Subglacial Aquatic Environments: Sources and Sinks of Carbon and Nitrogen

Trista J. Vick-Majors[1], Amanda Achberger[2], Alexander B. Michaud[1], Mark L. Skidmore[1], Eric S. Boyd[1], John E. Dore[1], Wayne Gardner[3], Kaijun Lu[3], Brent C. Christner[2], and John C. Priscu[1], with the WISSARD Science Team

[1]Montana State University, Bozeman, MT [2]Louisiana State University, Baton Rouge, LA [3]University of Texas Marine Science Institute, Port Aransas, TX

Introduction

Nearly 400 subglacial lakes have been discovered beneath the Antarctic ice sheet[1]. These environments contain active microbial ecosystems[2] and encompass stores of organic matter and nutrients of unquantified significance to Earth's biogeochemical cycles. We quantified pools and biologically mediated transformations of C and N in **Subglacial Lake Whillans** (SLW; Fig. 1), an "active" subglacial lake that ~decadally flushes subglacial water to the Ross Sea.

Figure 1. Map. **Subglacial Lake Whillans (SLW)** lies beneath 801 m of ice in West Antarctica in a relict marine embayment.

Methods

We used a hot water drill to gain microbiologically clean access[3] to SLW in January 2013. Shallow sediment cores (~40 cm) were collected using a Uwitec multi-corer. Water samples were collected with a Niskin bottle at mid-water column. Additional water samples used in N-cycling experiments were collected from the top of the multi-corer and stored frozen until use. Chemoautotrophy was determined in ref. 2. Heterotrophic C uptake and respiration were determined on ^{14}C-leucine amended water samples. NH_4^+ uptake (~assimilation+nitrification) and regeneration were determined on ^{15}N-NH_4^+ amended water samples[4].

Table 2. Physicochemical Characteristics of SLW

Ice Thickness (m)	Conductivity (µS cm^{-1})	Temperature (°C)	NO_3^- (µM)	NO_2^- (µM)	NH_4^+ (µM)	Dissolved Oxygen (µM)
801	720	-0.5	0.8	0.1	2.4	71.9

Ice thickness and water column characteristics from Reference 2

Table 3. C:N ratios of dissolved organic matter

Water Column	Surface Sediment Porewater	Flux ratio
95.2	14.5	10.0

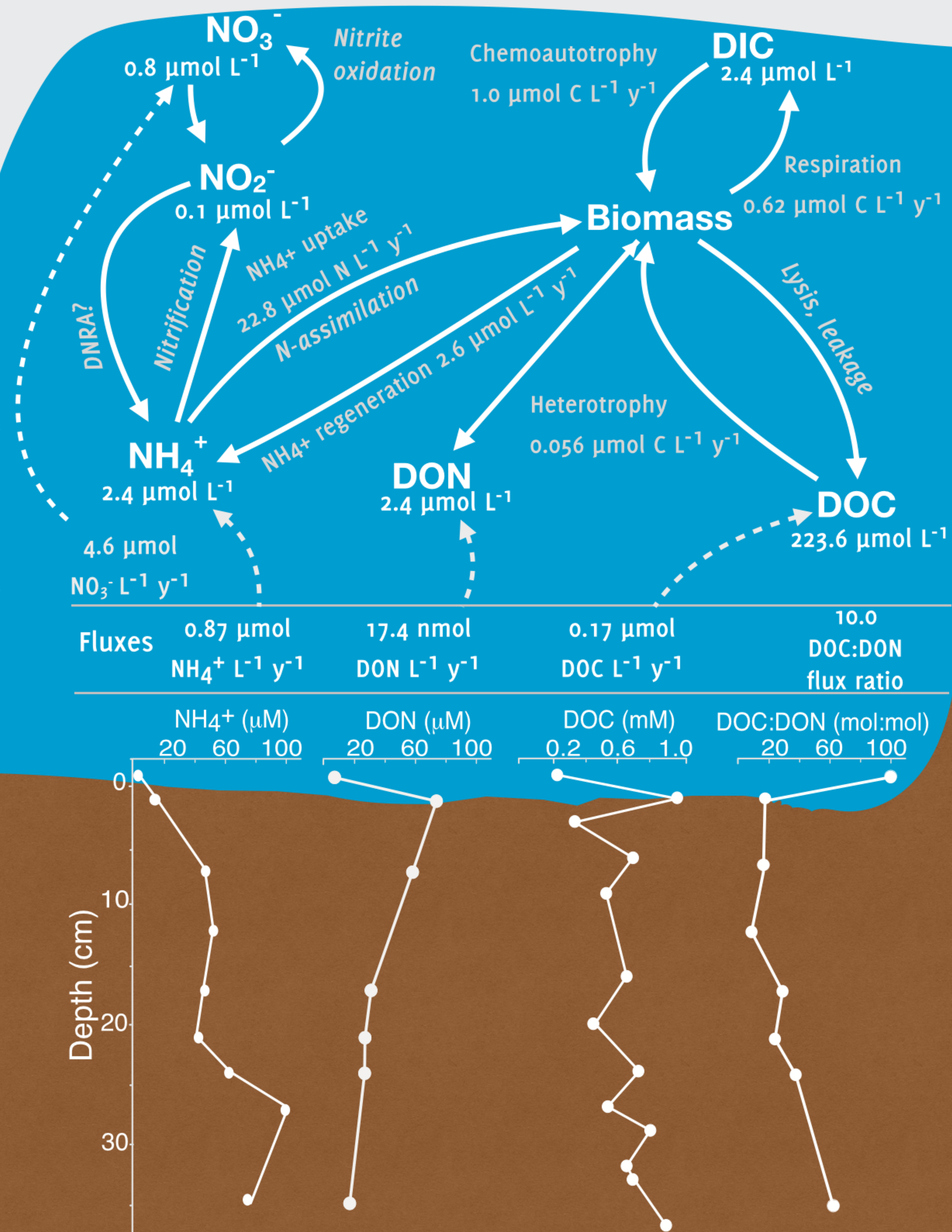

Figure 2. Schematic of C and N cycling in SLW and sediment porewater-to-water column profiles of NH_4^+, dissolved organic carbon (DOC), dissolved organic nitrogen (DON), and the C:N ratio of dissolved organic matter. Fluxes (dashed lines) were calculated from the top 2 cm of sediment to the water column using tortuosity corrected diffusion coefficients.

Table 4. Water Column C and N Balances

Source or Sink Term	µmol L^{-1} y^{-1} Carbon	Ammonium
Water column demand	0.68	22.8
Supply	1.2	3.5
Balance	+0.52	-19.3

Demand: C=Heterotrophy+Respiration; N=NH_4^+ Uptake
Supply: C=DOC flux + chemoautotrophy;
N=NH_4^+ sediment flux + NH_4^+ regeneration

Table 1. Summary of SLW Water Column Abundant OTUs

Closest Relative	% of OTUs	Putative Function
Candidatus Nitrotoga sp.	13	Nitrite oxidation, chemoautotroph
Candidatus Nitrosoarchaeum koreensis	2.5	Ammonia oxidation, chemoautotroph
Polaromonas glacialis Cr4-12	5.0	Heterotroph, dissimilatory nitrate reduction to NH_4^+

References 2 and 5

Conclusions

The water column microbial communities are a sink for N and a source of DOC. At the estimated rates of ammonium uptake, the annual demand is greater than the fluxes and than the standing pool of ammonium, indicating that either the rates are over estimates, or that there is another source of ammonium to the water column, possibly dissimilatory nitrate reduction to ammonium, ice fallout or water from upstream. The relative increase in C:N ratio in the water column DOM versus the flux ratio is also consistent with the idea that the water column is a sink for N, where N is consumed more quickly than C. The most abundant OTUs in the SLW water column, which account for >20% of the community, are also likely to be important in N-cycling. Taken together, these data show that while the sediment pore waters, which represent the relict marine material beneath SLW, provide N to the water column, N is likely to limit microbial activity within the decadal scale flushing timeframe estimated for SLW.

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