The response of soil biogeochemical cycling and microbial stoichiometry to water pulse events in a polar desert

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Introduction:

Rates of biogeochemical cycling in desert ecosystems are inherently constrained by water availability. Water pulses resulting from discrete climate events therefore can significantly alter biogeochemical processes. The McMurdo Dry Valleys of Antarctica, a polar desert region, have experienced discrete warming events that resulted in episodic pulses of water made available through permafrost and snow melt. Increases in nutrient supply and mobility with greater water availability were hypothesized to temporarily release soil communities from the limitations constraining their growth and activity that are inherent in a polar desert. The longevity of the influence of such water pulses will have implications for food web dynamics, organic matter processing, nutrient dynamics, and other microbially-influenced soil ecosystem processes.

Objective:

To determine the influence of water and nutrient (N, P) pulses on dry valley soil ecosystems, we used a field fertilization experiment to create episodic pulses of both a short (1-day) and longer (4-week) duration. We measured the response of microbial biomass and stoichiometry, as well as soil nutrient content and CO_2 flux. To investigate the role of landscape history, the experiment was conducted at two sites that differ in glacial till, and therefore *in situ* stoichiometry and biotic potential.

Methods:

Site: McMurdo Dry Valleys, Antarctica

Lake Fryxell basin
P > N

Lake Bonney basin
N > P

	Bonney	Fryxell
SOC (mg g^{-1} soil)	0.10 – 0.12	0.35 – 0.40
NH4+ (µg g^{-1} soil)	0.10 – 0.30	0.20 – 0.50
NO3+NO2 (µg g^{-1} soil)	0.75 – 1.30	0.30 – 0.50
PO4 (µg g^{-1} soil)	0.40 – 0.90	1.00 – 2.00
Microbial biomass (µg C g^{-1} soil)	5 – 10	20 – 30
Nematodes (no. kg^{-1} dry soil)	50 – 400	100 – 3000

Table 1. Range of *in situ* soil conditions in Bonney and Fryxell basins

Experimental Design:

Aqueous nutrient additions were added on Day 0 to four replicate blocks of long-duration and short-duration plots:

- C 15.27 g C m^{-2} as $C_6H_{14}O_6$ + 12.73 L H_2O m^{-2}
- N 2.69 g N m^{-2} as NH_4NO_3 + 12.73 L H_2O m^{-2}
- P 0.37 g P m^{-2} as Na_3PO_4 + 12.73 L H_2O m^{-2}
- CN 15.27 g C m^{-2} + 2.69 g N m^{-2} + 12.73 L H_2O m^{-2}
- CP 15.27 g C m^{-2} + 0.37 g P m^{-2} + 12.73 L H_2O m^{-2}
- W 12.73 L H_2O m^{-2}
- U un-amended

Water was re-applied weekly to all treatments in the long-duration plots.

Measurements performed weekly at long- and short-duration plots:
- Soil CO2 flux using LI-COR 8100

Measurements performed weekly at long-duration plots:
- Microbial biomass CNP using CFE protocol
- Soil NH_4^+ and NO_3^- content using KCl extractions
- Soil PO_4^{2-} content using $NaHCO_3$ extractions

Application of nutrient solutions
Fryxell Basin

Weekly soil sampling and CO_2 measurements
Bonney Basin

Re-application of water to long-duration plots
Fryxell Basin

Results:

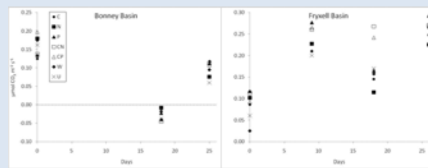

Figure 1. In the long-duration plots, soil CO_2 flux is controlled by changes in soil moisture over time, which differs between the two basins (Moisture*Basin*Day $P = 0.000$). Nutrient additions do not influence CO_2 flux ($P = 0.224$).

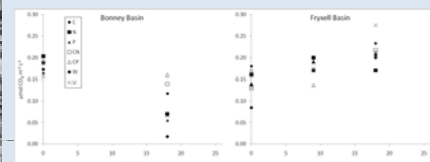

Figure 2. In the short-duration plots, soil CO_2 flux is controlled by changes in soil temperature over time, which differs between the two basins (Temperature*Basin*Day $P = 0.026$). Soil moisture marginally influences CO_2 flux ($P = 0.047$), but it does not interact with other factors. Nutrient additions do not influence CO_2 flux ($P = 0.268$).

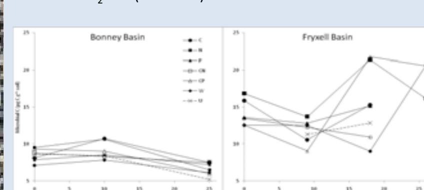

Figure 3. In the long-duration plots, microbial biomass does not correspond to nutrient addition.

Discussion:

- Soil moisture and temperature appear to be the main factors controlling soil CO_2 flux. This corresponds to previous research demonstrating the relative dominance of abiotic factors over biotic factors in controlling soil CO_2 flux (Ball *et al*. 2009). Given the large variability in weather during this field experiment, any influence of nutrient addition on the soil community may have been masked by larger fluctuations in soil moisture and temperature.

- Soil moisture is the dominant driver of soil CO_2 flux when water is available (long-duration plots). When moisture is low (short-duration plots), temperature dominates. This suggests that water pulses may influence the C cycle by altering the relative role of the dominant factors controlling soil CO_2 flux. For example, water pulses may result in more negative fluxes of CO_2.

- Microbial biomass does not respond quickly to changes in nutrient availability, even with greater availability of water. This suggests that greater nutrient availability resulting from water pulses will not influence microbial biomass in a predictable manner, at least on a seasonal basis. Recurring pulses (multi-year) may allow ample time for a microbial response.

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