In-Stream Nutrient Retention: Do Healthy Streams do it Better?

Paul A. Bukaveckas
Virginia Commonwealth University
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How are Nutrients Retained in Streams?

- Where do the nutrients go?
  - Short-term storage in organic matter through biotic uptake
  - Permanent removal through denitrification (loss of N_2 to atmosphere)
- What are the mechanisms?
  - Biotic: uptake of dissolved inorganic nutrients by algae and bacteria
  - Abiotic: trapping of particulate matter containing N & P

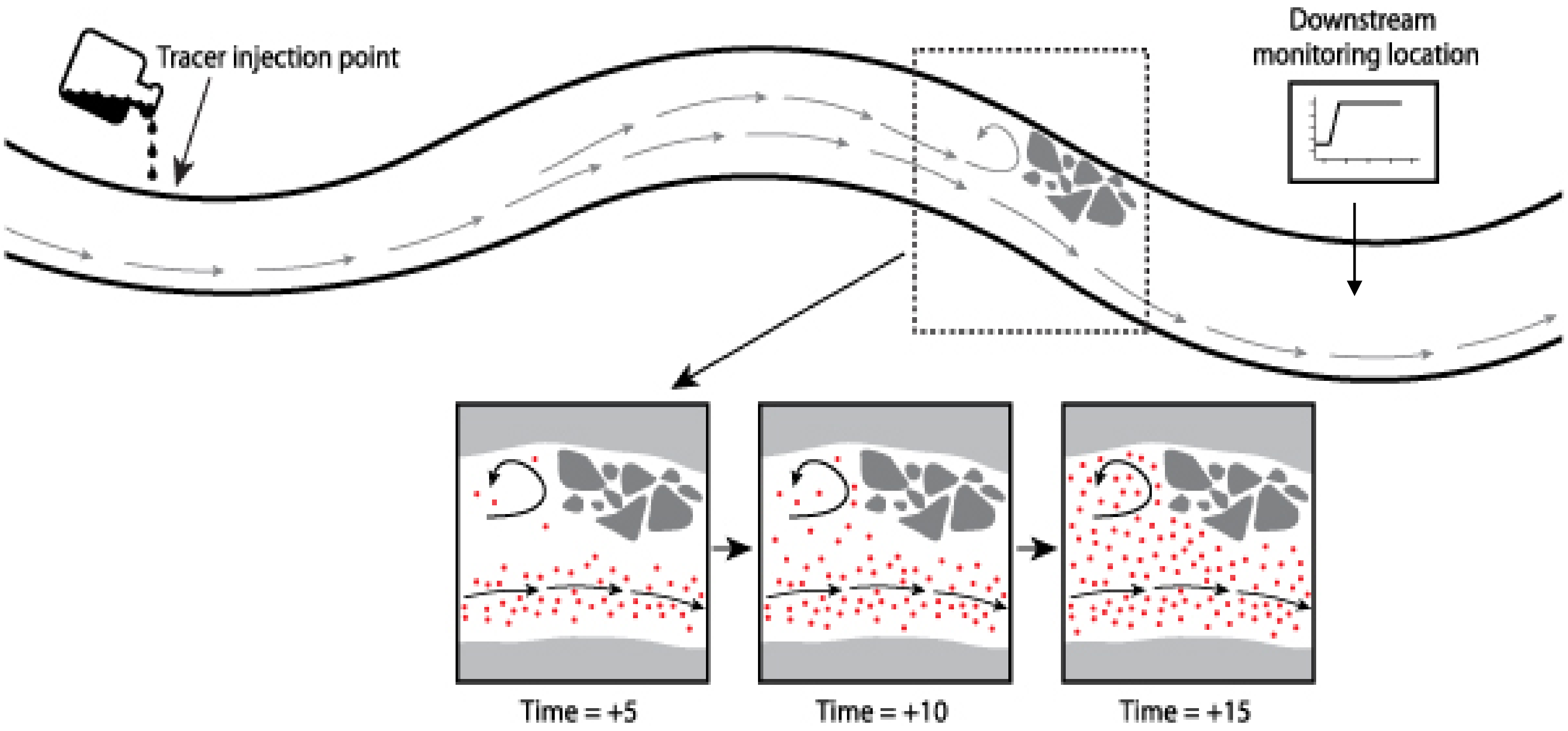
What Factors Determine Rates of Nutrient Retention?

Hydrology – governs the residence time of nutrients in the stream and therefore constrains retention.

- Transit time is largely determined by discharge (directly related to water velocity) which varies seasonally and during events.
- Importance of stream morphology
  - presence of transient storage zones (pools, backwaters, hyporheos)
  - Stream-floodplain connectivity


Low Discharge
NH 4
NO x
High Discharge
NH 4
NO x

Importance of transient storage to Nutrient Retention

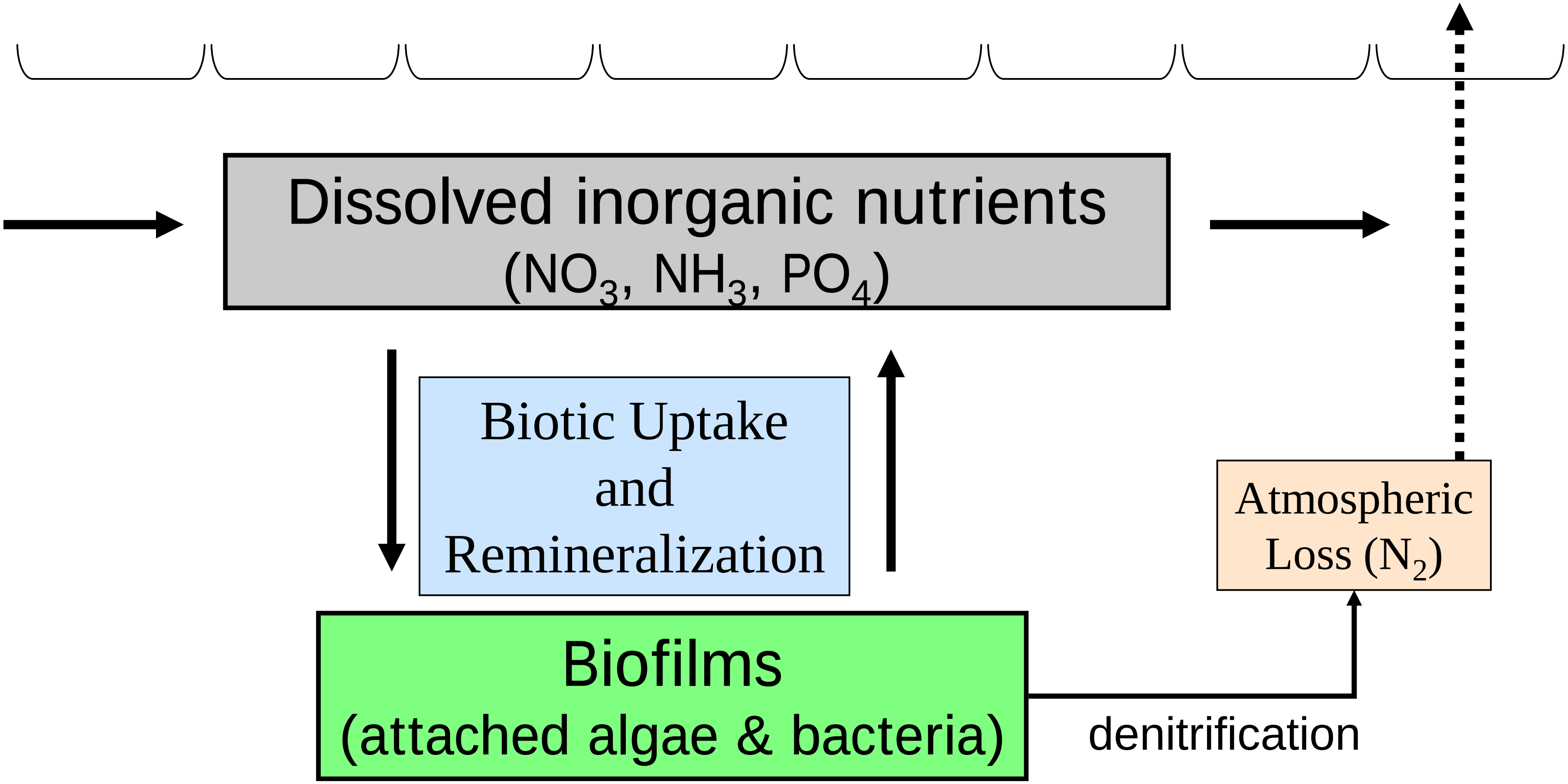


What Factors Determine Rates of Nutrient Retention?

Biology – stream metabolism: rates of autotrophic and heterotrophic production.

- Removal of dissolved inorganic nutrients through uptake by algal and bacterial communities that comprise benthic biofilms.
- What controls biotic production?
  - Heterotrophs: organic matter inputs, principally from riparian vegetation.
  - Autotrophs: light availability, degree of shading by riparian canopy

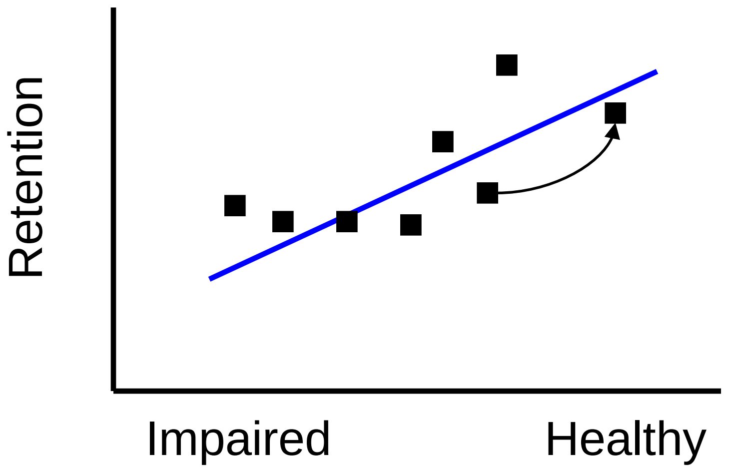
Nutrient Retention in Streams



Do healthy streams exhibit hydrologic and biological conditions favoring retention?

- Hydrology: un-disturbed streams are likely to exhibit more favorable conditions.
  - In-stream channel modifications diminish flow complexity, transient storage and stream-floodplain connectivity.
  - Land-use changes increase runoff.
- Biology: un-disturbed streams may or may not exhibit more favorable conditions.
  - Presence of riparian canopy enhances leaf litter inputs (heterotrophy) but diminishes light availability (autotrophy).

What is the empirical evidence?



Survey approaches: comparisons of nutrient retention among impaired and un-impaired streams.

Experimental approaches: comparisons of nutrient retention before/after restoration.

How is nutrient retention measured?

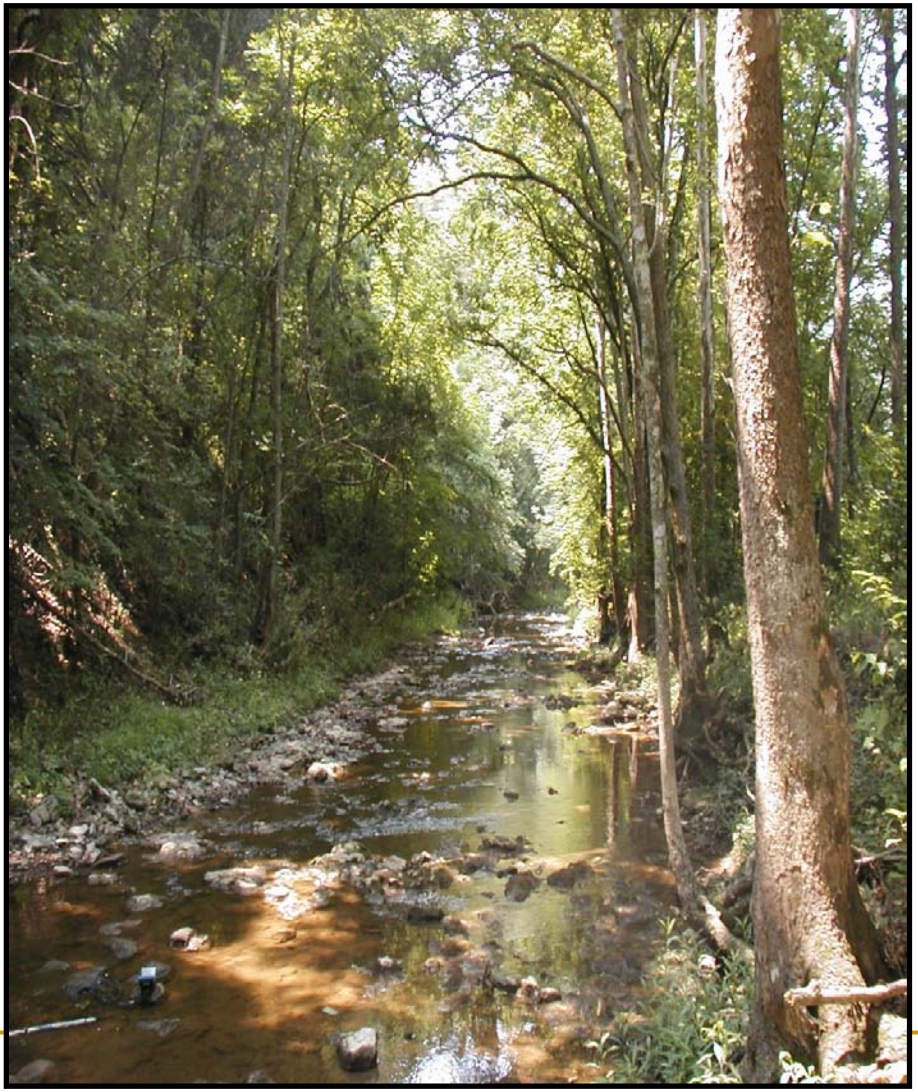
- Nutrients are injected into the stream along with a conservative tracer (e.g., dye or salt).
- The difference between the mass of nutrients injected and recovered (downstream) is used to estimate the mass retained.
- Results expressed as:
  - Nutrient uptake length (m)
  - Areal uptake rate ($mg/m^2/h$)

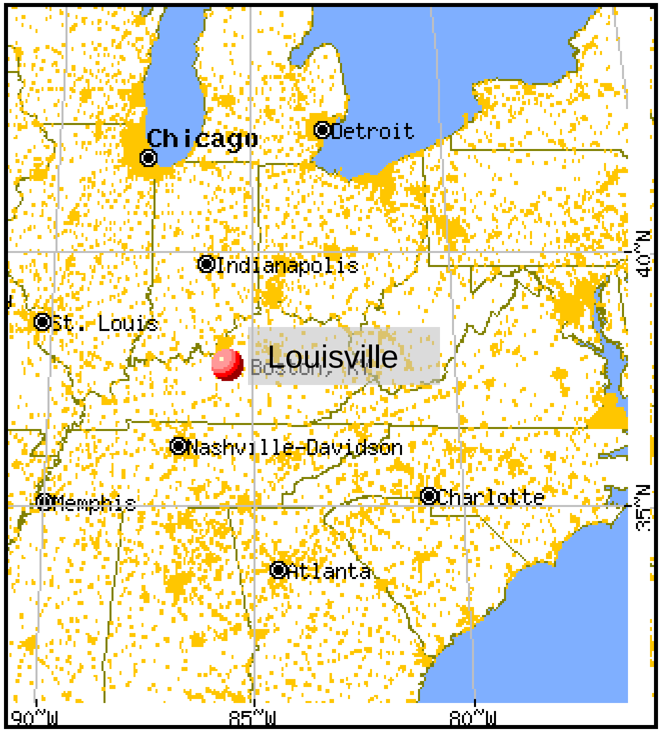
Results from Stream Surveys

- Lotic Intersite N Experiment (LINX) measured NO_3 retention in 72 US streams (8 regions x 3 each of undisturbed, urban and ag).
- Key Findings:
  - Uptake = 84% assimilatory (denitrification = 16%).
  - Stream hydrology (discharge), chemistry (NO_3) and biology (GPP) accounted for 80% of variation in NO_3 uptake.
  - Land use effects: impaired streams had greater NO_3 removal due to higher GPP but lower removal efficiency due to higher NO_3 concentrations.

From: Hall et al. (2009) Limnol. & Oceanogr. 54:653

Results from Stream Restoration





Wilson Creek, KY


Current location of Wilson Creek
Former floodplain of Wilson Creek

Left: Wilson Creek restoration in progress during summer 2003.

Right: Wilson Creek in spring 2005.

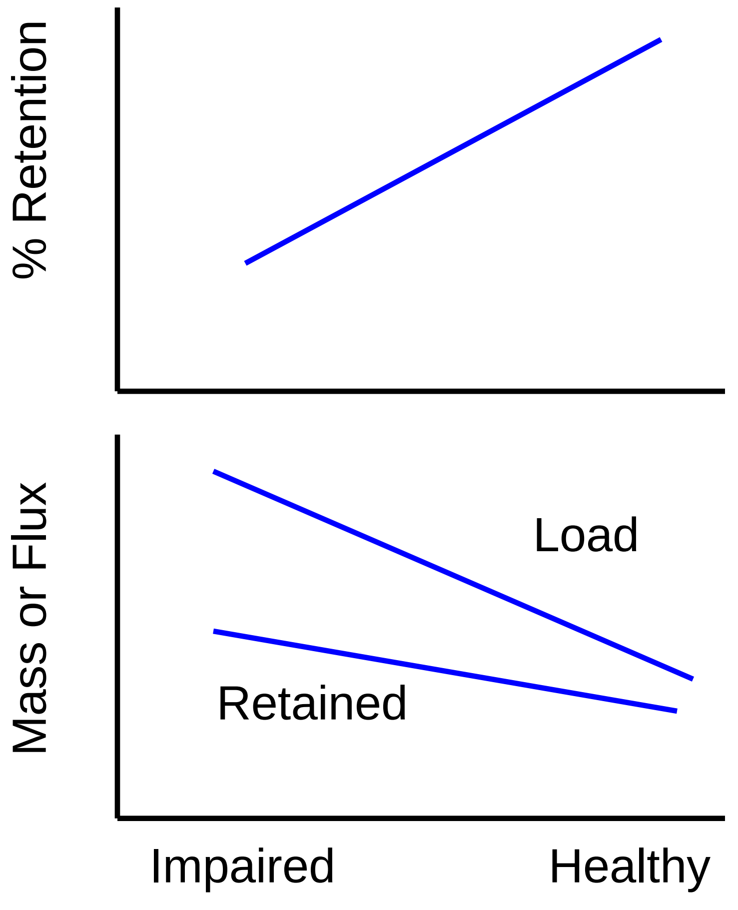
Effects of Restoration on N Retention

	Velocity ($m\ s^{-1}$)	Storage (k_1:k_2)	Uptake Length (m)
Reference			
All data	0.10	0.550	8,333
Pre-restoration			
All Data	0.20	0.281	20,000
Post-restoration			
All Data	0.15	0.405	617
w/o backwater	0.16	0.191	1,171
w backwater	0.12	0.918	360

Water velocity, Transient Storage and NO_3 Uptake Length (average distance traveled by NO_3)

From: Bukaveckas (2007) *Env. Sci. & Tech*. 41:1570

Concluding Points



Healthy streams exhibit greater retention efficiency than impaired streams.

However, absolute rates of nutrient retention are higher in impaired waters where loads are higher.