Diazotrophic activity and diversity in the Dry Valleys, Antarctica

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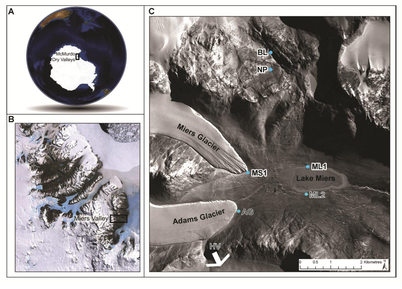
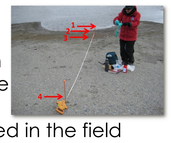
Introduction

The McMurdo Dry Valleys are the largest ice-free deserts on the continent of Antarctica. In the austral summer, darkness turns to 24 hour light and temperatures warm, causing glacier and lake ice to melt, bringing microbial mats near these water sources to life. This input is potentially important to microbially dominated Antarctic food webs, through carbon and nitrogen inputs from photosynthesis and N_2 fixation. Our goal is to determine the organisms responsible, the magnitude and drivers of activity and the effects of microbial mat activity on biological and geochemical factors.

Methods

Microbial activity and diversity was measured in microbial mat samples collected in the Miers Valley (see below) during January and December 2009.





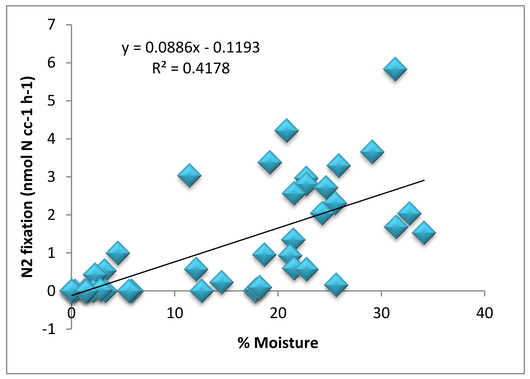
- Microbial mats along stream, lake and pond edges were sampled in transects away from the water edge (see right).
- N_2 fixation was assayed in the field with the acetylene reduction assay(Capone 1993).
- Bacterial activity was determined as the uptake up of ^{3}H-thymidine into cells.
- Nutrients were assayed with standard colorimetric methods. Dissolved organic carbon (DOC) and nitrogen (TDN) were measured with high temperature combustion followed by chemiluminescent detection (Sharp et al. 2004).
- Chlorophyll in the mats was extracted in 90% acetone and measured on a fluorometer.

1: Microbial mat N_2 fixation rates are high in sites around the Miers Valley

site	Jan 2009 (nmol N cc^{-1} h^{-1})	Dec 2009 (nmol N cc^{-1} h^{-1})
MS1	0.46 – 2.9	0.96 – 2.7
ML1	0.27 – 3.0	0.098 – 0.93
ML2		0.16 – 3.3
NP	1.8 – 5.8	2.3 – 17.5
BL	0.035 – 2.4	
AG		3.7
HV		2.0 – 2.6

Rates are high, and comparable with microbial mats found in other environments like desert streams (Grimm and Petrone 1997), marshes (Carpenter et al. 1978) and the marine intertidal zone(Bertics et al. 2010)

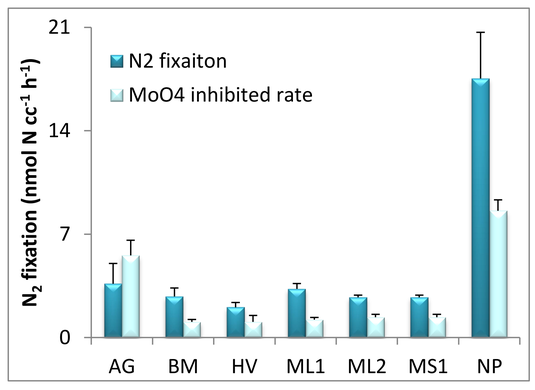
2: N_2 fixation activity is linearly related to soil moisture content



The wettest soils – aside from those located in the streams themselves – generally exhibit the highest activity.

3: *nifH* diversity is high. Sequences suggest sulfate reducers and *Geobacter* are important diazotrophs

4: Sulfate reducers may account for up to half of microbial mat N_2 fixation



$NaMoO_4$ can be used as a competitive inhibitor of sulfate reduction. SO_4 concentrations were determined to be ~1mM, therefore, 1mM $NaMoO_4$ was added to acetylene reduction assays to determine the sulfate reduction-dependent N_2 fixation rate. Heterotrophic N_2 fixation has been previously shown in lake ice aggregates (Paerl and Priscu, 1997; Olson et al. 1997) but it has not previously been linked to sulfate reduction.

5. Nutrient concentrations are elevated in mat porewaters, but are not linearly correlated with N_2 fixation rates. Bacterial productivity is driven by dissolved organic matter

	N fix	Thy incorp	Chl a	% moist.	Topsoil cells	Porewater cells	NO3+ NO2	SiO4	PO4	NH4	DOC	TDN
N fix	1											
Thy incorp	0.034	1										
Chl a	-0.089	-0.210	1									
% moist.	0.646	-0.009	0.055	1								
Topsoil cells	0.057	0.060	0.011	0.008	1							
Porewater cells	0.269	-0.840	0.015	-0.003	-0.089	1						
NO3+NO2	0.298	0.403	-0.152	-0.152	0.229	-0.088	1					
SiO4	0.295	0.266	-0.026	-0.109	-0.029	0.428	0.333	1				
PO4	-0.036	0.148	-0.002	-0.150	-0.101	-0.263	0.257	0.519	1			
NH4	-0.081	-0.324	-0.185	-0.178	0.368	0.161	-0.333	0.165	-0.149	1		
DOC	0.070	0.899	-0.366	-0.108	0.291	0.186	0.411	0.360	0.014	0.573	1	
TDN	0.000	0.884	-0.38	-0.003	-0.107	0.157	0.181	0.328	0.108	0.436	0.708	1

Correlation analysis of biological and geochemical factors in Miers Valley mats – significant correlations ($p<0.05$) shown in orange

Conclusions

- N_2 fixation rates are high in Miers Valley microbial mats – comparable to marine and freshwater mats in warmer climates, e.g. the Sonoran Desert (Grimm and Petrone 1997), Sippewisset Marsh (Carpenter et al. 1978), and a Southern California coastal intertidal zone (Bertics et al. 2010)
- Water drives the presence and activity of these mats
- Sequence data and sulfate reduction inhibition experiments suggest sulfate reducers are important contributors to N_2 fixation in microbial mats. It remains to be seen what determines the dominance of phototrophic versus heterotrophic diazotrophs
- Microbial mat porewaters show elevated inorganic and organic nutrient levels compared to glacial meltwater and flowing stream water
- Bacterial activity is strongly linearly related to dissolved organic carbon and nitrogen, suggesting carbon and nitrogen fixation indirectly drive heterotrophic bacterial activity

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