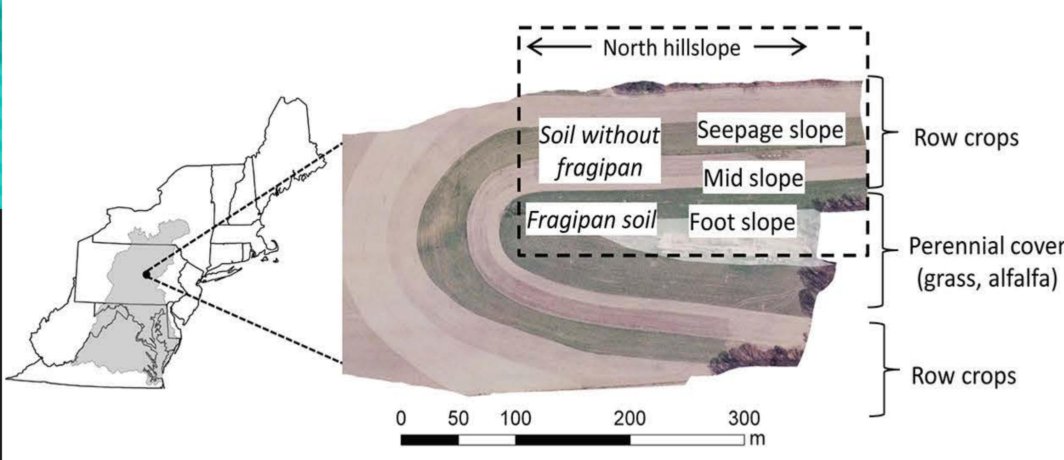
Legacy of Poultry Litter Management: Maryland



- High soil P as a result of 20+ years of poultry litter additions
- From 2000-2010, applications of three P-based rates of poultry litter were tested (no added P, crop P requirement, crop N requirement)
- Surface runoff monitored for first 5 years, soil sampled for entire duration
- No significant differences were detected for any measure of P (loss or extractable)
- Results seem to indicate that even with crop harvest and reduced application of P in fertilizer, it will take decades for soil to recover

Case Study 2 - Terrestrial

Hydrologic Mobilization of P on Hil Pennsylvania



- 2 year study of P losses in surface runoff
- Soil P in upslope row crops was 3x higher than required, while soil P in the riparian zone was near optimum
- Runoff volume of riparian zone was ~30 times greater than upslope, with ~3x more P load, BUT
  - Riparian zone runoff P concentration was nearly 6x <u>less</u> than upslope
- Riparian zone represented 6% of total area, but produced Legacy P yield equivalent to ~75% of watershed P loss
- Site hydrology can ultimately convert small amounts of P into major P loads

Case Study 3 - River

Legacy of Land Management P Export: Lake Erie Basin

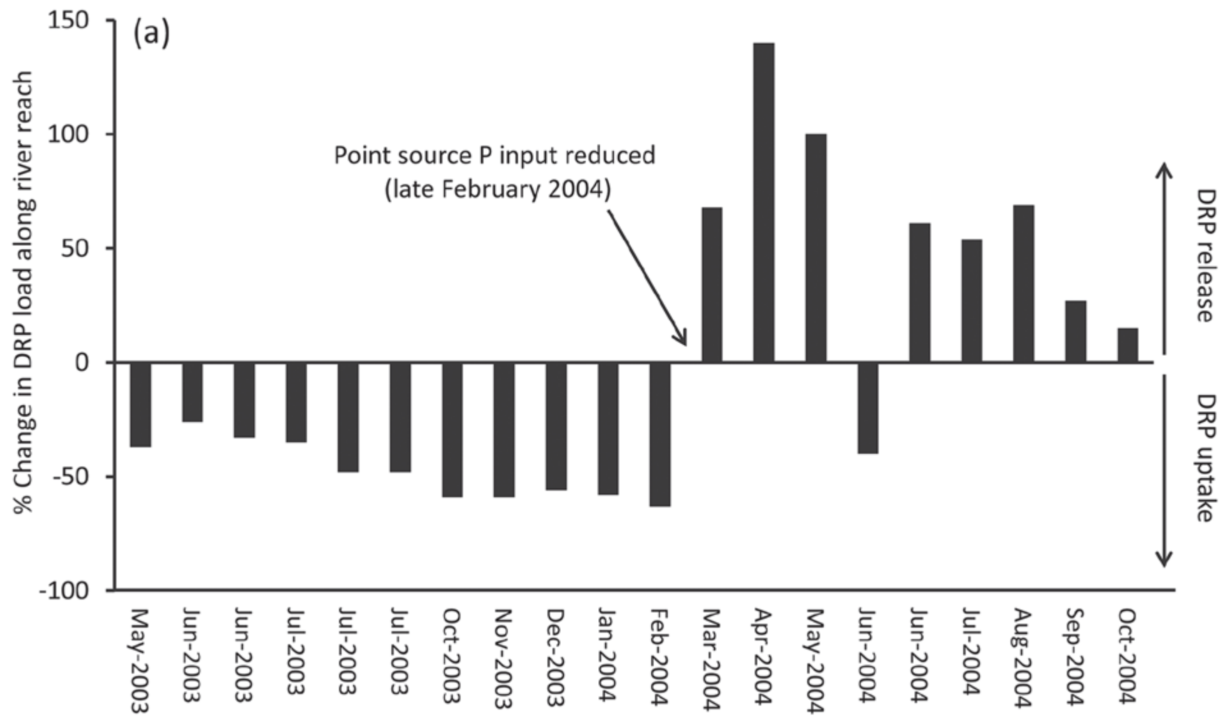
- P loads in 2 watersheds (Maumee and Sandusky river watersheds) since 1975; predominantly row-crops
- Conservation tillage and nutrient management planning adopted and studied
- From 1975-1995, mean annual flow-weighted dissolved P decreased 86%, and total P concentrations decreased 44%
- Since 1995, annual flow-weighted dissolved P concentrations have increased, but particulate and total P have declined
- Attributed to changes in rainfall distribution, legacy of chronic excess of P, a buildup of P at the soil surface after conversion to no-till methods, and increased manure application without incorporation into the soil during fall/winter
- Since 2005, tile drainage and legacy P input to Lake Erie has increased
- In 2010, dissolved P load was the highest it had been in 35 years

Case Study 4 - River
Short-term In-channel Fluvial P Legacies: River Lambourn, United Kingdom

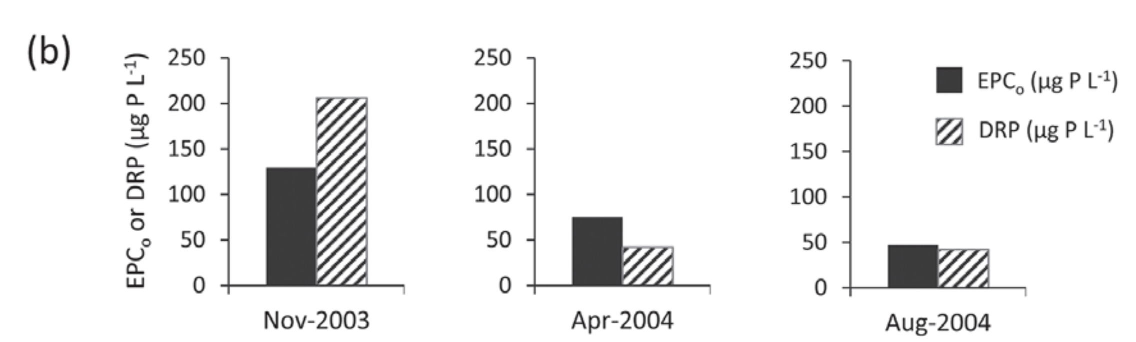
- Authors characterize the Lambourn River as a “relatively low-energy” stream
- The river had been exposed to a *point-source* input of P, which was “suddenly and dramatically” reduced
- River-reach mass balance and the sediment equilibrium P concentrations (EPC_0) were measured along 2.5 km of the river, before and after the point-source reductions
- Around 6 months after the point-source reduction, bed sediment EPC_0 values declined to equilibrium values of the rest of the river
- A higher flowing river with more active erosion would be expected to have a lag time shorter than 6 months, with more rapid removal of sediment as well

Case Study 4 - River

Short-term In-channel Fluvial P Legacies: River Lambourn, United Kingdom



a) Mass balance measurement, showing net loss of dissolved reactive P (DRP) in the water, due to net uptake of DRP by sediments; following reduction of P input, there is net release of DRP from sediments



b) EPC_0 measurements showing that bed sediments were net sinks during point-source P inputs, then became net sources of legacy DRP after point-source P reduction

Case Study 5

Legacy P and Lake Recovery after Remediation: Loch Leven, United Kingdom

- Shallow lake with a mean depth of only ~4 m, and a history of eutrophication
- Between the late 1970s and early 1990s, external P inputs were reduced by around 60%, by reducing inputs from a nearby mill (Phase 2), upgrading sewage treatment plants (Phase 3), and encouraging farmers to use less fertilizer and better management.
- Winter total P concentrations in-lake fell by 75%, and spring concentrations initially fell by 60%, compared to pre-management levels. However, summer concentrations *increased*
- The lowered winter, spring, and fall P concentrations, together with the increased summer P concentration, indicates a switch from external P loading to *internal* P loading (release of P from bed sediments the water column)

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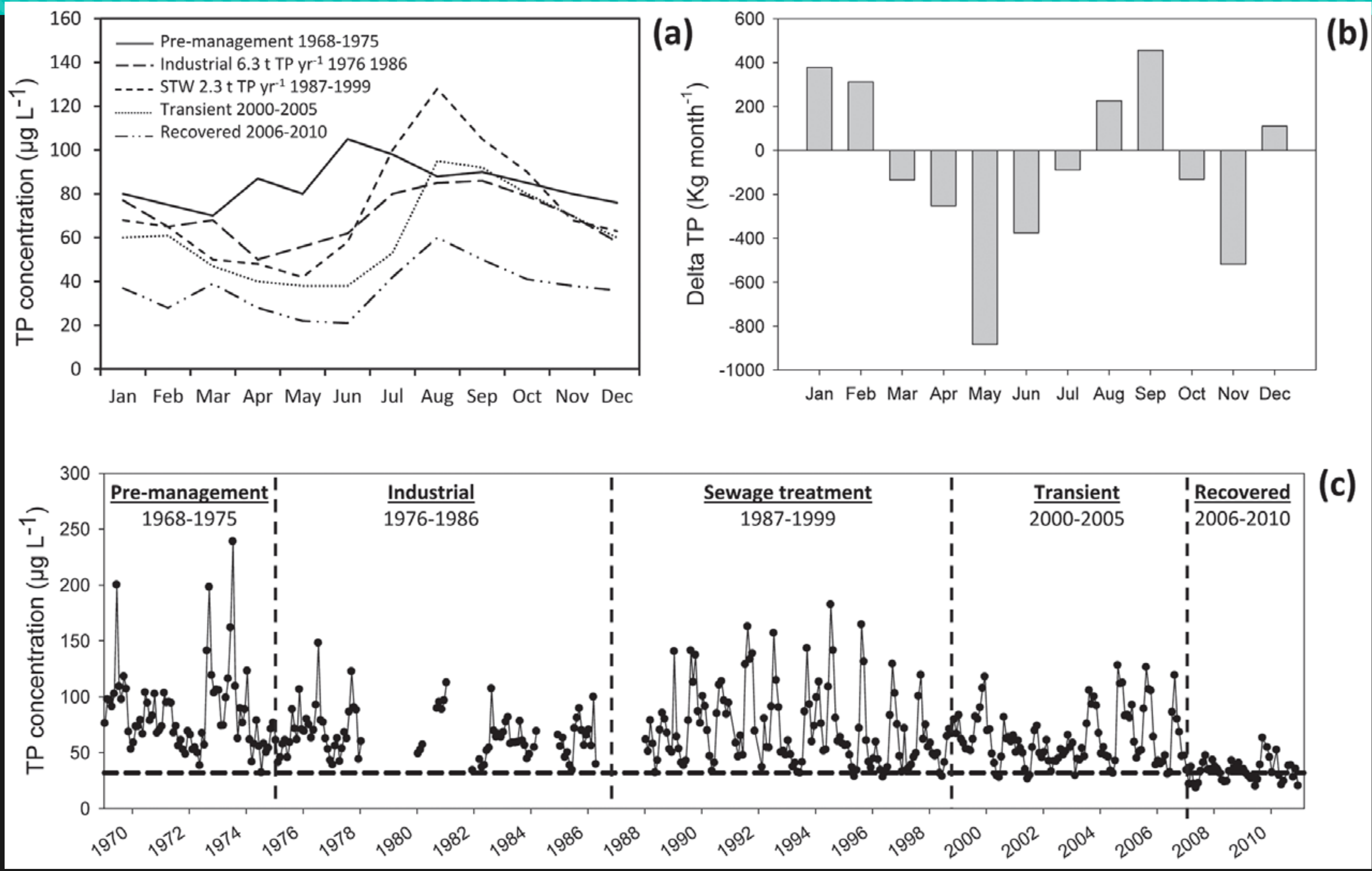

a) Changes in the mean monthly TP concentration during different Phases

b) Change in cumulative monthly downstream delivery of TP, post-management and pre-management. Positive values indicate losses from the lake

c) Long-term variation in monthly TP concentration from 1970-2010

Best Management Practices

- Discourage the loss of nutrients by retaining eroded soil, sediment, water, and nutrients, within the landscape
- Decrease the amount of P delivery to downstream environments and lessen the impact on water quality

- However, they can create long-term, continuing sources of Legacy P to receiving downstream environment
  - What’s better than a “Best” practice?

Questions for Discussion

- The Conowingo Dam in Pennsylvania has seen a 2 to 3-fold increase in P concentration in recent discharges, compared to similar discharges from the past, and is also 85% full with sediment. When dams like this are decommissioned, what impact do they have downstream, and how is this mitigated? What role do large tropical storms play?
- If the world suddenly decided to eliminate all excess P and fertilize plants based on their specific P requirements, which environments would improve the quickest, based just on Legacy P?
- How would Loch Leven have responded if it were significantly deeper than 4 m?