

NSF Responses to LTER Thirty-Year Review Report

The LTER Thirty-Year Review was commissioned to evaluate the promise of the program to address future research challenges and needs in ecology, ecosystem science, environmental biology, the integration of social and environmental science, and education. The team was asked to evaluate the ability of the current program to respond to future challenges, particularly with respect to a) increased needs for interdisciplinary research, b) unique research contributions provided by LTER, c) future structural needs for long-term research, d) the relationship between LTER and an increasing number of other, large research platforms, e) provision of adequate funding and potential addition of new sites, and f) effective NSF management. The team was also asked to address needed changes in the program itself as well as in its management by NSF.

Because some issues raised by the Thirty-Year Review raise significant concerns about the LTER program, it is NSF's responsibility to address these issues and to work with the LTER community to resolve them. NSF has developed responses to each of the Thirty-Year Review's recommendations, and these are provided below. While the numbering of the recommendations is consistent with the Thirty-Year Review Report, the order below indicates NSF's priorities. Recommendation #8 sets an important context within which all of the remaining recommendations must be evaluated. The remaining recommendations (their ordering) and responses reflect NSF priorities.

8. Resources are a key limiting factor for the future of the network. The network should: 1) make realistic prioritizations within the existing resource base to create more science per dollar, and 2) engage with NSF and others to pro-actively develop new resources. Prioritizations will include spending more on data and diversity. The case for new resources could be built around a new level of excellent science that addresses the big science questions that underpin society's grand challenges. In all cases, the best practices and tools for developing new resources could be shared across the network to improve the effectiveness of each site.

NSF considers it essential that LTER sites prioritize their research, data management, and education and outreach efforts. These priorities should highlight sites' scientific strengths and strengthen sites' abilities to address compelling research questions. NSF acknowledges that sites cannot excel in all of the areas identified in the Thirty-Year Review, and emphasizes the importance of developing priorities that advance long-term research. Priorities must be based on resources currently available. As the LTER community moves forward with clear and wise allocation of existing resources, NSF will consider seeking additional sources when they are available. At the same time, individual sites and the Network Office should examine other funding initiatives within NSF as opportunities to enhance the LTER research portfolio.

1. LTER must clearly articulate (a) what challenges long-term data are uniquely poised to answer and (b) what the LTER network can offer beyond a collection of excellent long-term studies on diverse issues at ecologically distinctive sites. For LTER to better justify significant additions of resources for current activities (and possibly the addition of new sites), it needs to clarify the grand challenges that individual sites and the network as a whole would be able to answer if such expansion took place.

NSF considers it critically important that the LTER community continues to define research questions and challenges that demand study on decadal time scales. The existence of 26 sites that have collected similar, core data over long time intervals provides additional, unique opportunities to address questions at broad spatial scales. NSF recognizes that the program's focus on long-term studies will not, and should not, remain static, and that new questions and new opportunities will arise continually.

LTER sites should identify research priorities that can be achieved with available resources. These priorities could be complemented, strategically, if additional funds or funding sources are identified. LTER sites have been very successful to date in leveraging NSF support to obtain funds for a diversity of projects. NSF encourages LTER sites to continue to pursue diverse funding sources to conduct the shorter-term studies necessary to fill gaps in understanding the drivers of long-term change. These studies will allow sites to build on their extensive datasets in order to develop deeper understanding of mechanisms and processes. NSF expects that the infrastructure and accumulated understanding arising from LTER efforts will generate positive interactions with non-LTER researchers, making LTER sites increasingly attractive as locations to address diverse research questions by a broad array of scientists. These additional activities may serve to attract future LTER researchers (see # 4, below).

While the possibility that NSF might announce competitions for new LTER sites exists, it is unlikely under current budget conditions.

5. Data management at each LTER site is adequate to excellent in its support of the current science questions at sites, but the LTER network as a whole must invest in making LTER data comparable across sites and more readily available to those interested in network-wide analyses. This problem can be remedied by either new resources for the network office or by re-directing some existing network office funding towards providing current and future scientists easy access to all LTER data from all sites. In particular, (a) the LTER Network Office must markedly expand its current data activities into a fully functional data management system that serves and archives all LTER data and metadata from all sites in a consistent and easily used manner to third-party users; and (b) each LTER site must fully support this LNO mission by publishing all data sets, in their entirety and with appropriate metadata, in a standard format with the network office and/or some other permanent repository in a timely manner.

NSF expects effective data management to be an integral part of LTER activities, both at individual sites and across the network of sites. These data management activities should be supported with core LTER funding. The creation and sharing of long-term data have been leading priorities since the program's inception, and the resulting data are valuable to the LTER community and to the broader ecological community. LTER data are valuable, however, only if they are available and locatable. Progress toward these goals has been made, with more significant progress by some sites than by others. As noted in the Thirty-Year Review report and in Robbins' accompanying evaluation, LTER information management must place a high priority on two separate but related goals.

First, the LTER community must make timely access to all core data their top priority. This must take precedence over efforts to develop more advanced features for documentation, data integration, or application services. The value of LTER data is diminished significantly if the

data cannot be easily discovered and accessed. Defining and implementing the most basic expectations for data release, publication of EML Level 2, and online access for all of the core datasets produced at individual sites must be accomplished.

Second, the network must strengthen its commitment to developing centralized data management services that its own leadership has identified as strategic priorities, and it must exercise the necessary oversight to ensure proper compliance with network-generated procedures. NSF has supported the development of a sophisticated Network Information System, but site-level data are not yet in full compliance with the network's Data Management Plan, and additional work is needed to facilitate data capture and interoperability. It is unclear how many LTER datasets meet the requirements of the Network Information System or the extent to which this system will be useful to individual sites. NSF acknowledges that additional resources may be necessary to accomplish this second goal, and the LTER Network Office and Network information managers are encouraged to seek the resources needed. Observations from the Thirty-Year Review indicate that the Network Office's data management efforts have yet to replace site-based efforts and appear to compete for the data managers' time rather than relieve it through economies of scale.

NSF expects LTER site PIs and their information managers to work together to accommodate the growing importance of participating in network based solutions as a more efficient means of managing data with available resources. Difficult decisions will be needed to balance the importance of local customized systems against reliance on shared network ones. NSF believes that the movement toward shared systems for fundamental data archiving and publishing will be rewarded with the flexibility to redirect more of the information managers' time to applying informatics methods to advance ecological research or to contributing to LTER's legacy of developing advanced eco-informatics methods and technologies.

NSF is considering steps to ensure that LTER data are readily accessible for use across sites and by scientists outside the LTER network. As an initial step, NSF will initiate discussions with LTER leadership and the information managers to arrive at an effective set of metrics and procedures to raise both individual and network performance on the most basic expectations of data management. Recent revisions to the NSF *Grant Proposal Guide* and the forthcoming LTER solicitation underscore the high priority that NSF places on data management, and on the need for LTER data to be available to a broad research community. A second step will be to strengthen NSF's oversight of LTER information management as a critical component of NSF-wide investments in informatics and cyberinfrastructure. Additional steps may include consideration of new partnerships with third-party institutions and resources, creative solutions for organizing information management efforts across the network, and cultural changes regarding data sharing and data publication.

3. Although all LTER sites should incorporate appropriate social-science data into their analyses, we are not convinced that social science research is, in its own right, a central value-added component for the network as a whole, but it may well be so at some individual sites. Before undertaking a major network-wide expansion of social science research, the value of such an expansion must be better articulated and demonstrated.

NSF agrees with the Thirty-Year Review that the integration of social sciences into LTER site research, as called for by the Integrative Science for Society and Environment initiative, has not been uniformly successful across all 26 sites. The research foci at some sites readily encompass social science questions (for example, the Phoenix, Baltimore, North Temperate Lakes, and Coweeta sites). At other sites, however, the relationship between ecological research and social science research is less apparent. While efforts have been made to explore questions related to the interaction between people and ecological systems, research on human activities sometimes has been descriptive in character, with little engagement of core social science theoretical issues.

To the extent that human activity at some level affects ecological and ecosystem dynamics at all LTER sites, researchers are encouraged to explore ways to conduct meaningful research on theory-driven, fundamental questions that relate to both human and natural system dynamics. Because it is unlikely that the core LTER budget will be able to support these efforts adequately, funding may need to come from other sources such as the Dynamics of Coupled Natural and Human Systems (CNH) Program, competitions associated with the Science, Engineering, and Education for Sustainability (SEES) investment area, and core programs in the NSF Directorate for Social, Behavioral, and Economic Sciences.

2. The richness of the long-term observational data gathered across the LTER network makes it uniquely and optimally poised to establish cross-site experimental studies of the mechanisms whereby factors such as climate change, nutrient loading, loss of biodiversity, shifts in species composition and food web structure, and invasive species impact ecosystem functioning and species dynamics. Although each site is likely suitable for only a subset of these experiments, the network as a whole would add immeasurably to ecological science by pursuing such coordinated multi-site experimental studies. We recommend that the network plan and actively seek funds for a coordinated program of cross-site experiments and related cross-site observations.

NSF expects that long-term research and data collection at LTER sites will result in syntheses that extend well beyond site-specific research. Integration of research efforts across LTER sites to advance cross-site experiments and observations has been an NSF priority since the program's inception. One of the unique aspects of the LTER program is the promise that research can be conducted at larger spatial scales through coordination across sites. Cross-site activities must be driven by compelling scientific questions, however, and not be a blanket mandate across all sites.

Some LTER sites, such as the Moorea Coral Reef site and the California Current Ecosystem LTER, are one-of-a-kind research programs. Cross-site activities for these sites may be a less productive use of resources than the development of collaborations outside the LTER network. These sites are well positioned to participate in other NSF-supported activities, such as the Ocean Acidification program. Other LTER sites that have developed nascent cross-site activities may also be well positioned to garner additional research support through participation in developing NSF programs that focus on issues such as coastal carbon cycling and sustainability, or the Dimensions of Biodiversity initiative.

While NSF is enthusiastic about the development of more cross-site interactions, these must be motivated by compelling scientific questions and inclusive of collaborations initiated at one-of-a-kind sites (see above) for which interactions within the LTER community are limited. As

questions requiring cross-site research arise, it will be essential for LTER sites to seek financial support from diverse funding sources, both within and outside of the NSF. NSF will continue to urge the LTER community to think strategically about research initiatives that reach beyond specifically targeted LTER funds.

4. To ensure success, the LTER sites should actively recruit a new generation of diverse scholars interested in dedicating their careers to experimental and observational studies at the continental scale.

NSF will consider as an important element within our merit review process plans to recruit new scientists to existing sites, including those with skills in large-scale spatial analyses. These recruits may represent all levels of experience from new PhDs to established researchers, with the expectation that they bring new approaches and skills to LTER research. NSF will also evaluate sites on their provision of clear succession plans. Leveraged research at LTER sites should be viewed as a low cost and rich source of potential recruits to the LTER network.

6. Citizen science shows increasing promise as an outreach and educational tool to local communities and to audiences with a diversity that reflects the nation. Some LTER sites are encouraging this, among their other educational activities. These efforts should continue and be initiated at other sites. Their success is partially predicated on increasing the diversity of scientists, staff and students at each site as role models to the citizen scientists and each site must enhance its efforts in this area.

7. Cross-site education programs should be a higher priority for funding and effort, both through the spread of the better program models and for education activities that truly leverage the network as a whole. The few cross-site educational programs that have been offered to date have been very promising but funding has been minimal. It is critical to identify funding mechanisms for cross-site education both within and beyond NSF. Such programs should emphasize participation by diverse students and stakeholders.

Although NSF recognizes the promise of an expanded education and outreach effort across LTER sites, we emphasize the need for sites to prioritize their activities to fit within core LTER funding. A realistic plan for implementing the recommendations of Thirty-Year Review will require prioritization, a stepped approach, and a consideration of programs that can be implemented with existing resources and personnel. We encourage the LTER community to consider funding through the Research and Evaluation on Education in Science and Engineering (REESE) program (NSF 10-586) before developing plans for expanded education and outreach activities and before hiring a Director for LTER Education and Outreach.

The provision of cross-site research and educational opportunities for graduate students involved with the LTER sites will be fundamental in building a community of young network scientists. The Network Office should play an active role in generating these opportunities.

4. As the goals and spread of long-term science continue to broaden, it is becoming critical to think beyond networked LTER sites, towards networks of networks (including but not restricted to an LTER-NEON network). The LTER network is uniquely poised to seek a leadership role in

achieving this goal, and should articulate a concrete vision statement about its leadership opportunities. To ensure success, the LTER program should actively recruit a new generation of diverse scholars pursuing experimental and observational studies at the continental scale.

The number of established observation networks, research networks and synthesis efforts has grown dramatically over the past decade, and each contributes in some unique way to an increasingly complex landscape of multi-disciplinary environmental research. LTER sites and the LTER network are encouraged to participate actively in appropriate efforts, and to anticipate ways in which LTER might contribute to as well as benefit from these groups. It is important for LTER sites to maintain open communication with these efforts and to ensure that efforts are not being duplicated. NSF does not encourage LTER sites to compromise their research strengths in order to assume a leadership role among these disparate ventures. LTER sites are encouraged to use existing or planned networks, observing platforms, and synthesis efforts to their advantage. Participating as one of many nodes in a more complex 'network' of sites could afford LTER opportunities to expand in new and compelling ways.

NSF does not consider NEON, OOI, or any of the several EON or EON-like activities to overlap with LTER but rather views them as complementary or synergistic activities. The former group of network observatories is primarily a set of observing platforms designed to accumulate streams of continuously collected data and to establish infrastructure to gather data that will ultimately be used to address very diverse research questions. In contrast, LTER is a research program motivated by specific and unique research questions. NSF supports the recommendation of the Thirty-Year Review that the LTER community identifies and solicits opportunities to use the NEON network for research that directly addresses LTER goals, and that LTER scientists collaborate fully with NEON efforts.