THE LONG TERM ECOLOGICAL RESEARCH NETWORK




2012 ANNUAL REPORT

THE LTER NETWORK is recognized internationally as one of the longest-lived and most successful large groups conducting ecology research. For more than three decades, the Network has provided the scientific expertise, research platforms and long-term datasets necessary to document and analyze pressing environmental changes. With nearly 2,000 scientists, educators and students, the Network consists of 26 competitively chosen sites in the continental U.S., Alaska, Antarctica and islands in the Caribbean and Pacific. These sites span agricultural lands, alpine tundra, barrier islands, coastal lagoons, cold and hot deserts, coral reefs, estuaries, forests, freshwater wetlands, grasslands, kelp forests, lakes, open ocean, savannas, streams and urban landscapes.

SITE KEY

AND – Andrews Forest
ARC – Arctic
BES – Baltimore Ecosystem Study
BNZ – Bonanza Creek
CCE – California Current Ecosystem
CDR – Cedar Creek
CAP – Central Arizona - Phoenix
CWT – Coweeta
FCE – Florida Coastal Everglades
GCE – Georgia Coastal Ecosystems
HFR – Harvard Forest
HBR – Hubbard Brook
JRN – Jornada Basin
KBS – Kellogg Biological Station
KNZ – Konza Prairie
LUQ – Luquillo
MCM – McMurdo Dry Valleys
MCR – Moorea Coral Reef
NWT – Niwot Ridge
NTL – North Temperate Lakes
PAL – Palmer Antarctica
PIE – Plum Island Ecosystems
SBC – Santa Barbara Coastal
SEV – Sevilleta
SGS – Shortgrass Steppe
VCR – Virginia Coast Reserve

CONTENTS

On the cover, from left to right:

MOOREA CORAL REEF LTER An adult orange-fin anemonefish and juvenile three-spot dascyllus share a sea anemone. Two decades of data enable investigators to understand species dynamics and reef resiliency to cyclones, bleaching events and corallivorous predators.

NORTH TEMPERATE LAKES LTER Ice breakup on Lake Mendota in the spring of 2010. Records of ice-on and ice-off dates since 1852 reveal a linear trend of decreasing ice duration, providing evidence of freshwater response to climate shifts.

KONZA PRAIRIE LTER Controlled burn study. Long-term measurements on watersheds with different fire return intervals are providing critical insights into how fire alters the structure and function of grasslands.

HUBBARD BROOK LTER A male black-throated blue warbler feeding nestlings. Long-term studies of habitat, forest management practices and climate in eastern forests, tropical forests and along migratory routes show how environmental changes impact the abundance of North American songbirds.

SBC LTER

MESSAGE FROM THE CHAIR: TRANSFORMING ECOLOGICAL SCIENCE

The LTER Network is moving forward with great optimism. Our transformative research is leading to a better understanding of the world around us, and is making it possible for humankind to mitigate the impact of environmental change in significant ways.

Our hopefulness is due in part to the many exciting things that happened in 2012, which was a very busy year for the Network. In addition to annual events, such as the LTER mini-Symposium and Science Council meetings, the National Science Foundation (NSF) conducted a site review of the Network Office and we hosted the triennial LTER All Scientists Meeting (ASM) in September. At the ASM, more than 700 researchers from around the world were treated to a wide variety of synthesis workshops, poster sessions and other forms of scientific exchange.

I'm also pleased to report that all 11 LTER sites that submitted renewal proposals to the NSF received funding to continue their important work. The Network remains a vibrant and exciting community that continues to explain how Earth's ecosystems respond to natural and anthropogenic forces.

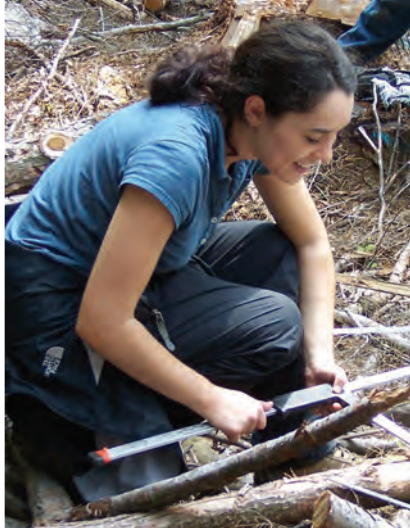
As a result of LTER research, we now have deeper insights into how coastal ecosystems can mitigate damage by hurricanes; how biodiversity enhances ecosystem services; and how marginal lands, rather than productive cropland, can be used for biofuel production. In order to use this research for the greater good, the LTER Network Office is poised to release the first working version of our new Network Information System (NIS). The NIS will provide easy access – through a single gateway – to a vast array of LTER datasets for research and education.

All of us at the LTER Network are pleased to share our goals and recent accomplishments in this first-ever Annual Report. We hope that the stories in these pages draw your attention to some of the Earth's most fragile ecosystems and the challenges they face.

Sincerely,

Scott Collins, Chair, LTER Science Council

LONG-TERM RESEARCH, REAL-TIME RESULTS



This inaugural edition of our annual report summarizes key findings from LTER sites, provides information on research plans at nine focal sites, and highlights important individual and group accomplishments during the last year.

2012 WAS A YEAR FILLED WITH ACCOMPLISHMENTS FOR THE LTER NETWORK

When the National Science Foundation (NSF) created the Long Term Ecological Research (LTER) Network in 1980, our world faced many ecological challenges. Today, not only do these same challenges exist, but the pace of change has accelerated. LTER Network scientists, together with our many global partners and collaborators, are working hard to find answers to our world's most difficult ecological questions.

In order to truly understand environmental change, researchers must undertake long-term observations and experiments. Processes such as climate fluctuations, alterations in land cover, and recovery after disturbances such as fires or hurricanes take years to consider. The ecological scientists at the 26 research sites that currently constitute the LTER Network are dedicated to just these types of ongoing studies.

We believe that our dedication is paying off, and that people outside the scientific community should know about the LTER Network's important work. This 2012 report – our first annual report written with the general public in mind – represents a new approach to communicating the results and implications of LTER science. This inaugural edition of our annual report summarizes key findings from LTER sites, provides information on research plans at nine focal sites, and highlights important individual and group accomplishments during the last year. It's a snapshot of a journey that remains long and challenging, but it captures the very essence of our existence as a long-term ecological research program, and provides a glimpse of what the future may hold.

2012 All Scientists Meeting

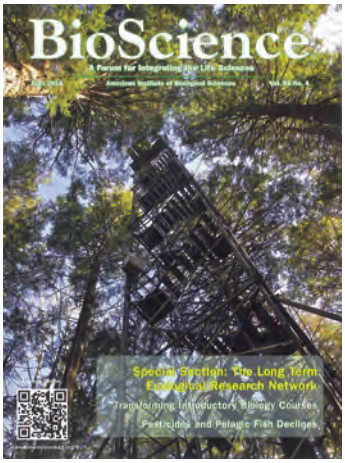
Estes Park, CO

BIG SCIENCE IN THE BIG MOUNTAINS

In September 2012, more than 700 scientists and graduate students attended the triennial All Scientists Meeting (ASM) in Estes Park, Colorado. Scientists and students from the LTER and International LTER communities compared ideas and approaches, and identified new directions for long-term research. This year's meeting provided inspiration for a wealth of new collaborations, 27 of which will be initiated in 2013. For more details, please read "Big Science in the Big Mountains: LTER ASM 2012" and other stories at news.lternet.edu.

PRESCRIPTIONS FOR POTENT POLICY

Scientists also shared ideas and research findings at the 11th annual LTER mini-symposium, held in March at NSF headquarters in Arlington, Virginia. Scientists and educators, along with Washington policymakers, came together to focus on the contribution of long-term research to sustainability science. Speakers from seven LTER sites offered lively presentations, highlights of which are included in this report. You can also watch videos of the presentations at intranet2.lternet.edu/documents/154.



NEW KNOWLEDGE, FREELY SHARED

Research generated by LTER scientists is freely shared with other scientists and the general public in more than 15,000 peer-reviewed articles, books and theses. In 2012, the journal *BioScience* published a special issue dedicated to the LTER Network. David Foster, Director of the Harvard Forest LTER site, was guest editor of the issue, which examined the causes and consequences of long-term environmental change and highlighted the globally important role of LTER science.

The special issue also included a paper that demonstrated how LTER science has influenced important policy decisions over the past decade. "LTER datasets and experiments help inform local- to national-scale decisions regarding climate change, pollution, fire, land conversion and other pressing environmental challenges," observed Charles Driscoll of the Hubbard Brook LTER site and leader of the team that prepared the paper.

Saran Twombly, the NSF's program director for LTER, added that the research reported in the special issue "demonstrates the unique and powerful insights that emerge from long-term studies and the analysis of long-term data. This research reaches beyond scientists to engage the public and decision makers."

David Foster

ACCESSIBLE DATA

Ecological scientists, educators and students greatly benefit from open access to LTER data. Data providers at the 26 LTER sites share information across the Network and beyond via the LTER Data Co-op. The Data Co-op's Network Information System (NIS) manages, stores and makes data available to the scientific community.

In 2012, the LTER Network Office developed a production version of the Provenance Aware Synthesis Tracking Architecture (PASTA), the core of the NIS. This version of PASTA addresses the challenge of Network-wide data access, and includes a new portal that allows scientists everywhere to find and access LTER data. Sites are already contributing data packages to the new repository, and NIS developers are creating new tools for analyzing and synthesizing cross-site data.

The LTER NIS will also become an integral part of DataONE (the Data Observation Network for Earth). This network, also sponsored by NSF, makes massive amounts of highly heterogeneous data from many archival sources accessible through a single gateway. As a DataONE Member Node, LTER will provide users with new information and access to a variety of exciting analysis tools.

CREATIVE COMMUNICATION

In order to tackle ecological problems, people must understand the issues. With that understanding, LTER recently renewed its dedication to the dissemination of research results to the scientific community, decision makers and the public at large. As first steps in the implementation of a new Strategic Communication Plan, LTER created a directory of site contacts, enhanced its communication capabilities and completely revised the LTER website to provide customized information that addresses the needs of specific user groups.

Communication also took a more creative form in 2012: Paintings, sculpture, poetry and videos inspired by LTER science filled the halls of the NSF at the mini-symposium in March, in an exhibit entitled "Ecological Reflections." The NSF-sponsored project paired artists with scientists, and can be viewed at ecologicalreflections.com.

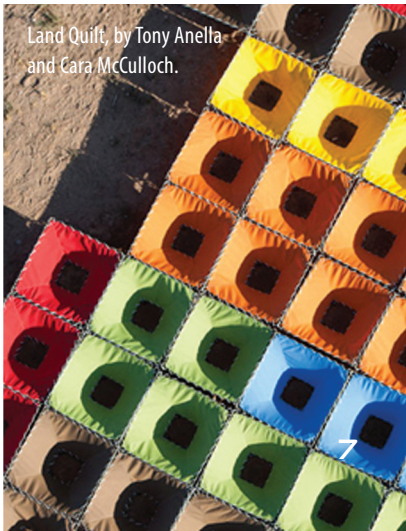
Dr. Cora Merritt, deputy director of the NSF, attended the opening reception where scientists and program officers mingled with the artists and learned about their inspirations. The exhibit was such a success that it was repeated at the All Scientists Meeting in Estes Park, Colorado and at the 2012 annual meeting of the Ecological Society of America in Portland, Oregon.

As part of our renewed emphasis on communication, LTER offered its first hands-on course for journalists at the Harvard Forest LTER site in May. Six science journalists – reporters from Austrian Broadcasting, the *Los Angeles Times*, BoingBoing.net, Discovery News and two freelance writers – participated in climate change research as part of the Marine Biological Laboratory's (MBL) Logan Science Journalism Program. Christopher Neill, an LTER scientist based at MBL's Ecosystems Center, designed the course to highlight LTER global change research and give journalists a hands-on window into the scientific process.

The journalists spent three days counting Hemlock Woolly Adelgids (invasive bugs native to East Asia), measuring tree seedlings in herbivore exclosures, quantifying carbon dioxide fluxes from a soil warming experiment and drilling down to ice-aged sediments in the Black Gum Swamp. This experience immersed the journalists in ecological science, offered them a greater appreciation for scientific research and provided them with an important context for LTER's work. The LTER Network hopes to inspire journalists to write about LTER projects by providing this course on an annual basis.

The NSF-sponsored exhibit, Ecological Reflections, featured a variety of artwork reflecting LTER science.


Vanishing Act, by Mindy Schnell.


Land Quilt, by Tony Anella and Cara McCulloch.

ACCOLADES FOR LTER SCIENTISTS

In 2012, several LTER scientists were recognized as leaders in their fields.

SCOTT COLLINS, principal investigator of the Sevilleta LTER and Chair of the LTER Science Council, was named President of the Ecological Society of America.

SUSAN G. STAFFORD, Chair of the National Advisory Board of the LTER Network and formerly of the Andrews Forest LTER site, was chosen as President of the American Institute of Biological Sciences (AIBS).

ALAN P. COVICH, a founding member of the Luquillo LTER program, was named President of The International Association for Ecology (INTECOL).

TONY IVES of the North Temperate Lakes LTER site received the Robert H. MacArthur Award, which is given every two years by the Ecological Society of America.

CHRISTOPHER CRAFT, a co-Principal Investigator of the Georgia Coastal Ecosystems LTER and professor of Rural Land Policy at Indiana University, was the 2012 Science Research recipient of the prestigious National Wetlands Awards by the Environmental Law Institute.

MICHAEL P. NELSON, a philosopher, was installed as a principal investigator at the Andrews Forest LTER site. One of seven keynote speakers, Nelson presented *Reflections on the Value of, and Challenges for, Long-Term Ecological Research* at 2012's All Scientists Meeting.

OUR VISION AND OUR MISSION

The LTER Network envisions a society in which exemplary science contributes to the advancement of the health, productivity, and welfare of the global environment that, in turn, advances the health, prosperity, welfare and security of our nation.

Thus, LTER's mission is to provide the scientific community, policy makers and society with the knowledge and predictive understanding necessary to conserve, protect and manage the nation's ecosystems, their biodiversity and the services they provide.

GUIDING PRINCIPLES

The LTER Network seeks to understand the long-term patterns and processes of ecological systems. To this end, Network scientists focus on six interrelated objectives:

1. **Understanding:** Gain knowledge of a diverse array of ecosystems at multiple spatial and temporal scales
2. **Synthesis:** Use the variety of Network sites to synthesize information gained from long-term research and theory development
3. **Information Dissemination:** Create well designed, documented databases that are accessible to the broader scientific community
4. **Legacies:** Create a legacy of well-documented observations, experiments, and archives of samples and specimens
5. **Training:** Develop a team of scientists who are equipped to conduct long-term, collaborative research
6. **Outreach:** Educate the broader ecological community, the general public, resource managers and policy makers

LTER NETWORK RESEARCH

Individual scientists, students and educators at the 26 LTER sites all contribute toward the LTER mission. Site-level work forms the foundation of knowledge, data, and observational and experimental legacies, while extensive field experience provides information that can predict responses to future ecological disturbances.

These efforts add to the basic body of scientific knowledge of long-term, large-scale ecological phenomena, and training programs increase the number of people with expertise in research and environmental problem solving. Ultimately, both site- and Network-level activities develop scientific capital – well-documented research, well-trained scientists and a well-informed citizenry.

The 26 LTER sites represent a wide variety of research emphases and approaches. Each site conducts a series of measurements and experiments directed towards the understanding of fundamental ecological principles, as well as studies addressing ecological issues specific to the site. The most common scientific approaches include observation, experimentation, comparative analysis, retrospective study and modeling.

CORE RESEARCH AREAS

Five research themes, known collectively as the Core Areas, are central to LTER Network science:

1. Pattern and control of primary production
2. Spatial and temporal distribution of populations, selected to represent trophic structure
3. Pattern and control of organic matter accumulation in surface layers and sediments
4. Patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface waters
5. Patterns and frequency of site disturbances

These Core Areas require the involvement of many scientific disciplines, over long time horizons and broad geographical scales. Core Area data are collected at regular intervals, so that information about an ecosystem's existing condition can be established prior to any experimental manipulation.

CROSS-SITE RESEARCH AND SYNTHESIS

The scientific infrastructure that the Network has built over the years – including the maintenance of databases and protocols in support of data discovery and acquisition – promotes and facilitates cross-site and regional analyses, leading to larger-scale synthesis and the development and testing of ecological theory.

The LTER Network offers the greater ecological research community, including students and foreign scientists, the opportunity to use its sites for both long- and short-term projects appropriate to individual sites, a group of sites or the Network as a whole.

INTERNATIONAL COLLABORATION

As a founding member of the ILTER Network, the U.S. LTER Network plays a central role in studying global ecological issues. Many LTER sites perform observations and conduct experiments with global partners. For example, LTER sites are working to study global comparisons of forest structure through the Center for Tropical Forest Science at the Smithsonian Tropical Research Institute – the program includes sites in 21 countries, encompassing 4.5 million individual trees from 8,500 species.

INFORMATION MANAGEMENT

When the LTER Network was first founded, scientists manually entered relatively small amounts of ecological data on an annual basis. Today, network sensors acquire much larger volumes of data each week. To address these changes, each research site has developed a system that supports its unique data life cycle needs, from data acquisition through publication.

Successful communication and coordination between the LTER Network Office and site information managers supports the LTER Network's research agenda, and has helped produce:

- Common metadata standards
- Standard approaches to information management
- Centralized information architecture for strategic data integration
- Data stewardship
- Curated data storage that promotes Network synthesis
- The creation of data legacies

EDUCATION

LTER research provides a variety of unique educational opportunities to students at all academic levels. The LTER science community includes academic and government scientists and educators, graduate and undergraduate students, and professional staff. As centers of excellence in ecological research, LTER sites hosted by universities, government agencies and non-profit research institutions also provide important training grounds for the next generation of scientists and leaders.

GRADUATE AND UNDERGRADUATE EDUCATION

The LTER Network offers excellent opportunities for graduate (including post-graduate) and undergraduate students, many of whom are supported directly through annual LTER awards. Other students use LTER facilities and equipment to support their research projects.

The Network also provides opportunities for the international interchange of students and faculty. In addition to typical university-based training, many LTER sites are involved in NSF-funded Integrative Graduate Education and Research Traineeship (IGERT) programs, and serve as hosts for Undergraduate Mentoring in Environmental Biology (UMEB) and Research Experience for Undergraduates (REU) site activities. The programs integrate field and laboratory techniques with education, providing students with a deeper understanding of the scientific process in ecology. Students in some of the programs come from a wide variety of disciplines, including chemistry, geophysics and biology. Some sites provide similar opportunities through private foundations and sources like the United Negro College Fund.

K-12 SCHOOLYARD LTER PROGRAM

In 1998, the LTER Network formally expanded its education efforts to include K-12 students and teachers, mainly through the Schoolyard LTER program, which is funded by NSF's Division of Environmental Biology (DEB).

The Schoolyard approach emphasizes the connection to local communities, for which an LTER site can serve as a "schoolyard" for understanding ecology and environmental science. The sites design their own programs to support a wide range of educational activities, including field trips and lab work for students and professional development workshops for teachers. All 26 LTER sites now participate in the Schoolyard LTER program.

THE DESERT DATA JAM COMPETITION

In 2012, high school science students in Las Cruces, New Mexico got the opportunity to jam, LTER-style. At the inaugural Desert Data Jam Competition, hosted by the Jornada Basin LTER and the Asombro Institute for Science Education, students developed ways to present Jornada LTER datasets to non-scientist audiences. The top 14 projects were displayed at the 17th Wildland Shrub Symposium in Las Cruces. At a May 22 awards ceremony, 10 students received honorable mentions and the top four student projects were awarded prizes. First place went to Paula Hoffmann Landau of Mayfield High School, whose children's activity and storybook focused on the population fluctuations of the desert cottontail and the Chihuahuan pocket mouse. Judges pronounced Hoffman's project highly creative, with the potential to reach a large audience.

SUSTAINABILITY SCIENCE IN ACTION

On March 5, 2012, scientists from various LTER sites gathered at NSF headquarters in Arlington, Virginia to present key research findings and discuss their practical applications. Six presentations are summarized below, and you can learn more and view the videos at http://bit.ly/12dZ4Le.

USING THE LANDSCAPE TO MITIGATE VULNERABILITY

B. L. Turner II, Arizona State University
Central Arizona-Phoenix LTER

The role of land system architecture – the mosaic of different land units within human environments – has been overlooked as a means of mitigating and adapting to environmental changes.

Early research has explored the ways in which land system architecture produces tradeoffs among ecosystem services in the Phoenix-Central Arizona area. The results of this research provide the foundation for a greater understanding of how specific land system architecture treatments can impact different facets of human well-being and increase the resilience of places, ecosystems, landscapes and regions to global changes.

It's clear that a fully developed assessment of land system architecture must account for spatial interactions and scale dynamics. The science community is poised to generate models that can provide the analyses in question, given various advances in remote sensing, GIS, spatial interactions and tradeoff assessments. Scientists could collaborate with the policy, planning and development communities to co-produce versions of these models, providing powerful tool sets for actionable science.

Land system architecture holds important implications for the vulnerability and resilience of human-environment systems.

ACTION-BASED SYSTEMS FOR URBAN SUSTAINABILITY

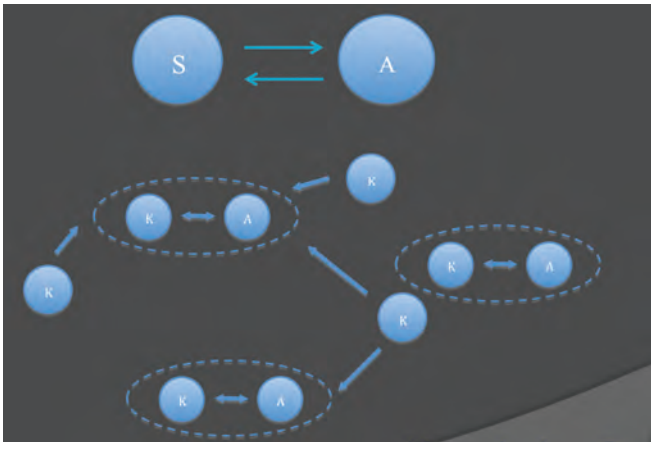
Tischa A. Muñoz-Erickson, International Institute of Tropical Forestry, USDA Forest Service
Luquillo LTER, San Juan ULTRA

When multiple, and often conflicting, stakeholders need to negotiate among tradeoffs, it can be more difficult to address the issues of resource depletion, energy sustainability and climate change.

Adapting lessons learned from the NSF's San Juan ULTRA-Ex (Urban Long-Term Research Area), strategies for overcoming this complexity have been designed to:

- Take the context of multiple interests and scientific disciplines into account
- Open up at multiple stages of knowledge production, so science can be adapted to better reflect societal needs and concerns
- Mirror the network of local institutions

LTERs and ULTRAs are in a unique position of conducting both fundamental research on sustainability, as well as building science-action linkages to inform current and future societal concerns.



Complex decision-making contexts are forcing researchers to rethink the assumption that science can translate solutions into action in a straightforward way.

INNOVATIONS IN DISTRIBUTED GRADUATE EDUCATION

Jeannine Cavender-Bares, University of Minnesota
Cedar Creek LTER

A multi-year, distributed graduate seminar focusing on research into sustainable development has attracted nearly 180 people from seven academic institutions during its first two years. Participants include scientists, graduate and upper-level undergraduate students, faculty, post docs and auditing students from several LTER programs.

The ongoing seminar utilizes an evolving, open curriculum to address core concepts in sustainability science. Students screen online presentations by intellectual leaders and collaborate via website and wiki, focusing on research on sustainable development.

Three key insights have emerged from the experience:

1. Constraints and values change with biophysical, cultural and institutional context. A conflict between U.S. and Mexican participants helped seminar organizers recognize the issue and develop a solution: a simple analytical framework for considering sustainability goals.
2. Common ground can be found "under the hood." By wrestling with contrasting approaches and metrics, participants were able to come to a consensus.
3. Merging perspectives across institutions can produce innovation. Students in Minnesota, for example, applied lectures on linking knowledge and action to nutrient management in Midwestern agriculture.

What we're learning is that bridging institutions, disciplines and cultures creates an educational environment that's much greater than the sum of its parts.

Is an interdisciplinary, cross-institution, cross-cultural course more than the sum of its parts?

USING LOCAL KNOWLEDGE TO ADVANCE SCIENCE

Gary Kofinas, University of Alaska Fairbanks
Bonanza Creek LTER, Arctic LTER

In the high latitudes of Alaska, where some of the planet's strongest climate change signals present themselves, indigenous rural residents pursue traditional livelihoods based on subsistence harvesting. These people represent an important opportunity to understand better climate change mechanisms, inform theory building on social-ecological system dynamics and create policy through an appropriate cultural lens.

LTER sites in Alaska use different approaches to link academic science with local knowledge. These include:

- A long-term ecological monitoring program using data from interviews with community elders and active subsistence harvesters
- Simulation models that help residents and researchers discuss adaptation options
- Participatory mapping that documents local knowledge spatially and integrates it with land cover and land use changes. The linking of local knowledge and GIScience is part of a LTER Network-wide program called Maps and Locals (MALS)

To successfully utilize local knowledge, scientific organizations must have sufficient human and financial resources, find time to build trust relationships and engage communities, and develop a spirit of innovation. Alaska's LTER studies have already shown that local knowledge can contribute to the sustainability and resilience of local communities.

The engagement of local communities in LTER research strengthens support and makes our work more relevant.

MANAGING FOR RESILIENCE IN MARINE ENVIRONMENTS

Russell J. Schmitt
University of California Santa Barbara
Moorea Coral Reef LTER, Santa Barbara Coastal LTER

Sudden shifts in an ecosystem's community state can have a big impact on its ability to provide services. In cases of hysteresis – which research suggests may be prevalent – an affected ecosystem is unable to return to its original state when conditions abate.

LTER scientists studying abrupt state shifts have proposed best practices for managing resilience in marine systems, outlining a quantitative framework that detects transitions and identifies the severity of response.

A recent macroalgae disturbance at the Moorea Coral Reef (MCR) LTER site gave scientists a rare opportunity to determine what strengthens and weakens resilience. Scientists discovered two main contributors to the reef's ability to bounce back:

1. The capacity of key herbivore populations (parrotfish) to respond rapidly to increases in their food supply.
2. The capacity for rapid reef re-colonization by coral larvae, due to strong connectivity with a reservoir of adults some distance away.

These findings have clear implications for managing resilience in similar environments. In addition to preventing overfishing, critical nursery habitats must be preserved and sources of coral colonists need to be identified and protected.

Preventing shifts that are inherently difficult to reverse should be an important management goal.

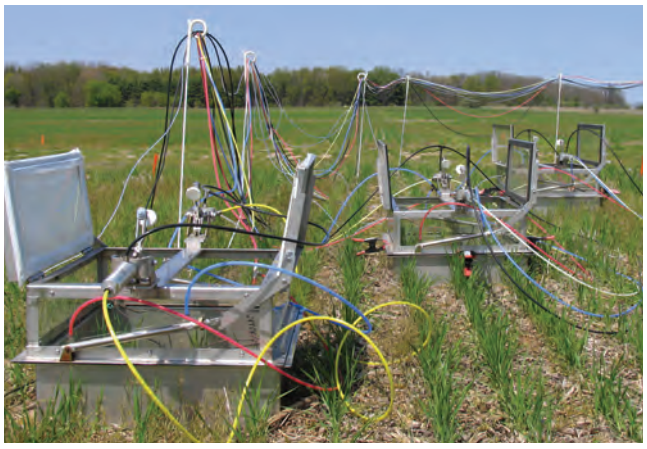
AGRICULTURAL SUSTAINABILITY AND NITROUS OXIDE MARKETS

Phil Robertson, Michigan State University
Kellogg Biological Station LTER

While supplemental nitrogen is crucial for achieving high crop yields to feed a growing global population, use in fertilizers has unintended impacts on biodiversity, water quality and climate. When nitrogen fertilizer is added to soil, it stimulates microbes to produce nitrous oxide (N_2O), a major greenhouse gas that's 300 times more effective at trapping heat than carbon dioxide (CO_2).

LTER research has revealed that N_2O emissions are related to nitrogen fertilization rates in such a way that relatively small decreases in fertilizer use can lead to large reductions in emitted gas. These findings provide a mechanism for greenhouse gas markets to compensate farmers for more efficient fertilization.

Over the past three years, the Kellogg Biological Station (KBS) LTER has partnered with the Electric Power Research Institute to create a Nitrous Oxide Reduction Protocol, which can be used to credit farmers for using nitrogen fertilizer more conservatively. The protocol was approved for use in 2012 by the American Carbon Registry and the Climate Action Reserve, and is in the final stages of approval by the Verified Carbon Standard. The protocol is also eligible for use in voluntary carbon markets, and the California compliance market is expected to use it in 2013.



Over-fertilizing – even a little – has a disproportionate effect on N_2O emissions.

LOOKING AHEAD TO NEW RESEARCH

Scientists at the 26 LTER sites in the continental U.S., Alaska, Antarctica, and islands in the Caribbean and the Pacific continue to test important theories about ecosystem vulnerability and resilience in the face of environmental change. As the duration of our studies increases, our long-term data become ever more valuable in interpreting changes in critically important ecosystems. Manipulative ecosystem experiments, comparative studies across ecosystems, and simulation models of ecosystem behavior complement our long-term observations.

The National Science Foundation (NSF) funds LTER sites through renewable, six-year grants. These grants are independently peer-reviewed and renewed, based on the soundness of the science at each site and the extent to which each site participates in the LTER Network and reaches out to the community at large. Support for the LTER Network is also provided by other Federal agencies including the US Department of Agriculture (USDA) Forest Service and the USDA Agricultural Research Service.

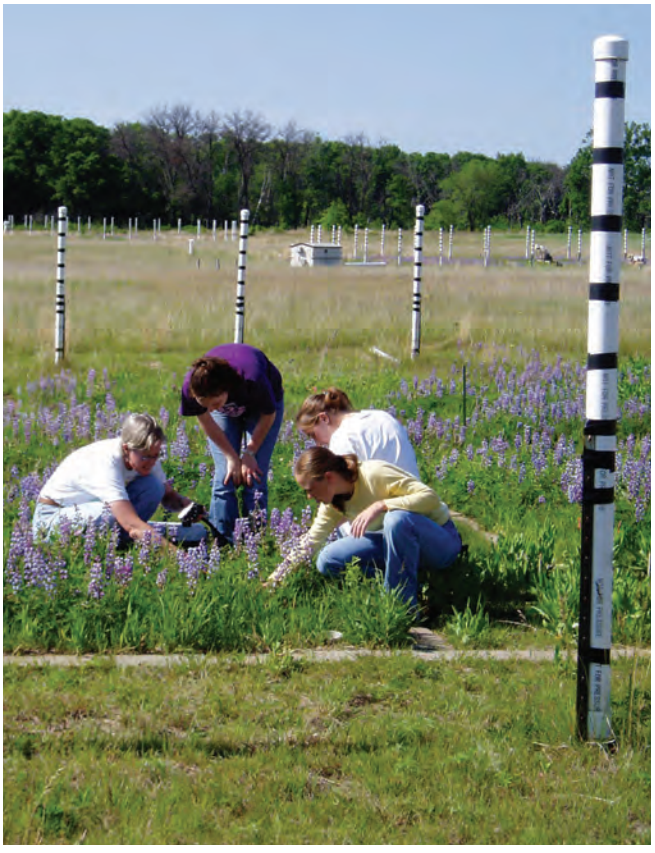
In the following section, we feature the nine sites whose funding was renewed in 2012 as examples of what we're accomplishing throughout the LTER Network.

CEDAR CREEK (CDR)

Research at CDR addresses how human activities alter the ability of grasslands and forests to remove carbon dioxide from the atmosphere, purify groundwater, produce sustainable biofuels and increase soil fertility.

CDR will use its next round of funding to examine the importance of tree species diversity for forest ecosystem functioning; overlay new warming and precipitation manipulations on existing experiments; coordinate a long-term manipulation of nutrients and consumers at 56 sites worldwide; expand research on the ecology and evolution of urbanizing ecosystems to uncover the impacts of residential development; and explore the nature of multiple nutrient limitation in aquatic ecosystems.

CDR will also expand its outreach through the promotion of K-12 teaching, training and learning; creative dissemination of results to the general public; and increased engagement with urban, underserved schools.



Ecologist Susan Barrott works in the field with a student research crew – Kally Worm, Lauren Losek and Emily Hockman.

FLORIDA COASTAL EVERGLADES (FCE)

Since 2000, FCE has examined how global climate change and shifting approaches to water management impact the sensitive Florida Everglades ecosystem and the region's 6 million residents.

Research focuses on how freshwater flowing through the Everglades influences both rehydration of the freshwater aquifer (which supplies the Everglades and Floridians with potable water) and carbon accretion (which buffers coastal systems from sea-level rise and storm damage). FCE is also engaged in socio-ecological studies of how human interactions with natural resources influence decisions about environment restoration.

Findings are disseminated through a web portal, video, presentations and publications. FCE also trains graduate students and offers K-12 programs in south Florida's majority-minority community. These efforts create a critical hub for Everglades restoration science and provide a global example of the successful conveyance of science into restoration policy.

An aerial view of the SRS 4B study area at FCE.

GEORGIA COASTAL ECOSYSTEMS (GCE)

GCE is committed to determining whether climate change, sea-level rise and human landscape alterations in and around estuaries, sounds and marshes cause transitions in dominant habitat types due to shifts in water delivery patterns.

Research to date has demonstrated that fresh, brackish and salt marsh wetlands provide different levels of ecosystem services, and that accretion in tidal fresh forests doesn't keep up with sea-level rise. New projects scheduled through 2018 include large-scale field manipulations, which will be used to assess thresholds between habitats and the potential for major changes in the domain.

To broaden scientific understanding of coastal ecosystems, GCE also reaches out to teachers, students, coastal managers and the general public. Through the GCE Schoolyard program, for example, participants have developed distribution plans for an innovative children's book produced by GCE, *As the Tide Comes In*.

Marsh grasshopper.

HARVARD FOREST (HFR)

For two decades, HFR has been investigating forest responses to human and environmental change across New England. In its next round of funding, HFR will apply long-term data from new and ongoing experiments to explore a variety of possible scenarios of future landscape change. The goal is to analyze and communicate the likely effects of climate change, biological processes and human land use on forest ecosystems over the next 50 years – and to use this research as a model for all LTER sites.

Elected officials play a key role in identifying the environmental factors to be studied, and HFR's research findings are distributed at key phases in the research process. The public receives information via outreach to news media and education programs for K-12, undergraduate and graduate students. These collaborative efforts fill critical knowledge gaps for scientists, the public and government decision-makers as they tackle societally relevant questions.

Beautiful Harvard Pond lies within the HFR LTER site.

JORNADA BASIN (JRN)

Using sophisticated simulation modeling based on databases going back to 1858, JRN is dedicated to uncovering the mechanisms of change in dryland ecosystems, so the consequences of potential future states can be predicted with greater accuracy.

Studies focus on five types of dryland change: shifts from perennial grasslands to desertified shrublands; reversals to grassland states; transitions among shrub-dominated states; invasions by non-native grasses; and transitions to human-dominated states.

Research findings are distributed to scientists, land managers and educators via workshops, seminars and an online newsletter. JRN also engages K-12 students and teachers in the field, and provides training opportunities to undergraduate and graduate students from four Hispanic-serving institutions in Arizona, New Mexico and Texas.

John Anderson, LTER site manager, and Dara Parker take readings at a weather station site. The weather station measures precipitation, wind speed, wind direction, temperature and humidity.

LUQUILLO (LUQ)

Based in Puerto Rico, LUQ studies changes in biodiversity, water quantity and quality, and other characteristics of tropical forests and streams. LUQ will continue its long-term studies of natural and human-made change drivers, including hurricanes and urbanization.

A large-scale, 18-year Canopy Trimming Experiment, for example, has revealed important resilience mechanisms that help forests recover from storms of certain strengths and frequencies. In another study, rainfall is manipulated in forest plots to look at how varied precipitation rates impact plants, biodiversity and biogeochemistry. And, to determine the long-lasting effects of land use on tropical diversity, LUQ is engaged in a 24-year study of 16 hectares of forest.

All of these studies are helping scientists develop scenarios of change and better understand the consequences of these scenarios for society.

Extreme rainfalls create flash flood conditions in the Rio Sonadora, Luquillo Mountains, Puerto Rico.

Seawalls line the eroding cliffs of the SBC coastline. This seawall, at Arroyo Hondo, is over a kilometer long and dates from the 1930s.

SANTA BARBARA COASTAL (SBC)

Established in April 2000, SBC investigates how changes in climate, ocean conditions and local land use impact giant kelp forests. The dynamic nature of these environments make them ideal for investigating questions that require decades, or even centuries, to address in other ecosystems.

Ongoing research focuses on developing a predictive understanding of how kelp forests respond to human and natural disturbances, material exchange at the land-sea margin and the movement of matter in the coastal ocean. Coordinated long-term measurements, field experiments and modeling are used to address questions of biodiversity, productivity, connectivity, climate change resiliency and landscape change.

Outreach to students, the media, government agencies, local industries and the general public is facilitated by SBC's web-based information management system, which offers easy access to data for a variety of end users.

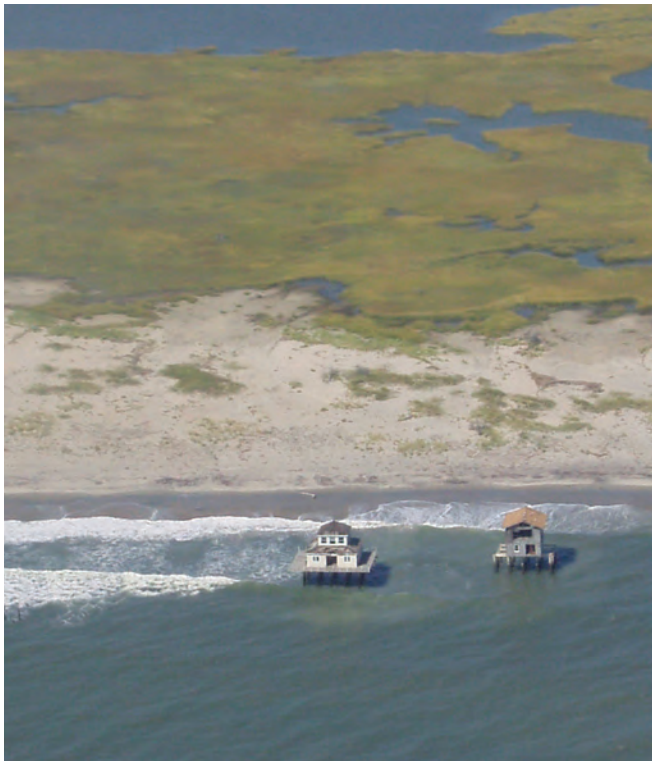
SEVILLETA (SEV)

SEV plans to expand its ongoing research into how climate variability and the physical environment interact to affect common species, community dynamics and ecosystem processes in the desert grasslands, shrublands and piñon-juniper woodlands of the northern Chihuahuan Desert.

In an effort to gain a comprehensive understanding of how global environmental change affects aridland ecosystems, SEV continues to study the impact of new and irregular rainfall patterns on the scarcity of water, nutrients and organic matter in soils, as well as the effect of shrub encroachment on biodiversity, carbon storage and soil nutrients.

SEV offers outreach programs that engage hundreds of local students each year, including an 11-week summer research and creative experience that brings together students from fine arts and ecology. To increase participation by members of underrepresented groups, SEV also participates in the Ecological Society of America's SEEDS Program.

Joe Fargione filling in the root donut, after taking a sample to monitor biomass below ground and to compare estimates of root production.



Houses on Cedar Island find that the land has left them behind. Barrier islands are dynamic with beaches that constantly change.

VIRGINIA COAST RESERVE (VCR)

VCR examines the impact of climate change, sea-level rise and intensified human use on coastal barrier systems, such as watersheds, marshes and barrier islands. These vital ecosystems provide storm buffering, support for commercial fisheries, carbon sequestration and other services in areas where more than half of the global human population resides.

VCR's research seeks to better understand the often catastrophic "tipping points" that can change a coastal ecosystem into something else quite rapidly. Using long-term observations, experiments and modeling, VCR's team of scientists hopes to move coastal ecosystems away from these tipping points and help them become less vulnerable to global change.

VCR partners with regional stakeholders to influence policy decisions, and broadly disseminates its findings through its website, publications and presentations. VCR also trains graduate, undergraduate and high school students (half of whom are women and minorities) to develop the next generation of environmental scientists.

KEY FINDINGS

LTER research not only advances ecological science, but it also has a positive impact around the globe. Every year, LTER scientists report important discoveries that have practical applications for enhancing human society worldwide.

H.J. ANDREWS EXPERIMENTAL FOREST (AND)

ART AND NATURE Scientists at AND have created innovative programs, like the widely emulated Long-Term Ecological Reflections, that bring together scientists and writers, artists, philosophers and other humanists. This blending of science with arts and humanities is transforming the way we understand and relate to the natural world.

ARCTIC (ARC)

ARCTIC WARMING ARC scientists documented how Arctic warming is thawing frozen ground (permafrost), creating hot spots of erosion, releasing nutrients into rivers and decomposing ancient organic carbon. This information is essential for managers and policymakers who must grapple with how to mitigate and adapt to future climate change.

BALTIMORE ECOSYSTEM STUDY (BES)

FOR THE PEOPLE, BY THE PEOPLE By exploring human values and attitudes, BES scientists have found that residents in poorer, ethnically mixed communities are as concerned about environmental problems as those in wealthier neighborhoods. This is contrary to long-held assumptions about which groups are most likely to be change agents for environmental rehabilitation and stewardship.

BONANZA CREEK (BNZ)

FIRE AND CLIMATE Through long-term studies of fire cycles and their links to climate, BNZ scientists have documented an increase in fire severity associated with recent climate warming. This will likely shift the Alaskan boreal forest from a spruce-dominated landscape to one dominated by broadleaf trees.

CALIFORNIA CURRENT ECOSYSTEM (CCE)

NEW CLIMATE PATTERN Long-term observations allowed CCE scientists to define a new climate pattern called the North Pacific Gyre Oscillation (NPGO), which may affect marine ecosystems around the world. This pattern links physical ocean changes, such as fluctuations in salinity and nutrients, with biodiversity and ecosystem processes in the eastern North Pacific.

CENTRAL ARIZONA-PHOENIX (CAP)

NEW ECOLOGICAL THEORY CAP scientists spearheaded efforts to integrate ecological and social research in urban ecosystems, by helping to develop the new sub-discipline of Urban Ecology. This transformative theory development has changed the way scientists – and the public – perceive the natural environment and approach environmental problem solving in cities.

COWEETA (CWT)

CONTROLLING PLANT INVADERS Invasive species are changing the structure and function of our native ecosystems and creating a need for new approaches to protect ecosystem services and biodiversity. Researchers at CWT have shown how ecological theory informs land management to eradicate invading species from affected areas.

HUBBARD BROOK (HBR)

WATERSHEDS AS LABORATORIES HBR scientists pioneered the small watershed approach, which transformed the study of forests by using whole watersheds as living laboratories. This groundbreaking tactic has fostered many new discoveries beneficial to science and society.

KELLOGG BIOLOGICAL STATION (KBS)

DIVERSE LANDSCAPES CURTAIL CROP PESTS Long-term research shows that diverse landscapes promote the control of insects without the use of chemicals. According to KBS scientists, increasing acreage of monoculture crops for biofuel production reduces landscape diversity and interferes with these biological control services.

KONZA PRAIRIE (KNZ)

RESTORING GRASSLANDS Human activity and environmental change have resulted in widespread loss of grassland ecosystems and the biodiversity and services they provide. Restoration studies in tallgrass prairie at KNZ are providing new insights into ecosystem functioning, and are contributing to the development of approaches that will improve the sustainability of restored grasslands.

MCMURDO DRY VALLEYS (MCM)

ORGANICS FROM MICROBES Long-term studies by MCM scientists in the cold, hostile and plant-free environment of Antarctica reveal that substantial amounts of dissolved organic material in lakes and streams originate from algae and bacteria. This demonstrates the role of microbes in the cycling of an important form of carbon in aquatic ecosystems worldwide.

MOOREA CORAL REEF (MCR)

MANAGING FOR RESILIENT CORAL REEFS By understanding how herbivores respond to disturbances that kill coral over large areas, MCR scientists have discovered critical keys to the rapid return to high coral cover. These findings highlight the crucial need for ecosystem-based management strategies that include protection of the vital nursery habitat of herbivorous fishes.

NIWOT RIDGE (NWT)

LIFE IN THE EXTREMES By sampling for microbial diversity and biomass in snowmelt runoff, NWT scientists discovered microbes living beneath the snow at extreme elevations, even in rock glaciers above the tree line, a barren environment previously thought to be devoid of life.

NORTH TEMPERATE LAKES (NTL)

LAKES IN THE LANDSCAPE NTL researchers developed the concept of the "lake landscape position." This explains the spatial variability in water chemistry and community composition that results from a shifting balance of groundwater, surface water and precipitation inputs.

PALMER ANTARCTICA (PAL)

PENGUINS AND CLIMATE CHANGE PAL scientists have documented an 85 percent reduction in Adélie penguin populations since 1974, and determined the cause to be altered cloud cover, winds, snowfall, sea ice cover and other climate-related changes.

PLUM ISLAND ECOSYSTEMS (PIE)

TIPPING POINTS PIE scientists discovered that marshes have "tipping points," beyond which sediment accumulation fails to keep up with rising sea levels. These tipping points, which cause marshes to drown, vary regionally and are influenced by dam building, land clearing and other human activities that affect sediment transport from the watershed.

SHORTGRASS STEPPE (SGS)

ECOSYSTEMS AND GRAZING HISTORY Having evolved in the presence of large herds of bison, the unique shortgrass steppe is well adapted to withstand heavy livestock grazing, currently its primary land use. SGS research has shown that grazing history best explains the combinations of life history, plant type and morphology of species found in grasslands worldwide.

NEXT STEPS AND FUTURE GOALS

The LTER Network will continue to work toward a better understanding of ecological issues and a more hopeful future. Specific steps and definable goals include:

A UNIFIED DATA SYSTEM

The LTER Network will soon offer a unified information system with more data, more access and more tools. The completion of the first phase of the Provenance Aware Synthesis Tracking Architecture (PASTA) framework permits the LTER Network to populate the Network Information System (NIS) with increased data from LTER sites. Development of new derived datasets will facilitate comparison and synthesis of LTER data, now made more accessible by the data portal. Network-wide efforts will improve the management of spatial and non-spatial data at LTER sites. The Network Office will continue to add key functions for management and analysis of Network data, and the assignment of Digital Object Identifiers will allow LTER to measure its re-use.

THE EXPANSION OF KEY PARTNERSHIPS

During the next year, the LTER Network will continue to strengthen and expand key partnerships in order to build a robust national scientific infrastructure for the ecological sciences. Continued cooperation with DataONE will expand the amount of LTER data available. The long-term partnership between the LTER Network and the National Ecological Observatory Network (NEON) enters an important new phase with the construction of the NEON facility. As building progresses, the LTER Network will strengthen scientific cooperation with the NEON community by focusing on research questions common to both organizations.

INTERNATIONAL OUTREACH

At the LTER All Scientists Meeting in 1993, a small group of international scientists created the International Long Term Ecological Research Network (ILTER) to provide a foundation for global-scale ecological studies. ILTER now comprises 42 national networks. In 2013, LTER will strengthen and expand this international partnership, and will honor it during the February 2013 mini-symposium, "LTER Research Beyond U.S. Borders: Celebrating the 20th Anniversary of the International LTER (ILTER) Network."

CONTINUED RESEARCH

Dedicated LTER scientists will continue to push the frontiers of ecological research in the coming year. For news about LTER's findings and insights, read LTER Network News at http://news.lternet.edu.

Thank you to the LTER Network sites for the use of photography in this publication. Credit is due to the site unless noted otherwise. **Cover:** Ice photo by John J. Magnuson (NTL); Fire photo by Eva Horne (KNZ); Bird photo by Nick Rodenhouse (HBR). **Page 5:** Autumn leaves by David Lee (HFR); Research student by Audrey Barker Plotkin (HFR). **Page 6:** Estes Park by Leanne Yanabu. David Foster by J. Beller. **Page 7:** Land Quilt by Robert Reck. **Page 8:** Scott Collins photo by Nancy Grimm; Christopher Craft photo by Lenka Kropfelova; Michael Nelson photo by Lina DiGregorio. **Page 9:** Sunset by John Porter (VCR); Pier by Hap Garritt (PIE). **Page 11:** Paula Hoffmann Landau by Jay Rodman, NMSU. **Page 12:** CAP research by Daniel Cavanaugh. **Page 13:** Climate station by Brian Charlton (BNZ). **Page 16:** FCE by Victor H. Rivera-Monroy and Robert R. Twilley, Louisiana State University. GCE by Steven Pennings. **Page 17:** HFR by John Burk. JRD by USDA ARS Information Staff. **Page 18:** LUQ by Ashley Golphin. SBC by Dave Hubbard. **Page 19:** SEV by Mike Friggens. VCR by Arthur Schwarzschild. **Page 20:** AND by Ben Nieves; ARC by W.B. Bowden; BES by J. Morgan Grove; BNZ by Dr. Teresa Hollingsworth; CCE by McOwiti O. Thomas. **Page 21:** CAP by Tim Trumble; KBS by K. Stepnitz; MCM by Rebecca Witherow. **Page 22:** MCR by Russell J. Schmitt; NWT by Steve Schmidt; PAL by J. Blum; NTL by Carl Bowser; PIE by James Morris.

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