Human impacts on nitrate dynamics in hyporheic sediments using a stable isotope tracer.

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Research Summary:

Aquatic ecologists are increasingly aware of the importance of interactions of surface water (SW) and ground water (GW) in the functioning of aquatic ecosystems (Hancock et al. 2005). While most aquatic ecologists would agree that the region where surface water/ground water interacts (hyporheic zone) is a critical interface, there is no common definition shared by hydrologists, geomorphologists, biologists and chemists. Perhaps the most fundamental problem is establishing the spatial and temporal dimensions of the hyporheic zone (Gooseff et al. 2003). In some cases, surface water may enter the hyporheic zone then return to the stream days later (Haggerty et al.2001, Gooseff et al. 2003).

Stream metabolic activity may be strongly affected by hydrologic exchange within the hyporheic zone (e.g. Crenshaw et al. 2002) as well as the hydraulic residence time in the hyporheic zone (Gooseff et al. 2003). Both processes can affect whole stream metabolism by controlling nutrient transformation and availability (Grimm and Fisher 1984). For example, Fellows et al. (2001) showed that hyporheic nitrate (NO_3) uptake (mg m^2 d^{-1}) was greater than benthic NO_3 uptake in three montane streams. Grimm and Fisher (1984) suggested that 50-70% of NO_3 was retained by hyporheic sediments of a desert stream. Hall et al. (2002), however, compared whole stream ammonium uptake to transient storage (a parameter commonly used to describe the size of the hyporheic zone) and found that transient storage only explained 14% - 35% of the variance of whole stream ammonium uptake. Direct measurements of hyporheic metabolic activities and nutrient dynamics in conjunction with whole stream methods may be a more sound approach for better understanding the contribution of hyporheic processes to stream ecosystem metabolism and biogeochemistry.

We conducted 24 hr $^{15}NO_3^-$ stable isotope tracer releases in nine streams with varied intensities and types of human impacts in the upstream watershed to measure nitrate (NO_3^-) cycling dynamics. Nine wells were installed in each stream and were inserted to 30 cm depth. Each well was sampled after 24 hr after the $^{15}NO_3^-$ injection and the samples were analyzed all major cations and anions, Br, $^{15}NO_3$ $^{15}NH_4$, $^{15}N_2O$ and $^{15}N_2$.

These experiments were conducted in the Southwestern region of the United States, specifically central New Mexico and the larger central Arizona area. Aqua Fria River (AFR), Rio Salado (RS) and Sycamore Creek (SYC) are reference streams. AFR is a desert stream ~110 km north of Phoenix (elevation ~1100 m). The study reach had a mean width of 3 m, a mean depth of 10 to 15 cm, and Q ranging from 10 to 15 L/s during the experiment. The reach is in a small canyon, although the channel receives full sunlight, surrounded by native vegetation consisting of mesquite and cottonwood (Grimm et al. 2005). SYC is located north of Phoenix (elevation ~ 700 m) and has been described extensively by others (Fisher et al. 1982, Grimm 1987, Martí et al. 1997). The experimental reach had a Q of 21 L/s and was shallow with a mean width of 4 m. It was surrounded by native vegetation (similar to SYC). Rio Salado is a reference stream on the Sevilleta National refuge and LTER (sev.lternet.edu) in central New Mexico. RS is a intermittent stream but is fee by a perennial spring that flows year round and had a discharge of 6.1 L/s (Table 1) and was vegetated by native plants.

The impacted streams include Rio Rancho drain (RRD) Bernalillo Drain (BOD), Rio Puerco (RP), and San Pedro River (SPR) (Table 1). All impacted streams were located in central New Mexico. Rio Rancho Drain is an irrigation ditch in Rio Rancho NM and runs parallel to the middle Rio Grande. The drain is used for irrigation and transportation of runoff from the surrounding neighborhood. The discharge was 18 L/s during the injection and was dominated by native vegetation. BOD is located in Bernalillo NM which is ~ 15 miles north of Albuquerque. It is an agricultural drain, which drains crop farms and had a discharge of 24 L/s. RP is a highly impacted stream (agricultural), located on the northern border of the Sevilleta LTER and wildlife refuge (see above) and is dominated by non-native vegetation with a discharge of ~3 L/s.

The surface water NO_3 and NH_4 concentrations were very low in all streams ranging from 0.45 to 220 μg/l and below 5 μg/l respectively. The wells NO_3 concentrations ranged from 0.0 to 35 μg/l and NH_4 concentrations were very low across sites. There was high variability in % surface water among all the wells (Table 2). This is a proxy for connectivity between surface water and groundwater. We did detect $^{15}NO_3$ in all of the wells measured (Table 2) and in some cases the del values were as high in the wells as in the surface water. There was also a large signal for $\delta\ ^{15}NH_4$ in the wells and in particular, the agricultural wells (Table 2). This could be an indication of a novel nitrogen pathway: dissimiltory nitrate reduction to ammonium. This is critical because this indicates that the nitrogen is not being removed from the stream as it would in denitrification (N_2).

In general N uptake is driven by instream concentration Fig. 1a, however this does not hold true in the desert southwest Fig. 1b. However, NO_3 uptake (ktot, d^{-1}) is strongly correlated with % surface water (Fig. 2). Essentially, the more connection there is in desert stream ecosystems the more N is utilized. In addition, the lower the connection with surface is negatively correlated with $\delta\ ^{15}NH_4$ (Fig. 3). This could be problematic because the NO_3 is being converted to $^{15}NH_4$ and staying in the system and not being released into the atmosphere as a non-harmful byproduct such as N_2. Our study suggests that connection between surface water and ground water is very important in the removal of harmful nitrogen products in the desert southwest. It also suggests that when the connection is lost there may be storage of nitrogen and it may not be released.

This project is one of the first to tie together N uptake and hyporheic processes in so many streams in the desert southwest. This is important in order to really understand how N responds in streams with modified stream bottoms (canalization and sturture) as well as experiencing anthropogenic N inputs. Relinking the hyporheic zone with the surface stream within spatial and temporal frameworks that does exisit and not on the time scale we study is important to really understanding N transformation, retention and delivery in stream ecosystems. This approach ties together the complex issues of varying N concentrations (although low in the southwest), hyporheic zone size (channel complexity), N uptake and N dynamics in stream ecosystems

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Stream	Stream type	lat./long.	Catchment size (ha)	Discharge (l/s)	width (m)	depth (m)	Reach length (m)	Sediment characteristics
AFR	REF	**34 21’ 5.1”** 112 06’ 12”	6,590	11.2	3.1	0.17	110	sand/silt/ cobble
RS	REF	34.4097 -106.854	344,744	6.1	3.7	0.014	140	sand
SYC	REF	33.7533 -111.506	27,453	21.3	3.7	0.026	190	sand/cobble
RRD	URB	35.1979 -106.645	329	18	4.7	0.12	215	silt
BOD	AGR	35.3267 -106.547	94	24	2.9	0.17	195	silt
RP	AGR	34.4097 -106.854	1,584,719	2.5	1.3	0.084	306.8	silt
SPR	AGR	35.2108 -106.305	9,624	4	2.0	0.016	165	gravel/silt

Table 1. Site descriptions of the 7 streams sampled in central NM and central AZ.

	Stream $\delta^{15}NO_3$	**Well** $\delta^{15}NO_3$	**Well** $\delta^{15}NH_4$	**%SW**
Ag #1 (BOD)	1100	29	156	60-100
	650	25	55	14-76
	95	21	43	61-74
Ag #2 (RP)	1623-1804	871-1142	146-206	0-100
	321-379	35-591	59-63	7-41
Ag #3 (SPR)	415	25-411	51-54	18-100
	350	13-286	13-37	44-100
	160	35-71	6-22	13-100
Ref #1 (AFR)	1990-2000	89-117	18-26	76-100
	714-790	22-98	51-68	81-100
	423	42-48	3-8	56-100
Ref #2 (RS)	2479-2888	1320-1604	-4 to 9 for all	48-92
	1271-1472	348-448		7-99
	1305-1366	24-35		14-100
Ref #3 (SYC)	2334	34- >2000		2-100
	3229	1500-3000	0.9-166	38-100
Urban (RRD)	1922	48-114	NA	40-81
	1100	7-12		24-100
	1034	11-21		1-80

Table 2. Stream $\delta^{15}NO_3$, $\delta^{15}NO_3$, well $\delta^{15}NH_4$ and % surface water in the seven different systems. Each row consists of averages of each component in each well transect in the stream.

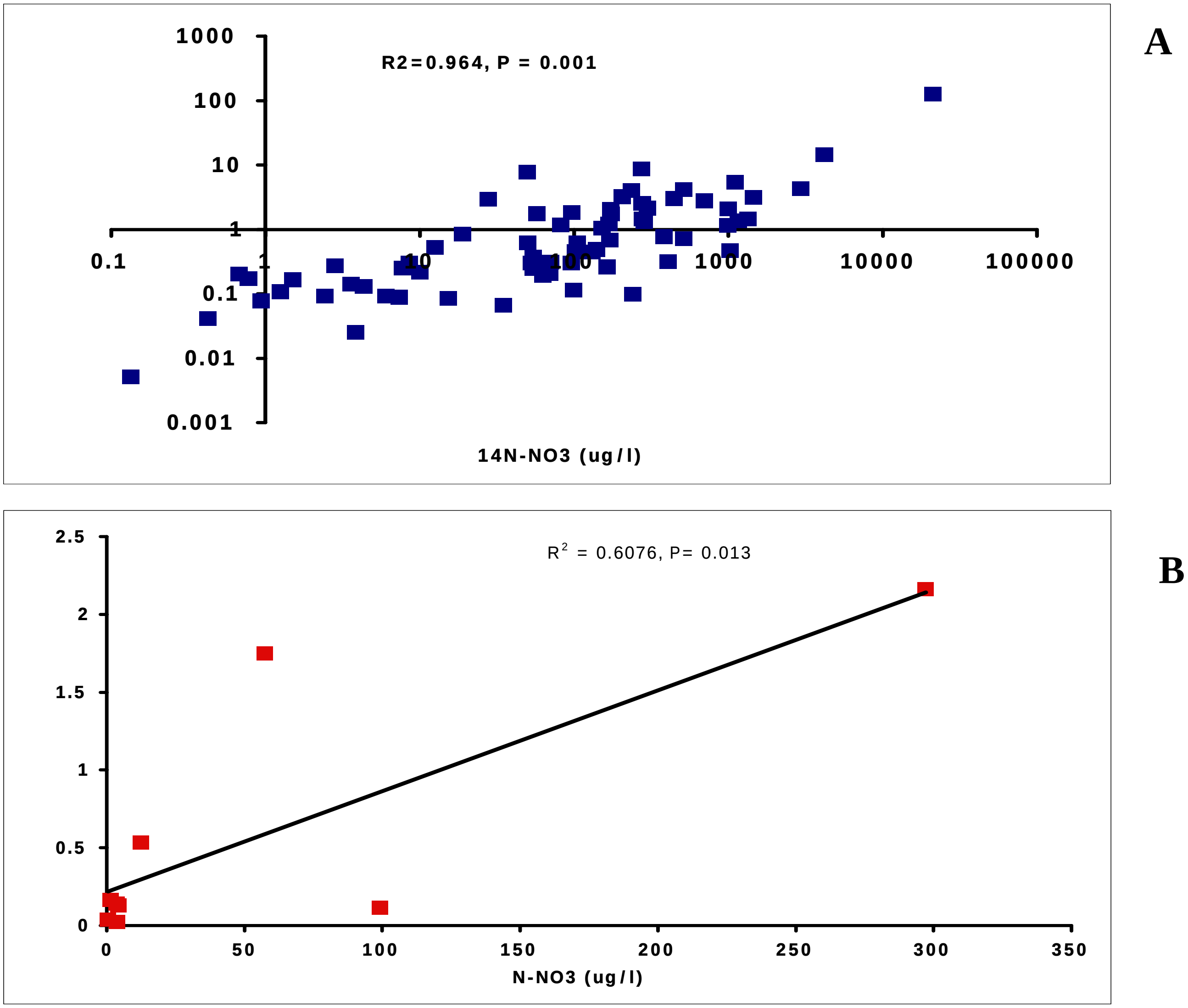

Figure 1. Panal A represents 72 streams and the correlation between NO_3 concentration vs. NO_3 uptake rate (ug m^{-2} s^{-1}). Panal B represents the same correlation within the 7 sites in the southwest.

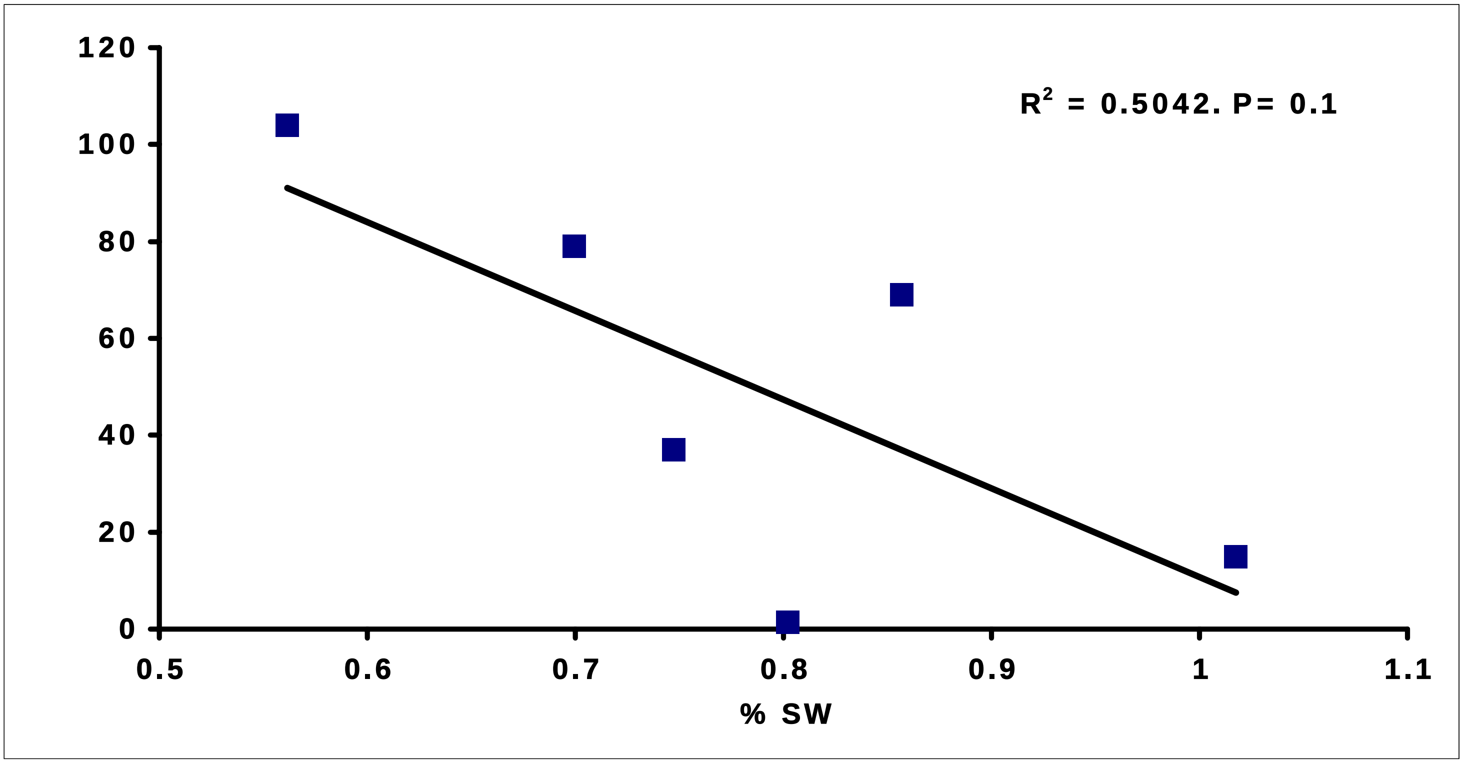

Figure 2. The graph represents %SW (arcsinsqrt corrected) versus well $\delta^{15}NH_4$ in the 7 study streams.