RIVERINE PROCESSES

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PLAN FOR PRESENTATION

- Provide some background information on nutrient transport in rivers
- Physical and biogeochemical processes that affect transformations and downstream transport
- Nitrogen and phosphorus – carbon
- General presentation – set the stage for later discussions

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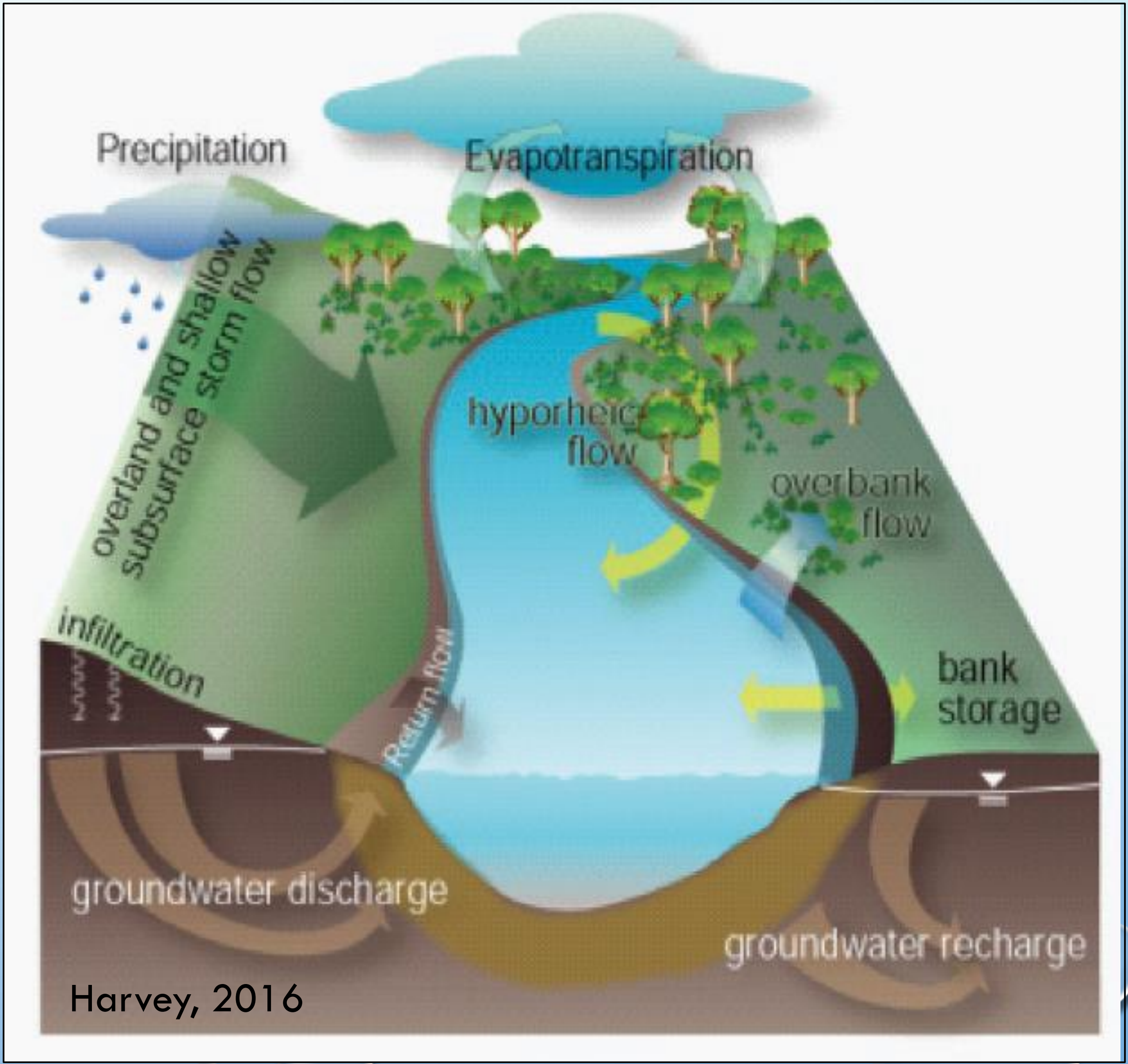
THE RIVERINE ENVIRONMENT

- **Dynamic** – mix of biogeochemical and hydrologic processes occurring
- **Complex –** several processes occurring at once, varying processes along the length of the channel
- **Source processes –** add nutrients to the river
- **Sink processes –** remove nutrients from the river
- **Estuarine perspective –** net transport of nutrients to the bay

HYDROLOGIC SETTING

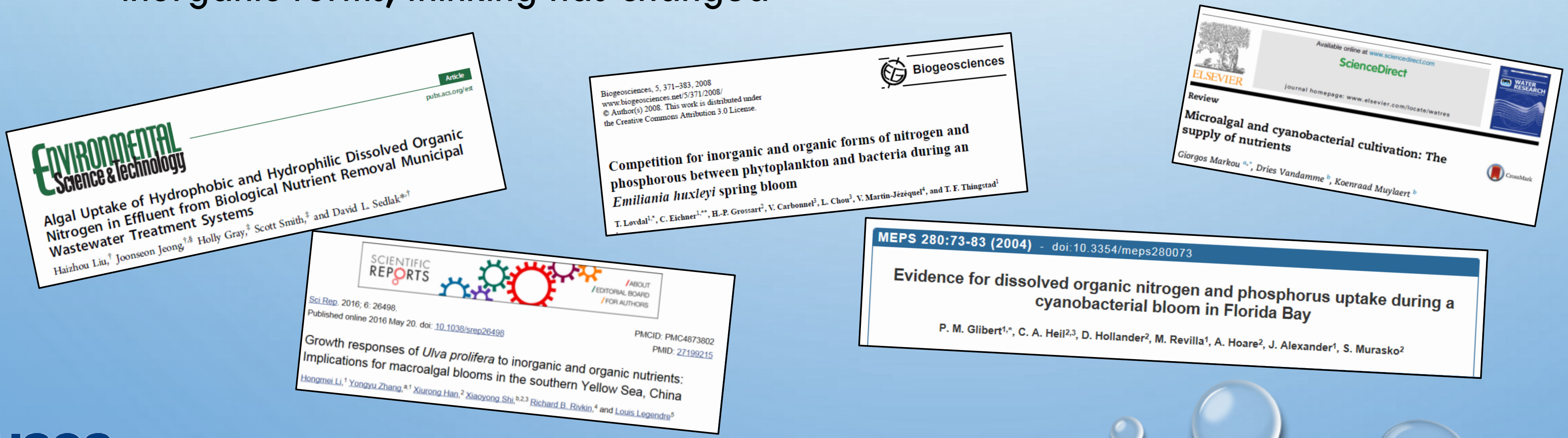
- Water entering the channel – tributaries, gw discharge, overland flow, unsaturated zone, direct precipitation, point sources
- Water leaving the channel – gw recharge, bank storage, overbank flow, withdrawals
- Exchange – hyporheic zone



Harvey, 2016

NUTRIENT FORMS

- Nitrogen – NO_3^-, NH_4^+, NO_2^-, DON, Particulate N (inorganic and organic)
- Phosphorus – Orthophosphate (PO_4^{3-}), DOP, Particulate P (inorganic and organic)
- Assimilation – uptake by plants, algae, bacteria, fungi, classic ecology, organisms take up the inorganic forms, thinking has changed


Environmental Science & Technology
Article
pubs.acs.org/est
Algal Uptake of Hydrophobic and Hydrophilic Dissolved Organic Nitrogen in Effluent from Biological Nutrient Removal Municipal Wastewater Treatment Systems
Haizhou Liu, Joonseon Jeong, Holly Gray, Scott Smith, and David L. Sedlak

Biogeosciences, 5, 371–383, 2008
www.biogeosciences.net/5/371/2008/
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Biogeosciences
Competition for inorganic and organic forms of nitrogen and phosphorous between phytoplankton and bacteria during an *Emiliania huxleyi* spring bloom
T. Løvdal, C. Eichner, H.-P. Grossart, V. Carbonnel, L. Chou, V. Martin-Jézéquel, and T. F. Thingstad

Available online at www.sciencedirect.com
ScienceDirect
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ELSEVIER
WATER RESEARCH
Review
Microalgal and cyanobacterial cultivation: The supply of nutrients
Giorgos Markou, Dries Vandamme, Koenraad Muylaert

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Sci Rep. 2016; 6: 26498.
Published online 2016 May 20. doi: 10.1038/srep26498
PMCID: PMC4873802
PMID: 27199215
Growth responses of *Ulva prolifera* to inorganic and organic nutrients: Implications for macroalgal blooms in the southern Yellow Sea, China
Hongmei Li, Yongyu Zhang, Xiurong Han, Xiaoyong Shi, Richard B. Rivkin, and Louis Legendre

MEPS 280:73-83 (2004) - doi:10.3354/meps280073
Evidence for dissolved organic nitrogen and phosphorus uptake during a cyanobacterial bloom in Florida Bay
P. M. Glibert, C. A. Heil, D. Hollander, M. Revilla, A. Hoare, J. Alexander, S. Murasko

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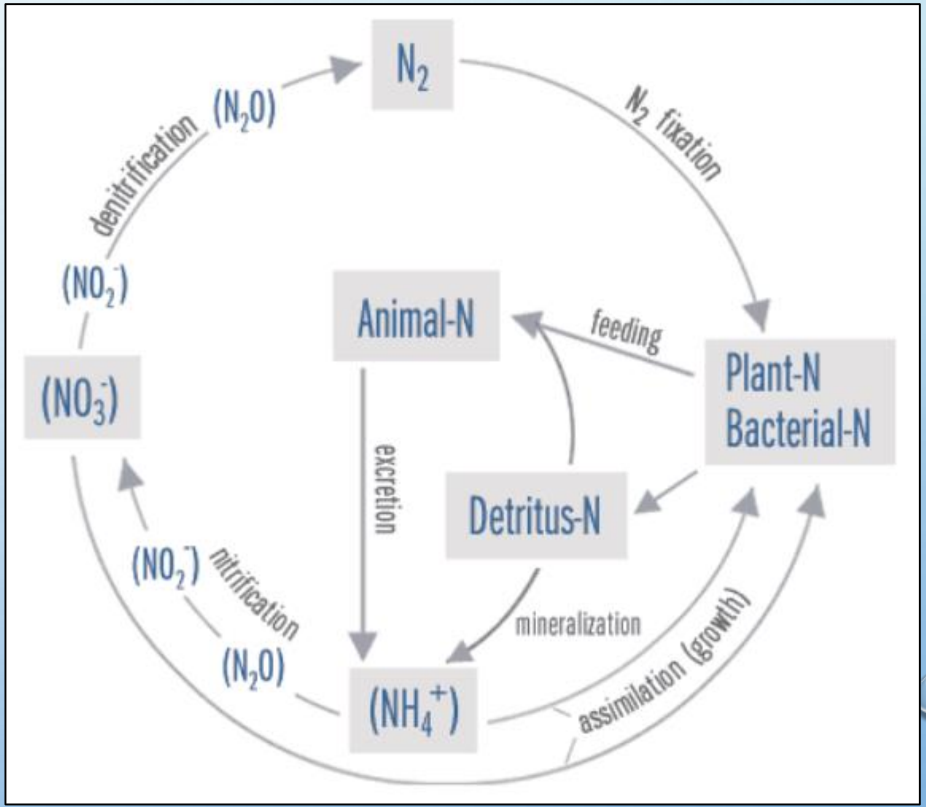
NITROGEN PROCESSES AND CYCLING

- Assimilated N and P can be re-mobilized:
  - N-mineralization – OrgN to NH_4^+, OrgP to PO_4^{3-}
  - Nitrification – NH_4^+ to NO_2^- to NO_3^-
- Denitrification – NO_3^- to N_2, low O_2, permanent loss
- N_2 fixation – bacteria, plants



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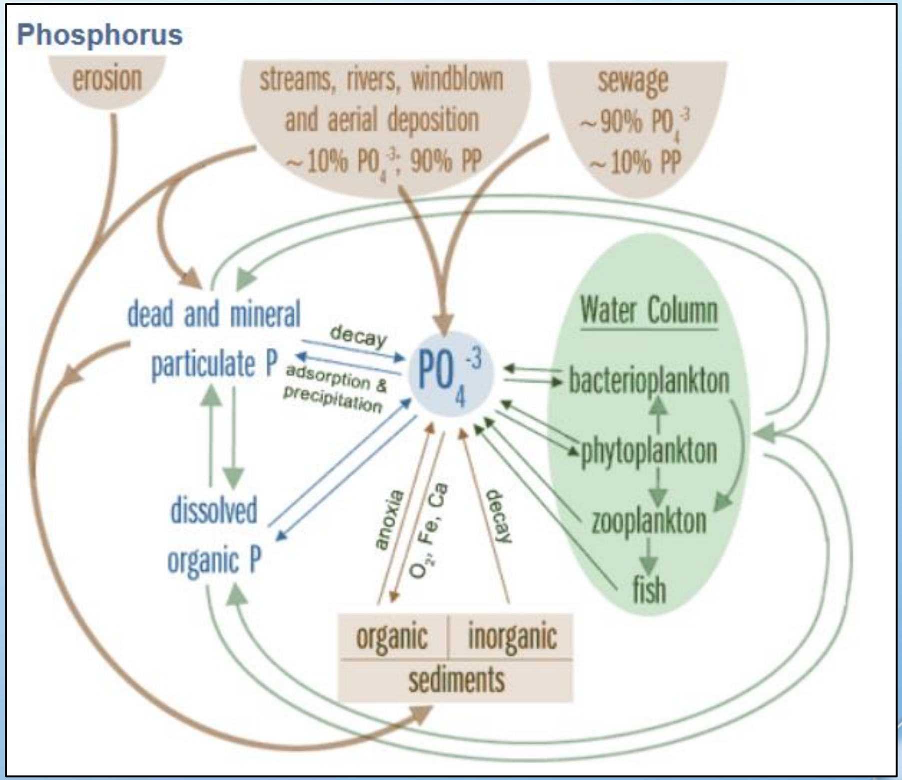
PHOSPHORUS PROCESSES AND CYCLING

- Phosphorus mineral associations:
  - Adsorption/desorption – Fe and Al oxyhydroxide minerals
  - Coprecipitation – Fe oxyhydroxide
  - Dissolution – apatite ($Ca_5(PO_4)_3(F,Cl,OH)$), FeS
- Phosphorus has strong association with sediment



BIOGEOCHEMICAL TEMPLATE

- Uptake C, N, P – plants, algae, bacteria
- **Autotrophic** – energy from light or chemical transformation
- **Gross primary production** – energy conversion rate by autotrophs
- O_2 produced

Nutrients

- Decompose organic matter –bacteria, fungi
- **Heterotrophic** – energy from breakdown of organic carbon
- **Respiration** – rate at which organisms utilize energy
- O_2 consumed

Eutrophication

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BIOGEOCHEMICAL SETTING - 1

Plants

Periphyton – algae, bacteria, fungi

Plankton – drifting, floating

Assimilation is potentially temporary

Drivers and limiting factors –
light, T, O_2, nutrients

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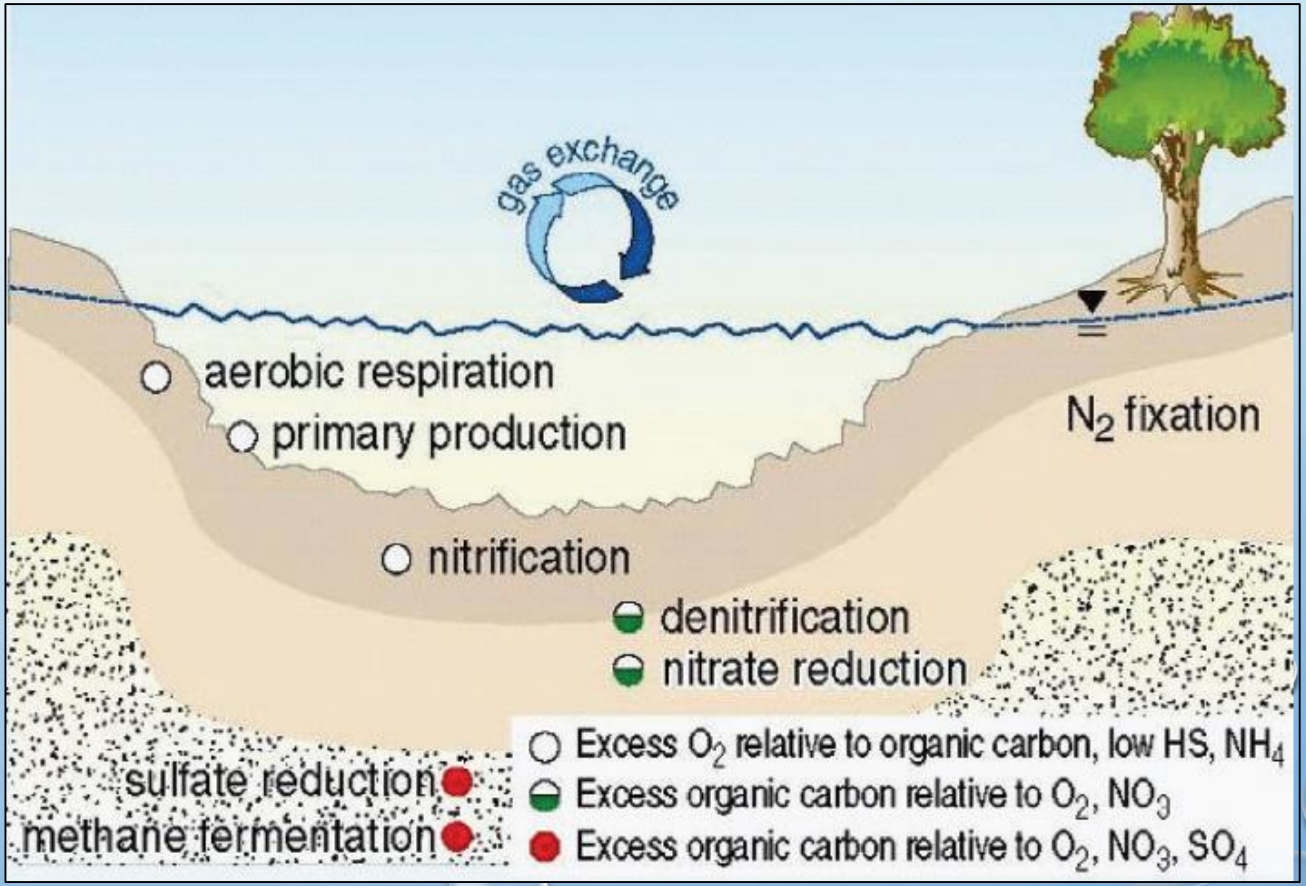
HYPORHEIC ZONE

- Surface water and groundwater mix
- Dynamic environment – low O_2 water mixing with high O_2 waters
- Nitrification/denitrification
- Mobilization/sedimentation - P
- Precipitation/dissolution of P-bearing minerals – O_2 imp for Fe minerals
- Dominance of processes varies with flow conditions, season



Harvey and Gooseff, 2015

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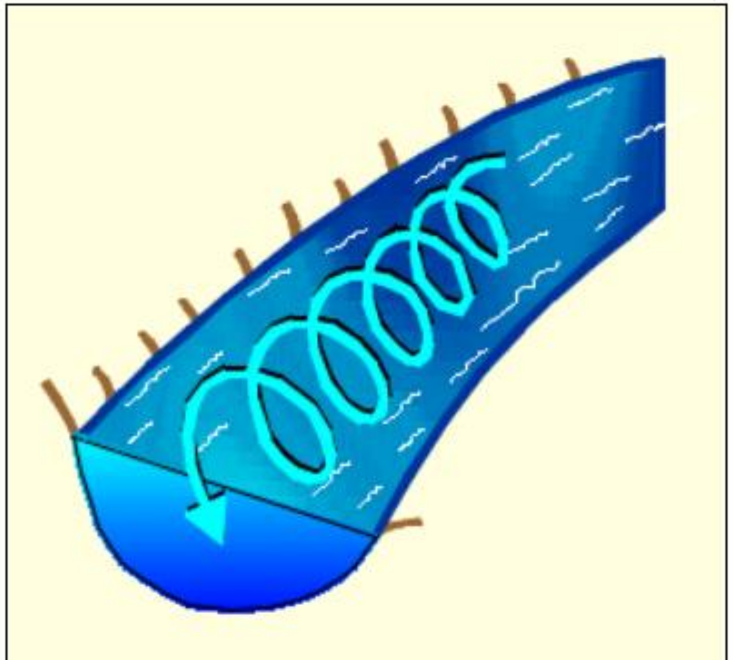
NUTRIENT STOICHIOMETRY

- The balance of chemical elements and energy within an ecosystem
- Redfield ratio – C:N:P = 106:16:1, average of phytoplankton in the oceans
- Example – river with plankton uptake at the Redfield ratio, nutrient ratio in the water is 140:30:1, nutrients will be taken up until all of the P is depleted
- **Limiting nutrient** – phosphorus most common in fresh waters, nitrogen most common in marine waters
- Oversimplification – micronutrients, light, other complicating factors

NUTRIENT SPIRALING

- Transport of a nutrient downstream can be viewed in terms of a spiraling length
- Mean distance a nutrient travels in one cycle – assimilation, detritus, mineralization, mobilized
- One cycle is transport distance in the water and after taken up by biota before the nutrient is re-mineralized
- Nutrient with high supply relative to demand – long spiraling length
- Limiting nutrient – short spiraling length
- Determined by tracer studies



The nutrient cycle, in conjunction with downstream transport, describes a spiral.

Courtesy of: Hebert, P.D.N, ed. Canada's Aquatic Environments [I
CyberNatural Software, University of Guelph. Revised 2002.
www.aquatic.uoguelph.ca

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RIVER MASS BALANCE

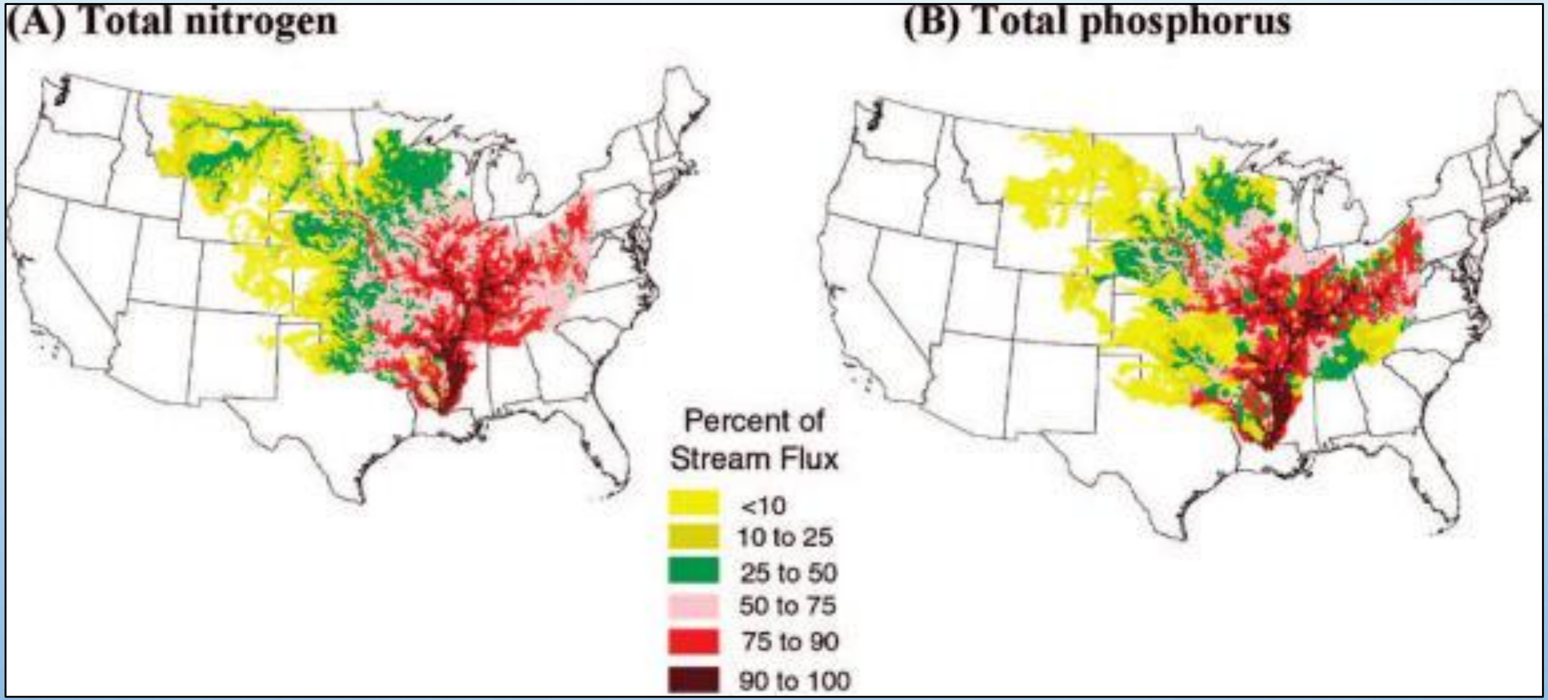
- Inputs - nutrient mass that enters the channel from all sources, gw, tributaries, precipitation, point sources, etc.
- Outputs - nutrient mass that leaves the channel – water withdrawal, distributaries
- Gain or loss from biogeochemical processes
- Nutrient load at the river outlet
- Rivers are typically a mass sink for nutrients – dynamic, depends on flow, season, others

NITROGEN REMOVED DURING RIVER TRANSPORT

- Potomac River – 60 to 68%
- Susquehanna River – 63 to 76%
- James River 61 to 72%
- Average loss rates based on a model
- Small stream losses are much greater as a function of unit surface area – streambed area/volume is greater
- Large river losses are greater in terms of total N mass – longer residence times
- Percent loss of N – often greater in small streams, but factors such as dams that affect residence time can alter this pattern

Seitzinger et al., 2002

COMPARISON OF N AND P LOSSES



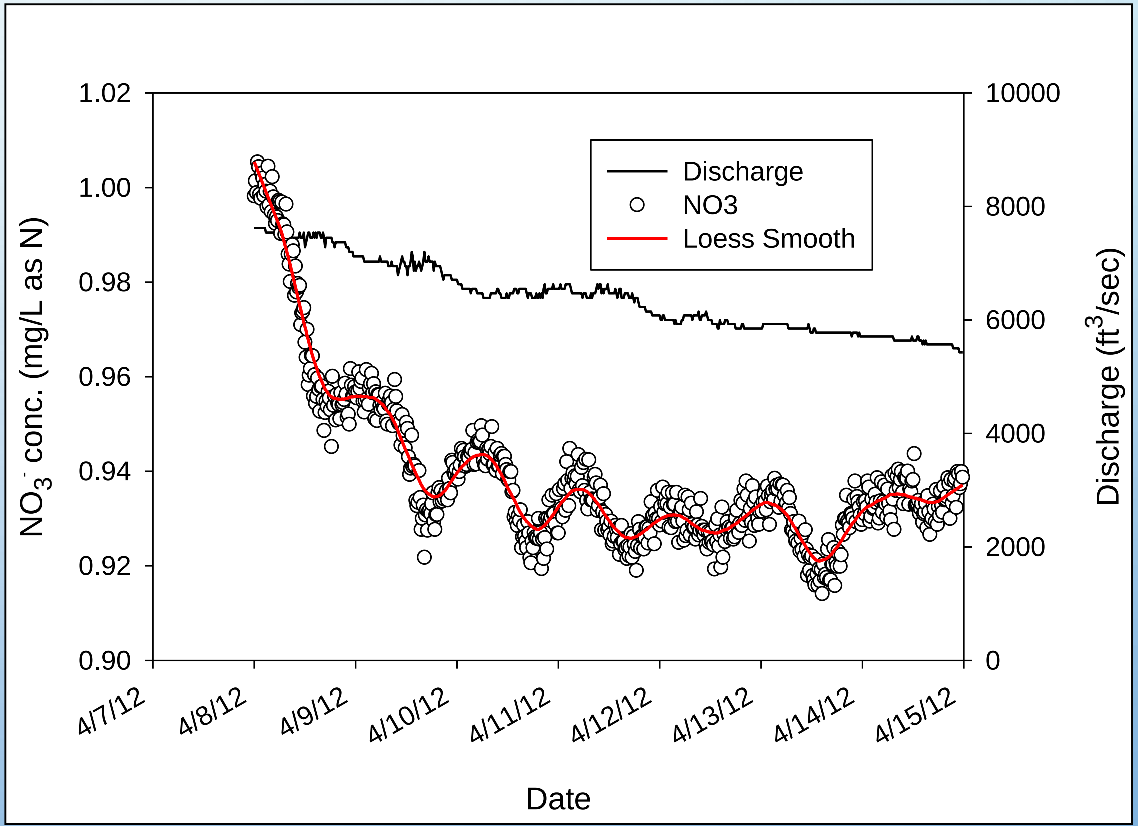
Alexander et al., 2008

ESTIMATING RIVERINE NO_3^- LOSSES – NEW APPROACH

- Method developed by Miller et al., 2016, WRR, 53: 330-347
- Applied high frequency NO_3^- sensor data – allows continuous estimates throughout the year, effects of seasonal climate- and flow-related variation
- Based on a linear relation between groundwater influence and NO_3^- in winter when in-stream processes are minimal – mixing model
- In-stream loss = 23% in Potomac R, 11% in smaller suburban and agricultural tribs
- Seasonal in-stream losses – summer > spring > fall > winter

DIEL NO_3^- CYCLING IN POTOMAC RIVER

- Declines during day – photosynthesis
- Peaks over night – no assimilation
- Calculate uptake rate
- Losses less than total in-stream NO_3^- loss



Burns et al., 2016, Freshwater Science, 35: 1117-1132

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TIMING AND SEASONALITY OF NUTRIENT UPTAKE

- Uptake by photoautotrophs dependent on light availability – peak in spring in forested watersheds, often peaks in summer in non-shaded river channels
- Increasing water temperature tends to increase rates of most biogeochemical processes – includes both sources and sinks
- Less nutrient retention as discharge increases – highest flows large losses of particulate forms, described as an increased risk due to climate change, floodplain interactions

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LARGE HYDROLOGIC EVENTS

SUMMARY

- In-stream and near-stream environment is complex and highly dynamic – hydrologic complexity, nutrient transformations, sources and sinks
- Net nutrient mass losses in rivers – varies with discharge and season
- Nitrogen – soluble, NO_3^- dominates, limiting nutrient in estuary
- Phosphorus – insoluble, transported with sediment, limiting nutrient in rivers
- High frequency data are providing new insights to seasonal and flow-related dynamics, estimates of uptake rates