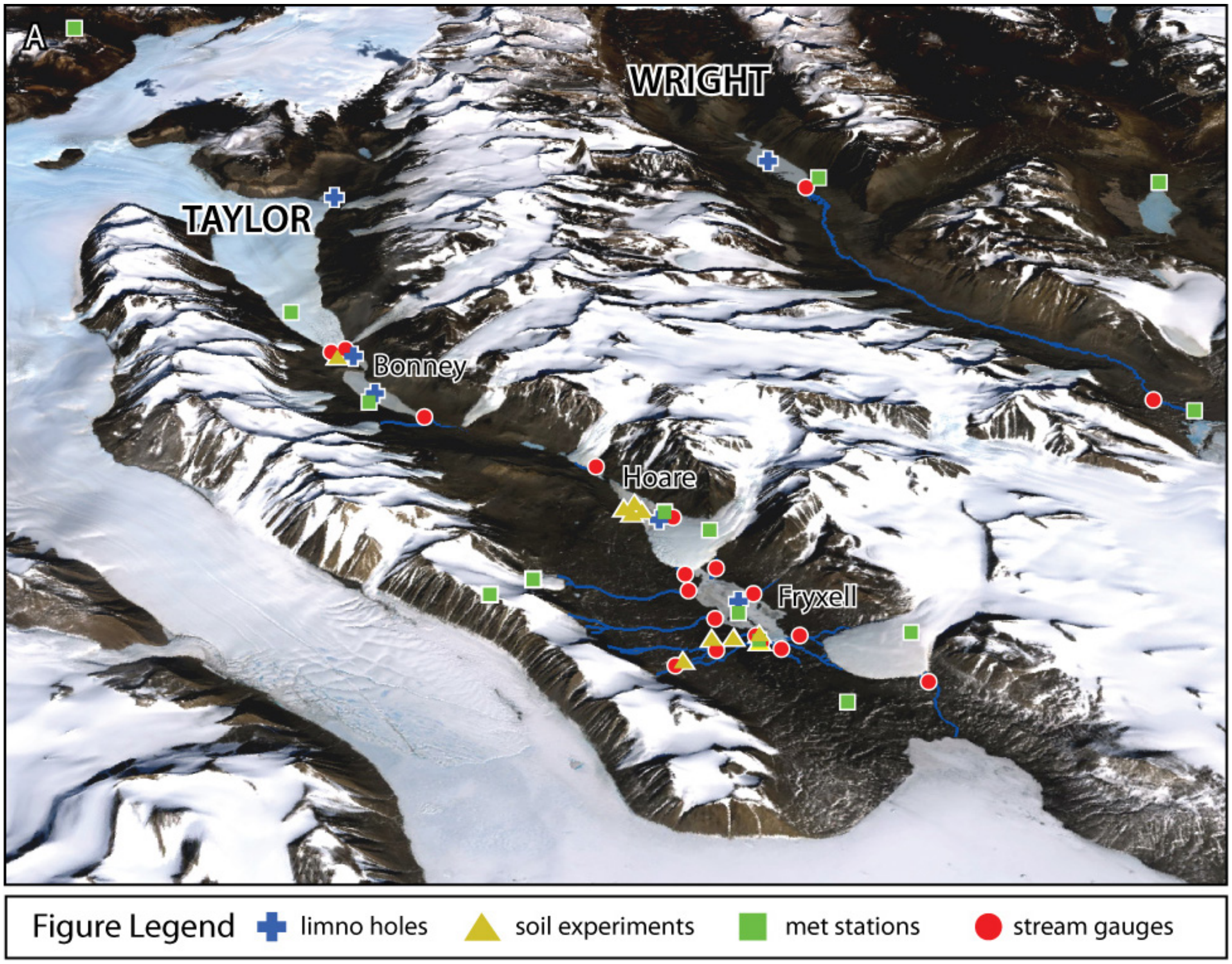


MCMLTER- 2013/14 Site Review Booklet

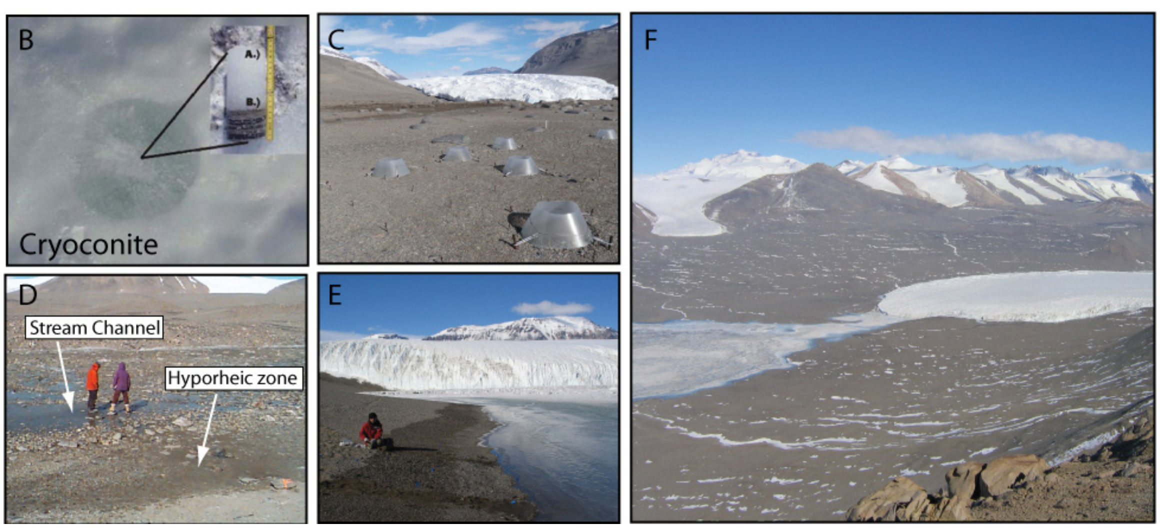


Table 1. Relationship of Research Plan to MCM4 Hypotheses

Hypothesis	MCM4 Activities
H1. Pulse events (wind and melt) increase hydrological and biological connectivity across landscape units	Monitoring: met stations; *in situ* stream, soil, aeolian particle counters, and lake sensors; glacier mass balance; glacial sediments/cryoconites; stream flow; lake level and lake ice variations; lake chemistry and biological activity; focused sampling along environmental gradients; time-series lake sediment traps; expansion to Miers and Garwood Valleys; aeolian traps ; soil active layer monitoring Experiments: surface and subsurface soil wetting experiments; lakewater enrichment experiments; metagenomic analysis across landscapes Modeling: valley scale mechanistic transport models that include both routing of meltwater from the glaciers through the streams to the lakes, formation of new wetland systems, and aeolian transport of sediment onto glaciers and lake ice during strong katabatic wind events
H2. Summer pulses of liquid water produce transient moist habitats with altered biological diversity and ecological complexity	Monitoring: meteorological stations; *in situ* stream; soil and lake sensors; glacier mass balance; geochemisty/biology of cryoconite holes; soil active layer monitoring Experiments: surface and subsurface soil wetting experiments; lakewater enrichment experiments; experiments to determine adaptive response of biota to climate driven hydrology; ongoing soil stoichiometry experiments; bacteria and invertebrate density in margin habitats; phylogeny/function via metagenomic analysis; production/respiration rates; landscape specific stoichiometry Modeling: As described for H1
H3. Increased connectivity enhances rate, variance and the coupling of biogeochemical processes across the landscape.	Monitoring: As in H1 with the addition of: C:N:P ratios and metagenomic analyses (phylogeny/function) measured on material collected over an annual cycle in the aeolian and lake traps and related to stoichiometry and phylogeny from potential source pools (e.g., wetted soils, stream mats, lake mats); expansion to Miers and Garwood Valleys; geochemisty/biology of cryoconite holes Experiments: surface and subsurface soil wetting experiments; lakewater enrichment experiments; experiments to determine adaptive response of biota to climate driven hydrology; ongoing soil stoichiometry experiments; biomass of bacteria and invertebrates across landscape units, and rates of NPP and respiration under both dry and wet conditions and under experimentally modified soils Modeling: As described for H1
H4. Emergence of wetted habitats varies with local geography and history of landscape development.	Monitoring: Quickbird imagery; in situ sensors; telemetry to define locations of new wetland habitats; mapping, image analysis of buried ice and groundwater seeps Modeling: As in H1 but refined to include permafrost melt

Overview: Hypotheses of hydrologic and aeolian drivers of ecological connectivity

The McMurdo Dry Valleys (MDV) is a polar desert on the coast of East Antarctica, a region that has not yet experienced the climate warming that is now occurring elsewhere. The MCMLTER project has documented the ecological responses of the glacier, soil, stream and lake ecosystems in the MDV to a cooling trend that occurred from 1986 to 2000, which was associated with the depletion of atmospheric ozone. In anticipation of the eventual amelioration of the ozone hole in the next 50 years, our overarching hypothesis is:

Climate warming in the McMurdo Dry Valley ecosystem will amplify connectivity among landscape units leading to enhanced coupling of nutrient cycles across landscapes, and increased biodiversity and productivity within the ecosystem.

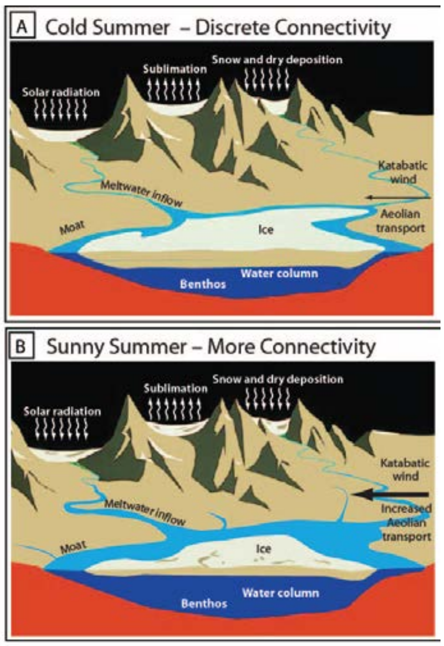


Fig. 1. Schematic diagram of Dry Valleys contrasting cold to sunny summers.

In MCM 4, we are examining contemporary patterns in ecological connectivity in the MDV as a basis for predicting future changes and hypothesize that warming will act as a slowly developing, long-term press of warmer summers, upon which transient pulse events of high summer flows and strong katabatic winds will be overprinted (Fig. 1).

In the past decade, we have observed the end of the cooling trend and three summer climate events which have caused high streamflows and strong winds (Fig. 2). These events are not correlated with increased summer temperatures, but rather are associated with the persistence of the ozone hole over the MDV into mid-summer, when the sun is directly overhead (Jaros et. al., submitted). These high streamflows and sediment deposition have dramatically changed many aspects of the Dry Valley landscape.

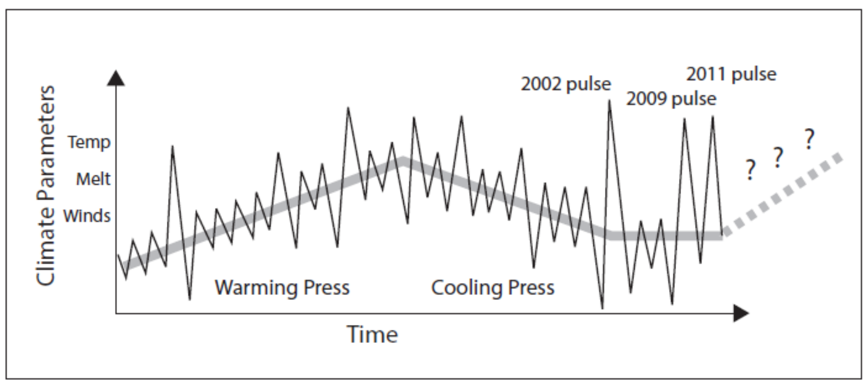


Fig. 2. Revised conceptual diagram of presses and pulses.

Our specific hypotheses (see inside cover) address the ways in which pulses of water and wind will influence contemporary and future ecosystem structure and function.

If increased ultraviolet radiation in mid-summer is indeed the primary driver, then these events may represent millennial extremes, exceeding in magnitude conditions that may occur with the sealing of the ozone hole (Fig. 3).

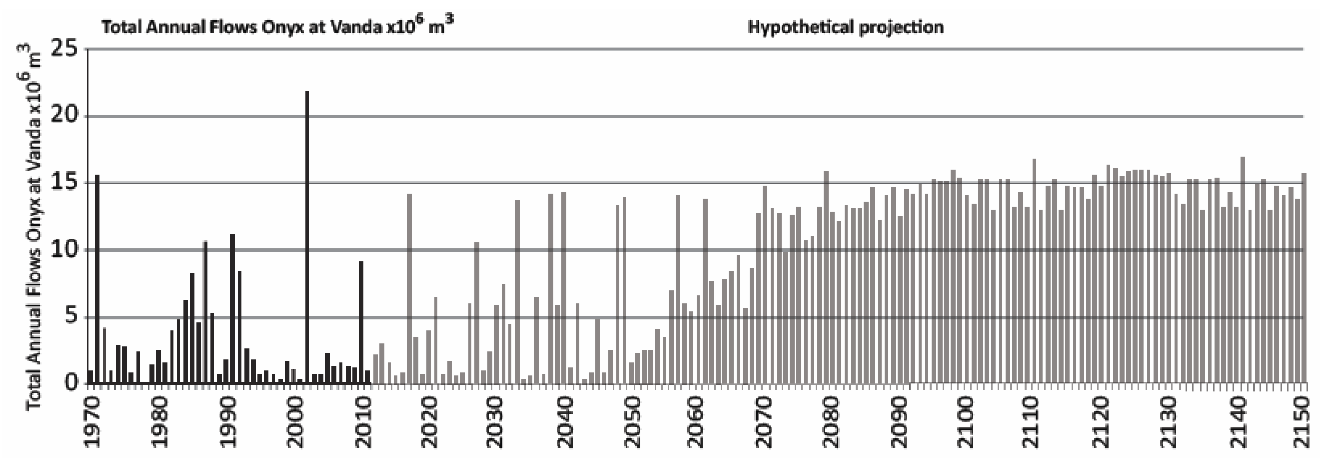
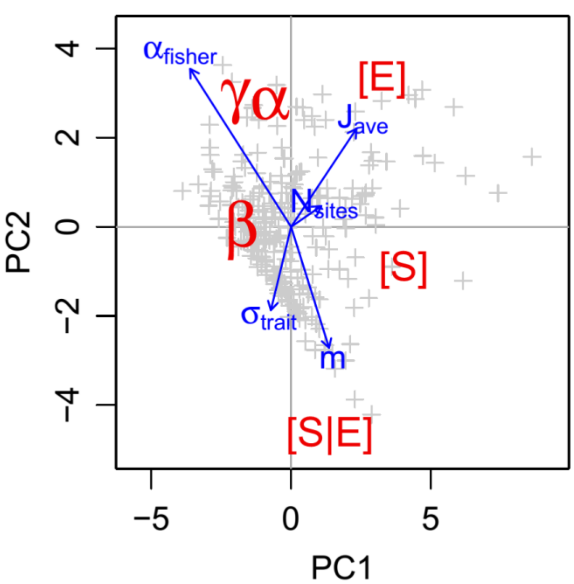


Fig. 3. Revised hypothetical projection based on positive influence of ozone hole persistence on glacial meltwater generation.

Metacommunity Dynamics in the McMurdo Dry Valleys and Beyond… - Jeb Barrett

The metacommunity concept is a major advance in ecology because it provides a theoretical framework to link ecological processes with biodiversity patterns at multiple scales. Metacommunities consist of assemblages of interacting species, typically linked over broad spatial scales by ecological processes influenced by spatial dynamics, environmental factors, and species traits. Diversity patterns in a metacommunity are thus influenced by niche-based species-sorting and dispersal dynamics. In recent analyses of soil microbial diversity in the MDV and across the Transantarctic Mountains, we found that distinct components of the microbial community respond to environmental gradients at different spatial scales and environmental contexts (Sokol et al. 2013, Van Horne et al. 2013).

We (Sokol and Barrett) have been supported by the LTER Network Office to develop a metacommunity simulation model (MCSim, Sokol 2013, https://sites.google.com/site/metacommunitysimulation/) to understand how metacommunity dynamics influence observed diversity patterns in Antarctic soils, and across the LTER network. We are developing a model of metacommunities simulating biodiversity patterns at local and regional spatial scales, and estimating the sensitivity of biodiversity to different types of shifts in metacommunity dynamics. This simulation-based approach not only provides insight into the dynamics that organize microbial metacommunities in the MDV, but also provides a framework to understand similarities and differences in biodiversity patterns for a wide range of taxa and ecosystems.



Principal Component Analysis of diversity outcomes for 260 metacommunity simulations. Each "+" represents a simulated metacommunity. Simulations were ordinated by alpha-, beta-, and gamma-diversity (Jost 2007), and the environmental [E] and spatial [S] components of beta-diversity calculated using variation partitioning (Borcard et al. 2004, Peres-Neto et al. 2006). Simulation parameters that most influenced diversity outcomes are plotted as vectors. In the model, niche breadth (σ_{trait}) is a parameter that determines the neutrality of the simulations.

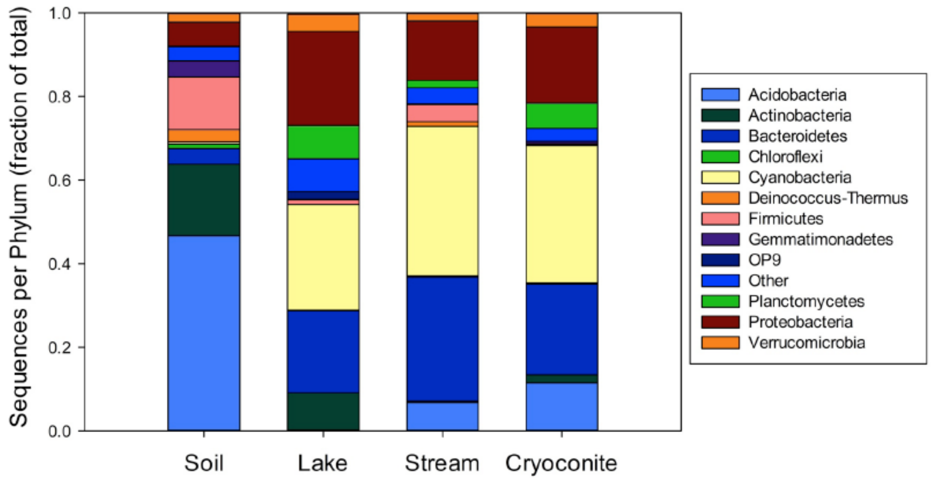
<u>Selected Parameters:</u>

- The legacy of the initial regional species richness and evenness (α_{Fisher}, Fisher et al. 1943)
- Rate of introduction of novel species into the metacommunity (v, Hubbell et al. 2001)
- Dispersal limitation modeled as the slope of a dispersal kernel (w)
- Connectivity to the regional pool (m) as determined by immigration
- Niche breadth (σ_{trait}), increased niche breadth results in greater functional equivalence among species in the regional pool, decreasing the influence of niche-based species sorting and increasing the neutrality of the simulation (Gravel et al. 2006)
- Assemblage size (J, Hubbell 2001)

Field Guide to MCM Biota – Byron Adams

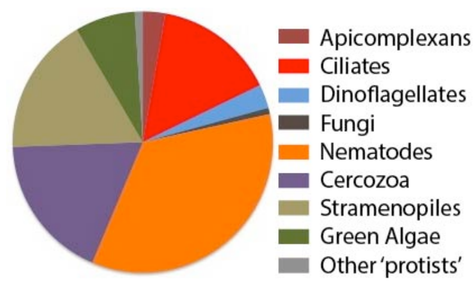
Although the abundance and diversity MCM DV biota is low relative to most other ecosystems, recent and ongoing work reveals that representative taxa from most of the major lineages of the Tree of Life are present and functioning. Diatoms in particular serve as excellent indicators of environmental change, and MCM DV diatoms showcase this utility via the Antarctic Freshwater Diatom Database (http://huey.colorado.edu/diatoms/about/index.php).

Bacteria: Although taxonomic diversity is lower than most ecosystems, functional diversity in the MCM can be as high as temperate forests. Diversity and endemism is higher than previously thought, and highly structured by landscape unit.



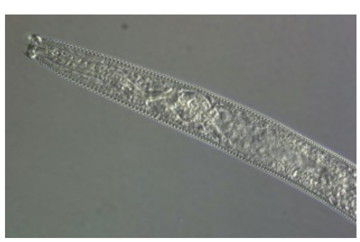
Benthic diatom: *Luticola mutica*

Archaea: Present in Lake Mat samples (Lake Fryxell moat), Lake Fryxell deep anoxic water and lake sediments, and a minor component of soil.
Viruses: Lysogneic bacteria can make up to 89% of bacterioplankton
Fungi & Yeasts: 7 endemic fungal species, one genus, 35 cosmopolitan genera; present in soils and lakes; 2 genera (5 species) of endemic yeasts.
Protozoa (Ciliates, Cercozoa & Dinoflagellates): restricted to moist soils, streams & lakes; no known endemic morphospecies.
Diatoms (Stramenopiles): 62 species; distribution varies by environmental harshness: endemic species are common.
Bryophytes: Dominant species (*Bryum argenteum, B. pseudoturquetrum and Ceratodon purpureus*) are widespread throughout Antarctica.
Cyanobacteria, Algae & Lichens: 20 species of lichens, only 11 on the valley floor; the most common microbial mats in the streams and moats are black (*Nostoc sp.*), orange (*Oscillatoria spp., Phormidium spp*) and green (*Prasiola calophylla, P. crispa*).
Metazoa: Tardigrada (8 species), Rotifera (4 species) Nematoda (5 species), Collembola (one species), Acari (two species).



Abundance & diversity of eukaryote 18S rRNA from MCM Dry Valley soils (1000 amplicon gene reads)

Cyanobacterial filament: *Nostoc* sp.



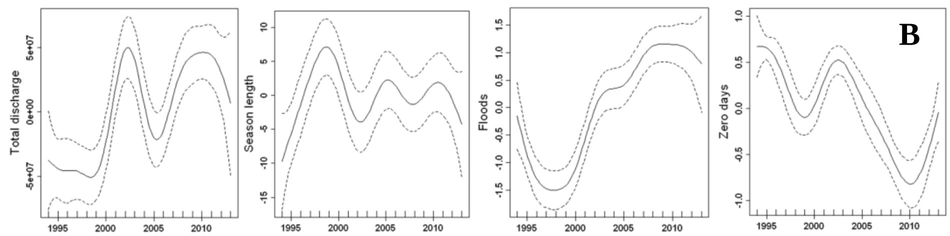
Nematode*: Scottnema lindsayae*

Tardigrade: *Milnesium* sp.

Acari*: Stereotydeus mollis*

Stream ecosystem responses and biomass and organism transport from cryoconites, stream microbial mats to lakes - Diane McKnight

Microbial mats in Dry Valley streams persist through winter and are revived with summer streamflow (Fig. 1A). Tyler Kohler, PhD student, evaluated controls on mat biomass of 3 mat types (orange, black, and green) to changing hydrology over 20 years by creating smoothed trends from generalized additive mixed models (Fig. 1B) and comparing trends with Pearson Correlation Coefficients. Mat biomass collectively decreased during the middle of the record coinciding with a period of low flows and a "flood" summer (Fig. 1C). In-channel mats (orange and green) were more strongly correlated with hydrologic variables, such as zero days, than marginal mats (black) (Fig. 2). Season length and total discharge were important variables for all mat biomass models ranked by model selection using Akaike's Information Criterion. We hypothesize that mats will be resilient to expected changes in hydrology in the MDV.



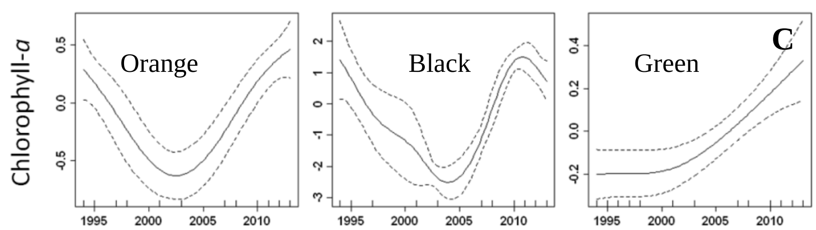


Fig. 1. (A) Orange and black mats in Von Guerard Stream, variation in (B) hydrologic variables and (C) chlorophyll-a by mat type. (Kohler et. al., submitted)

These microbial mats are sources of organic material to the lakes. James Cullis, PhD student, studied transport of particulate organic matter (POM) during diel flow peaks and observed clockwise hysteresis effects, indicating that POM transport is supply limited (Fig. 3). Hysteresis effects were simulated using a model based on sediment transport in streams. Large variations in POM transport dynamics among diel flood pulses were found to be related to time since a resetting flood and regrowth of potentially mobile biomass.

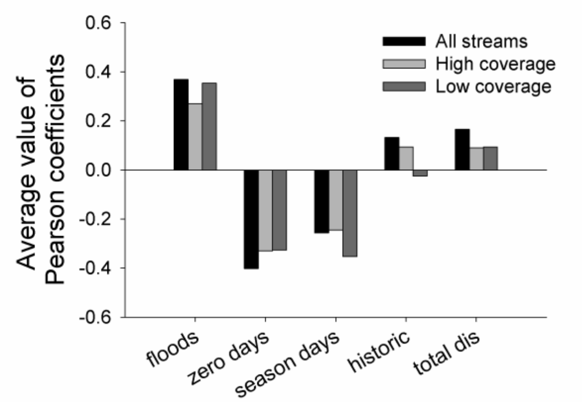


Fig. 2. Pearson Correlation Coefficients for chlorophyll-a and biomass with different hydrologic variables (Kohler et. al., submitted)

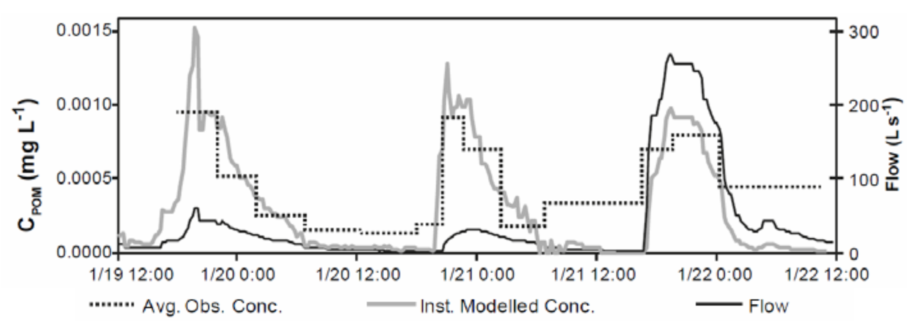


Fig. 3. POM concentration in Von Guerard Stream compared with flow and simulated POM. (Cullis et. al. 2013)

Lee Stanish, former PhD student, used the diatom distribution in POM to identify habitats which provide POM to lakes and streams (Fig. 4; Stanish et.al. submitted). She also documented strong co-occurrence patterns among diatoms and cyanobacteria and heterotrophic bacteria in these mats (Stanish et. al., 2013).

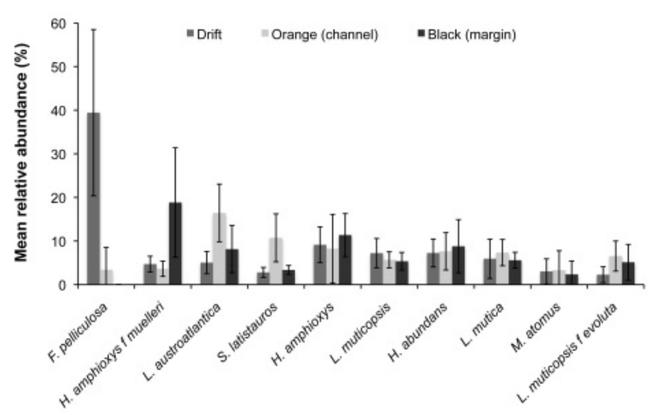


Fig. 4. Relative abundances of diatoms transported with POM (drift) compared to diatoms in orange and black mats

Pulse-Press Project – Jeb Barrett

Climate warming in polar regions is associated with thawing of permafrost, resulting in significant changes in soil hydrology, biogeochemical cycling, and in the activity and composition of soil communities. While ongoing, directional climate warming can elicit such responses over decadal time scales, their manifestation typically occurs as discrete thawing pulses. Indeed, in the McMurdo Dry Valleys of Antarctica abrupt changes in community structure and biogeochemical cycling in terrestrial and aquatic ecosystems following a summer warming event (Jan. 2002) exceeded the influences of a decadal cooling trend in both magnitude and rate of response (Foreman et al. 2004, Barrett et al. 2008). Thus, we anticipate that climate-mediated permafrost changes and their associated impacts on soil communities and biogeochemical cycles may occur over seasonal time scales. **Our objective is to simulate different frequencies of permafrost thawing events in Antarctic permafrost soils**. Since the top horizons of most Antarctic soils are dry permafrost (*i.e.*, there is insufficient water content to generate ice-cement), with ice-cement or massive ice typically below 30 cm, permafrost thawing events are likely to result in subsurface movements of water that may manifest as groundwater seeps down gradient.

The south-facing hillslope of Many Glaciers Pond showing the location of the Pulse-Press Project. The large black structure on the ridge is a 1000 gallon holding tank. White boxes are insulated instrument power arrays and data storage modules (Photo: MCM LTER).

We designed a long-term study to address these objectives using a water diversion experiment introducing two frequencies of water additions from a natural pond to trenches excavated to the depth of ice-cement. In Dec. 2011 we established three sets of permanent plots (7.5 X 15m) on the south-facing hillslope above Many Glaciers Pond in Taylor Valley. High-resolution LIDAR imaging, instrumentation, and comprehensive pre-treatment sampling of all plots was conducted in Dec. of 2011, and in Jan. 2013, prior to an additional round of pre-treatment sampling and then initiation of the experiment anticipated in Jan. 2014. Instrumentation consists of thermocouples, delta-T moisture probes and water activity probes buried at multiple active-layer depths every 2 m down-gradient from the water-addition trenches. The three different plots will receive the following different treatments:

> PRESS Treatment: Annual water additions sufficient to raise soil water to 10% water content (as observed during the melt event in Jan. 2002). This is achieved by pumping water from Many Glaciers Pond to a holding tank above the experimental plots, from which we will apply water by gravity feed to a trench during the warmest week of the year (typically the 1st or 2nd week of Jan.).
>
> PULSE Treatment: Same as above, but water diversions added only in alternate years to simulate a lower frequency of thawing permafrost
>
> Positive Control: Trenched and instrumented, but no water additions

Sampling campaigns consist of 84 soil samples (28 per treatment) collected from permanent plots for quantification of soil biota (invertebrates determined by microscopy and bacteria by 16S rRNA sequencing) and intensive geochemical analyses.

This experiment will address the overarching hypothesis: *Climate warming in the McMurdo Dry Valleys will amplify connectivity among landscape units leading to enhanced coupling of nutrient cycles across landscapes, and increased biodiversity and productivity*. Specifically, this experiment was designed with H2 & H3 of the MCM4 proposal in mind. Simulated permafrost thaw is expected to mobilize solutes and nutrients within the active layer of treated plots, resulting in homogenization of the fine scale variation in surface geochemistry typically observed in this region (e.g. Barrett et al. 2006 & 2009). In contrast, responses of biotic communities to enhanced water availability and connectivity are expected to be complex. For example, wet sediments in stream channels and on lake margins typically have larger populations and more diverse invertebrate communities than dry environments (Treonis et al. 1999; Ayres et al. 2007), but lower diversity of bacteria (Takacs-Vesbach et al. 2010, Zeglin et al. 2011, Sokol et al. 2013). Most of our understanding of the response of soil biota to increased water availability comes from studies of spatial gradients (*e.g.*, Simmons et al. 2009, Takacs-Vesbach et al. 2010, Geyer et al. 2013). Fewer examples demonstrate temporal community responses to changes in soil resource availability (Barrett et al. 2008b), and little is known about the response of soil bacterial communities to environmental change in this region, though a recent study examining the activity of soil bacterial communities following addition of isotopically labeled water and organic matter showed that certain taxa of the phylum *Proteobaceria* were enriched during *in situ* incubations (Schwartz et al. in review).

Prediction

- Greater solute mobility and lower coefficient of variation in surface geochemistry in manipulated plots vs control plots
- Decreases in the dominant, arid-soil adapted species of invertebrate (*Scottnema lindsayae*) and increases in subordinate species adapted to wet sediments
- Changes in bacterial community composition between manipulated and control plots
- Changes in soil communities will be most significant in PRESS treatment and intermediate in PULSE plots, with greater compositional similarity between PULSE and control plots, relative to PRESS plots

Limnological Studies - Peter Doran and Cristina Takacs-Vesbach

Lakes are the only perennial liquid water environments in the MDV; they maintain biological activity year-round with food webs dominated by phytoplankton and bacteria (Priscu et al.1999; Vick et al. 2013; Kong et al. 2012). Perennial ice-cover limits turbulent mixing and most lakes are strongly stratified by temperature and salinity (Spigel and Priscu 1998). The major influences on the chemical composition of lakes are their landscape positions and climate history (Lyons et al. 2000; Dore and Priscu 2001).

Autonomous monitoring equipment and lake hydrology surveys

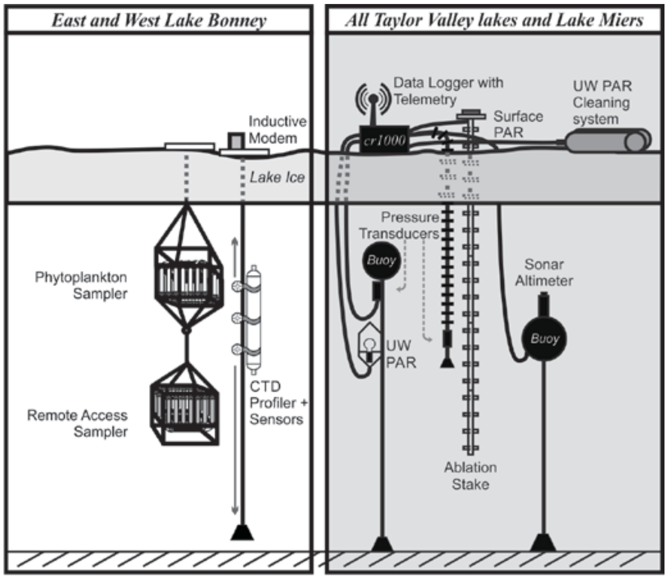


Fig. 1. Schematic showing autonomous sampling (left) and monitoring (right) equipment deployed in MCM LTER lakes

We maintain year-round equipment: stage, ablation (mass loss from lake ice by melt or sublimation), ice thickness, surface PAR and under-ice PAR data continuously (Fig. 1). In addition we conduct surveys during the summer field season to manually measure lake levels and surface ablation against established benchmarks. This past year, PhD student Hilary Dugan published the long term lake ablation record, which established the summer ablation rates of 0.2–0.7 mm w.e.d^{-1} and winter rates of 5–31 mm w.e.d^{-1}. The up-to-date lake level record is shown in Fig. 2.

Through an equipment grant from NASA, an EAGER award from NSF, and logistics co-ordination with the MCM, we installed new Autonomous Lake Profiling and Sampling (ALPS) stations in both lobes of Lake Bonney this season. The ALPS stations will profile the lakes year-round at regular intervals (currently every other day) measuring temperature, conductivity, photosynthetically available radiation, chlorophyll-a fluorescence, phytoplankton pigment diversity, turbidity, dissolved oxygen, methane, and carbon dioxide. The stations also have automated water filtration samplers to collect and preserve samples from regions of peak biomass for geomicrobiological analysis over the year (at a minimum, collections will be made every other week, which is less than the doubling time of the organisms). Filtered lake water will be analyzed for dissolved organic carbon, dissolved inorganic N and P species, and ion chemistry. The particulate matter on the glass filters will be analyzed for particulate organic C, and N. Metabolic and phylogenetic diversity will be assayed using metagenomic and metatranscriptomic methods on filter concentrated and preserved samples.

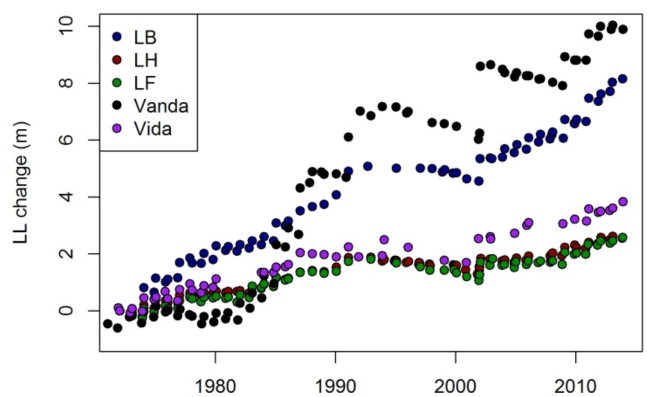


Fig. 2. Lake level changes documented by the MCM LTER.

Limno Runs

At least twice a summer lakes are visited for an exhaustive assessment of water column physical, chemical and biological rates (a regularly updated manual detailing our sampling and analyses protocols is available here: http://www.montana.edu/priscu/DOCS/LTER%20methods%20web%20page/Method_Manual_AC_23_Feb_2011.pdf). Given the addition of Lake Miers to our monitoring program during MCM4, we carefully evaluated our lake monitoring activities and reduced the frequency of limno runs in the Taylor Valley lakes and have reduced sampling efforts at Lake Hoare. We continue to conduct limno runs at Lake Bonney and Lake Fryxell.

Given our more than 20 years of accumulated limnological data and evidence of changing lake levels, we are integrating the long-term physical, chemical, and biological data from the lakes to understand the role that increased connectivity has on ecosystem function. These closed-basin lakes are reservoirs of history, integrating many centuries of autochthonous and allochthonous inputs. We have recently shown that there is a coincident change in lake heat contents and volumes (Fig. 3). There was a general loss of volume during the cooling trend before 2001, and since then, a general increase in volume and heat content of all lakes. Mean lake temperature trends through time suggest that the lakes are potentially receiving more water directly from glaciers (relative to streams) as mean water temperatures cool, but heat and water mass increase.

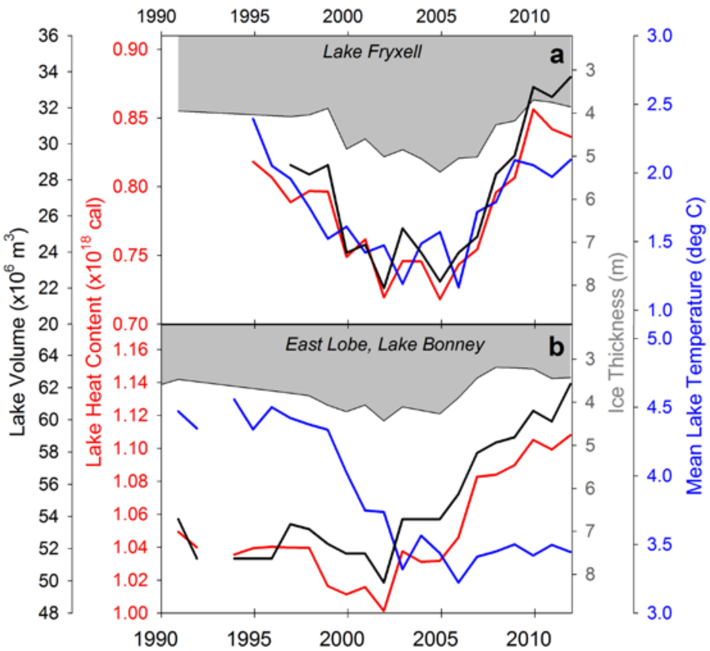


Fig. 3. Decadal changes in lake volume, heat content, ice thickness (gray fill), and volume-weighted mean temperature for (a) lake Frxyell and (b) East Lobe of Lake Bonney.

Lake Integrative Connectivity Experiment (Lake ICE)

Lakes represent the most biologically productive landscape unit in the MDV and respond to processes occurring valley wide. We conducted the lake experiment described in the proposal to address our overarching hypothesis that climate warming in the MDV will amplify connectivity among landscape units leading to enhanced coupling of nutrient cycles, increased productivity, and biodiversity (Takacs-Vesbach et al. in prep). The Lake Integrative Connectivity Experiment (LakeICE) was designed specifically to quantify the effect of increased MDV connectivity on lake autotrophic and heterotrophic productivity and community composition (hypotheses 1-3). We expect lakes to experience increased input from streams, cryoconites, aeolian sediments, and fluvially deposited algal/cyanobacterial mats, and an overall increase in nutrient input. Surface water (1 m below the bottom of the ice cover) from East Lobe Lake Bonney was amended experimentally with material from the surrounding basin (aeolian sediment collected from the surface of Lake Bonney, wetted sediments from the surrounding soils, *Nostoc* mats from ponds in the basin, cryoconite material collected from the Canada Glacier, and stream water) to simulate increased material transport resulting from potentially increased melt within the MDV ecosystem. These materials were encased in 12,000 Dalton dialysis tubing and incubated in 10 L microcosms of lakewater for 2 days to approximate a pulsed event. The dialysis tubing ensured that only macromolecules or exudates from the materials would be leached into the lake water microcosms. Biological productivity, biological diversity and selected chemical parameters were then monitored in microcosms incubated over 6 days under simulated temperature and light. Primary productivity increased in the microcosms in response to the cryoconite and aeolian treatments only, whereas bacterial productivity responded to all treatments, and was accompanied by enhanced uptake of inorganic N and P. At the same time, bacterial 16S rRNA gene richness initially increased in all treatments relative to the controls, but then decreased in nearly every treatment by the end of the experiment. Changes in community composition were largely attributed to variations in the relative abundance of members of the Bacteroidetes, Proteobacteria, and Cyanobacteria. Data from the LakeICE experiment show that lake productivity, diversity, and community composition can respond rapidly to increased nutrients input resulting from climate induced connectivity in the MDV.

Modelling, Water Tracks, and Weathering Connectivity – Michael Gooseff and Berry Lyons

Over the past decade, we have developed a conceptual model that documents the connectivity of glaciers (primary source of water) to lakes on the valley floor via stream channels. The stream channels provide two important functions beyond conveyance of water and associated solutes and energy to lakes – (1) they provide habitat for algal mats that include diatom and microbial communities, and (2) they accommodate active exchange of water between the channel and the hyporheic zone underneath and adjacent to the channel. We have demonstrated that MDV streams have the highest silicate weathering rates published. A simple end-member mixing model of dilute glacial meltwater (with an electrical conductivity signature of ~18 uS/cm) and hyporheic waters (~175 uS/cm) is used to quantify the continuous influence of hyporheic zones on flow that reaches the stream gauges (Fig. 1).

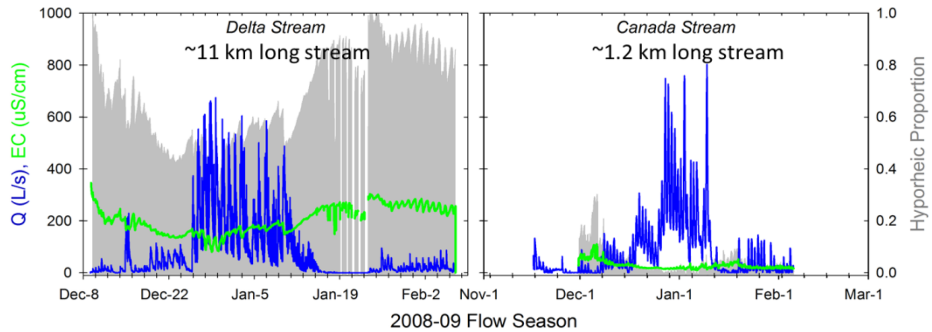


Fig. 1. Long and short stream discharge, electrical conductivity, and hyporheic influence plotted continuously through the 2008-09 flow season. Note that the long streams have stream water that has been more substantially influenced by hyporheic exchange than short streams.

Energy balance modeling across the landscape

We have completed extensive, complex modeling of meltwater generation on MDV glaciers, which included new representations of radiation influences on ice melt within 20 cm, but *below* the surface of the glacier (Hoffman et al., 2008; Hoffman, 2010). These results indicate that there is extensive shallow subsurface melt water generation across these glaciers. We propose modeling the impacts of hydrologic connectivity across the landscape by quantifying distributed changes in surface energy balance of wetted and dry soils. To inform this model and provide calibration data, we will be measuring time series of distributed surface temperatures in the 2013-14 field season using an infrared camera. An improved quantification of the impacts of changes to water distribution across the landscape will allow for an improved characterization of the associated ecological implications.

Landscape connectivity beyond stream channels

Flow records from our stream gauging network indicate that, on average, the last decade (2002-12) has been wetter than the previous decade (1993-01). As such, we have observed many 'water tracks' – wetted sediments across the landscape originating from snow and ice melt lacking obvious channels but that collect and redistribute inorganic solutes downslope (Levy et al., 2011). We recently mapped these wetted soil features across the Dry Valley landscape using high resolution remote sensing (Fig. 2). Our results indicate that these features cover less area than stream channels (Langford et al. in review), but may be important to transporting solutes across the landscape because concentrations of salts are several orders of magnitude higher in water tracks than in streams (Levy et al. 2011).

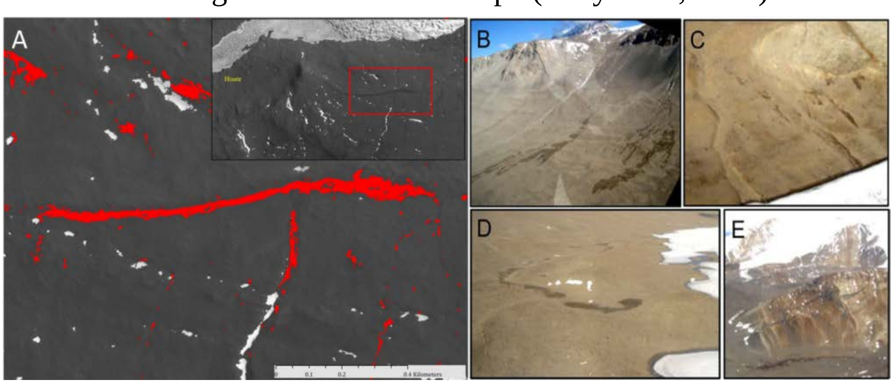
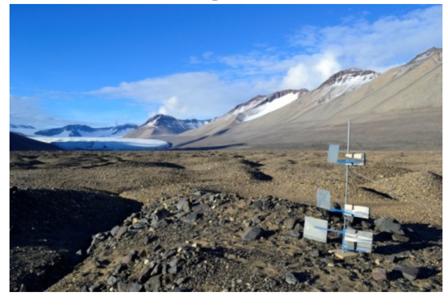


Fig. 2. (A) Remote sensing identification of wetted soils just south of the Canada Glacier in Taylor Valley, and (B-E) several examples of water tracks/wetted soils observed across the McMurdo Dry Valley landscape.

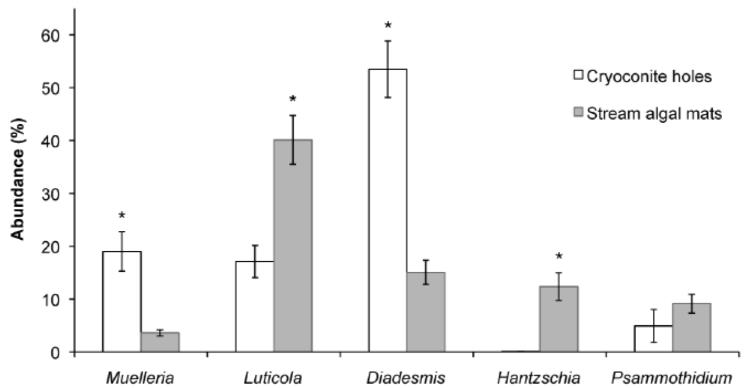
Local, Regional and Global Connectivity – Byron Adams and Diane McKnight



Aeolian Connectivity: To address our hypothesis that changes in aeolian transport will influence the distribution of soil organisms and ecological connectivity, PhD student Alia Khan is collecting material at about 10 sites in the MDV distributed to identify long range and within valley transport (particle collector installation at right). This research is conducted in collaboration with New Zealand researchers. **(H1)**

Transport Markers: Black carbon (BC) aerosols may travel thousands of kilometers before they are scavenged by rain or snow, after which they are stored in snow, soils and sediments. In the MDV local sources of BC are present, e.g. helicopters and generators. We aim to quantify aeolian transport processes by using the local production of BC as a tracer for aeolian connectivity Based on a previous study estimating inputs of carbon from helicopter traffic, we are now measuring the transport and distribution of black carbon in aeolian particles, streams and lakes, and will be modeling the processes controlling the fate in the lakes. **(H1)**

Interconnected Bioreactors: Cryoconites are cylindrical holes formed when windblown sediment melts into ice, often supporting microbial metabolism. We predict that with warmer summers cryoconites will expand and increase connectivity across the glacier (with other cryoconites) and to meltwater streams. Lee Stanish and others found that cryoconites have distinct diatom communities (at right) and that there is a species richness gradient corresponding to distance inland from the coast. **(H3)**



Mean relative abundances of the most abundant diatom genera in cryoconite holes and stream algal mats. Genera that are more abundant in one habitat than another are noted by an asterisk ($p<0.0001$).

Terrestrial Observation Network: Over a decade ago, scientists and program managers from the United States, New Zealand, and Italy came together to "*… conserve and protect the unique and outstanding environment of the McMurdo Dry Valleys … especially the value of the extensive scientific datasets that have been collected*."

In a similar spirit of international cooperation we initiated the McMurdo Dry Valleys Terrestrial Observation Network (MCM TON) to assess and address environmental change on Dry Valley ecosystems. Alongside our colleagues from New Zealand, Italy, Korea, and Australia, we have developed:

- i) the minimum core set of measurements
- ii) the requisite standards and protocols
- iii) a draft data coordination and development plan
- iv) tools for assessing the effectiveness of current environmental protection guidelines.

By coordinating international experimental and observational measurements through the MCM TON, we have significantly increased our ability to measure key processes associated with environmental change in Dry Valley ecosystems, as well as assess the effectiveness of environmental stewardship and management policies. **(H1-4)**

Future Scenarios - Peter Doran

The future of Taylor Valley under projected warming is one of reduced lake ice cover, increased lake volume and reduced soil habitat in the lower valleys. A new model as part of a Maciek Obryk's PhD thesis is near completion and predicts that under current climate trends (last 10 years), the lakes will start to seasonally ice-out within the next few decades (Fig. 1). This will dramatically increase summer light levels and wind driven mixing, and alter many chemical and biological processes. In the longer term, as lake levels rise, Lake Hoare and Fryxell will merge into one lake which flows into McMurdo Sound (Fig. 2). That lake will be at 80 m asl. Lake Bonney will grow until it spills into the Hoare/Fryxell Basin. The height of the greater Lake Bonney will be ~125 m asl (interpolated bedrock sill is currently under the Suess Glacier). The lakes may quickly become joined depending on the resistance of that sill. At current rates of lake level increase, the joining of the lakes may occur in 400 to 500 years.

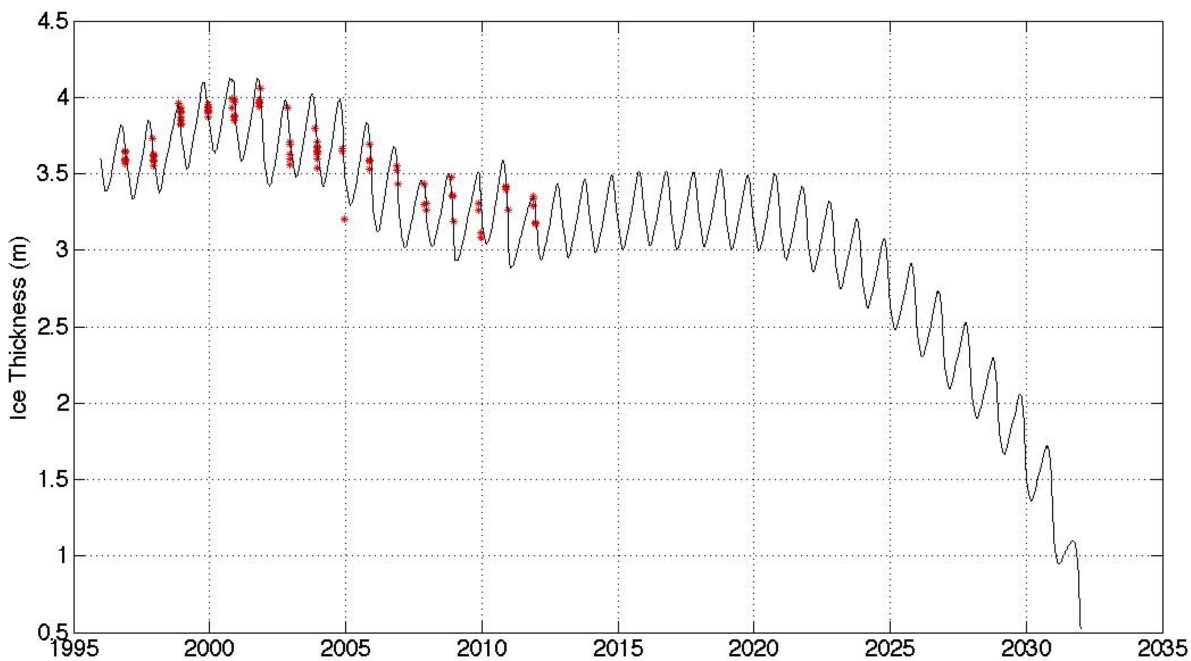


Fig. 1. The simple physics based ice cover model is solved using a one-dimensional heat equation dynamically coupled with atmosphere and the underlying water column. Future ice thickness prediction is based on daily averages calculated using 10-years of data (2002-2012). Red points are observations, black line is model prediction.

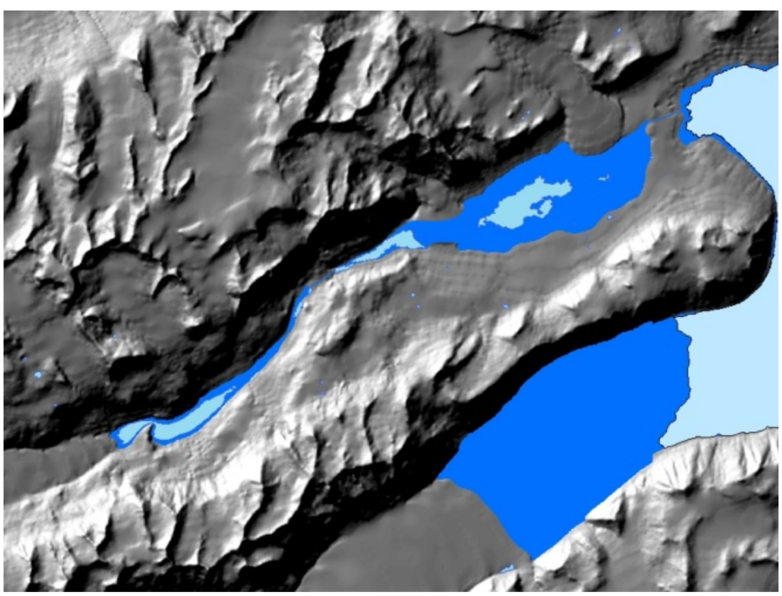
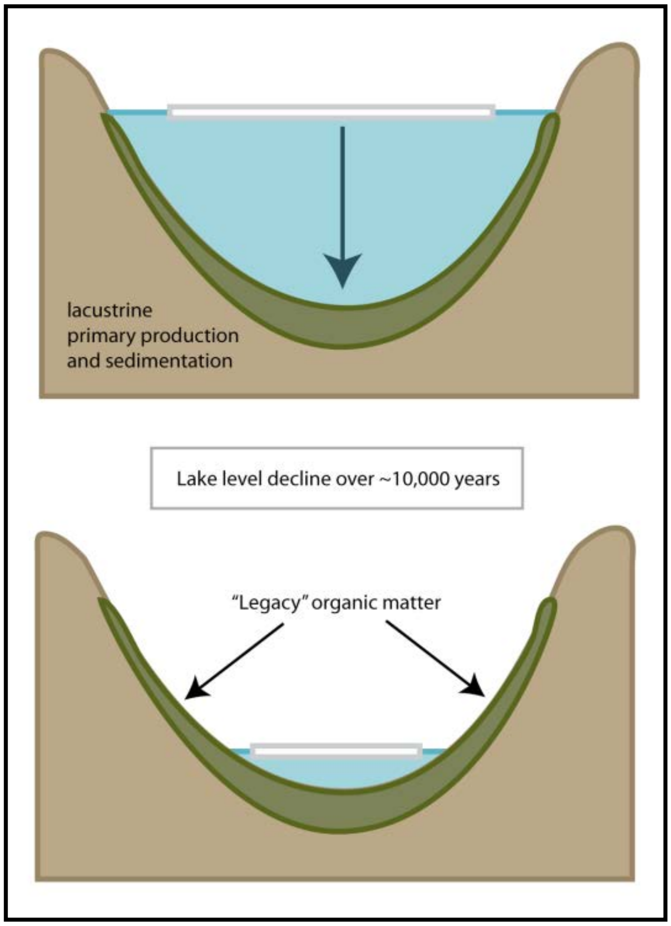


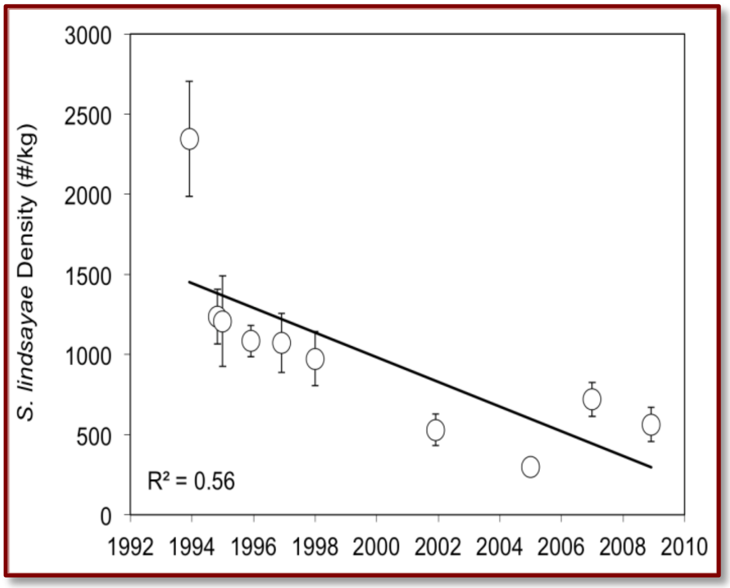
Fig. 2. Projected future of Taylor Valley based largely on a digital elevation model and knowledge of critical sill points. Sea level is depicted at 10 meters above present, which is viewed as a worst case scenario with WAIS collapse

Climate and Resource Legacies in Taylor Valley: The Influence of Paleolake Washburn on Soil Biogeochemistry and Biodiversity – Ross Virginia

Climate driven variations in lake levels since the Last Glacial Maximum have created "resource legacies" seen today as gradients of biogeochemical properties in soils and lakes. Associated with these gradients in organic matter, limiting nutrients, and salts are contemporary organism abundances and biodiversity.

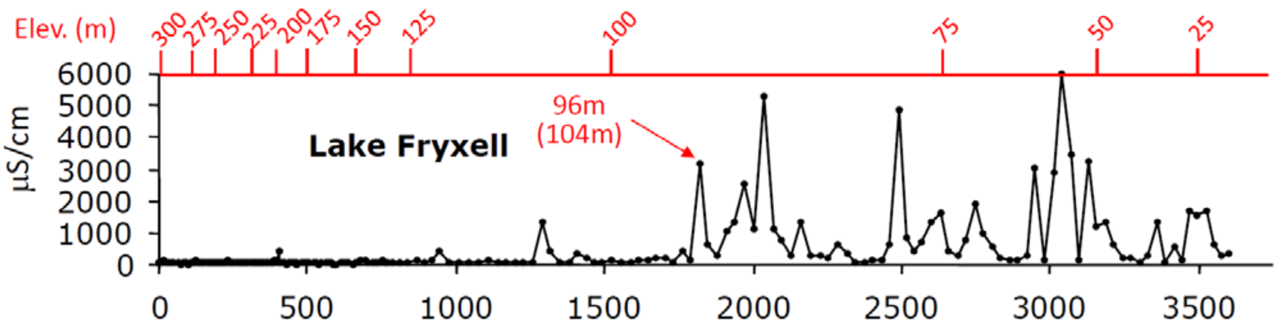


Scottnema lindsayae is the dominant soil nematode in dry soils where its population distribution defines the limits of habitat suitability (function of organic matter, salinity, moisture) and its population variation is an indicator of environmental change.

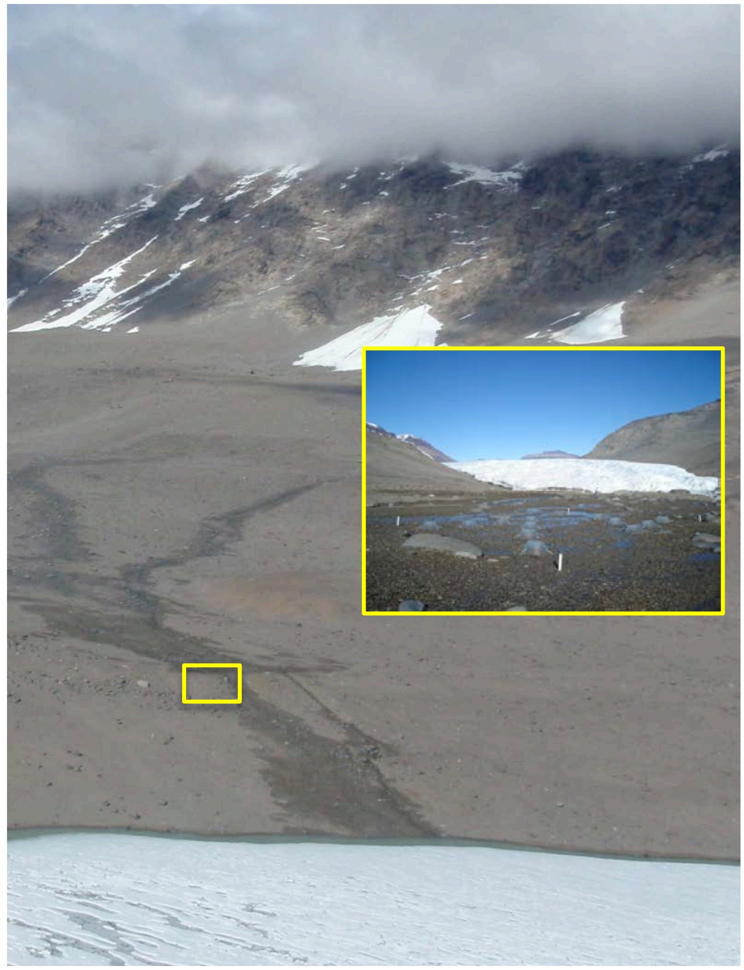


Long-term soil studies along an elevation transect (ET) in Taylor Valley (1994-) and newly established long term plots in Miers and Garwood Valleys (MCM3) allow assessment of changes in soil habitat suitability and soil biota associated with changing hydrologic connectivity in the dry valleys. *Scottnema* abundance has declined in the ET and in control plots from other multi-year experiments from 1993 to the present.

An example of a soil legacy from lake level variation is the high spatial variation in soil salinity observed at lower elevations (25-100m elev.) near existing lakes. Soil invertebrate biodiversity and abundance are closely associated with salinity and soil water content, both of which are changing in response to recent pulse warming events in summer.

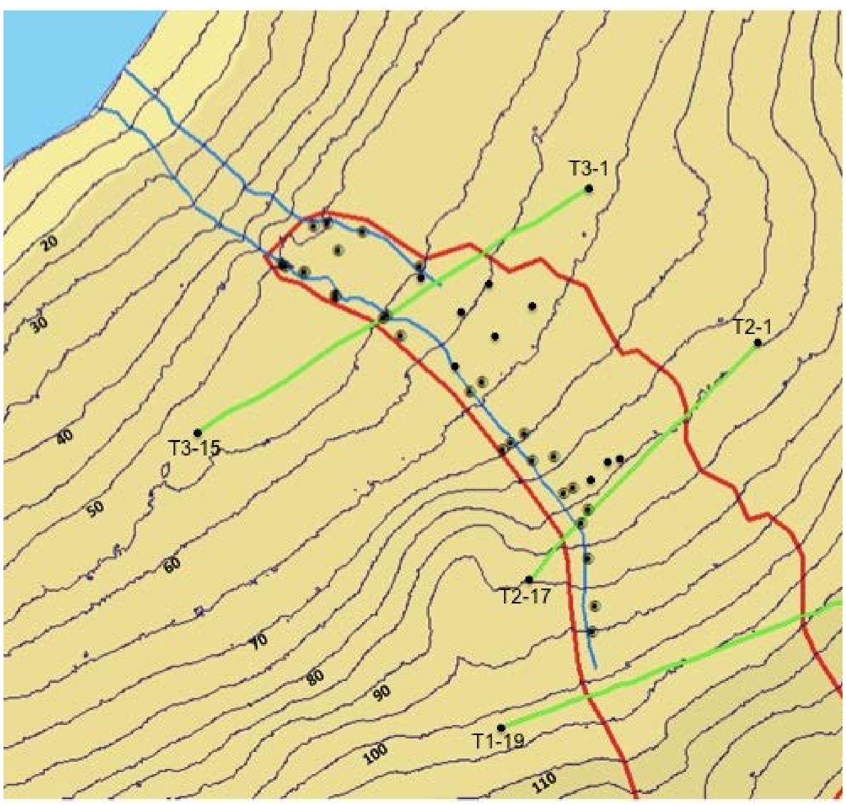


Wormherder Creek: Ecosystem connectivity and species distribution – Diana Wall



Wormherder Creek is an ephemeral stream and wetland system that has had flow only three times in the past 20 years. Located near Lake Bonney in Taylor Valley, in most years this hillside is bone-dry, making it an ideal site to investigate the long-term effects of extreme pulse/press events. The insert (right) shows an experiment that was flooded during the high flow of 2001-02 and 2008-09. We hypothesized that climate driven increases in the frequency and magnitude of high-flow events will lead to increased connectivity and subsequent redistribution of nutrients and biota across the landscape.

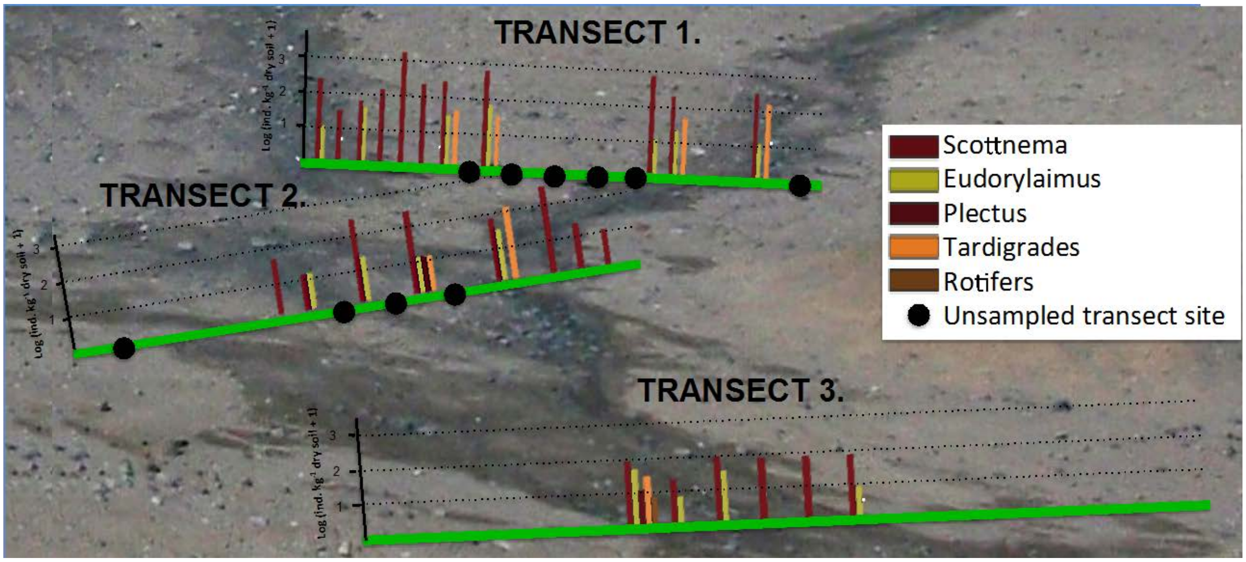
Study design: In 2008-2009, we used GPS to record the wetted zone, conducted a tracer study to explore the hydrology of the watershed and we analyzed soil samples within the wetted zone to determine how the flow of water influenced soil chemistry and soil fauna communities. Soil communities within the wetted zone were related to soil properties and aboveground water flow within the watershed (Nielsen et. al., 2012). We continued and expanded the sampling of this watershed in the field season of 2009-10 (see map below, and http://mcmsitereview.lternet.edu/sites/default/files/Click%20Here%20to%20Play%20Movie.m4v for a fly-over animation of the site).



Blue lines – main streams: both drain into Lake Bonney
Red lines represent the wetted zone
Black dots inside the red line represent the 39 samples analyzed in 2008-09

In 2009-10 we resampled these sites and established 3 transects (**green lines**, 51 sampling points) across the watershed to compare the fauna in the dry and the wet areas and monitor the development of soil communities as dry, depauperate soils become colonized over time. This setup encompassed 61 samples inside the wetted area and 29 samples outside of the wetted area.

Results to date: The flow of water increases soil water availability and drastically decreases salinity within the wetted zone compared with the surrounding dry soils. Soil fauna distribution graphs (below) show the abundance of the three nematode genera, tardigrades and rotifers in samples collected along the three transects (**green** x axis) overlain over a photograph of the study site during flood (darker soils indicate wetting). Transect 1 was located furthest uphill and transect 3 furthest downhill. In the middle of transect 1 are a series of samples without soil fauna that coincides with the presence of a small, dry hill. Soils here were most similar to the dry soils outside the wetted zone.



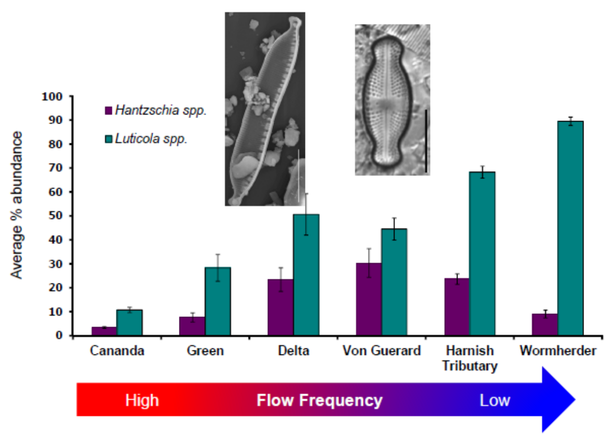
The effect of the pulse event (flood) was twofold:

1. Periodic leaching of salts from flooding reduces soil osmotic stress to levels that are more favorable for soil organisms. The increased hydrological connectivity within the landscape unit led to improved habitat suitability, leaving a strong positive effect on soil animal abundance and diversity.

2. The hydrological pulse created increased connectivity within the watershed, providing increased reactivation and dispersal opportunities for soil fauna.

This study clearly demonstrates a lasting carry-over effect of extreme events on the distribution of soil fauna. It seems that any particularly extreme event or an increase in the frequency of less severe extreme events will change the biogeochemistry thus influencing the habitat suitability and colonization success of soil biota.

This study also provides insight into diatom community composition. Stanish et. al. (2012) showed that the relative importance of diatoms from the two genera with many endemic species varied along a gradient of flow frequency, with species of *Luticola* becoming dominant in Wormherder Creek.

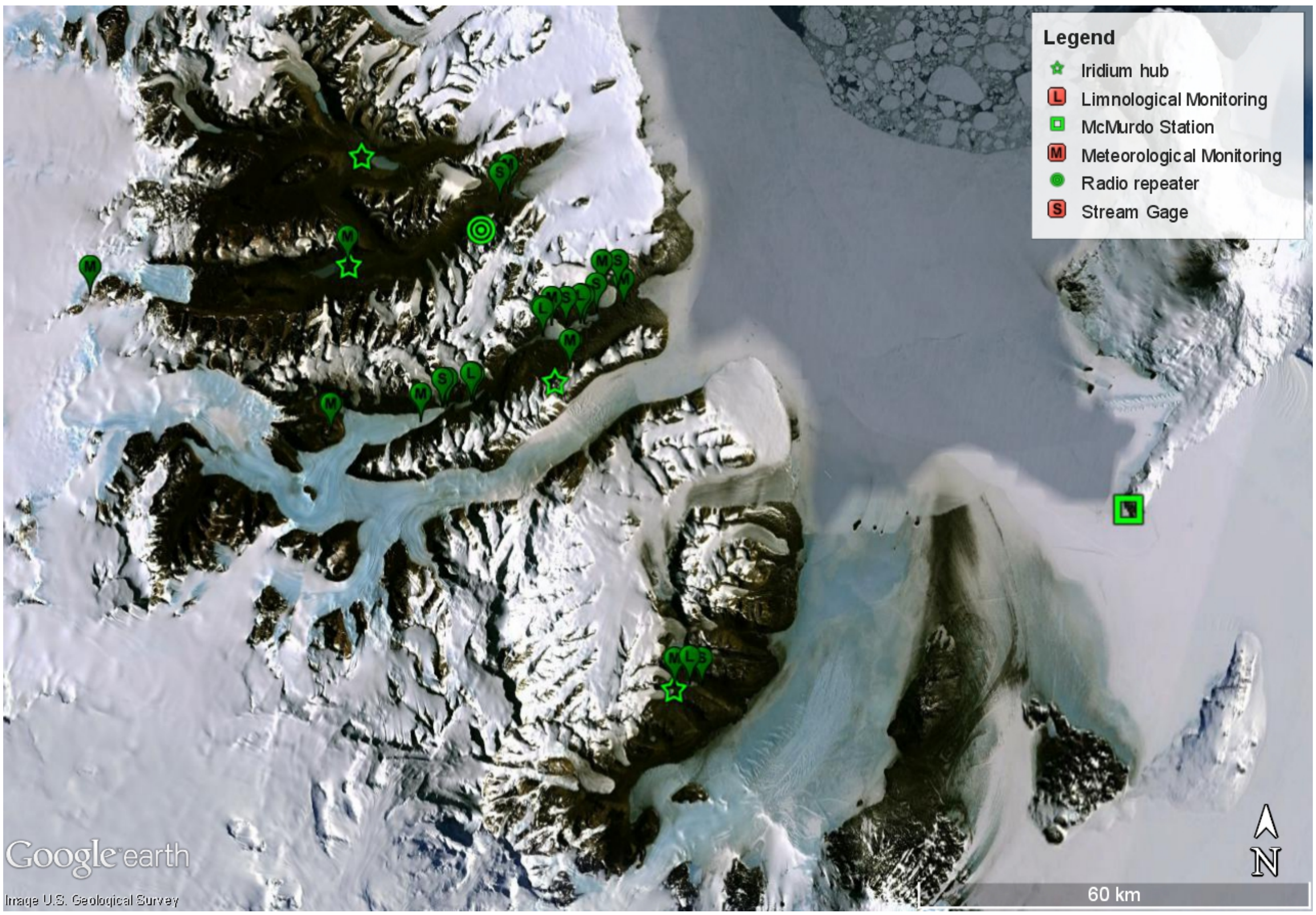


Conclusions: The colonization of soil fauna within this landscape is limited by 'thresholds,' meaning that soil conditions have to reach a favorable state before successful colonization can occur. After this, environmental gradients, and in this system, soil moisture in particular, will influence community assembly greatly by determining which species will be able to survive in a particular spot. As models forecast extreme events to become more pronounced in the dry valleys, over time we predict an increase in habitable areas, greater productivity and more complex soil food webs. Thus, the Wormherder Creek study site serves as an excellent natural experiment for monitoring the effects of predicted increases in the magnitude and frequency of pulse events and increased connectivity in this ecosystem.

Telemetry and the monitoring program – Diane McKnight

Beginning the 2010-2011 season, we have installed a telemetry network that utilizes the Iridium satellite network and radios to connect 14 meteorological stations, 8 stream gages, and five lake monitoring stations to transfer data year round. Four hubs, often co-located at a monitoring site when topography allows, receive satellite phone calls originating in the US to open a connection, then sequence through as many as seventeen different data loggers via radio communications to harvest the latest data. This connectivity allows for crucial end-of-melt-season data collection, and over-winter monitoring of system components allowing the prompt repair of faulty equipment as soon as possible. Additionally, real-time summer connectivity to remote locations allows us to prioritize site visitation: we can quickly respond to changing environmental conditions, like peak stream discharges; or determine if a visit to a remote, and difficult to reach location is warranted.

Data is collected every six hours in summer, and daily in the winter (stream gages only transmit data from Oct – Mar) and promptly sent to the main LTER server (http://www.mcmlter.org/nearRT.htm).



Biodiversity – Peter Doran and Cristina Takacs-Vesbach

With the application of molecular biology techniques to investigate MDV biodiversity, a surprising level of bacterial (Cary et al. 2010, Takacs-Vesbach et al. 2010; Van Horn et al. 2013) and protist (Bielewicz et al. 2011; Xu et al. in review) richness has been revealed Although bacteria comprise a significant proportion of MDV biomass (Takacs and Priscu 1999; Foreman et al. 2007; Stanish et al. 2012), we know relatively little about their physiology and thus about their ecology and roles in biogeochemical cycling. To truly understand connectivity within the MDV (and hence, to address our hypotheses in MCM4) requires an understanding of the biodiversity, distribution, and functional roles of specific organisms within the environment and their responses to climate driven pulses and presses. Our approach is to determine spatial and temporal variations of microbial diversity, distribution, and function across all major habitats (cryoconites, streams, lakes, and soils) and determine changes in response to experimental manipulations (see sections on LakeICE and P3). Previous microbial 16S and 18S rRNA gene assays in the MDV have produced a large diversity of sequences from specific terrestrial and aquatic habitats (e.g., Gordon et al. 2000; Glatz et al. 2006; Barrett et al. 2006; Porazinska et al. 2009; Vick-Majors et al. 2013, Michaud et al. 2012). In MCM4, we are using our molecular data to investigate the role that microbial distribution and function play in ecosystem level process MDV-wide.

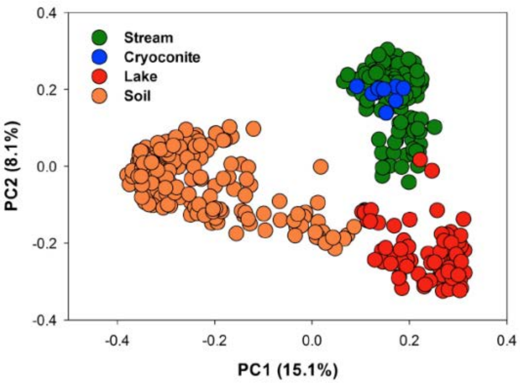


Fig. 1. PCoA of MDV bacterial communities (unweighted Unifrac) from all major habitats.

In Y1 of MCM4, we collected 425 samples from cryoconites, streams, lakes and soils throughout the Taylor, Wright, and Miers Valleys and analyzed 16S rRNA gene diversity to determine a baseline distribution of microbial communities throughout the McMurdo Dry Valleys. The data showed that bacterial alpha, beta, and gamma diversity is greatest in streams, followed by lakes and soils, and that phylogenetic diversity does not differ significantly between lakes and soils. Significant habitat filtering is observed among the samples (Fig. 1, Anosim significance of weighted and unweighted Unifrac clusters $P<0.05$) suggesting a lack of community connectivity despite physical connectivity among habitats. This result is surprising given that diel stream pulses transport significant amounts of mat biomass into lakes (Cullis et al. 2013) and that large flow events as in 2001/2002 resulted in a two-fold reduction of stream biomass (Stanish et al. 2011). Distributions of abundant and rare sequence types among the habitats indicate that the most abundant sequences from each habitat comprised 5 to 40% of the sequence types in other habitats, but the rare sequence types are most often restricted to one habitat type. We intend to repeat similar collections this year (Y3) and in Y6 to address temporal variation. Additional analyses we are exploring include variation partitioning to assess the relationship between beta diversity and environmental and spatial gradients (Sokol et al. 2013), which has revealed contrasting taxon specific distributions for soil communities.

We are using stable isotope probing (Schwartz et al. submitted), metagenomics (Fierer et al. 2012, Takacs-Vesbach et al in prep.), and metatranscriptomics (Buelow et al. in prep) in our work to assess how MDV organisms respond to simulated connectivity within the context of our experiments. Preliminary results suggest that our modest metagenomic sequencing effort includes data from all three domains of life, in addition to viruses, and that using a comparative metagenomics approach, spatial variations in the datasets are discernable. We have also successfully extracted RNA from soils and lakewater and completed Illumina sequencing of eight metatranscriptomes (six from a soil amendment experiment described in Van Horn et al. submitted and two from the primary productivity maxima of Lake Bonney). Ongoing analyses of these datasets are focused on identifying how community function changes with increased moisture and nutrients by identifying over- and under-represented transcripts in relation to experimental amendments performed during MCM4. Ultimately, our goal is to determine how ecosystem function will be altered in response to increased connectivity.

Education and Outreach –Adrian Howkins and Diane McKnight

STEM Outreach: Through a partnership with CU’s 'Learn More About Climate' program, Ph. D. student Alex Mass has been engaging students in the Denver/Boulder area and beyond through their interest in Antarctica to promote learning in STEM fields. Alex held a Chancellor’s Fellowship for Excellence in STEM Education during 2012/2013. As an aspect of this fellowship Adrian Howkins will also serve as an advisor for this component of her thesis, building on her minor in Environmental Anthropology. Through these activities we have observed how the presence of a student scientist who has *been* to Antarctica can engage children and enable them to regard science, engineering, and remote fieldwork research as a tangible future possibility. Focusing on grades 4-8, Alex has met with classrooms to discuss concepts of polar and earth sciences as well as describe life for scientists in the field. This season Alex has used Skype and an engaging blog (http://mcmsitereview.lternet.edu/node/24) to connect with classrooms.

LTER Schoolyard Book Series: Antarctica has connections to many parts of the world through the Antarctic Treaty System. Our children’s book, *The Lost Seal* is an International Polar Year publication, and a Spanish language and bi-lingual edition of the book are planned through the schoolyard LTER series. The target audiences for these new editions will be Spanish-speaking communities in the US, and also educators in Latin America.

The English edition presents a number of paintings by schoolchildren in the US, Britain, New Zealand and Australia. To help readers relate to the Spanish and bi-lingual editions, we will include paintings from school children in Latin America. Adrian Howkins presented material from *The Lost Seal* to children in eight different classes at three schools in Argentina and Chile in the spring of 2013 (The German School of Punta Arenas in Chile, The Escuela José Manuel Balmaceda of Viña del Mar in Chile, and the Cristoforo Colombo School of Buenos Aires in Argentina). Chile and Argentina have strong connections to the Antarctic continent, and the study of Antarctica is included in the curriculum.

After introducing himself and his connection to Antarctica, Howkins read *The Lost Seal* story in Spanish with pictures and videos from LTER work in the McMurdo Dry Valleys. Following lively question and answer sessions, the schoolchildren were asked to paint pictures related to the story, which are now posted to the *The Lost Seal* section of the MCM website (http://mcmlter.org/lostseal/search.html). These class visits offered an excellent opportunity to talk about LTER research in a cross-cultural learning environment. In total, over 100 pictures were drawn, and we will chose a number of these to be included in the published versions of the Spanish and bi-lingual editions.

Guido, Cristoforo Colombo

Gustavo, German School of Punta Arenas

Javiera, German School of Punta Arenas

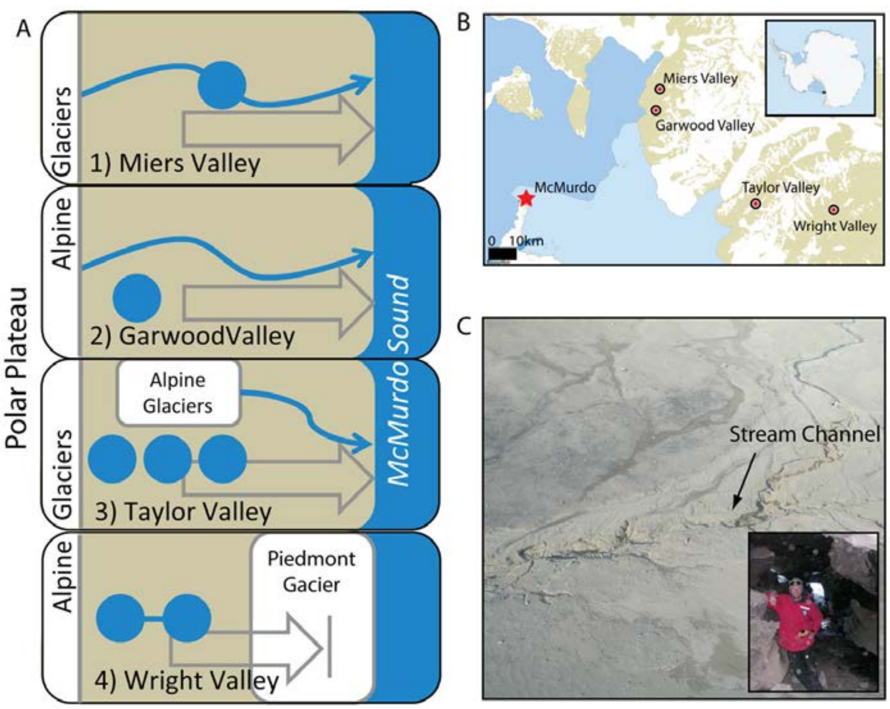
Brontis, Escuela José Manuel Balmaceda

LTER SOM/DOM Characterization Workshop: We have continued to collaborate with LTER investigators from several other sites (FCE, CAP, and HJA) in advancing the use of spectroscopic methods to characterize organic material. The mose recent workshop was held on May 2013 in Boulder, CO. (http://news.lternet.edu/Article2880.html)

New monitoring and Lake, Stream, and Soil Research – Byron Adams and Berry Lyons

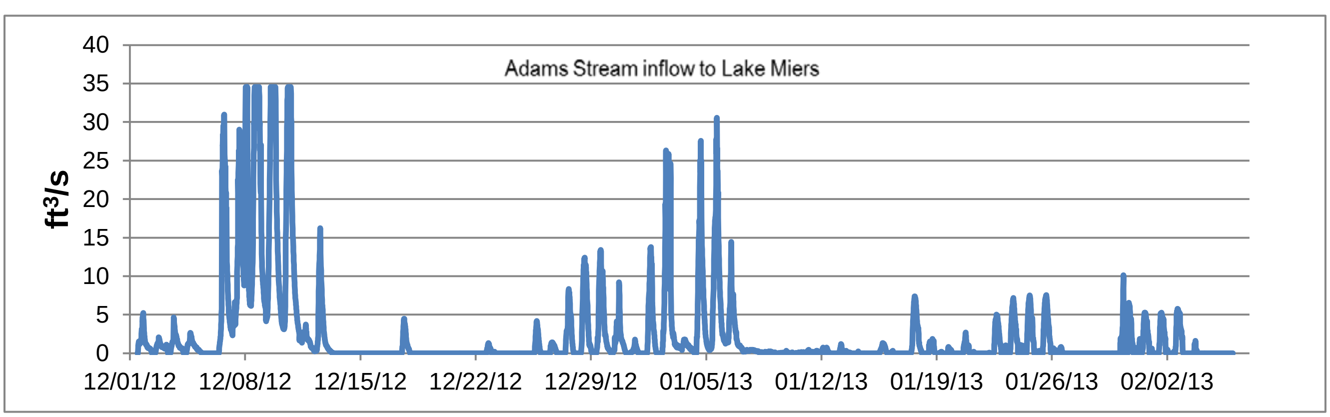
One of the most ambitious expansions of MCM4 is the establishment of monitoring stations beyond Taylor and Wright Valleys, into Miers and Garwood Valleys. The addition of these two unique valley systems is a natural complement to investigating the role that topological variation plays in biogeochemical processes (H3), and provides insight into the potential future conditions in Taylor Valley.

Prior to this proposal the aquatic studies of MCM-LTER were focused on the closed basin lakes in Taylor Valley. Because these lakes have no outlets, the high solute concentration influences many in-lake processes. Lake Miers is the major flow-through lake in the MCM system and by monitoring both the inflow and outflow streams, we will be able to determine to what extent the lake is a biogeochemical reactor under more dilute conditions and at what rate various solutes are removed. The Garwood system is also much different than the Taylor Valley ones as the valley itself is underlain by large amounts of buried ice that can impact both the geochemistry and the hydrology of the system. In addition, Garwood Stream flows directly into the ocean, and provides an assessment of direct terrestrial-marine connectivity in the MCM region.



(A) Changes in connectivity mediated by geographic variation among valleys:1) aeolian (gray arrow) and freshwater fluxes interact with flow-through lake, 2) aeolian and freshwater fluxes **from distal** sources carried by a large stream, 3) aeolian and freshwater fluxes from near-coast sources with closed basin lakes, and 4) piedmont glacier blocks all but aeolian sources.
(B) Location map of MDV
(C) Thermokarst erosion of Garwood Stream after a warm summer hydrological pulse event.

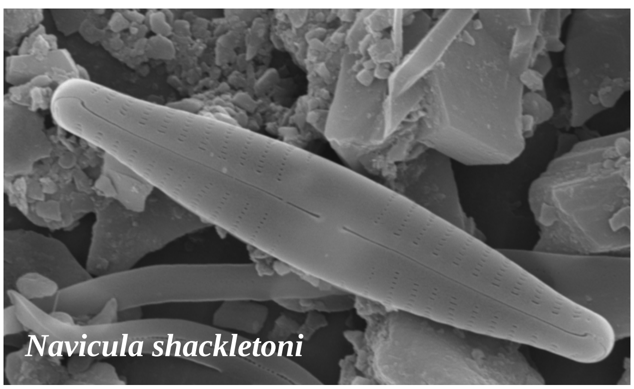
New monitoring experiments established here include meteorological stations, stream gauges, algal transect sites, lake stations, elevational transects (soil), aeolian material fluxes, focused sampling along environmental gradients, soil active layer monitoring, mass flux quantification and metagenomic analyses of samples associated with nearly all of these activities.



Early Exploration and Diatom Biogeography – Adrian Howkins

Ernest Shackleton's Cape Royds Hut is among the most famous historic sites in Antarctica. Recent years have seen Shackleton's stature grow as the Antarctic explorer who led by example and "never lost a man," largely at the expense of the reputation of Captain Scott who is often seen as having been somewhat aloof and distant from his men. The light, open-plan layout of the Cape Royd's hut contrasts starkly with Captain Scott's darker and more segregated hut at Cape Evans, reflecting their respective leadership styles. The huts remain, and restoration efforts by the New Zealand based Antarctic Heritage Trust (http://www.nzaht.org/) ensure that they continue to offer a wonderful insight into the lives of explorers during the heroic era of Antarctic exploration (roughly 1895-1917).

The history of Antarctica's heroic era can contribute to contemporary scientific research. In the Dry Valleys, our environmental history work is advancing our understanding of the recent past, before the ozone hole. As will be discussed in a Sunday evening science lecture, in much the same way that the relatively simple ecosystems of the McMurdo Dry Valleys offer a useful location for asking important ecological questions, the relative simplicity of Antarctic history offers a useful model for thinking about collaborations between historians and ecologists.



Navicula shackletoni

During the Shackleton expedition's stay at Cape Royds James Murray collected a significant number of diatom samples. Back in London, the diatoms were examined by the pioneering father and son team of W. West and G.S. West who identified thirty taxa from eight genera, eight of which were described as new species (West and West 1911). Since this was one of the first investigations of its type in the region, coupled with the very low species richness in Antarctica, this paper became highly influential for the next 100 years. As a result, Cape Royds is the type locality of roughly 1/6th of the continental flora, including several endemic Antarctic species which are common but always present at low relative abundance in DV streams.

As more diatomists collected samples from the Antarctic, their identifications have been based on either a European flora, or the work of pioneers like West and West. With the modest descriptions and illustrations that West and West provided with limited technology, species have, for the last century, been force-fitted to the description of particular taxa, resulting in "species drift" with "concepts" for many species. Given the utility of diatoms in answering past and present ecological and biogeographical questions in the Antarctic, the need for advances in diatom taxonomy has become apparent.

In a collaboration with our European colleagues, we are working towards a unified Antarctic flora. Our first step is to reinvestigate the diatoms from Cape Royds. Using the historical records of the Shackleton expedition we are identifying the various sites where Murray and his colleagues collected diatom samples. While some of the sample sites are fairly obvious, others take some historical research to identify. This resampling project will clarify important uncertainties in Antarctic diatom taxonomy, and will reveal which conditions favor these species. M.S. student Aneliya Skaeva will be looking for similar habitats in the MDV that might be sources for aeolian distribution of these diatoms to the streams and cryoconites.

Major accomplishments of MCM4

New research on ecological connectivity-highlights:

1) Episodic periods of high hydrologic connectivity control spatial and temporal patterns of soil biota (pg. 13-14)
2) Metacommunity dynamics in the MDV can be simulated based on niche-based species-sorting and dispersal dynamics (pg. 2)
3) Daily pulses of microbial mat material are transported from streams to the lakes (pg. 4)
4) Increased streamflow following the end of the cooling trend has driven increases in biomass and distribution of stream microbial mats (pg. 4)
5) Distinct microbial communities occur in major components of the MDV landscape (pg. 16)
6) Loss of perennial ice-cover on the lakes could occur within the next 50 years (pg. 11)

New proposed experiments:

1) Completion of the LakeICE experiments demonstrating microbial responses to inputs during periods of enhanced transport of water and sediment (pg. 8)
2) Installation of the Pulse-Press soil wetting experiment (pg. 5-6)
3) Collection of samples of aeolian materials to inform design of sediment on ice experiment (pg. 10)

Enhancement of monitoring programs:

1) Integration of historical perspectives into understanding lake level change and species distributions of benthic diatoms (pg. 19)
2) Continuous telemetry of met station, stream gauge, and limnological stations using a hub and spoke approach (pg. 15)
3) Expansion of monitoring program to Miers and Garwood Valleys (pg. 18)
4) Implementation of aeolian sample collection in collaboration with New Zealand program (pg. 10)
5) Development of new continuous biological monitoring and sampling technology for lakes to potentially track wintertime processes (pg. 7)