Assessing the Transporter/Transformer Hypothesis Using a Nitrogen Budget for the Lamprey River, NH

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How Does a River Segment Regulate N Inputs?

River corridors move nutrients from terrestrial sources to downstream receiving waterbodies.[1,2] To better understand the ecological role of individual river segments in regulating nutrient inputs, we applied a mass balance appraoch[3] to portions of the Lamprey River, NH. **Objective:** Determine whether nitrogen (N) inputs are conservative or reactive within individual river segments.

Research Questions:

1) **What is the biogeochemical role of the Lamprey River watershed as an ecosystem – is it a transporter or transformer of N (Fig 1.)?**
2) **How does the biogeochemical role of the Lamprey change over spatial and/or temporal scales?**

Methodology

Annual N loads were calculated for individual sampling stations using paired volume-weighted mean annual concentrations and annual runoff. Incremental N loads (Δ storage) were calculated between upstream and downstream monitoring stations (Fig. 2) using the equation:

$$Inputs + \Delta\ Storage = Output$$

Loads were calculated for total dissolved nitrogen (TDN), dissolved inorganic nitrogen (DIN), and dissolved organic nitrogen (DON).

Inputs: N load at upstream stations of a river segment
Output: N load at downstream station of a river segment
Δ storage: Difference between downstream output and upstream inputs

Potential Mass Balance Outcomes

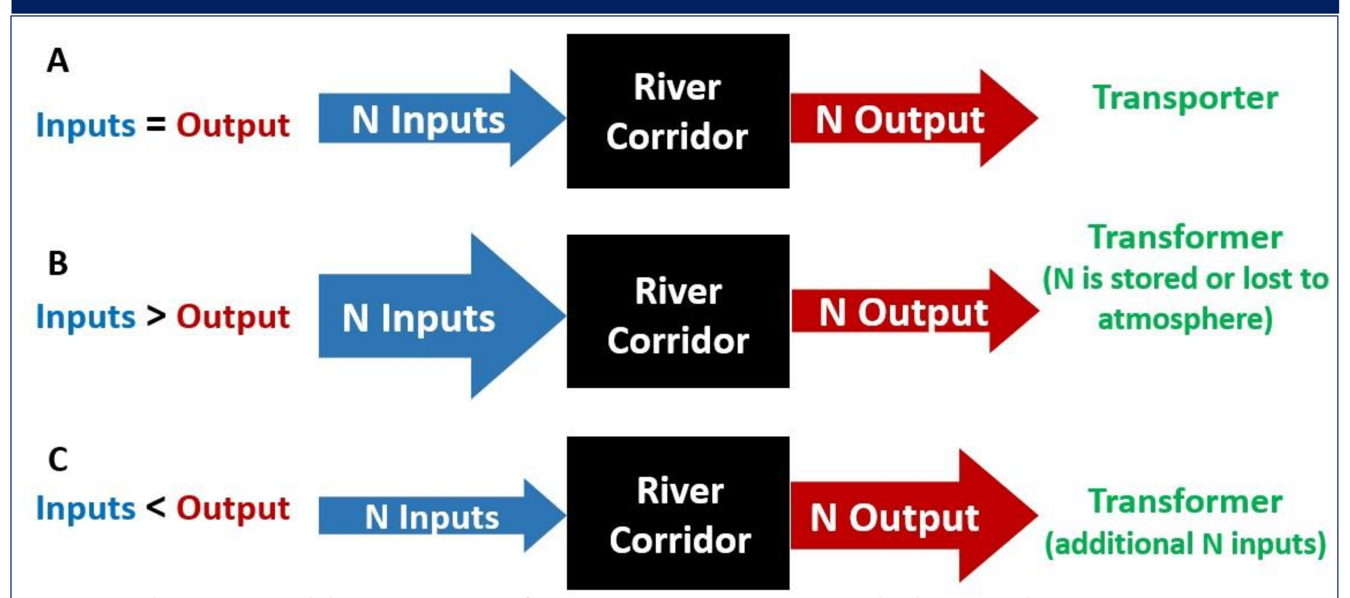

Fig. 3. Three possible outcomes for river segment mass balance The river is a *N transporter* when N inputs equal N output (A). The river is a *N transformer* when inputs and outputs are not balanced (B,C).

A positive N incremental load indicates a net accumulation between stations, driven by a combination of additional, unmeasured N inputs and *in situ* N fixation (Fig. 3C). A negative N incremental load indicates a net loss of N between stations, due to permanent removal (Fig. 3B).

Transporter/Transformer Hypothesis Applied to River Segments

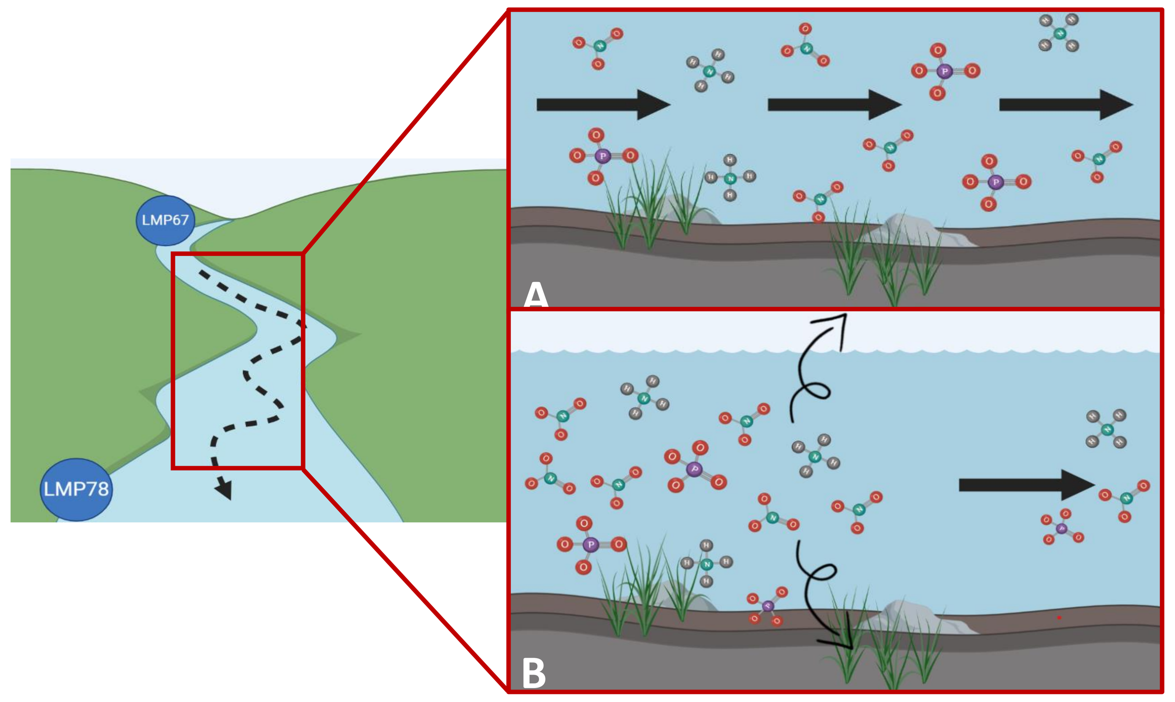

Fig. 1. Conceptual diagram of the transporter-transformer hypothesis.[4] As water moves downstream between stations (left), nutrients can be conservatively transported (A) or reactively transformed due to biogeochemical pathways that remove or temporarily store nutrients (B). Created with BioRender.com

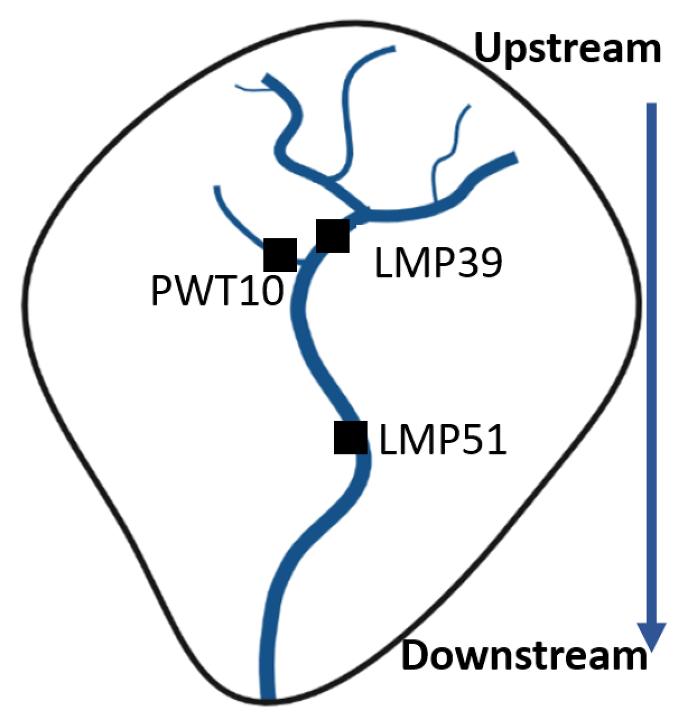

Fig. 2. Watershed schematic of a river segment, defined by an upstream, mainstem station (LMP39) and a downstream station (LMP51). N inputs for this segment are the nutrient concentrations at the mainstem station, LMP39, and the tributary PWT10. N output is the measured concentration at LMP51.

River Segment N Output Exceeds N Inputs

Table 1. Median incremental N loads for Lamprey River segments across 2 decades (grouped by water years). Stations are ordered from headwaters to river mouth, with tributaries placed relative to their confluence with the mainstem. Green values indicate highest loads for each decade and blue values highlight negative loads.

Station ID	Decade 1 (2000-2009) N Incremental Load (kg/ha/yr)			Decade 2 (2010-2019) N Incremental Load (kg/ha/yr)		
	TDN	DON	DIN	TDN	DON	DIN
LMP07	1.39	0.96	0.43	1.13	0.81	0.30
LMP19	1.88	0.94	0.94	1.46	0.87	0.56
NBR12	1.63	1.10	0.53	1.34	0.98	0.36
LMP27	2.43	1.37	1.03	1.78	0.97	0.87
LMP39	2.93	1.28	1.65	2.63	1.23	1.34
PWT10	1.48	1.01	0.48	1.28	0.93	0.35
LMP51	7.33	1.00	6.31	7.56	1.54	5.87
RMB04	2.47	1.31	1.16	2.09	1.13	0.96
NOR27	1.84	1.29	0.55	1.50	1.11	0.38
BDC0.30	-	-	-	11.93	2.91	9.17
LTR20	1.98	1.10	0.88	1.58	0.97	0.60
LMP67	1.40	1.39	0.04	-0.37	0.99	-1.16
WHB01	5.35	0.95	4.46	4.46	0.70	3.69
LMP78	1.56	1.69	-0.13	2.06	1.60	0.46
MLB01	5.26	0.56	4.94	3.96	0.45	3.55

- Incremental N loads were mostly positive, indicating upstream input was less than downstream output.
- Large incremental TDN loads at LMP51 are attributable to upstream DIN wastewater treatment discharge.
- High DIN and TDN incremental loads at BDC0.30 are likely due to high agricultural land use (~58%) in the sub-watershed.
- 3 sampling stations over the 2 decades showed negative median DIN and/or TDN incremental loads, indicating those river segments contributed to the transformation and loss of N either through temporary or permanent removal pathways.

Homogenization of TDN Pool Along Mainstem of Lamprey River

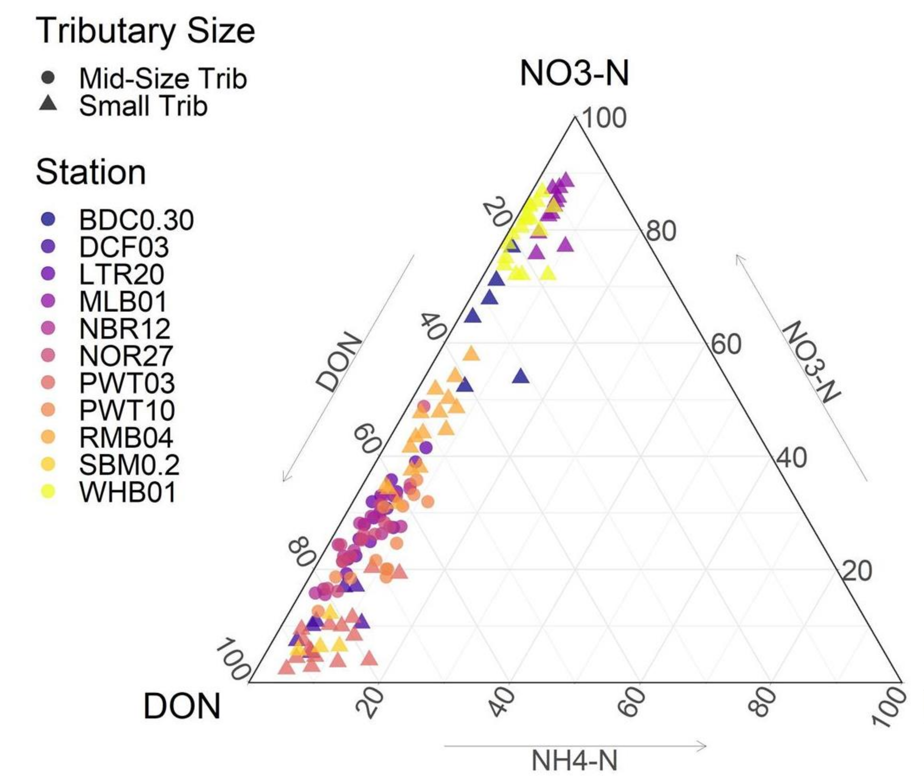

Fig. 4. Ternary plot of NO_3^-, NH_4^+, and DON annual loads for Lamprey River tributaries, shown as a percentage of overall TDN annual load. Loads are color-coded by sampling station, with shapes indicating tributary size.

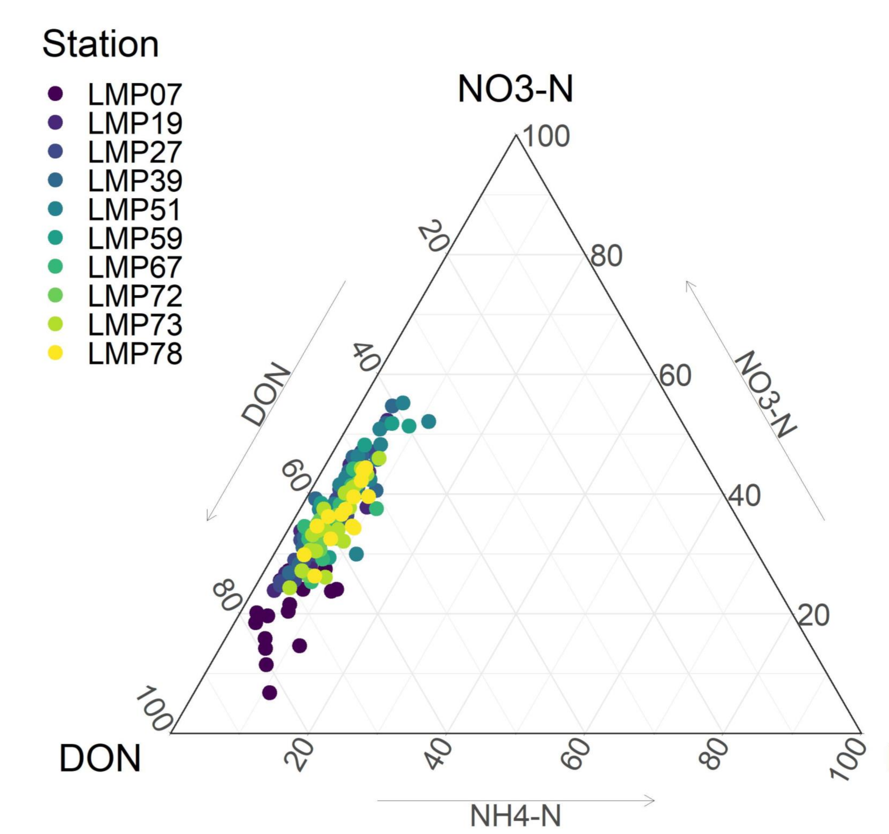

Fig. 5. Ternary plot of mainstem Lamprey River annual loads for NO_3^-, NH_4^+, and DON, shown as a percentage of overall TDN annual load. Loads are color-coded by mainstem sampling station ID.

N Transformation of the TDN Pool

The Lamprey mainstem homogenizes tributary inputs (Fig. 4) of DON and NO_3, resulting in minimal differences in TDN composition among mainstem sampling stations (Fig. 5). Differences in the %DON may be influenced by the presence of wetlands, or lack thereof. The dissolved organic matter pool has been shown to increase with increasing wetlands.[5] Here, higher wetland area along the mainstem may help homogenize upstream tributary DON inputs (Fig. 7).

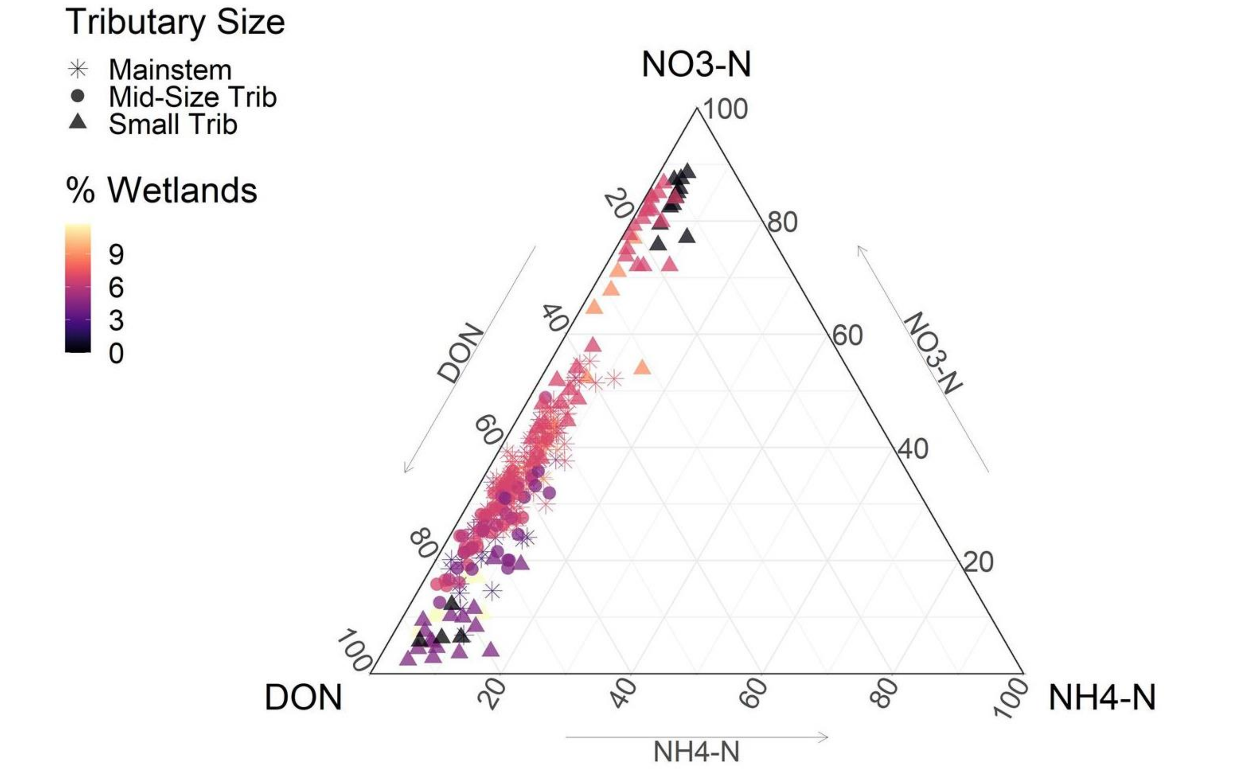

Fig. 6. Ternary plot of annual NO_3^-, NH_4^+, and DON loads for all 21 sampling stations, shown as a % of TDN annual load. Shapes indicate tributary size and color gradient represents the percentage of wetlands within each sub-watershed.

Conclusions

- The Lamprey transforms N, as inputs & outputs did not balance.
- Positive incremental loads indicate downstream N output is greater than upstream N input. This suggests additional N is entering river segments, either from internal production or additional unquantified sources (ex. septic system leakage).
- Ternary plots highlight how N is transformed as water flows downstream by allowing for comparison of TDN composition across individual river segments.
- Refining the mass balance approach for river segments will include **estimating inputs of N from unmonitored tributaries.** This will help determine if N removal is masked by unmeasured N inputs.

Acknowledgements

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Questions about this poster? Email Anna at al1290@wildcats.unh.edu

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