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

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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
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

Dissolved inorganic nutrients
(NO₃, NH₃, PO₄)

Biotic Uptake
and
Remineralization

Biofilms
(attached algae & bacteria)

denitrification

Atmospheric Loss (N₂)

denitrification
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/m²/h)
Results from Stream Surveys

Lotic Intersite N Experiment (LINX) measured NO₃ 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 (NO₃) and biology (GPP) accounted for 80% of variation in NO₃ uptake.
- Land use effects: impaired streams had greater NO₃ removal due to higher GPP but lower removal efficiency due to higher NO₃ concentrations.

From: Hall et al. (2009) Limnol. & Oceanogr. 54:653
Results from Stream Restoration

Wilson Creek, KY
Left: Wilson Creek restoration in progress during summer 2003.

Right: Wilson Creek in spring 2005.
## Effects of Restoration on N Retention

<table>
<thead>
<tr>
<th></th>
<th>Velocity (m s(^{-1}))</th>
<th>Storage (k(_1):k(_2))</th>
<th>Uptake Length (m)</th>
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</table>

Water velocity, Transient Storage and NO\(_3\) Uptake Length (average distance traveled by NO\(_3\))

From: Bukaveckas (2007) *Env. Sci. & Tech.* 41:1570
Healthy streams exhibit greater retention efficiency than impaired streams. However, absolute rates of nutrient retention are higher in impaired waters where loads are higher.