I. RESEARCH HIGHLIGHTS

HIGH ELEVATION ECOSYSTEMS: HISTORICAL RELICTS OR NOVEL ECOSYSTEMS?
The degree to which humans function as keystone species is diminished in the alpine relative to subalpine and lower elevation ecosystems, but includes extirpation and reductions in apex predators (thereby increasing impacts of important vertebrate herbivores such as elk as well as the introduced herbivore, moose), as well as documented alpine impacts from the current suite of global change drivers. NWT work has documented impacts of these changes to date, and studies are in place to detect further changes. Treeline change is underway but influenced by opposing drivers. While warming appears to be increasing tree seedling establishment and survivorship, stress-related insect outbreaks are affecting mature trees in the NWT area (e.g., Xiong et al. 2011).

Seastedt et al. (2008) recognized that the reality of ecosystem change was profoundly affecting the conceptual frameworks used to inform the applied ecological topics of conservation biology and restoration ecology. The emerging socio-ecological framework for mitigating and adapting to global environmental change (e.g., Chapin et al. 2010, 2011) has been revisited by Seastedt et al. (in press) to demonstrate how changing (novel) ecosystems can either facilitate or at least function as neutral entities within proactive conservation and restoration frameworks.


SOCIO-ECONOMIC HIGHLIGHTS
NWT LTER scientists have begun a new and innovative research program to integrate socio-economic and biophysical data collected in high alpine ecosystems. In the past year, senior personnel Dr. Catherine Keske, a new contributor to NWT LTER starting in 2011, has published basic and applied research studies that have contributed to the advancement of knowledge in high alpine recreation, environmental economics, and coupled natural and human systems.

Dr. Keske’s basic economic research (Keske, Lohman, Loomis, 2012) contributes to the socio-economic survey literature. Keske et al. (2012) examine whether respondents report their willingness to pay on an individual vs. a per group basis when asked generally about an increase
in costs to visit a high alpine research area. Knowledge gained by this research advances non-market valuation environmental research and economic survey work.

Dr. Keske’s research team has also developed a soil index model to assess the soil damage as a result of high mountain recreation. Dr. Keske’s graduate student has published a book (Lohman, Keske, and Kelly, 2011), and is preparing a manuscript for the academic literature. During the next year, this integrated model will provide a framework to measure the trade-offs between environmental impacts from recreation, and economic growth.

As an example of applied research, Dr. Keske and collaborator Dr. John Loomis also found that visitors did not reduce their expenditures for high mountain recreation, even when economic conditions had declined and the nation was in a recession (Loomis and Keske, 2011). This study contributes to the applied macroeconomic and environmental economics literature.


NIWOT RIDGE: LONG-TERM STUDY OF PLANT COMMUNITIES

Diane Ebert-May, Department of Plant Biology, Michigan State University
David Johnson, Postdoctoral Researcher, University of Texas, El Paso

Determining decade time-scale responses of alpine ecosystems to global change drivers is difficult because most alpine regions lack sustained monitoring. We developed a probabilistic matrix model that was based on the measurement of plant species cover and abundance in permanently marked plots established on Niwot Ridge, Colorado in 1971 during the International Biological Programme (IBP) and resampled in 1991 and 2001. Assuming future change can be inferred from past change, we extrapolated change for 100 years from 1971 and correlate trends for each plant community with time series of environmental data (1971-2001). Models predict a decreased extent of snowbank vegetation and an increased extent of shrub tundra by 2071. Mean annual maximum temperature and nitrogen deposition were the primary a posteriori correlates of plant community change. The model showed a strong decoupling of dry vegetation types from wetter vegetation types and forecasts suggest the prevalence of snowbank vegetation will decrease, shrub tundra will increase, and that moist meadow will change little by 2071. We view these results as hypotheses that can be tested by future resampling efforts and experimental studies. However, results from experimental studies as well as decadal time scale observations of changes in other alpine ecosystems and comparison of 1946 and 2002 aerial photography support the findings of the our study. Testing these hypotheses, and in particular that snowbank vegetation is decreasing and shrub tundra is increasing, has important implications for
understanding changes in ecosystem structure and function, particularly biodiversity, surface energy budgets and cycling of water, carbon, and other plant nutrients.


MICROBIAL ECOLOGY
In collaboration with an NSF Microbial Observatories grant to Schmidt, work at NWT LTER has resulted in the discovery of many new groups of microorganisms (through the application of molecular approaches) and extended our understanding of which microbes are functioning (and what biogeochemical processes they are carrying out) in low temperature environments. For example, Schmidt’s group has discovered many large (sub-phyllum level) new groups of fungi, some of which are functioning under the alpine snowpack and others that function only at very high elevations. One such group was named Soil Clone Group 1 (SCG1) in our original publications (Schadt et al. 2003, Porter et al. 2008). At first the traditional mycology community was very skeptical about the existence of these previously unknown groups of fungi, but recently the existence of SCG1 was verified and accepted using standard culturing approaches, and are now called the Archaeorhizomycetes (Rosling et al. 2011). These fungi are now recognized as being ubiquitous in soil systems and many labs around the world are trying to figure out what they are doing in soil systems. Likewise, our discovery of new large groups of zoosporic fungi (chytrids) in high elevation ecosystems are starting to be verified by more traditional mycologists, and research into the ecological roles of these unusual fungi is only just beginning (Schmidt et al. 2012). Thus work at NWT LTER has spawned new sub-fields of research and has stimulated research by mycologists worldwide.


NUTNET
NWT LTER is an enthusiastic partner within NutNet. An important manuscript based on data from this program was published this past year (Adler et al. 2011). For more than 30 years, the relationship between net primary productivity and species richness has generated intense debate in ecology about the processes regulating local diversity. The original view, which is still widely accepted, holds that the relationship is hump-shaped, with richness first rising and then declining with increasing productivity. Although recent meta-analyses questioned the generality of hump-shaped patterns, these syntheses have been criticized for failing to account for methodological differences among studies. NutNet addressed such concerns by conducting standardized sampling in 48 herbaceous-dominated plant communities on five continents, including NWT LTER. They found no clear relationship between productivity and fine-scale (meters^2) richness within sites, within regions, or across the globe. Ecologists should focus on fresh, mechanistic approaches to understanding the multivariate links between productivity and richness.

GLOBAL WARMING EXPERIMENT CONDUCTED BY UC MERCED
PI L. Kueppers
NWT LTER has supported global change research conducted on Niwot Ridge by UC Merced. The experiment uses infrared heaters to warm soil and plant surfaces by an amount comparable to current average projections of climate warming in the year 2100 along an elevational gradient from forested areas to alpine areas. Recently, to determine how genetics and climate may interact to affect seedling establishment, they transplanted recently germinated seedlings from high- and low-elevation provenances (HI and LO, respectively) of Pinus flexilis in common gardens arrayed along an elevation and canopy gradient from subalpine forest into the alpine zone, and examined differences in physiology and morphology between provenances and among sites. Plant dry mass, projected leaf area, and shoot: root ratios were 12-40% greater in LO compared with HI seedlings at each elevation. There were no significant changes in these variables among sites except for decreased dry mass of LO seedlings in the alpine site. Photosynthesis, carbon balance (photosynthesis/respiration), and conductance increased >2x with elevation for both provenances, and were 35-77% greater in LO seedlings compared with HI seedlings. There were no differences in dark-adapted chlorophyll fluorescence (F(v)/F(m)) among sites or between provenances. The results suggest that for P. flexilis seedlings, provenances selected for above-ground growth may outperform those selected for stress resistance in the absence of harsh climatic conditions, even well above the species' range limits in the alpine zone. This indicates that forest genetics may be important to understanding and managing species' range adjustments due to climate change.


LANDSCAPE-LEVEL NITROGEN IMPORT AND EXPORT IN AN ECOSYSTEM WITH COMPLEX TERRAIN
Knowledge of import, export, and transport of nitrogen (N) in headwater catchments is essential for understanding ecosystem function and water quality in mountain ecosystems, especially as these ecosystems experience increased anthropogenic N deposition. In this study, we linked spatially explicit soil and stream data at the landscape scale to investigate import, export and transport of N in a 0.89 km² site at the alpine-subalpine ecotone on Niwot Ridge. For two of the major N inputs to our site, N deposition in the snowpack and N fixation, a complementary
relationship was found across the study site, with greater abundance of N-fixing plants in areas with less snow and substantial snow inputs in areas with low N fixer abundance. During the initial phases of snowmelt, mixing model end members for oxygen isotopes in nitrate (NO$_3^-$) indicated that a substantial quantity of NO$_3^-$ is transported downhill into the forested subalpine without being assimilated by soil microbes. After this initial pulse, much less NO$_3^-$ entered the stream and most but not all of it was microbial in origin. Rising $\delta^{15}$N in stream NO$_3^-$ indicated greater influence of fractionating processes such as denitrification later in the season. NO$_3^-$ from both atmospheric and microbial sources was not exported from our site because it was consumed within the first several hundred meters of the stream; ultimately, N exports were in the form of dissolved organic nitrogen (DON) and particulate N (PN). The results of this study suggest that the highest elevation dry alpine meadows rely more heavily on N fixation as an N source and experience less of the effects of anthropogenic N deposition than mid and lower elevation areas that have more snow. Our data also suggest that mid-elevation krummholz, moist meadows, and talus slopes are exporting N as NO$_3^-$ shortly after the onset of snowmelt, but that this NO$_3^-$ is rapidly consumed as the stream flows through the subalpine forest. This consumption by assimilation and/or denitrification currently provides a buffer against increased inorganic N availability downstream.


SNOW HYDROLOGY

A major contribution to the hydrologic and ecological communities includes the significant value added to data sets on the spatial distribution of snow and related energy balance parameters collected at the NWT LTER site. These data sets represent one of the most comprehensive collections of alpine hydrology in North America, yet their usage by the community has been limited as the data have not been adequately quality controlled. We have done rigorous quality control on these data and have developed a database of several meteorological and hydrological variables collected from a disparate field campaigns and continuously running climate stations. The end result is an unprecedented multi-year data set that will be a resource for decades into the future. We have already begun disseminating this information within the community, e.g., Matthew Sturm is using the snow density data as the only North American mid-latitude snow data in a forthcoming paper on global snow density distribution.

In addition, the synthesis of the data sets and modeling results of this study have led to new understanding of snowmelt processes in mountainous regions. The general contributions are:
1) Documentation of the large role of turbulent fluxes associated with snowmelt in continental climates versus maritime climates via a 10-year detailed assessment.
2) Detailed summary of the spatial distribution of snow water equivalent illustrating the significant role of wind redistribution of snow in continental climates leading to significantly more spatial variability in snowpack relative to maritime climates.
3) Illustration of the decoupling of snowmelt timing and streamflow timing in continental climates associated with significant groundwater contributions to streamflow versus the surface water dominance found in the maritime catchment.
INNOVATIVE USE OF GPS TO MEASURE SNOW PROPERTIES

Snow is an important component of the climate system and a critical storage component in the hydrologic cycle. However, in situ observations of snow distribution are sparse, and remotely sensed products are imprecise and only available at a coarse spatial scale. GPS geodesists have long recognized that snow can affect a GPS signal, but it has not previously been shown that a GPS receiver placed in a standard geodetic orientation can be used to measure snow depth. At the NWT LTER saddle site, we are working with Kristine Larson of aerospace engineering to investigate whether changes in snow depth can be clearly tracked in the corresponding multi-path modulation of the GPS signal. While we concentrate on snow depth, this is a first step towards measuring SWE using GPS receivers. Given that there are already hundreds of GPS receivers operating in snowy regions of the U.S., it is possible that they could meet the cost requirement for an in situ snow network.

We installed a research grade GPS receiver in August 2009 at the Saddle site on Niwot Ridge to test the ability of a GPS to measure snow properties. The newer GPS instruments work on L-band frequencies in the microwave region of the electromagnetic spectrum, which have been shown to track snow properties from remote sensing platforms. In Gutmann et al. (2011) we present snow measurements using GPS interferometric reflectometry (GPS-IR). GPS-IR measures a large area (~ 100 square meters), and existing GPS installations around the worlds have the potential to expand existing snow measurement networks substantially. GPS-IR uses a standard, upward pointing, geodetic GPS installation to measure the snow surface via the reflected multi-path component of the signal. We report GPS-IR snow depth measurements made at Niwot Ridge from October 2009 through June 2010. This site is located in a topographic saddle at 3500 m elevation with a peak snow depth of 0.9 to 1.7 m in the region near the GPS. GPS-IR measurements are compared to bi-weekly manual snow surveys, a continuously operating scanning laser system, and an airborne LIDAR measurement. The GPS-IR measurement of peak snow pack (1.36 to 1.76 m) matches manual measurements (0.95 m to 1.7 m) in the region near the GPS. GPS-IR has root mean square error of 13 cm and a bias of 10 cm compared to the laser, although differences between the measurement locations make comparison imprecise. Over the melt season, when the snowpack is more homogenous, the difference between GPS-IR and the laser is reduced (RMS = 9 cm, bias = 6 cm). In other locations, the GPS and the LIDAR agree on which areas have more or less snow, but the GPS estimates substantially more snow on the ground (1.58 and 1.02 m) than the LIDAR (1.15 and 0.71 m).

II. RESEARCH ACTIVITIES

Here we focus on new activities for 2011.

New Grant: CNH: DYNAMICS OF COUPLED NATURAL AND HUMAN SYSTEMS IN THE COLORADO FRONT RANGE WILDLAND/URBAN INTERFACE: CAUSES AND CONSEQUENCES

$1.43 million, September 2011 to October 2014, Patrick Bourgeron PI

In the US, the wildland-urban interface (WUI) occupies 9% of the conterminous surface area and contains nearly 39% of all housing units. A prime example of the serious modifications of the interactions between environmental and socio-economic dynamics in the WUI is the sharp increase in the likelihood of severe disturbances (such as wildfires and insect outbreaks) in large portions of these areas. The central goal of this project is therefore to analyze the interactions between environmental, social, and economic domains at multiple spatial scales, and to forecast the effects of these interactions on patterns of dynamic changes and ecological resilience across the WUI of the Colorado Front Range (COFR).

An overarching hypothesis provides the focus of the research: The increase in connectivity between landscapes and people, reflecting the increased use of cultural services (exurbanization, recreation) in the COFR WUI, along with increasing punctuated climate-driven disturbances, such as fires and mountain pine beetle outbreaks, increases the connectivity of disturbances among landscapes, leading to new stable states, less landscape heterogeneity, and potential decreases in key ecosystem services. To address this hypothesis, three general objectives are formulated: identify the mechanisms by which dynamics in ecological, social, and economic domains interact at three spatial scales to affect internal controls and feedbacks; identify the mechanisms by which ecological, social, and economic attributes contribute to maintenance or loss of resilience in the study area; evaluate the implications of different environmental and growth policies on resilience when threshold interactions among the three domains and spatial scales are considered.

The research approach comprises five parts: (1) narratives used to define the boundaries of the systems under study, their key components, important ecosystem drivers, and characteristics of socio-economic structures; (2) a process-based simulation framework linking a spatially explicit landscape model with a set of land-use/land-cover models and a model of housing growth and modification; (3) an analysis of housing density and building/landscaping characteristics to investigate land use within an environmental economic framework; (4) a hierarchical modeling study of nonlinearity and analysis of resilience; and (5) synthesis and scenario planning to collectively address the questions.

Intellectual merit: First, the approach integrates several elements of the rapidly expanding WUI that have not been well developed. Second, by focusing directly on the relationship of WUI resilience in the ecological, social, and economic domains at multiple scales, this project will contribute to the development of general theories of these relationships in space and time. Third, the proposed investigations provide the first test of the components of an integrated, process based, and theoretical framework for understanding WUI responses to changes in ecological, social, and economic dynamics.
Broader impacts: First, the establishment of collaborative ties and partnerships will allow interactions among a diverse set of science programs in the dissemination of data, tools, and knowledge to a broad base of managers, planners, decision-makers, and industry groups. Second, the project’s contribution to education will be implemented through a variety of programs that are expected to have a strong impact on students of varied ages and levels, as well as members of the general public.

New Grant: THE ROLE OF DUST ON SNOW AND OTHER AEOLIAN INPUTS IN SOIL FORMATION AND BIOGEOCHEMICAL CYCLING IN BARREN, ALPINE CATCHMENTS
$556,774, August 2011 to July 2014, Natalie Mladenov PI

There is an urgency to improve our understanding of how biogeochemical cycling and surface water quality in high-elevation catchments are responding to climatic changes. The combination of increasing temperatures and dust emissions, melting glaciers, and surprisingly high amounts of microbial activity in recently deglaciated soils, suggest aeolian inputs of carbon and nutrients to barren alpine catchments may have an important and, thus far, unexplored role in nitrification and soil formation. To gain a better process-level understanding of how alpine ecosystems will respond to changes in climate, atmospheric deposition, and energy, this project seeks to investigate the initial phases of weathering and biogeochemical cycling in barren, high-elevation soils. An overarching hypothesis that defines this project is that dust and other atmospheric inputs are important pathways to soil formation and biogeochemical processes, such as nitrification, in barren, alpine catchments.

Intellectual Merit: While there is a general consensus that climate change and atmospheric deposition to mountain catchments influence many ecosystem functions, much still remains to be learned about the fundamental biogeochemical processes occurring in barren soils. By building on long-term hydrological and biogeochemical data at the well-studied Green Lake 4 (GL4) catchment in the Colorado Front Range and recent breakthroughs in snowmelt and hydrochemical modeling [Molotch et al. 2008], the research team can lead a fairly ambitious integration of modeling with a process-level understanding of biogeochemical cycling acquired from new field and laboratory studies proposed here. New insights gained from investigating aeolian wet and dry deposition, microbial community composition, rates of microbial processes, and stream and soil water quality, and from conducting coupled snowmelt-biogeochemical modeling will improve the capability to forecast changes in the biogeochemical cycling and hydrology of high-elevation watersheds with a changing climate. Given the global relevance of this research, a subset of activities will be conducted at other CZO sites in the US as well as at international alpine sites. The proposed research will use novel spectroscopic techniques, stable isotope and cation analyses, and bioavailability experiments combined with soil chemistry and mineralogy to evaluate the provenance and chemical quality of aeolian deposition. Given unprecedented rates of glacier melting worldwide, the improved representation of biogeochemical processes is relevant for C- and P- limited mountain catchments on a global scale.

Broader Impact: The inclusion of US CZO sites and international alpine sites in the characterization of dust on snow and other aeolian inputs will expand the relevance of this topic
and facilitate an international dialogue on the processes explored in this research. Skyline High School students participating in the St. Vrain Math, Engineering, and Science Achievement (MESA) Program, which seeks to improve achievement by Latino students, will develop their own summer research projects, mentored by the PIs and graduate student and supported with stipends through this project. To stimulate enrichment of MESA high school science teachers, NSF Research Experience for Teachers supplements will be sought. Once a year 8-10 MESA high school students will take a field trip to CU during the INSTAAR Open House, an annual event that showcases INSTAAR research. Results of this project will be disseminated as peer-reviewed publications and via the NWT LTER data management program at http://culter.colorado.edu/NWT/.

**New Grant: ESTABLISHING A COLLABORATIVE EFFORT TO ASSESS THE ROLE OF GLACIERS AND SEASONAL SNOW COVER IN THE HYDROLOGY OF THE MOUNTAINS OF HIGH ASIA**

**$5,400,000, September 2011 to August 2015, Co-I Mark Williams, PI Richard Armstrong**

A University of Colorado Boulder team is partnering with United States Agency for International Development (USAID) to assess snow and glacier contributions to water resources originating in the high mountains of Asia that straddle 10 countries.

Richard Armstrong and Mark Williams, the two faculty members leading the four-year study, said the aim is to provide a comprehensive and systematic assessment of freshwater resources in the so-called “High Asia” region, which encompasses five mountain ranges and watersheds totaling roughly one million square miles. The area under study is roughly equal to one-third of the contiguous United States.

This assessment will be crucial in helping to forecast the future availability and vulnerability of water resources in the region, beginning with accurate assessments of the distinct, separate contributions from melting glacier ice and seasonal snow to river discharge. Such data ultimately will provide a better understanding of the timing and volume of runoff in the face of climate change, said the CU-Boulder researchers.

The High Asia mountains funnel water into such major river basins as the Ganges, Brahmaputra, Indus, Amu Darya and Syr Darya. The High Asian mountain ranges under study include the Himalaya, Karakoram, Hindu Kush, Pamir and Tien Shan. The mountain ranges straddle Bhutan, Nepal, China, India, Pakistan, Afghanistan, Kazakhstan, Uzbekistan, Kyrgyzstan, and Tajikistan.

Through the partnership, scientists and students within the 10 countries will carry out collaborative research with CU-Boulder scientists. The project will also support satellite data processing by CU-Boulder staff and trainings for local institutions and observers within the study area to collect water and precipitation samples for the project.

While about one-third of the world’s population depends to some degree on freshwater within the High Asia hydrological system, not enough data presently exists on river and stream flows and the contribution of seasonal snow and glacier melt to paint an accurate picture of the water resources there, said Armstrong, a senior research scientist at CU-Boulder’s National Snow and Ice Data Center, or NSIDC.
The team requires an accurate quantitative portrait of each major river basin and sub-basin in High Asia. The Indus River for example, which is fed by waterways from the Himalaya, Karakorum and Hindu Kush mountain ranges, comes together at the city of Besham, Pakistan, “where it immediately turns into the largest irrigation system in the world,” said Williams. “The sources of water in High Asia feeding the major foothill regions where most of the people live are really the crux of this study.”

Armstrong said there is a lot of misinformation in the public arena regarding glaciers, including reports that glaciers in the Himalaya are receding faster than anywhere else in the world and, if this rapid melting continues, rivers are on track to first flood and then dry up. “Those reports simply are not true”, Armstrong said.

USAID is an independent United States government agency that provides economic, development, and humanitarian assistance around the world in support of the foreign policy goals of the United States. “USAID wants to know how the High Asia water resources affect local populations,” said Armstrong, also a fellow at the CU-headquartered Cooperative Institute for Research in Environmental Sciences. “They are looking at this challenge from a sustainability perspective, including what is going to happen to rivers like the Indus and the Brahmaputra in the next 20 years.”

The researchers will use remote-sensing satellite data from NASA, the European Space Agency and the Japanese Space Agency to develop time-series maps of seasonal snowfall amounts and recent changes in glacier extent, said Williams, a fellow at CU-Boulder’s Institute of Arctic and Alpine Research and CU-Boulder’s geography professor. They also will use local meteorological and river discharge data from throughout the High Asia study area.

“What’s really driving this study are questions about water security,” said Williams. “There is a lot of international interest in accurate water resource data from the High Asia region and what the water security consequences are, since water conflicts between countries can escalate rapidly. This study should provide answers as to what is real and what is false.”

“Once we have a picture of recent and current conditions, we can go forward and run computer ‘melt models’ based on the temperatures at various elevations, giving us trends in snowmelt and glacier melt by region and time,” said Armstrong. “That’s when we start to come up with water volumes for individual rivers and streams from both melting snow and ice.”

The modeling results will be verified using geochemical and water isotope “tracer” techniques studies developed at CU that allow researchers to follow water as it courses through mountain landscapes. Previous studies by Williams and his research group showed high mountain groundwater in Colorado dominated by snowmelt can be locked underground for decades before emerging into downstream waterways. "These isotopic and geochemical measurements provide unique fingerprints, allowing a CSI-like approach to tracing water sources," said Williams.

Critical to the project is the university’s expertise in remote sensing research through NSIDC -- including assessing changes in Earth’s snow and ice cover -- and INSTAAR’s research on the
physical, chemical biological processes in “critical zones,” which are the areas between treetops and groundwater. INSTAAR administers both the Long-Term Ecological Research site at Niwot Ridge west of Boulder and the Critical Zone Observatory project in the Boulder Creek watershed for the National Science Foundation.

One of the biggest project challenges will be to obtain data from some of the most remote regions on Earth, said Williams. The water, rain and snow samples collected by collaborators within the study area will be sent back to CU-Boulder for analysis.

This research will bring together scientists and government officials in the countries of High Asia to coordinate and compare results on what part of river flows come from glaciers and seasonal snow. This sharing of information is very important because the rivers of Asia can cross several country borders. USAID support will contribute to this research and coordination and the University of Colorado will be making archived and new data on snow and ice easily available to all countries and its citizens.

The CU team will hire Asian project managers and collaborate with research scientists affiliated with various Asian institutes. “We already have some good scientific contacts in the region, people we know who are reliable and who can deliver,” said Armstrong.

A number of CU undergraduates and graduate students will be involved in the study and support will be available to Asian students by way of the funding provided to Asian project partners.

“One of the main project goals is to transfer scientific understanding to people in the region who can continue these measurements and analysis once the USAID project is finished,” said Armstrong. “The idea is to provide the local population with the information they need to make decisions that will increase sustainability as land use and climate change.”

NIWOT RIDGE: LONG-TERM STUDY OF PLANT COMMUNITIES
Diane Ebert-May, Department of Plant Biology, Michigan State University.
Diane resampled the 30 permanent LTER vegetation plots (originally established in 1971) in the Saddle during summer of 2011. She collected cover and presence data for all vascular plants. This will enable testing the model described in the previous section and will contribute a 40-year plant community data set to the LTER program. She anticipates a rapid turn around time for the data analysis and manuscript production. Further, she agreed that the data will become part of the LTER database upon publication of the results.

EXPERIMENTAL MACROECOLOGY: EFFECTS OF TEMPERATURE ON BIODIVERSITY
PIs: James Brown, Robert Waide (University of New Mexico), Michael Kaspari, Zhili He, Jizhong Zhou (University of Oklahoma Norman) and Brian Enquist (University of Arizona)
NWTLTER is one of the test sites for this new macroecology grant. The increased diversity of living organisms from the poles to the tropics is one of the most pronounced features of life on Earth, but it lacks an explanation. One universal feature of this relationship, as seen across the land, oceans, lakes and rivers, is that hotter environments have more organisms of all kinds
(animals, plants and microbes). In this study, a big-picture approach will be used to study the
effect of temperature on biodiversity. It will generate mathematical models for how temperature,
through its effect on chemical and biological processes, affects ecological interactions and
patterns of biodiversity. NWT LTER personnel are working directly with this group to obtain the
necessary measurements for their program.

CROSS-SITE LTER PROJECT ON MICROBIAL FUNCTIONING
PI’s Mark Bradford (Yale), Noah Fierer (CU Boulder), and Rebecca McCulley (Univ. of
Kentucky)
NWT LTER is a participant with an NSF-funded, cross LTER project on whether trade-offs in
enzyme activities manifest at the level of microbial community function. We collected and sent
to the PI’s several soil samples using their protocols.

BOULDER CREEK CRITICAL ZONE OBSERVATORY
The alpine area of the NWT LTER is one of three headwater catchments that comprise the NSF
(GEO) Boulder Creek Critical Zone Observatory (BC-CZO). Altitudinal gradients are among the
most powerful ‘natural experiments’ for testing ecological and evolutionary responses of biota to
gephysical influences, such as differences in air temperature. Partnering with the BC-CZO
allows us to evaluate the ecology and hydrology of the Colorado Front Range along a large
altitudinal gradient: Green Lakes Valley (3,500 m), Como Creek (2,900 m), Gordon Gulch
(2,400 m), and Betasso (1,830 m) catchments. Initial results show that headwater catchments
along this elevation gradient process nutrients differently. A key component of the NWT
LTER/BC-CZO partnership is the development of compatible hardware, software, and data
standards to facilitate the integration and synthesis of information across the two programs.

Williams, Mark W., Rebecca T. Barnes, Jordan N. Parman, Michele Freppaz, and Eran Hood.
2011. Stream Water Chemistry along an Elevational Gradient from the Continental Divide to
the Foothills of the Rocky Mountains, Vadose Zone Journal, doi:10.2136/vzj2010.0131,
10:900-914.

NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON)
NWT LTER is partnering with NEON to establish a transect across the mountains from the Great
Plains to the Colorado Plateau to address source-receptor relationships between land use change,
climate change, and human activities on movement of dust, nutrients, and water, across a region
we call the Prairie, Peak, Plateau (P3) region of the U.S. West. NWT LTER is the core site for
NEON domain 13 and the SGS LTER is the core site for the adjacent climate domain 10,
effectively bounding the Colorado Front Range. The NEON transect is critical to understanding
the changes wrought by soil disturbance, dust deposition, and agricultural and urban nitrogen
emissions – from eutrophication and acidification of soils and lakes, to impacts on snow and
Western water supply.

HIGHEST EDDY COVARIANCE SITE IN THE WORLD
Since June 2007, the continuous yearlong measurements of net ecosystem exchange of CO2 and
the complete surface energy balance using the eddy covariance methods has changed our
understanding of carbon and water cycling in alpine tundra. To understand how local “hot spots”
of respired carbon activity are controlled by snow cover, soil temperature, and soil moisture, we
have presented papers on the alpine surface energy balance at national conferences (America Geophysical Union Fall Meetings, 2010 and 2011), and publications (Knowles et al. 2011).


SAMPLING ATMOSPHERIC DUST
NWT LTER is supporting a new high volume dust sampler that is part of a larger network of such samplers being deployed across Utah and Colorado. This network is described at http://moab.colorado.edu/TSP.html and is an effort to better understand the regional transport of mineral dust from deserts to mountainous regions. Jason Neff has been leading the effort to develop this network and presented the results to federal and tribal stakeholders in 2011.

Neff JC, Desert dust in the western US; the role of human disturbance on dust storms and aerosol loads in the rural West. NOAA Seminar, 2011.

NETWORK SERVICE: INFORMATION MANAGEMENT
Hope Humphries, NWT LTER Information Manager, is a member of the LTER GIS Working Group, and helped plan an upcoming workshop for this group on the management, documentation, and publication of spatial data into the Network Information System (GeoNIS). The workshop will be held at INSTAAR, CU-Boulder, in February 2012. She participated in a workshop on streaming QAQC for sensor networks (SensorNIS), held at Hubbard Brook LTER October 25 to 27, as well as in a Drupal Ecological Information Management System (DEIMS) workshop, including training in the Drupal content management system, at LNO from November 7 to 11. She also attended the LTER Information Manager’s annual meeting and the Environmental Information Management Conference in Santa Barbara, California, from September 26 to 29.

NETWORK SERVICE: ILTER
Involvement in the European mountain LTER network.
NWT LTER has been a leader in developing an international LTER program in Europe devoted to mountain areas. M. Williams and P. Bourgeron participated in a workshop: The Mountain LTER Workshop, LTSER, Col de Lauterat France, 14-16 September 2011. A first version of the Mountain LTER network homepage based on that workshop can be found at: http://gmba.unibas.ch/mountainLTER/mountainLTER.htm. Williams gave a plenary talk at that workshop.
ILTERT and USLTER International Committee.

**USLTER International Committee:** P. Bourgeron was the three-times elected senior co-chair of the IC from September 2003 to October 2011. In this capacity, he led the development of several initiatives aimed at promoting and increasing the collaboration of US scientists with international colleagues, as well as increasing the international visibility of the USLTER. Achievements of the IC include, but are not limited to: increased collaboration with the Chinese LTER (CERN), an NSF funded project on eco-hydrology with the Mexican LTER, and acceptance of the ISSE framework by several key ILTER members (European LTSER, Mexico, Chili, South Africa, and Japan among others). The co-chair position also included the reorganization of the ILTER as a viable science institution ([http://www.ilternet.edu/](http://www.ilternet.edu/)) guided by a strategic plan ([http://www.lter-europe.net/document-archive/central/ECOLEC-D-08-00262.pdf](http://www.lter-europe.net/document-archive/central/ECOLEC-D-08-00262.pdf)). Detailed activities of the IC are summarized in annual reports that can be found at [http://intranet2.ilternet.edu/documents/committee-documents/international-lter-committee](http://intranet2.ilternet.edu/documents/committee-documents/international-lter-committee). Other projects under the ILTER umbrella are summarized below. Bourgeron remains on the IC as a member.

**ILTERT Science Committee:** P. Bourgeron was reelected in 2010 for a second term (2011-2005) as Chair of the ILTER Science and program Committee. The role of the committee is to formulate broad network-wide avenues of research and promote collaboration among ILTER members. Duties include organizing science workshops during the ILTER annual meetings, developing a science agenda and initiatives (see below), and organizing synthesis workshops (see below).


**USLTER and ILTER Workshop at Ecosummit 2012:** a workshop on ecosystem services ([http://www.ecosummit2012.org/symposia-bourgeron.html](http://www.ecosummit2012.org/symposia-bourgeron.html)) organized by Bourgeron and Roy Chowdhury will include scientists from four LTER networks (US, France, China and Mexico). The Chinese LTER (CERN), the USLTER, and the ILTER will jointly sponsor the workshop. A synthesis paper is planned and the Chinese delegation will visit selected US sites.

**French-US LTER collaboration:** Bourgeron has been a member of the French LTER executive science committee since 2007 and was appointed President of the committee in November 2011. In this capacity, Bourgeron co-organized, with Yvan Lagadeuc (French LTER network Director), the first French ASM held in Rennes, France, in October 2011 ([http://www.za-inee.org/colloque2011/spip.php?rubrique2](http://www.za-inee.org/colloque2011/spip.php?rubrique2)). Other USLTER scientists presenting at the meeting included Scott Collins and Morgan Grove.

**NETWORK SERVICE:** OTHER ITEMS
Williams is a member of the LTER Network Executive Board and the organizing committee for the All-Scientists Meeting in Estes Park in September. He is also a co-lead on the “Disappearing Cryosphere” working group.

III. OUTREACH ACTIVITIES

NWT LTER FINAL REPORT 2004-2010
OUTREACH HIGHLIGHTS

Collaborative Outreach.
Thirty-four undergraduates from institutions around the country were introduced to alpine eoclimatology on June 16-17 by Niwot Ridge LTER researcher Chris Ray and her graduate student Liesl Erb. Hosted by UNAVCO¹ and UCAR², the students were participating in the RECESS³ and SOARS³ programs, dedicated to increasing diversity in the earth and atmospheric sciences. This collaborative outreach project brought all 34 students to Rocky Mountain National Park for immersion in alpine research. An evening program featured a whimsical but educational video about the importance of winter snow cover for the persistence of alpine mammals. The video, produced this year using NWT LTER outreach funds, was very popular—students referred to it enthusiastically throughout the next day as they hunted through alpine landscapes for buried data.

Geocaching for Science. One week before the program, temperature data loggers were placed strategically in snow-covered vs. exposed locations within an alpine block-field. Students were tasked with finding the loggers, and were provided with coordinates, GPS units, and photographs to aid in their searches. Conditions were more than challenging during the hunt, with bouts of snow driven by winds well over 70mph. Students from places like Jamaica and Puerto Rico were completely unfamiliar with the vagaries of mountain weather, and all students gained a new appreciation of data collection in the alpine. Success! Eleven students worked in small groups to
retrieve sensors, analyze data and compare results among groups. Instructor-led and peer-to-peer learning expanded each student’s skills in data analysis. Most (9 of 11) students participating in this portion of the program were from under-represented groups (Black, Hispanic and Native American) and the majority (6 of 11) was female. Students calculated statistics on site microclimates, and compared microclimates among sites with different slope aspects, amounts of snow cover, and known presence or absence of the American pika. Results were discussed with reference to current hypotheses about the importance of snow cover for overwinter survival of the pika—after Dr. Ray presented an overview of recent pika research.

**Follow-up.** Niwot Ridge LTER researchers will continue to work with UNAVCO and UCAR to establish this new activity as an annual component of our outreach efforts. In addition to leading the development of key activities this year, we also led in rainy day planning for this event, providing the My Water kit and book for use during the program in case the students were stuck indoors on the big day. Next year, we plan to incorporate My Water activities in any weather.

1UNAVCO is a non-profit, university-governed consortium, facilitating geoscience research and education.  
2UCAR (University Corporation for Atmospheric Research) promotes partnership in a collaborative community dedicated to understanding the atmosphere.  
3RESESS (Research Experiences in Solid Earth Science for Students) is a summer internship program sponsored by UNAVCO and dedicated to increasing the diversity of students entering the geosciences.  
4SOARS (Significant Opportunities in Atmospheric Research and Science) is a summer internship program sponsored by UCAR and dedicated to broadening participation in the atmospheric and related sciences.

**Niwot LTER Field Trip.**  
The Universities Council on Water Resources held a field trip to the Mountain Research Station as part of their Boulder Creek Watershed Tour on Monday July 11, 2011. Nine people participated in the field trip, including the trip organizer, Curry Rosato. Participants are interested in water and the West, snowpack, aquifers, and reservoirs. NWT LTER employees Kurt Chowanski and Jennifer Morse led the group to the MRS C1 site. The group looked at the Ameriflux tower and discussed timing of snowmelt and ecosystem responses. They also looked at the recently installed piezometers, soil lysimeters, and soil moisture profiles. They discussed findings that rain does not percolate into the soil deeper than about 1 m. They also looked at the C1 SNOTEL site and talked about this year’s snowpack. The field trip was on a tight schedule, and the group headed down.

**My Water Comes from the San Juan Mountains.**  
This year, the Mountain Studies Institute (MSI) community - including you - joined together and successfully launched a region wide education initiative called My Water Comes from the San Juan Mountains. Because of your support, 16 schools in the San Juan Mountain region were gifted with 1319 copies of the My Water Book along with 24 curriculum guides, activity kits, and teaching supplies! Thanks to you, MSI, Fort Lewis College, University of Colorado-Boulder, and our partners were able to provide a meaningful and applicable watershed tool that will be utilized year after year to educate the future leaders of our region. We would like to share with you some of the project details and accomplishments over the past year. Without you, these successes might not have been possible!

*My Water Comes from the San Juan Mountains Project Overview*
MSI, Fort Lewis College and University of Colorado- Boulder collaborated to adapt a children’s book from the Boulder area to the San Juan Mountains. The book takes children on an illustrative journey from the snow falling high in the San Juan Mountains to the water in their faucet tap. It introduces children to the distinctive wildlife, ecosystems, and diverse uses of water along the way from the mountains to the desert. By learning about their local environment, children experience connection to their “place” and the natural resources on which they depend. The new book highlights the western San Juan Mountain watersheds and communities and incorporates art and quotes from school children in La Plata County.

MSI, Fort Lewis College and Partners Support Local Schools
MSI, Fort Lewis College, and our partners provided the book, a companion activity guide, and activity box free to classrooms in the southwestern San Juan Mountains in Archuleta, Dolores, La Plata, Montezuma, and San Juan Counties. Teachers and school districts were offered free workshops to introduce the teachers to the resources and take them through the activity guide. Participating Schools (as of December, 2010)

- Archuleta 50 Joint: Pagosa Elementary;
- Bayfield 10Jt R: Bayfield Elementary;
- Dolores RE-2(J): Seventh Street Elementary, Rico Elementary;
- Durango 9R: Animas Valley Elementary, Florida Mesa Elementary, Fort Lewis Mesa Elementary, Park Elementary, Needham Elementary, Riverview Elementary, Sunnyside Elementary;
- Durango 9R/Diocese of Pueblo Catholic School Net.: St. Columba School;
- Ignacio II JT: Ignacio Elementary, Ignacio Intermediate;
- Mancos RE-6: Mancos Elementary;
- Silverton: Silverton Elementary;
- Telluride R-1: Telluride Intermediate.

Special Thanks to the 2009-2010 Project Supporters!
Support for the Book comes from the University of Colorado at Boulder/National Science Foundation Schoolyard Long-Term Ecological Research (LTER) Project, Southwestern Water Conservation District, Mountain Studies Institute (in-kind), and Fort Lewis College (in-kind). Support for the Activity Guide, Supply Boxes, and Workshops comes from La Plata Electric Association (LPEA) Education Grant Program, Coutts & Clark Western Foundation, Trout Unlimited Five River Chapter, Fort Lewis College (in-kind), and Mountain Studies Institute (in-kind).

Extensions to the Project: 2011-2012
Thank you again for your time, support, and generosity towards MSI and our regions’ education. We hope to continue spreading My Water supplies to other valleys incorporated in the San Juan Mountains watersheds not included in this first round of outreach through the delivery of 360 more books. These regions include north of the San Juan Mountains and the San Juan River portion of the Rio Grande valley. You can play an active part involving these new schools, and by continuing to support MSI and the My Water Project. Please feel free to contact Project Manager, Anne Izard, by phone 970.387.5161 or email: anneizard@gmail.com with any questions or additional details. Thank you again for your time, support, and energy!
DRAFT REPORT OF FINDINGS FROM CHILDREN’S BOOK SERIES WORKSHOP
2011

I. Background
The mission of the LTER Schoolyard Book Series is to engage children and their families in learning about the earth's ecosystems, both locally and internationally, through narratives that reflect the dynamic research being conducted at the National Science Foundation's Long-Term Ecological Research (LTER) Sites. The Book Series is aligned with the foundational values of the LTER Network’s long-term ecological research program and the associated Schoolyard LTER (SLTER) program that successfully combines scientific research with K–12 science education. The underlying “schoolyard” approach emphasizes the connection to local communities, for which the LTER site can serve as a “schoolyard” for understanding ecology and environmental science. This approach helps students develop empathy for their local environment (“Environmental Empathy”) as discussed by Sobel (1996) and is consistent with developmentally appropriate elementary science education (McKnight 2010).

The series has published three books, in order of initial publication date: My Water Comes from the Rocky Mountains and My Water Comes from the San Juan Mountains (Niwot Ridge LTER), The Lost Seal (McMurdo Dry Valleys LTER), Sea Secrets: Tiny Clues to a Big Mystery (Palmer LTER, California Current LTER). The fourth book is in press, One Night in the Everglades (Florida Coastal Everglades LTER) and will be published in English and Spanish. The fifth book, And the Tide Came In... (Georgia Coastal Ecosystems LTER), is in the illustration phase and the illustrator for the sixth book, Kupe and the Corals (Moorea Coral Reef LTER) is being selected. The seventh book, Seeking the Wolf Tree (Hubbard Brook LTER), is currently in the editing phase. Finally, an eighth book is in development by the Plum Island LTER.

II. The Schoolyard LTER Children’s Book Series Workshop
The 2nd Children’s Book Series Workshop, held at the University of Colorado at Boulder (INSTAAR) in February 2011, was organized to enhance the educational impact of books in the SLTER Book Series and identify strategies to refine the vision and implementation of the project. The major themes that were the focus of the workshop were 1) developing educational resources to support each book, 2) publishing Spanish editions and 3) ensuring the developmental appropriateness of the books and associated resources. This workshop builds on the previous successful Book Series Workshop, held in 2004, at which the current prospectus for the Book Series was developed. The 2nd Book Series Workshop was attended by 35 people, representing 9 LTER sites, and included past and prospective LTER authors, as well as professional educators, children’s science book illustrators and authors, editors and publishers.

At the workshop, participants involved in the currently published books shared experiences with using the books in classroom and informal education settings. Overall, these experiences
demonstrate that the children’s books serve as a resource on multiple levels to support better understanding of ecological principles and environmental science, improving science and environmental literacy at the elementary level. The illustrations and engaging narratives open the eyes of children to scientific research and inspire a sense of wonder in the natural world, while also encouraging reading. The successful introduction of science and environmental literacy concepts at the elementary level can then influence the ways in which science is taught at multiple grade levels. Because the books are well received by elementary teachers, they have enhanced partnerships between educators and site scientists. The books also promote informal learning because they are available directly to the public. For example, *My Water Comes from the Rocky Mountains* (NWT LTER) is sold in visitor center gift shops at a number of National Parks, including Rocky Mountain, Grand Teton, Glacier and Mesa Verde. At the same time, the Book Series development has promoted connections and cross-site collaborations among Schoolyard LTER site Education and Outreach coordinators.

### III. Goals for Advancing the Book Series

Workshop participants collaboratively generated the following four goals to move the Book Series forward. Each goal has multiple objectives and associated recommendations:

1. **Strategies for Aligning with Developmental Stages.** A key theme of the workshop was the importance of paying careful attention to the developmental appropriateness of future books and associated educational resources. In his keynote address, Professor David Sobel, a highly respected scholar of environmental education and author of *Beyond Ecophobia*, outlined the developmental stages as: **empathy** (ages 4-7, recommends activities where students “become” animals, ex. playing charades and acting out different animals’ behaviors, characteristics, etc), **exploration** (ages 8-11, ex. interacting directly with animals), **social action** (ages 11-14, ex. caring for animals) and **initiation** (ages 15-18, ex. civic action to protect animals and habitats).

Professor Sobel suggested that in moving forward, the Book Series should clearly identify the intended audience’s age and target the books, illustrations, and educational resources for that specific development stage. Should the Book Series choose to reach multiple developmental stages, one option would be to develop multiple educational resources, each targeting a different developmental level. Another approach to achieve this developmental differentiation in the book itself would be to separate story content from science content so the narrative stands on its own and can be read by younger readers while the science content is presented in sidebars, or in a separate section at the end of book, or in teacher’s guide that accompanies the book. One recommendation was that in the future the Book Series Review Committee should play a central role in honing the developmental appropriateness of future books and resources.

2. **Strategies for Publishing Spanish Language Editions.** Several speakers at the workshop reviewed their experience with translations in Spanish and other languages. There are important considerations for Spanish Language editions within the Book Series. It is important to establish **outreach liaisons** at each LTER site for translated books. These colleagues can help develop an initial book concept that is culturally appropriate and help to disseminate translated drafts of the book and illustrations through variety of outreach networks to obtain important feedback. For Spanish books, it is important to consider the idioms that are best matched with the intended region where the book will be primarily used.
There are **tradeoffs** in the book content that should be considered. One approach is to have a truly bilingual book (both languages in same edition). A bilingual book inherently contains less text and less science-related information. However, there is the possibility to include more information in the sidebars. Another approach is to publish two different editions of the book, e.g., English and Spanish editions. The advantage of publishing the books in one language is that there can be more text, providing more space to develop ideas and transmit information.

A particular challenge in publishing Spanish language children’s science books is to identify ways in which the book can be brought to the **target audience** of children and their teachers and families. This task of bridging the gap between the published book and the public should be addressed once the narrative has been developed and can be achieved by involving educational organizations in the translation process. Once the book is published, the educational team can then explore further ways to inform the intended audience that the book (translation/bilingual) is available. The distribution of the books over the internet is an important resource in this context, as book stores stock limited numbers of bilingual children’s science books, if any at all.

**3. Strategies for Design and Dissemination of Educational Resources.** Participants at the workshop recognized the need to develop effective strategies for the design and dissemination of **educational instructional materials** that are consistent across the LTER Book Series program. One major first step is to create a **framework** for the design of instructional materials that can be organized to address **educational standards** at the national and state level, such as the one shown in Figure 1. The workshop participants recommended that a common or “universal” template be created that is clearly organized and consistent with **effective learning approaches** (ex. problem-based learning, case-based learning, inquiry science, place-based learning). The overall framework can be built to sustain phases in the development of specific educational components over time.

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**Figure 1 – framework for online access to educational resources**
The framework should have the following characteristics: 1) Demonstrate *cross-curricular connections* in math, science, technology, geography and language arts; 2) Promote *interdisciplinary connections* (biology, chemistry, physical and earth science) and 3) *Link* materials with Climate Literacy threads.

In terms of implementation, dissemination and broader impacts of educational instructional materials, a consensus was reached that the framework should be presented through a web-based portal, linked to a primary site for each book. The portal would serve to 1) house learning materials in a clearly delineated manner and give access of the materials to the general public. The web portal would also help to forge collaborations among educators and between educators and scientists as new materials are added within a framework. These features will also promote the Schoolyard LTER program, allowing education and outreach coordinators and colleagues to bring in additional resources to the SLTER program.

At the school district level, the sites that are currently using books have worked successfully with local teachers. These teachers have provided specific accounts of the grass roots impact of books. For example, Ian Schwartz from the Boulder Valley School District reported that the My H2O curriculum is actively used in the district, with the 10 resource tubs maintained by the district having been used 42 times so far during 2010/11 school year. Marcie Bidwell from the Mountain Studies Institute reported that their program has distributed 1,319 books and 24 resource material sets to 16 schools in the San Juan Mountain region to date. It was proposed that teachers at the local level could work with the Book Series more formally as “Teacher Ambassadors” and be involved with books currently adopted by classrooms.

Another recommendation was to explicitly build upon the “schoolyard science” concept as the educational materials are developed. The books provide a ready means to connect teachers and their students with graduate students and researchers who feel comfortable participating in outreach activities with the book as a guide. These students can then help conduct actual research projects in the literal schoolyard to directly engage elementary students in the experience of discovery and answering questions using the scientific method.

Other issues that were discussed related to implementation at the state level and assessment. One challenge is dissemination and maintenance at the state level of physical materials (like FOSS kits) that support the use of the books and facilitate active, hands-on learning. The My H2O Kits are successfully maintained and supplies periodically replenished in Boulder by the district’s science distribution center, where teachers check the kits out. A similar state level approach could be established via partnerships with federal funded state education programs such as the BOCES (Boards of Cooperative Educational Service) programs and MESA (Mathematics Engineering Science Achievement) programs. In terms of assessment, it may be appropriate to embed assessment of educational materials in the framework presented on the portal. For the design of the assessment tools, it may be possible to connect with College and University School of Education programs to set up work study projects where graduate student(s) evaluate and assess how the books and related educational resources are impacting learning over time.

4. **Strategies for Refining the Framework of the Series.** In order to *refine the framework* of the Book Series, many participants, including the publisher, recommended that a clear process
for publishing books in the series be maintained with oversight of content provided through the Book Series Review Committee. The scientists and educators involved in the Book Series should also address the potential role of professional authors in the writing process. The publication process that was based on distribution of funds for the Book Series by the Book Fund Committee is not currently active given that the Book Fund has been fully allocated.

A major recommendation from the workshop was to secure continued funding for the Book Fund, on the order of $50,000, which can then be supplemented through other donations. The Book Fund provides an important service of receiving funds donated from diverse organizations and individuals. For example, the *My Water* (NWT LTER) books were supported by the River Watch board and the Bounder County Community Fund, organizations that would not have been able to contribute financially through the University.

It was emphasized that the goals of the individual site’s SLTER program in developing a book to achieve their outreach goals will remain the primary consideration and that the potential for a trade market for a book on a particular topic will remain secondary. These considerations serve to identify the target audiences for the books and the value of translations. For example, the MCR LTER team plans to publish the *Kupe and the Corals* book in multiple bilingual translations (English/Tahitian, French/Tahitian, English/Hawaiian and English/Spanish) based on the educational partnerships of their SLTER project. Workshop participants emphasized the importance of maintaining grade level/developmental appropriateness through the review and editorial process, including piloting the narrative in a classroom setting.

Workshop participants emphasized the significant need for LTER Network level support and coordination of the Book Series in order to 1) **improve the management of books’ developmental process** and 2) **organize and maintain the web-based educational resources**. The proposed “Book Series Project Manager” would be located at the LTER central office to coordinate network level outreach (see example web portal) and carry out key responsibilities where timely follow-through is essential.

**Recommendations:**

1) **Clarify process**
   a. Create flow charts to streamline the production of books
   b. Revise and update current documents for prospective authors
   c. Update and revise RFP documents for the Book Fund
   d. **Obtain additional funds for Book Fund** of about $50,000 to support books currently in process

2) **Network level support and coordination:**
   a. Oversee book publishing and production deadlines, communication and follow up
   b. Oversee Book Fund timelines
   c. Coordinate with network level Information Manager for cyber-infrastructure support
   d. Coordinate with Schoolyard Education program
   e. Design Network level outreach for the series