

McMurdo LTER Site Review

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SECTION 1 RESULTS SINCE 1998

With the submission of the second six-year grant of the McMurdo Dry Valleys LTER (MCM-II), the research group added two new PIs, Ross Virginia, Dartmouth College, and Peter Doran, University of Illinois at Chicago, and lost Bob Wharton, Desert Research Institute and Cathy Tate, USGS. In addition, we added four formal collaborators: Gayle Dana, Desert Research Institute; Johanna Laybourn-Parry, University of Nottingham; Ian Hawes, National Institute of Water and Atmospheric Research, New Zealand; and David Marchant, Boston University. Since the submission of MCM-II in January of 1998, we have produced 42 published papers in refereed journals, with 9 more currently in press and an additional 16 in preparation or in review. We have also produced 18 book chapters, 12 dissertations and theses, and 49 abstracts from national and international meetings. We have supported 23 graduate students, 7 post-doctoral fellows, and 15 undergraduate students, including 6 REUs (Research Experience for Undergraduates). A total of over 56 collaborators have been involved during the last 3.5 years since the submission of MCM-II.

In addition to our synthesis volume, which was published prior to the submission of MCM-II (Ecosystem Dynamics in a Polar Desert: The McMurdo Dry Valleys, Antarctica (Priscu, 1998) American Geophysical Union's Antarctic Research Series), an entire issue of BioScience (December 1999) was devoted to papers by MCM PIs. The issue contained five full-articles and an introductory paper. Below we summarize the main results of our research on each of the major landscape units, including our recent progress in modeling and synthesis.

Meteorology

Collection of meteorological data and servicing of meteorological stations have continued. A new meteorological station was installed in Beacon Valley. We discovered a large climatic gradient in Taylor Valley and believe it to be significant to stream flow generation (Fountain et al., 1999a) and to the soil ecosystems. Therefore, we have redoubled our efforts to measure snowfall. We encountered significant problems with automatic methods, and although we continue to investigate these methods, we established manual snow measurements at 3 locations in Taylor Valley.

We have also established a network of lake ablation stakes and sensors to help monitor changes in ice thickness (and its causes) because it directly affects biologic communities in the lakes and the communities within the lake ice (Fritsen and Priscu, 1999). In the 2000-2001 season, we finally received permission to erect our snow fence experiment as outlined in our proposal. The purpose of the fence is to simulate conditions of increased snow accumulation and its effects on soil communities. It will be a major integrative exercise for MCM, as well as allow us to compare our results with those of NWT and ARC, which have conducted similar experiments.

Currently, the first 6 years of weather data from MCM-LTER have been analyzed and are summarized in Doran et al. (in review, b). Because we have come to understand that katabatic winds are an important meteorological phenomenon influencing the transport of organic and inorganic material in the valleys (Fountain et al., 1999b) and

affecting the winter climate, we have developed a katabatic climatology for all the meteorological stations in the valleys (Nylen, in prep). The results have helped to explain some of the divergent meteorological conditions in the valleys, which we hope will help to explain the variations in ecosystem processes that we have observed throughout the valleys.

Glaciers

The core data of the glacier mass change continue to be collected. A manuscript in preparation (Fountain et al.) summarizes the glacier mass balance variations that we observed since the start of the MCM-LTER. To help understand the variations in mass balance and meltwater production, we have investigated the applicability of synthetic aperture radar images (SAR) for monitoring the snowpack on glaciers. We found that despite the well-known capabilities of SAR to penetrate snow covers, we could detect the snowline (Bardel et al, 2001). Moreover, we could also detect differences in the SAR brightness of the lakes, which we presume results from the temperature of the lake ice cover and presence of liquid water within the ice cover (Bardel, 2001: MS thesis).

A primary focus of the glacier investigations is to relate our meteorological data to meltwater production by the qualification and quantification of in-situ glacial processes. Determining the controls on meltwater generation has been difficult because summer temperatures typically hover just below the melting point. Lewis (1999) investigated the physical controls on melt from the vertical cliffs that form the terminus of the glaciers. These are important sources of melt water during cool summers. Bomblies et al. (in review) investigated the role of solar radiation orientation on melt patterns from different glaciers. Fountain and his co-workers have observed the importance of spatial variations in snow cover (Fountain et al., 1999a, 1999b). Based on this work, we have come to realize the fundamental importance of solar radiation in warming the ice to melting temperatures as well as the significance of surface albedo and topographic geometry in the generation of melt. During these investigations we have been struck by the large roughness features on several of the glaciers. Two theses have investigated these structures in relation to their importance for melt production. A Ph.D. thesis by Karen Lewis (2001) investigated the basins of Canada Glacier. She found that the basins produce more melt than the "normal" broad lateral surface of the glaciers under cool, cloudy conditions typical of the summer climate. However, during cloudy periods they produce less melt. We believe the development of these basins is derived from cryoconite holes, which are initiated from aeolian sediment being deposited on the glacier surface. In fact, all the large roughness features result from lower albedo surfaces generated by some source of geologic material. On Taylor Glacier, the large melt channels are derived from medial moraines. Johnston's work (MS in progress) has shown that these channels could be 1200 years old and a legacy of past glacial activity.

In collaboration with Dr. Martyn Tranter, the chemistry of the supraglacial streams and cryoconite holes on several glaciers in Taylor Valley have been investigated. The purpose of this work was to identify spatial variations in water on the glaciers that might precondition the chemical characteristics of the streams on the valley floor. This is one contributing cause to the differential chemistries of Lakes Hoare and Fryxell (Lyons et al., in review). Chemistries of cryoconite holes contrast starkly with streams and result from microbial activity in these ice-covered holes. We suspect that microbial life may be

resident for years in these unique environments. A better understanding of the biogeochemistry of these cryoconite holes has become an important MCM-LTER activity and another important area of multidisciplinary integration.

Recent glaciochemical studies of snow from accumulation zones of three glaciers in Taylor Valley indicate accumulation rates from the seasonal CI peaks. We determined that the net snow accumulation rate on Commonwealth Glacier is $\sim 3 \text{ cm yr}^{-1}$. This may be the first empirical precipitation rate determined for Taylor Valley. In addition, snow pit data have allowed us to determine NO_3^- fluxes to the entire valley. These flux measurements will be utilized to better constrain N fluxes to the soils and aquatic ecosystems in Taylor Valley.

Streams

The operation of the stream gauging network in Taylor and Wright Valleys has continued during MCM-II. The recent stream discharge data and former lake level data indicate that annual stream flows to Lake Bonney from 1973 to 1995 were significantly greater than from 1903 to 1973, with an average rate of increase in annual stream flow of 4% per year during the latter period (Bomblied, et al, 2001). Our long-term data demonstrated a decrease in flow from the early 1990's to present (Doran et al., in review).

Our previous work had suggested that the exchange of water between the stream channels and their hyporheic zones was an important factor in controlling water chemistry. Based on recent isotopic measurements, we observed that stream water is retained in the hyporheic zone for periods exceeding the annual summer flow season. Sublimation of water from the hyporheic zone results in a flux of moisture to the atmosphere and a concentration of solutes in the soil.

Recent studies (Nezat et al., in press; Maurice et al., in press; Gooseff et al., in review) have found that chemical weathering rates in Taylor Valley streams are as high as rates in temperate regions due to rapid hyporheic zone exchange. During the 1998-99 season, we collected more water samples to determine the diurnal, seasonal and longitudinal changes in stream chemistry. Total suspended solids were also measured. Initial examination of suspended load in the streams suggests that the streams with higher suspended loads have higher chemical weathering rates (i.e., Lyons et al., 1997; Nezat et al., in press). In general, the suspended load was high at the beginning of the summer, then decreased, remaining relatively proportional to stream discharge throughout the rest of the season.

Taxonomic descriptions of cyanobacteria and diatoms in the streams have been developed. Diatoms in streams are more diverse than cyanobacteria with a high number (about 50%) of endemic species. Nitrogen cycling was investigated in another stream injection experiment and concurrent ^{15}N incubation experiments. Results from these experiments suggest that the hyporheic zone is an important site of denitrification and further supports the importance of stream algal mats in NO_3^- uptake and conversion to NO_2^- . In addition, we have performed experiments to evaluate the effect of anthropogenic disturbance on algal mats in the streams. Results showed that after algal mat removal at least two full summer growing seasons are required for full regeneration of mats.

Lakes

Lake level and ice thickness measurements and maintenance of automatic lake monitoring equipment continued. After a long period of lake level rise (1903 to ca. 1990), levels have been receding over the last decade in response to cooler summers and decreased stream flow. Cooler, quiescent conditions in summer reduce sublimation loss from lakes partly compensating for the decreased stream flow. Lake ice thickness has increased since 1986 by an average of 11 cm yr^{-1} in response to the lower temperatures. Also, high-precision thermistors in the lakes show that relatively large temperature variations occur in mid-winter, suggesting a yet-to-be described mixing process.

Measurements of chemistry and microbial activity continued in the lakes. In addition, Priscu was funded to study sources and sinks of dimethylsulfide (DMS) in Lake Bonney and to examine microbial activity in the permanent lake ice. Extremely high DMS levels ($> 350 \text{ nM}$; ocean average = $\sim 3 \text{ nM}$) have been found in the deep waters of the west lobe of Lake Bonney, presumably related to phytoplankton production in the upper water column. High levels of dimethylsulfoxide (DMSO) were also discovered in the deep waters of the east lobe of Lake Bonney ($> 300 \text{ nM}$); no simple explanation currently exists for its presence although recent measurements of DMSO in particulate matter implies that certain microalgae may be producing it *de novo*. The lake ice is a microbially dynamic feature of the lakes, supporting actively growing cyanobacterial and bacterial populations. These populations may play an important role in the carbon dynamics of the lakes.

Time series sediment traps were deployed in Lake Bonney in December 2000 to determine the magnitude and timing of sediment flux from the ice covers to the lake. This is being done in order to assess C, N, and P loss from the euphotic zones of the lakes. A new research effort was also initiated to understand the role of viruses on bacterial dynamics within the lakes. Preliminary results show that the burst size of infected bacteria within Lake Bonney averages 30 prophage. Electron microscopy revealed a number of infected bacteria that were in poor health indicating that viruses may play a major role in regulating bacterial numbers within the lakes.

We have presently counted all of the phytoplankton samples from all three lakes and there has been an apparent change in phytoplankton species that relate directly to the decreased flow of water into the lakes from 1993 to 2000.

Long-term benthic experiments initiated during MCM-I continued in Lake Hoare. Two re-samplings have been performed on the sediment addition experiment established during the 1996/1997 season. The experiment will be completed during the 2002/2003 season. Preliminary results show that colonization of allochthonous sediment additions occurs from below, and that the thickness of the introduced sediment dictates the rate of colonization. An inadvertent discovery of this experiment was that disturbance of the microbial mat (e.g. by experimental apparatus, or by natural sediment falling through the ice) leads to the mat lifting off the bottom. We plan experiments to test this hypothesis in the future. We have also established new near-shore benthic colonization experiments, defined benthic colonization rates, and confirmed annual growth layering in the microbial mats. This is collaborative work between Doran and Hawes. Lake isotopic processes continue to be investigated in order to interpret sediment records to be collected during the 2002/2003 season.

Helium isotopic and other rare gas compositions were measured in the lakes in Taylor Valley during the 1999-2000 season. The hypolimnion of the west lobe of Lake Bonney has the highest ^4He value ever measured in a non-geothermal water. High ^3He values suggest previously cosmogenically-produced flux of ^3He into the bottom water as well. Various minor elements (Sr, Ba, B) and isotopes ($\delta^{37}\text{Cl}$) were also measured to help constrain the sources of solutes and the evolutionary histories of the Taylor Valley lakes (Lyons et al., 1998; Lyons et al., in review).

An NERC grant to Dr. Laybourn-Parry allowed a post-doctoral fellow to work with McKnight and Priscu in 2000-2001. The project involved measuring the balance between photosynthesis and heterotrophy in the cryptophytes of Lakes Fryxell and Hoare. The data show that the flagellates have to feed to meet their carbon requirements and that in November (2000) up to 33% of their carbon uptake is obtained through feeding. In December, the carbon fixed by photosynthesis accounted for a greater portion of their carbon requirements. There were also marked differences in the balance between photosynthesis and heterotrophy related to the position of the cryptophytes in the water column. Laybourn-Parry is currently writing up these data for publication and it will also be presented at a Royal Society meeting in London in September 2001 (Coping with the Cold), as an invited lecture.

Soils

Ongoing monitoring of biological, chemical, and physical properties of soils in the Hoare, Bonney and Fryxell basins continued. This included abundance and diversity of soil biota, PAR, soil and air temperature, soil moisture and salinity. The long-term experiments examining the role of factors involved in global climate change on soil biodiversity were continued. Data after 5 years of treatments show an overall decline in the nematode populations on the plots, but no consistent effects of warming, water addition, or carbon amendments. Data collected from the elevational transect for a period of 6 years indicated specialized habitat requirements for invertebrate species. In addition, overall current climatic changes were illustrated in temporal changes of soil invertebrates.

We are investigating biological and nutrient connectivity between different components of the dry valley landscape. A network of wind-blown sediment traps has been installed throughout Taylor Valley. These are monitored annually, and already living nematodes have been recovered, confirming the dispersal of these invertebrates by wind. Our research has shown that nematodes survive desiccation as anhydrobiotes, perhaps contributing to their wide dispersal across the valley features. Similar invertebrate species have been identified in soils, streams, lakes, and most recently glaciers. We hypothesize that these habitats are linked through recirculating biotic communities.

New experimental plots were constructed in the Lake Fryxell, Hoare and Bonney basins to examine the influence of microclimate on soil biodiversity, decomposition, C cycling and nutrient bioavailability. Initial samples were taken to characterize the environment. Two snow fences were constructed, one in each of the Fryxell and Bonney basins, in the 00/01 season. These will result in an accumulation of snow over the winter, and the effect of increased moisture availability on soil biota will be determined in subsequent years. Preliminary data from naturally occurring snow accumulation zones indicates that distribution of certain invertebrate species might be linked to the

distribution of snow patches on the dry valley landscape. Perennial snow packs may have significant influence over soil microclimate and distribution of soil resources and soil biota.

Soil organic carbon sampled at low elevations in the valley is strongly influenced by legacy carbon derived from lacustrine and marine sources. In contrast, soil organic carbon at higher elevation shows less potential contribution from past lakes and has an isotopic signature for C and N consistent with production accumulated from the activities of cryptoendolithic microbial communities and soil algae over very long time scales. This pattern implies that today's soil food web in the valley may be supported by C fixed long ago. We continue to investigate the influence of geomorphic and biological legacies on soil organic matter quantity and composition, the physical and biological controls over *in situ* soil CO₂ flux, and have recently started studies of soil inorganic N concentrations and nitrate flux across landscape gradients. Our objective is to construct a carbon budget for Taylor Valley linking soils to the other ecosystems (lakes, glaciers and streams) and to begin understanding the role of nitrogen in carbon cycling and for soil biota.

Field work over the past two seasons has shown that soil CO₂ flux is strongly influenced by a temperature driven physical process and that some soils absorb CO₂. This presumed physical process has been modeled and the contribution of soil biota to total CO₂ flux has been determined for locations spanning Taylor Valley. There are interesting site differences in both the physical and biotic flux of CO₂ throughout Taylor Valley that we are attempting to relate to the distribution of soil invertebrate communities. Based on laboratory incubations in progress, active components of Taylor Valley soil organic matter represent an unusually high proportion of soil organic carbon and their kinetics with can be approximated with 2nd order models. We are also studying C and N isotopic signatures of different size fractions of soil organic matter to try to constrain possible sources (legacy vs. contemporary) to these pools.

Soil inorganic N pools in habitats where biological activity is expected to be high have a large proportion of ammonium relative to nitrate. Soil nitrate flux (measured with exchange resins) in these habitats appears to be more indicative of biological sources of nitrate (nitrification) than physical ones (deposition of marine aerosols).

Our work continues to examine how soils pattern the spatial distribution of biological activities, with an emphasis on understanding how soils and their life are linked to the other systems of Taylor Valley.

Ecological Modeling

Our modeling efforts include development of conceptual and mathematical models, both within the MCM-LTER program and in conjunction with other US and international colleagues. The key milestone in conceptual development was the legacy hypothesis underlying long-term, broad-scale control of dry valley ecosystems (addressed elsewhere). Moreover, our views expanded the emerging concept of ecological legacies in the larger scientific community beyond a paradigm based mainly on anthropogenic and/or disturbance effects (Franklin et al. in review).

Our mathematical models include budgetary and dynamic formulations of biological, geochemical and physical phenomena. Fountain is modeling energy relationships defining glacier mass balances driving hydrological regimes controlling

long and short-term dynamics of the dry valley system (Lewis et al. 1998, 1999). Doran is leading efforts to evaluate short and long-term patterns in climate associated with energy balance, hydrology and ecosystem behavior (Doran et al. in review). A collaborator (Dana), is starting a related NASA project, "Integrating modeling and remote sensing for monitoring potential responses to climate change in the McMurdo Dry Valleys." Her work, in collaboration with Doran, Wall, Virginia and Moorhead will allow us to utilize remote sensing information to "scale-up" our meteorological data through the valley system. McKnight has simulated hydrological patterns in the dry valleys over the past century based on recent measurements of stream flow and lake level fluctuations (Bomblies et al., 2001). Lyons' geochemical models are providing insights that are particularly relevant to aquatic ecosystems of past and present (Lyons et al. 1999).

Within a biological context, carbon budgets and nutrient dynamics are part of our efforts to quantify whole-valley biogeochemical processes. Burkins et al. (2000) published the first complete carbon budget of Taylor Valley. Pools and fluxes of C and/or N have been quantified for soil and phytoplankton communities (Priscu et al. 1999, Fritsen et al. 2000, Burkins et al. 2001), and corroborate the legacy hypothesis of dry valley dynamics in that neither soil nor plankton communities approximate steady-state. Lyons et al., (2001) quantified the impact of anthropogenic (i.e. science) activities on the carbon and nitrogen budget of Taylor Valley. Physiologically based models of NPP in benthic microbial communities in lakes and streams (Hawes et al., 2001, Schmeling, 2001) have been used to evaluate both N transformation in streams (Moorhead et al. 1998, in prep) and production in upland wetlands (Moorhead et al., in prep). A food-web model revealed inconsistencies between standard allometric relationships for planktonic organisms and energy flux through planktonic food webs in dry valley lakes (Moorhead, in prep). Finally, a population model of a soil nematode (*Scottinema lindsayae*) has demonstrated the impacts of ambient temperatures on distributions and survival on this endemic species.

Other

a. Regionalization. In April 2001, a NSF sponsored workshop entitled "Victoria Land Antarctica, Coastal Biome: Marine-Terrestrial Biocomplexity Across a High Latitudinal Environmental Gradient" was held at the Byrd Polar Research Center. This initiative could lead to a more regional approach to the study of ecosystem structure, function and biodiversity along the Victoria Land coast. MCM-LTER would provide an on-going long-term data set from which other sites along the gradient (72°S – 85°S) could be compared. Lyons and Priscu are on the coordinating committee of this group. This is also an international effort with involvement of New Zealand and Italian scientists.

b. Human Dimensions. Virginia working with Oran Young (Director, Inst. of Arctic Studies, Dartmouth College) have begun a collaboration with PIs of both MCM and ARC with the intention of a workshop leading to an intersite research proposal on "Environmental Policies, Resource Regimes, and the Dynamics of High Latitude Ecosystems". A workshop proposal was submitted to the NSF Biocomplexity Program as our first step. We propose to take advantage of the combination of biogeochemical similarities and anthropogenic differences in high-latitude ecosystems to develop a

research program to test a range of hypotheses about the dynamics of human/nature interactions. Treating biocomplexity as a set of potential feedback relationships between social institutions and ecosystem functions, we intend to develop a program that will use quantitative methods to shed light on (1) ecosystem responses to various types and levels of human activities and (2) regulatory/institutional feedbacks arising from various types and levels of ecological change.

c. International Collaborations and Databases. Moorhead received a NSF-International grant to examine data archives and field notes stored at NIWA, continuing a long history of collaboration between NIWA (New Zealand) and the MCM-LTER. Moorhead's graduate students spent two summers extracting data from old notebooks, proofing existing electronic files, transforming files into new formats (MS-Excel and MS-Access), and helping with analyses of new data. In return for access to these data, Moorhead applied mat and nutrient models to ecosystems of primary interest to NZ scientists, and helped to develop joint research projects. This collaboration resulted in joint manuscripts (Hawes et al., 2001, Moorhead et al. In prep.), an international presentation (Moorhead et al. SCAR), and two graduate student theses (Burnett, 2000, Schmeling, 2001).

Drs. Ian Hawes and Clive Howard-Williams (NIWA) have agreed, in principle, to provide more general access to Antarctic data of interest to MCM-LTER. These include biological and physio-chemical data collected by New Zealand scientists from the early 1960's to the present.

d. Year-Round Research. The plan of MCM-II PI's is to conduct a year-round research program focused primarily on the lake ecosystems. The initial stages of developing the program have begun and NSF is aware of the unmet opportunities that can be addressed by such an effort. The logistics involved in winter research pose new activities for OPP and are currently under consideration. Dr. Priscu obtained NSF funds and chaired a Winter Science Workshop in 1999 where over 25 scientists involved in Antarctic research met and discussed the importance and logistical challenges of this type of work. The report is referenced within (Priscu, 2001). This activity will be a major thrust for MCM-LTER in the next few years and will produce important new data that will help us address our research objectives.

LTER Publications (since last renewal)

(1) Journal Articles

- Adams, G. A. and Wall, D. H. (2000) Biodiversity above and below the surface of soils and sediments: linkages and implications for global change. *BioScience* **50**, 1043-1048.
- Bardel, P., Fountain, A.G., Hall, D. and Kwok, R. (in press) Synthetic Aperture Radar Detection of the Snowline on Polar Glaciers, Taylor Valley, Antarctica. *Annals of Glaciology*.
- Bardgett, R. D., Anderson, J. M., Behan-Pelletier, V., Brussaard, L., Coleman, D. C., Ettma, C., Moldenke, A., Schimel, J. P. and Wall, D. H. (in press) The influence of soil biodiversity on hydrological pathways and the transfer of materials between terrestrial and aquatic ecosystems. *Ecosystems*.

- Barrett, J. E., Virginia, R.A. and Wall, D. H. (in press) Trends in resin and KCl-extractable soil nitrogen across landscape gradients in Taylor Valley, Antarctica. *Ecosystems*.
- Berger, G. W. and Doran, P. T. (in press) Luminescence zeroing tests in Lake Hoare, Taylor Valley, Antarctica. *Journal of Paleolimnology*.
- Bomblyes, A., McKnight, D. M. and Andrews, E. D. (in review) Controls on streamflow generation from alpine glaciers in the McMurdo Dry Valleys. *Journal of Arctic, Antarctic and Alpine Research*.
- Bomblyes, A., McKnight, D. M. and Andrews, E. D. (2001) Retrospective simulation of lake level rise in Lake Bonney based on recent 21-year record: indication of recent climate change in the McMurdo Dry Valleys, Antarctica. *Journal of Paleolimnology* **25**(4), 477-492.
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- Burkins, M. B., Virginia, R. A. and Wall, D. H. (2001) Organic carbon cycling in Taylor Valley, Antarctica: Quantifying soil reservoirs and soil respiration. *Global Change Biology* **7**, 113-125.
- Burnett, L., Moorhead, D. and Hawes, I. (in preparation) Controls on deep chlorophyll maxima in lakes of the Antarctic, Dry Valleys. *Limnology and Oceanography*.
- Campbell, I. B. (2002) Soil characteristics at a Long Term Ecological Research site in Taylor Valley, Antarctica. Danish Polar Geography, in press.
- Chatfield, E. and McKnight, D. M. (Submitted) Cyanobacterial mat regrowth in Green Creek, McMurdo Dry Valleys, Antarctica. *Polar Biology*.
- Conovitz, P. A., MacDonald, L. H. and McKnight, D. M. (Submitted) Spatial and temporal active layer dynamics beneath three ephemeral streams in the McMurdo Dry Valleys, Antarctica. *Journal of Arctic, Antarctic and Alpine Research*.
- Courtright, E. M., Wall, D. H. and Virginia, R. A. (2001) Determining habitat suitability for soil invertebrates in an extreme environment: the McMurdo Dry Valleys, Antarctica. *Antarctic Science* **13**(1), 9-17.
- Courtright, E. M., Wall, D. H., Virginia, R. A., Vida, J. T., Frisse, L. M. and Thomas, W. K. (2000) Nuclear and mitochondrial DNA sequence diversity in the Antarctic nematode *Scottinema lindsayae*. *Journal of Nematology* **32**, 143-153.
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- Doran, P. T., Berger, G. W., Wharton, Jr., R. A., Lyons, W. B., Davisson, L., Southon, J. and Dobb J. (1999) Dating Quaternary lacustrine sediments in the McMurdo Dry Valleys, Antarctica. *Palaeography, Palaeoclimatology, Palaeoecology* **147**, 223-239.

- Dore, J. E. and Priscu, J. C. (2001) Phytoplankton phosphorus deficiency and alkaline phosphatase activity in the McMurdo Dry Valley lakes, Antarctica. *Limnology and Oceanography* **46**, 1331-1346.
- Ewel, K. C., Cressa, C., Kneib, R. T., Lake, P. S., Levin, L. A., Palmer, M., Snelgrove, P. V. B. and Wall, D. H. (In Press) Managing critical transition zones. *Ecosystems*.
- Fountain, A. G., Lewis, K. J. and Doran, P. T. (1999a) Spatial and climatic variations and its control on glacier equilibrium line altitude in Taylor Valley, Antarctica. *Global and Planetary Change* **22**, 1-10.
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(3) Dissertations/Theses

- Alger, A. S. (1999) Diatoms of the McMurdo Dry Valleys, Antarctica: a taxonomic appraisal including a detailed study of the genus *Hantzschia*. Master's thesis, University of Michigan.
- Bardel, P. (2001) Mapping polar glaciers using synthetic aperture radar. Master's thesis, Portland State University.
- Bomblies, A. (2000) Climatic controls on streamflow generation from Antarctic glaciers. Master's thesis, University of Colorado.
- Brown, A. (2001) The Influence of Mixotroph Growth on DOM Chemistry in Pony Lake, a Eutrophic Coastal Pond in Antarctica. Master's report, University of Colorado.
- Burnett, L. (2000) Dynamics of the deep chlorophyll maximum within the lakes of the McMurdo Dry Valleys, Antarctica. Master's thesis, University of Toledo.
- Conovitz, P. A. (2000) Active layer dynamics and hyporheic zone storage in three streams in the McMurdo Dry Valleys, Antarctica. Master's thesis, Colorado State University.
- Gooseff, M. N. (2001) Modeling hydrologic influences on biogeochemical processes in Dry Valley streams. Ph.D. Dissertation, University of Colorado.
- Lewis, K. (2001) Energy balance of a rough glacier surface, Canada Glacier, McMurdo Dry Valleys, Antarctica. Ph.D. dissertation, University of Colorado.
- Neumann, K. (1999) Carbon dynamics in lakes and streams of Taylor Valley, Antarctica. pH Dissertation, University of Alabama.
- Schmeling, J. (defense pending) Carbon dynamics of benthic microbial mats in Lake Hoare, Antarctica. Master's thesis, University of Toledo.
- Takacs, C. D. (1999) Factors affecting the distribution and dynamics of bacterioplankton biomass and diversity in Taylor Valley lakes, Antarctica. Ph.D. Dissertation, Montana State University.

Treonis, A. M. (1999) Environmental controls of the diversity, activity, and function of soil nematodes in the McMurdo Dry Valleys of Antarctica. Ph.D. Dissertation, Colorado State University.

(4) Other Publications

Doran, P. T. and Forman, S. L. (2000) Extinct saline groundwater discharge on Mars? *Science* **290**, 713-714.

Priscu, J.C. (ed.) (2001) Year-Round Access to the McMurdo Region: Opportunities for Science and Education. Special publication 01-10, Department of Land Resources and Environmental Sciences, College of Agriculture, Montana State University, USA, 60 pp.

Priscu, J. C. and Wolf, C. Limnological Methods for the McMurdo Long Term Ecological Research Program.

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Web sites:

MCM-LTER web site: <http://huey.colorado.edu/LTER/>

MCM Schoolyard LTER Site: <http://www-bprc.mps.ohio-state.edu/EnvironmentalGeochemistry/Lyons/schoolyard-LTER/index.html>

Taxonomic descriptions (with photomicrographs) of the diatom taxa are posted on the database web site: <http://www-personal.umich.edu/~asalger/HomePage/Home.html>

Limnological Methods for the McMurdo Long Term Ecological Research Program by Priscu, John C. and Craig Wolf
<http://www.homepage.montana.edu/~lkbonney/DOCS/Data.html>

Doran's research site: <http://www.uic.edu/~pdoran/home.htm>

Fountain's research group: <http://www.geol.pdx.edu/Glaciars>

Priscu's research group: <http://www.homepage.montana.edu/~lkbonney>

Wall's research group: <http://www.nrel.colostate.edu/soil/MCM>

LTER Academic Lectures

During 1998-99, Lyons gave seminars at North Carolina State University, University of Nebraska, University of Connecticut and Ohio State University on MCM-

LTER activities. He was also an invited participant at the annual WAIS meeting in 1999. Lyons gave seminars at University of Toledo and University of Akron in 2001, about MCM research activities. Lyons was the invited plenary speaker at a session entitled "Interactions between the Cryosphere and Biogeochemical Cycles" at the joint Geological Society of America, Geological Society of London meeting in June 2001.

During 1998-99, McKnight was invited to speak at the Gordon Research Conference. She also gave presentations about the hydrology and biogeochemistry of streams in the McMurdo Dry Valleys at the annual meeting of the Water Resource Institute at Kent State University (Keynote speaker); Seminar in Ecology Program Colloquium, Colorado State University; Seminar in Environmental Sciences series, Colorado School of Mines; and, Seminar in monthly meeting of University of Colorado Biology Super group. In fall 2000, McKnight presented an invited talk at a NRC workshop on interactions between hydrology and ecology that highlighted the MCM-LTER studies. She also spoke to the undergraduate biology club at the University of Colorado, and at the National Center for Atmospheric Research (NCAR) about the hydrology and biogeochemistry of streams in the McMurdo Dry Valleys.

Lyons, Priscu and Doran were invited participants to the International Workshop on Lake Vostok in Cambridge, England. Each made a presentation. Priscu has elected to co-convene a working group of specialists to direct the exploration of Lake Vostok and other subglacial lakes.

Priscu was a Distinguished Lecturer at University of Alberta, Edmonton, Canada (Feb 27 – Mar 3, 2001). Other lectures include: Laudenberg Memorial Lecture, University of Western Alberta, Canada (Apr 1-3, 2001); "Geomicrobiology of ice," invited lecture, Princeton University (Apr 10, 2000); "The lakes of the McMurdo Dry Valleys," invited lecture to the Astrobiology Institute, Arizona State University (Apr 1-2, 1999); and "Deep oceans of our Solar system," invited lecture, University of Washington School of Oceanography.

Wall gave invited talks about biodiversity and ecosystem functioning at Global Ecology at the Frontier of a New Science Symposium, Carnegie Institute of Washington, Stanford CA (September, 2000), and at All Scientists Meeting of the LTERs, Snowbird, Utah (August, 2000). Other invited talks included "Soil biodiversity and Sustainability" at the National Geographic Society Committee on Research and Exploration, Washington, DC (July, 2000); "Biological Education in the Next Century; Challenges for Organismal/Integrative Biology" at AIBS President's Summit, Arlie, VA (November, 1999); "Soil biota and survival in extreme environments" at University of Colorado Astrobiology Workshop, Boulder, CO (February, 2000); "Function down under: soil biodiversity and nematodes in root disease and decomposition" at the 12th Biennial Conference of the Australasian Plant Pathology Society, Adelaide, Australia, (September, 1999); and, "Soil Food Chains" at USA/EU Workshop on the Use of Molecular Tools in the Study of Ecology and Ecosystem Dynamics, National Science Foundation, Washington, D.C. (September, 1999). Blecker has presented "Life and Research in Antarctica" to the Soil and Crop Science Department, Colorado State University, Fort Collins, CO. Treonis gave a talk entitled "Nematode Survival in the Dry Valleys of Antarctica" at the Departments of Plant and Soil Science & Anatomy and Zoology joint seminar, University of Aberdeen, Scotland (October, 1999). Porazinska et al. presented "Invertebrates in frozen systems: the cryoconite holes of the Antarctic Dry Valleys" at

the Ecological Society of America Meeting, Madison, WI. Porazinska et al. also presented “How stable are nematode populations in the Antarctic Dry Valley soil ecosystem?” at the Ecological Society of America Meeting, Snowbird, UT.

Presentations by Fountain’s research group include: Bardel et al., “SAR imagery of Commonwealth Glacier, Taylor Valley, Antarctica” North American Cartographic Information Society Meeting (October 2001) and Bardel, et al, “Synthetic Aperture Radar Detection of the Snowline on Commonwealth and Howard Glaciers, Taylor Valley, Antarctica” at the International Glaciological Society Symposium on Remote Sensing in Glaciology, Silver Spring, MD, June, 2001. Johnston, et al., will present “Channel morphology on Taylor Glacier, McMurdo Dry Valleys, Antarctica” at the American Geophysical Union meeting, San Francisco, December 2001.

Moorhead presented “A model of carbon fluxes within the pelagic food web of an Antarctic lake” and “A model of nitrogen uptake in an Antarctic stream” at the National Institute of Water and Atmospheric Research, Christchurch, New Zealand, May 2000. Moorhead and his students, Schmeling and Burnett, presented the following three talks at the ESA meeting 2000: “Dynamics of the Deep Chlorophyll Maximum in Lakes of the McMurdo Dry Valleys, Antarctica”, “Carbon fluxes within the pelagic food web of an Antarctic lake: Even slower than expected” and “Carbon flow dynamics in benthic microbial mats of Lake Hoare, Antarctica.” Moorhead, Hawes and Howard-Williams presented “Organic matter in upland wetlands of Taylor Valley, Antarctica: A pulse-reserve system?” at the Scientific Committee on Antarctic Research (SCAR) international meeting, Amsterdam, The Netherlands, August 2001.

MCM-LTER Datasets Electronically Available - Field Data

Category / Title	<u>Short Term</u> / <u>Long Term</u> Study
<u>I. Bathymetry</u>	
Bathymetric Polynomials	ST
Bathymetry Raw Data Files	ST
Bathymetric Values From Contour Map Digitizing	ST
Depths, Areas, Volumes	ST
Bathymetric Hypsographic Function Values	ST
<u>II. Geochemistry</u>	
Major Ion Concentrations for Glacier Ice, Snow and Melt Water Samples	LT
Major Ion Chemistry for Miscellaneous Locations Throughout Taylor Valley	ST
Limnological Water Column & Pore Water Cations/Anions	ST
Limnological pH's 1993-2000	LT
Lake Nutrients 1993-2000	LT
Particulate Organic C&N concentrations in Dry Valleys Lakes 1993-2000	LT
Lake Chemistry / Dissolved Inorganic N 1996-2000	LT
Lake Chemistry / Dissolved Inorganic C 1993-2000	LT
Lake Chemistry / Dissolved Organic C 1993-94, 1996-2000	LT
Lake Chemistry / Dissolved Oxygen and Associated Temps. 1993-2000	LT
Lakes / Winkler Data 1994-95	ST
Miscellaneous Stream Chemistry Samples Throughout Taylor Valley	ST
Stream Nutrients (nitrate, nitrite, ammonium, SRP) 1990-2000	LT
Stream Chemistry / Dissolved Organic Carbon 1990-1991, 1993-2000	LT
Stream Chemistry / Dissolved Inorganic Carbon 1990-1996	LT
Stream Chemistry / Major Ion Concentrations 1993-1999	LT
Stream Conductivity, pH 1990-2000	LT
Major Ion Data for Lake Ice Samples	ST
Limnological Chemistry / Major Ion Concentrations 1991-2000	LT
Stable Isotope Data for McMurdo Dry Valley Lakes	LT
Isotope Ratios for Taylor Valley Streams 1993-1995	LT
<u>III. Glaciology</u>	
Glacier Snow Densities 1993-2000	LT
Glacier Mass Changes 1993-2000	LT
Average Stake Heights, Snow Depths Found at Glacier Stakes 1993-2000	LT
Glacier Stake Heights, Snow Depths 1993-2000	LT
Canada Glacier Ice Temperatures 1998	LT
Canada Glacier Eddy Correlation Data 1994-1996	ST
Glacier Mass Balance Summary 1993-2000	LT

IV. Hydrology

Discrete Stream Gage Measurements pre-1980 (pre-LTER)	LT
Mean Daily Stream Gage Measurements 1969-1997	LT
Discrete Stream Gage Measurements 1980-1989 (pre-LTER)	LT
Discrete Stream Gage Measurements 1990-2000	LT
Taylor Valley Water Budgets 1993-1997	LT
Field Meter Stream Measurements 1990-2000	LT
Stream Team Field Manual	LT

V. Limnology

Ice Thickness, Piezometric Depths for Taylor Valley Lakes 1995-1999	ST
Winter Phytoplankton 1990-1991 (pre-LTER)	ST
Summer Phytoplankton 1992-1995	ST
Chlorophyll-A Concentrations in Lake Hoare Benthic Mats 1996-2000	ST
Lake Chlorophyll, Primary Productivity, Respiration 1993-2000	LT
Phytoplankton Densities 1993-2001	LT
Phytoplankton Photos	LT
Dissolved Oxygen, Photosynthetically Active Radiation 1993-2000	LT
Bacterial Productivity and Density 1993-2000	LT
Lake Temperature and Conductivity 1993-2000	LT
Microzooplankton Species in Lake Fryxell January 1994	ST
Lake Fryxell Ciliates, Bacteria, Nanoflagellates January 1992, 1994	ST
Cryptophyte, Ciliate, Heterotrophic Nanoflagellate Abundances 1996-98	ST
Flagellate Grazing in Lakes Hoare and Fryxell 1997-98	ST
Ciliate Grazing Rates 1997-98	ST
McMurdo Dry Valleys Lake Levels 1991-2000	LT

VI. Meteorology

Commonwealth Glacier Meteorological Station Measurements 1993-2001	LT
Average Meteorological Measurements for Canada Glacier 1994-2001	LT
Lake Brownworth Meteorological Station Measurements 1994-2001	LT
Lake Bonney Meteorological Station Measurements 1993-2001	LT
Lake Vanda Meteorological Station Measurements 1994-2001	LT
Canada Glacier Meteorological Station Measurements 1995-2001	LT
Lake Hoare Meteorological Station Measurements 1993-2001	LT
Lake Fryxell Meteorological Station Measurements 1993-2001	LT
Lake Vida Meteorological Station Measurements 1995-2001	LT
Explorer's Cove Meteorological Station Measurements 1995-2001	LT
Taylor Glacier Meteorological Station Measurements 1994-2001	LT
Howard Glacier Meteorological Station Measurements 1993-2001	LT
Beacon Valley Meteorological Station Measurements 2000-2001	LT

VII. Soil Ecology

Chlorophyll-A Responses to Long-Term Algae Amendment 1994-1997	LT
Soil Moisture Responses to Long-Term Algae Amendment 1994-1997	LT
Soil Organism Responses to Long-Term Algae Amendment 1994-1997	LT

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Soil Organism Responses to Long-Term Soil Manipulation 1993-1998	LT
Chlorophyll-A Responses to Long-Term Soil Manipulation 1994-1998	LT
Soil Moisture Responses to Long-Term Soil Manipulation 1993-1998	LT
Soil Temperature Probe Measurements in Long-Term Soil Manipulation	LT
Elevational and Topographic Effects on Soil Moisture, Biota 1993, 1995	ST
Elevational and Topographic Effects on Soil Chemistry 1993	ST

VIII. Stream Ecology

Stream Algae Ash-Free Dry Mass 1994 - 1997	LT
Algal Species, Morphotype Descriptions	ST
Stream Algae Photosynthesis/Light Measurements 1995	LT
Stream Algal and Moss Biomass 1994-1997	LT
Stream Algae Primary Productivity 1995, 1996, 1997	LT
Stream Invertebrate Taxa Qualitative Abundances 1994, few 1996	LT
Stream Algal Abundances 1994, 1996 for Von Guerard Lower Site	LT
Diatom Taxa of Taylor Valley	

IX. Study Locations

Locations, Dates, Codes for Lake Chemistry, Biology Samples	ST
Locations of Limno. Holes, Dive Holes, Lake Level Measurements	ST
Stream Lengths for Taylor Valley Streams	ST
Stream Gage Locations	ST
Stream Transect Locations	ST
Coordinate List of Stream Transect Points	ST
Coordinate List of Stream Gage Features	ST
1993-94 Geodetic Survey Results / Stream Transect Reference Marks	ST
GPS Data, Optical Observations Producing Coordinate Files	ST
Glacier Stake Locations	ST
1996-2001 MCM-LTER GPS Coordinate Locations	ST
Relative Positions of Stream Transect Line Points	ST
Meteorological Station Locations	ST
Glacier Stake Locations	ST
Soil Measurement Locations	ST

Use of on-line datasets by investigators not directly associated with MCM-LTER

Meteorological data:

Stephen Barnard, Meteorologist, Radian Corporation, Triangle Park, NC

Dr. Jaakko Putkonen, Geological Sciences, University of Washington

Dr. Nancy A.N. Bertler, Antarctic Research Centre, Victoria University, Wellington, NZ

Dr. Andy Monaghan, Polar Meteorology Group, Byrd Polar Research Center, The Ohio State University

Dr. Nick Lancaster, Desert Research Institute, University of Nevada, Reno

Glacier Data:

Dr. Ed Waddington, Geophysics Program, University of Washington

Dr. Curt Cuffey, Department of Geography, University of California, Berkeley

Lake Data:

Chris Fritsen, Desert Research Institute, University of Nevada, Reno

John Dore, University of Hawaii

Bess Ward, Princeton

MCM-II Cross-site and LTER Network Related Activities, Presentations, etc.

Presentations at 2000 LTER All Scientists Meeting (ASM), Snowbird, UT

Fountain, A.G. and Lyons, W.B., "Century to Millennial Scale Climate Change and Ecosystem Response in the McMurdo Dry Valleys, Antarctica"

Lyons and McKnight, "Small Watershed Studies at MCM"

Moorhead, D. L., "The importance of resource legacies to the structure and function of dry valley ecosystems"

Nezat et al., "Stream Monitoring by Students in Seattle, WA and Tuscaloosa, AL in Collaboration with the McMurdo Dry Valleys LTER"

Wall, D. "Biodiversity and Ecosystem Functioning: The Need for Long Term Ecological Research" Plenary talk.

Welch et al., "Climate and hydrologic variations and implications for lake and stream ecological response in the McMurdo Dry Valleys, Antarctica"

ASM 2000 Workshops chaired by MCM-LTER PI's

Fountain and Lyons co-chaired workshop on "Century to Millennial Scale Climate Change and Ecosystem Response"

McKnight worked with Eran Hood, a graduate student in NWT-LTER to organize a workshop, "Dissolved organic matter (C & N) in soil interstitial water, lakes and streams: approaches for functional characterization" at 2000 LTER All Scientist's Workshop. This workshop included lab demonstrations of DOC/DON fractionation.

Priscu co-chaired a workshop, "Microbial biogeography: cross-site comparison of aquatic systems"

Wall co-chaired a workshop, "Soil and sediment infauna studies in LTER and ILTER sites"

Wall organized a workshop, "The DIVERSITAS- International biodiversity observation year: raising the profile of biodiversity science. Where are we now and what more is needed?"

Other LTER activities

Doran, Cross-site work with Arctic Tundra and North Temperate Lakes looking at mixing in ice-covered lakes. An informal collaboration was initiated at ARC by Wharton that Doran took over and expanded to include NTL. High-precision

- thermistor strings have been monitoring year-round temperature at 8 depths in Toolik Lake (ARC) and Crystal Lake (NTL). This equipment is identical to that installed in the MCM lakes and will allow comparison of under-ice mixing conditions.
- Fountain, A.G., Climate change and ecosystem response, McMurdo Dry Valleys, Antarctica: The importance of legacy. Presentation at Fall LTER Coordinating Committee meeting in Santa Barbara (1999).
- Lyons visited the Fu-shan LTER site (Taiwan) in December, 2000. Paper presented at joint Geological Society of America and Geological Society of London meeting in Edinburgh in June, 2001 on data collected there.
- Lyons is co-chair with B. McDowell (Luquillo), D. Long (Kellogg Biological Station), C. Bowser (North Temperate Lakes), and G. McPherson (Konza Research Prairie Research Natural Area) of Chemical Weathering Rates and Landscape Development LTER Working Group. This group sponsored a discussion group at the ASM in Snowbird. This group was initiated in 1998 and has had two formal meetings.
- Lyons and Priscu co-convened the Victoria Land Latitudinal Gradient Workshop, April, 2001, Ohio State University, which is related to MCM-Regionalization.
- Lyons represents MCM on the LTER Coordinating Committee.
- Lyons represented the LTER Network as an invited speaker at the Development of a North American Regional Action Plan for Environmental Monitoring and Assessment in March, 2001. He spoke on the environmental monitoring taking place through LTER.
- McKnight was a member of the Hubbard Brook Site Review team (2001)
- McKnight is co-investigator with Mark Williams and Bill McDowell (Hubbard Brook and Luquillo) on a cross-site comparison on methods for DOC and DON fractionation.
- Moorhead, D. L., Regional Modeling at LTER Sites. San Diego Supercomputing Center (SDSC) meeting, Nov 8-11, 1999, San Diego. Participant.
- Priscu chaired a NSF workshop on the importance of winter research in the McMurdo area to science and education. September 1999.
- Priscu chaired or was a member of the McMurdo Users Committee, 1995-present.
- Priscu is the US biology representative to SCAR, 2000-2006.
- Priscu chairs a group of specialists on Sub-glacial Antarctic Lake Exploration (SALE, web site: <http://salegos-scar.montana.edu/>)
- Virginia, R. A. 1998. Soil Heterogeneity: The Jornada Basin and McMurdo Dry Valley LTER Comparison: Some like it hot, some like it cold. Jornada Basin Symposium, New Mexico State Univ., Las Cruces, July 1998.

Virginia, R. A., Panel Discussion: Teachers Experiencing Antarctica and the Arctic: The PI Experience. TEA Orientation Meetings, US Army CRREL, Hanover, NH. August 7, 2001.

Virginia, R. A., The Antarctic Dry Valleys: Soil Ecosystems in the Extreme. Seminar presented at the Teachers Experiencing Antarctica and the Arctic orientation meetings, US Army CRREL, Hanover, NH. August 9, 2001.

Wall, D.H. *Belowground Diversity, Does it matter for Agriculture?*, Invited Plenary Speaker at KBS LTER, Michigan State University Symposium in Agricultural Ecology. Michigan State University, East Lansing, MI. April, 2001.

Confidential material intentionally excluded.

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Section 3. Site Management

Lyons became the lead PI of MCM-LTER in March of 1998 while he was at the University of Alabama. At that time, Dr. McKnight was (and continues to be) the PI responsible for data management. Lyons appointed an Executive Committee consisting of Drs. Fountain, Priscu and Wall to help manage MCM and to decide on issues dealing with science management, personnel, the allocation of field slots and the selection of collaborators. This system continues to work well. The panel in their summary of the MCM-II proposal stated that there is "no evident weakness in site management" and that "recent changes in leadership and PI structure have been effective."

In December of 1999 Lyons moved to The Ohio State University to become Director of Byrd Polar Research Center. The administration of the grant and the Program Office of MCM-LTER moved with him. This move went smoothly and no science or administrative "downtime" occurred. Ms. Carmen Nezat at OSU has functioned at 30% time as the Administrative Assistant for MCM-LTER. She has been in charge of organization of communication and shared documents between the PI's. Ms. Nezat is also responsible for the administration of MCM-Schoolyard LTER Program. Ms. Kathy Welch at OSU has been responsible for the preparation of the final field planning document (SIP) that must go to Raytheon and finally to NSF each April. Both Ms. Nezat and Ms. Welch have helped Lyons prepare all documents needed for NSF, LTER Network and for field team members. In part of his negotiations with OSU, 50% of each of their salaries are paid for by MCM-II and OSU pays the other 50%.

The PIs meet twice per year. The first meeting is in late February or early March in order to review the past field season and plan for the next one. (Field season plans must be in to the NSF contractor by mid April.) Per the recommendation of the last site review team, the second meeting (held in the summer), is a "science" meeting and, in most years, students, technicians, post docs, etc. are invited to attend and asked to make presentations. The site of these meetings has been primarily in the Denver area at Boulder or Fort Collins to minimize travel costs for the majority, but this year we have begun to rotate the meeting sites among the home institutions of all the PI's. The PI's continue to have conference calls and Doran and Priscu are formulating a plan for monthly teleconferencing via PC.

Lyons, in his role as lead PI, was formally reviewed by all PI's this past year. Dr. Wall chaired the review committee, and the summary of the review is enclosed. The PI's appear to be satisfied with the current leadership direction and structure within MCM-LTER. All PIs at our 2001 Science Meeting agreed that Wall, Priscu and Fountain would maintain their positions in the EC. As pointed out by the last site review team, "the PI's have very good to excellent interpersonal working relationships." This has continued over the ensuing 4 1/2 years.

We continue to receive numerous requests from both US and foreign scientists to work on the MCM-LTER site. As we noted in our proposal, we are limited every year by the number of individuals that NSF can support in the field, yet we continue to develop important new collaborations, as well as maintain our long-standing ones. We continue to maintain our very strong ties to scientists from New Zealand involved in the Antarctica New Zealand research program. This includes our formal collaborator, Dr. Ian Hawes,

among others. Dr. Daryl Moorhead, through NSF-International Program support has successfully collaborated with Dr. Hawes and his colleagues on data mining and modeling efforts, while Dr. Peter Doran has worked with him in the field investigating the benthic algal mats in Taylor Valley lakes. Other formal collaborators have also been active, with Dr. Gayle Dana being in the field during the 2000-2001 season. In addition, Dr. Johanna Laybourn-Parry sent a post-doctoral fellow into the field with MCM-LTER in 2000-2001 and is planning to be in the field this coming season. Drs. Diana Wall and Ross Virginia will host two British Antarctic Survey scientists this coming season. Recent past successful collaborations include those with Dr. Robert Poreda, University of Rochester, on rare gas composition of the lakes and with Dr. Martyn Tranter, University of Bristol, on the biogeochemistry of glacier melt. Next year Dr. Doran will host Dr. Martin Melles, Alfred Wegener Institute for Polar and Marine Research, University of Leipzig, for sediment studies of the lakes. We believe that MCM-LTER is one of the leaders in the network with regard to international cooperation and scientific visibility. PI's will continue to collaborate with scientists in all sub-disciplines in order to advance the scientific objectives of MCM-LTER.

Section 4: Data Management

The MCM-LTER data and information management system is housed at INSTAAR, Univ. of Colorado. We have adopted the general features of the NWT-LTER data system (Ingersoll et al. 1997), also located at INSTAAR, including a centralized data system with different levels of access, which is managed by a half-time database manager with a part-time assistant. The database manager is supervised by Dr. McKnight and works with PIs and collaborators to meet database needs and to merge data sets relating to common sampling sites and times. Our system is designed to minimize the time between data collection, data submission, acquisition of metadata, and to provide timely public access to data files and other site related information (e.g. bibliographic resources, site news).

A distinguishing feature of the MCM-LTER is the high degree of coordination among investigators in planning each field season, which carries over to the data management program. The database manager can anticipate which data sets will be submitted following the analysis of the field data at the home institution. Data sets are routinely submitted to the database manager in an electronic format after quality assurance by the investigator. Our core data sets are 1) continuous year-round (such as meteorological data), 2) continuous during the austral summer (stream flow), and 3) determined for discrete time points at specific locations (e.g. lake water chemistry). Following the approach presented by Ingersoll et al. (1997), we recognize the following types of data:

Type 1- Electronic data: e.g. continuous meteorological data

Type 2- (Electronic) Hard copy data: e.g. field measurements and analysis of discrete samples

Type 3- Electronic manipulated data: e.g. continuous and discrete stream flow data which have been interpreted by using rating curves determined for each season.

The database manager is not directly involved in primary data entry, but rather merges the Type 2 data sets to verify that a record is complete and to identify inconsistencies that can be resolved by querying the field team. The Type 1 and Type 3 data sets are from established meteorological and stream gauging networks and, thus, requires only slight modifications between years.

Data are entered into electronic files in the field and at co-principal investigators' home institutes. When appropriate, both the original data format and data resulting from investigator interpretation are submitted to the database manager via file transfer protocol. These files are typically submitted as spreadsheets in PC-format. Metadata (documentation describing the data files) are submitted electronically and/or by specifying a publication containing the necessary information. Metadata are updated with specific information pertinent to the field season on an annual basis. The McMurdo LTER dedicated database computing system consists of hardware with both UNIX and Microsoft Windows operating systems. A UNIX based Sun/SunBlade 1000 Server forms the core of the database operation. It is used to collect data submitted electronically, store information in relational database structures, and provide web-server capability for access to LTER scientists and the general public. Both this server and a Dell 530

Workstation are used to prepare submitted data for including in the relational database. This includes manually entering data and text from hard copies when necessary, processing data with QA/QC scripting, adding comment annotation when necessary, and revise formats for representation in a relational mode in both Microsoft Access and Oracle8i. Archiving of data is done with the Sun/SunBlade1000 and an external drive-bay, which are backed up daily. In addition, a Sun/Ultra-Enterprise 150 and a Sun/SparcStation 5 client are dedicated clients for data analysis including full GIS functionality through the SunBlade 1000. Available software includes Microsoft Word, Excel, and Access, Visual Basic, Arc/INFO, ArcView, Oracle 8i, as well as general text editors and HTML coding.

The data accessible through the web are typically text forms generated from the current Microsoft Access database files. Concurrently, an Oracle8i database has been constructed and is organized through the geographic and temporal alignment of the Microsoft Access datasets. The large Type 1 and 3 datasets have been migrated to the new Oracle 8i database and we are in the process of migrating the Type 2 datasets. Currently, the bibliographic information that is accessible through the web is derived through direct queries of the Oracle 8i database. When the complete migration of all datasets to Oracle 8i is completed, a full web interface to the Oracle 8i database will be developed. The Microsoft Access database will be fully maintained until that stage.

The data manager communicates with all science teams before the field season about the sampling plan, permitting preparation of templates for data entry and cross-relational file structure in anticipation of data submittal. At the end of the field season, the data manager receives the actual sampling schedule (e.g. sampling dates and depths for each lake, sample dates and location for glacier, soil and stream field measurements and samples) and prepares a master data template for use by the investigators in submitting their data.

The MCM-LTER has two categories of Type 2 data; fast acquisition data obtained within a few months of the field season (e.g. water chemistry data), and slow acquisition data for which the analysis is more time-consuming or costly and results are unavailable for 6-12 months or more (e.g. bacterioplankton, phytoplankton, soil biota species abundance). The data manager tracks the progress of both categories of Type 2 data. This information about progress is used to devise long-term plans for allocating resources for subsequent analysis. The data manager performs the final quality assurance and quality control prior to a data set being made available to the community and organizes the metadata for the submitted data sets. The data manager also posts updates regarding availability of delayed Type 2 data on the web site.

Upon request and time permitting, the data manager generates composite data sets from algorithms provided by the investigators. For example, one composite data set is the annual solute flux to a dry valley lake from a given stream or for all streams flowing into that lake. This employs continuous Type 3 data from the hydrologic network and discrete chemical data obtained for samples collected at specific times. The data manager works with the investigator to document the quality of the composite data set for a particular year. This approach is illustrated in Figure 1.

The MCM-LTER has a record of timely submission of data to the database manager. We have a sequential procedure to ensure that timely data submission is maintained. The data manager keeps the supervising investigator (Dr. McKnight) informed of status on a

weekly basis. In the case of a substantial delay or lack of response to the data manager's inquiry, Dr. McKnight contacts the investigator to discuss plans that meet the needs of other investigators. Dr. Lyons, as the lead PI, conducts further discussion as needed. Persistent, unsatisfactory conditions may be considered in planning for future field seasons and allocation of resources. Because each field season is planned by the MCM-LTER as a team, investigators have a strong incentive to be current with their submission of data.

GIS Capability. The previous GIS of the Taylor Valley, which was developed at DRI, has been superseded by VALMAP which was developed by Dr. Mike Prentice at the University of New Hampshire with support from NSF-OPP. In this new more complete GIS, the coordinate system and network of previously established benchmarks have been rectified to be compatible with use of GPS in the field to locate sites in the McMurdo Dry Valleys. This represented a critical and labor-intensive step. We are currently in the process of developing links with VALMAP that will allow us to use the GIS to locate study sites for generation of maps, and to develop new data overlays.

The project goal is to develop links between the Oracle 8i database and VALMAP. We propose that this will be accomplished with the use of the ARCSDE database software from Environmental Systems Research Institute (ESRI). This software allows integration of spatial information along with tabular information and acts as an application server to deliver spatial data to multiple users and applications. A fully functional database of spatially referenced information will be developed with joint collaboration between Dr. Prentice and the McMurdo LTER data management staff and made available directly through the data management office at INSTAAR. The VALMAP software, which provides web-interface capabilities of creating map overlays of existing datasets, will also be served through the data management office at INSTAAR. This will provide general users the ability to query and generate maps with user specified scales and composition, while simultaneously allowing LTER scientists to access specific data sets for temporal/spatial extension and analysis. Development of further spatial representation and analysis capabilities can be produced by Dr. Prentice as potential future releases of the VALMAP software.

Data Accessibility and Schedule. Data accessibility is driven by the timing of the annual field season and completion of data analyses. The continuous data sets (Type 1 and 3) are submitted to the data manager within 2-4 months after completion of the field season in mid-February. When these data are posted in the MCM-LTER database they are immediately available to other MCM-LTER researchers and the broad scientific community. This corresponds to an annual updating of the Type 1 & 3 data sets.

Type 2 data sets of core monitoring data and experimental data from either short term or long term manipulative experiments are made available to the MCM-LTER investigators once the merger of the data submitted has been completed, shortly after the field season. The core monitoring data are made accessible to the scientific community one-two years after the end of the field season. For example, the Type 2 core data sets from the 1993/94 through 1999/2000 seasons currently are available through the web.

Information management services. Information distribution is largely handled through the World Wide Web. In addition to maintaining data files available for downloading via the MCM website, the MCM database management also maintains a bibliographic database of MCM-LTER publications. The present bibliographic tool allows for PIs to be responsible for maintaining the bibliography through a simple interface. The tool consists of a set of HTML templates for data entry and update, backed by a set of Java Server Page scripts for interacting with the Oracle database. Bibliographic entries submitted by each PI to the database are written to an intermediate file, which the database manager can review to determine completeness and comparability before entering it in to the existing database. Planned future enhancements include text search on all the fields in the bibliography database. The database manager is responsible for regular review of the site and will request that PIs update the site when necessary. Also through the main MCM web site the public is able to view details of the overall project (information on PIs, project descriptions, etc.), and connect to related web sites at Ohio State University, Montana State University, Colorado State University, INSTAAR, and the USGS.

SECTION 5 OUTREACH

Educational Outreach

Lyons, Welch and Nezat have been actively involved with the three MCM Schoolyard LTER schools and their teacher representatives (Barb Schulz, Lakeside School, Seattle, WA; Kim Ouderkirk, Tuscaloosa Academy, Tuscaloosa, AL; Carol Landis, Linworth Alternative School, Columbus, OH). In addition to presentations at the schools (see below), we have sponsored annual meetings for the teachers to discuss goals, issues, etc., about the project. The teachers have also visited each other's classrooms in order to coordinate sampling protocols so that data could be compared among the three schools, as well as to Taylor Valley stream data, and to provide information to the students about their "sister" Schoolyard sites in the U.S. Ms. Ouderkirk presented a paper at the Annual Geological Society of America Meeting in Denver, CO in October 1999. Lyons, Welch and Nezat gave a presentation at Tuscaloosa Academy (April, 1999) about the dry valleys. Lyons spoke to Barb Schulz's class at Lakeside School and gave a talk at the Watershed Education Project meeting sponsored by the Thornton Creek Project in Seattle, WA (October, 1999). Nezat demonstrated proper water sampling techniques to the Lakeside students involved in the project, and assisted the class in water sampling (October, 2000). In addition, a web site was developed with the help of MCM-LTER staff for the Tuscaloosa Academy Schoolyard site. Also, a web site was developed to link the two MCM Schoolyard sites with the MCM-LTER site so that data would be available to the two schools as well as anyone wishing to access it. Nezat helped to organize a workshop, "Learning from LTER data in K-12 classrooms" at the LTER All Scientists Meeting, 2000 and gave a presentation about the activities of the Schoolyard LTERs associated with MCM.

Lyons was also involved in the COSI (Center Of Science and Industry) mentoring program in Columbus, OH. He discussed Antarctic-related climate change issues with 5 area high school students (Summer 2000). In addition, Welch gave a presentation to 5th grade students at Sacred Heart School in Hampton, NH (September 2000) and to the 5th grade students at Barrington Elementary School in Columbus, OH, (September 2001). Nezat gave a presentation to a biology class at Opelousas Catholic High School in Opelousas, Louisiana (October 2000). Nezat and Welch gave three presentations at the Lincoln Park Elementary School in Columbus, OH for Career Day in May 2001.

Elissa Elliott and Valerie Sloane worked with Priscu's group with Teachers Experiencing Antarctica during the 1998-99 and 1999-2000 seasons, respectively. During the 1999-2000 season, two TEA alumni, Barbara Schulz and Peter Amati, returned to the ice under a new grant, TEA for TWO, that is supervised by MCM-LTER. Schulz and Amati conducted their own experiments, as well as trained people in McMurdo to transmit useful information to U.S. high school teachers and students.

McKnight hosted a 1999 INSTAAR Open House for middle school groups with a full day of presentations about research in the dry valleys.

Fountain gave two presentations at the Vancouver Academy of Arts and Academics (March 2000, 2001). Nylen gave presentations at Alameda Elementary

School (March 2000) and Mountain View Middle School (June 2000). Johnston gave presentations at Dunaway School (June 2000 and Nov 2000).

Virginia's group has begun working with a local high school teacher through the Teaching Experience in the Antarctic (TEA) program as well as giving presentations at Marlboro Elementary School in Marlboro, VT. Melody Burkins advised two first-year undergraduates in a research project concerning organic matter properties in Taylor Valley soils. The undergraduates were part of Dartmouth's award-winning Women In Science Project (WISP) and presented their research in a public science symposium at the end of the spring 1999 term.

Wall's group has participated in outreach activities in local schools. Blecker has presented "Life and Research in Antarctica" to the Poudre High School, Fort Collins, CO. Wall gave a talk entitled "Women in Antarctica" to Philanthropic Educational Organization for Women in Estes Park, Colorado (1999). Andy Parsons and Steve Blecker presented "Antarctica: Valley of the Dead?" - an interactive display about research in the McMurdo Dry Valleys, at the Denver Museum of Nature and Science on September 21st, 2001.

Public Activities

During 1998-99, Fountain gave presentations at Portland Rotary Club, Portland Geology Society of the Oregon Country, Department of Geology, and Oregon State University. He also gave presentations at Lake Oswego Rotary Club (March 2000) and Geophysics Program, University of Washington (May 2000). Bardel gave a presentation at General Motors Retirement Club (April 2000). Nylen gave a presentation at Portland State University (April 2000).

A number of PI's (i.e. Lyons, McKnight, and Priscu) have presented "Sunday Night Science Lectures" at McMurdo Station, Antarctica, over the past three years.

Media Attention

Doran granted interviews resulting in articles to New Scientist, Knight Ridder Press, CBS Evening News with Dan Rather, and a USA Today web page. McKnight was interviewed on TV news about climate change and tourism in Antarctica.

Icy Clues to Earth's Future; Antarctic Researchers Face a Mass of Mystery, Written by Curt Supplee, Washington Post, February 21, 1999

Lexington Herald-Leader, March 3, 1999: Target: The Oldest Life on Earth

Lexington Herald-Leader, March 4, 1999: Testing Ground Found for Exploration of Mars

New Scientist, April 17, 1999: Like Nothing on Earth

BBC special on subglacial lakes "The Lost World" featured Priscu. Priscu also had interview in Wired, Smithsonian, Newsweek and Discovery magazines regarding his work on ice, and participated in a live NPR program called Science Friday with Ira Flatow. Priscu was recently (May 2001) featured on 15-minute segment on NPR's "all things considered" and is advisor for NPR's DNA files.

Several press reports were generated about Kevin Lavigne, a 2000-01 TEA from Hanover High School, Hanover, New Hampshire (sponsored by Ross A. Virginia):

The Great White Lab. 2001. David J. Hoff. Education Week Volume XX Number 22, pp. 36-43. Feb. 14, 2001. <http://www.edweek.org/ew/vol-20/22antarctica.htm>

Polar Attraction. 2001. David Hoff. Teacher Magazine, April 2001, pp. 24-31.

N.H. Teacher Conducts "Dry Run" of Antarctic Experiments. David Hoff. Education Week, Dec 13, 2000.

<http://www.edweek.org/ew/ewstory.cfm?slug=15hanover.h20>

Dartmouth Professor And Hanover High School Teacher Team Up To Research Antarctic Life Patterns. News from Dartmouth, Dec. 20, 2000.

<http://www.dartmouth.edu/~news/releases/dec00/antarctica.html>

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- Rodríguez, M. A. (1995) Habitat-specific estimates of competition in stream salmonids: a field test of the isodar model of habitat selection. *Evolutionary Ecology* **9**, 169-184.