In-stream nutrient concentrations: how stream-groundwater exchange and nutrient uptake interact in stream networks

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What processes set nutrient concentrations in stream networks?

- Uplands -> instream concentrations?

- Stream network physical and biological processes modify nutrient concentrations
  - stream-groundwater exchange
  - concentration-dependent nutrient uptake

- How do these physical and biological processes combine and interact to modify and buffer stream network concentrations?
Streams gain water from and lose water to groundwater…

These processes typically occur simultaneously!

Gross gains and losses

(Covino et al, in review)

(Winter, 1995)
Gain and Loss

Gain = f (Upslope Area)

\[ Q = 16.8 \ (\text{WA}) \]
\[ r^2 = 0.82 \]

Loss = f (Discharge)

\[ \% \ Q \loss \ per \ 100m^{-1} \]

We can use these relationships to scale across network!

Covino et al, *WRR*, in review
Gains, losses, and hydrologic turnover

- Streams **GAIN** and **LOSE** water at each reach

- Resulting **hydrologic turnover** results in streamwater compositions weighted towards proximal locations
Bull Trout Watershed, Sawtooth Range, ID, USA

11.4 km²
Model Results: Bull Trout
- Water is simultaneously gained and lost along stream reaches: hydrologic turnover

- This exchange process results in stream source compositions weighted towards proximal locations.

- How does biological uptake combine with physical exchange?
Nitrate uptake kinetics: Bull Trout watershed

- Quantified by nutrient addition experiments over ~4 km of stream network

- Uptake increases with concentration, but approaches saturation: Michaelis – Menten

Covino et al, 2010, *L & O Methods*
Kinetic curve buffering: upstream affects downstream

![Graph showing nutrient uptake rate vs. nutrient concentration. The graph depicts a curve where nutrient uptake increases with nutrient concentration. Two sections of the curve are highlighted: one indicating lower nutrient uptake and another indicating higher nutrient uptake.]

Nutrient uptake
Lower uptake
Higher uptake
Physical + Biological

\[ R_i \]

- **Bio**
- **Loss**

- **Gain**
- **Loss**

\[ Q_i \]

\[ R_n \]

- **Bio**
- **Loss**

- **Gain**
- **Loss**

\[ Q_n \]
So, when we put these pieces together:

- Concentration declines from initial input levels but stabilizes
- Due to combination of groundwater support and kinetic-curve buffering
- Organization of inputs, network flowpaths, and kinetic-curve characterization matter
Different watersheds = different distributions of concentration
Biological AND Physical control on nutrient concentrations

- Exchange of stream and ground water supports the stream concentration towards groundwater concentration

- Concentration-dependent biological uptake buffers stream network concentrations

- Combination of these physical and biological processes lead to inertia in stream concentrations

- Shape of watersheds, networks, and kinetic curves can result in distinct spatial patterns of concentration
Thanks! Questions?

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