Chapter 14
Network Level Science, Social-Ecological Research and the LTER Planning Process

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Abstract This chapter provides a personal perspective and history of the LTER Planning Process that took place from 2004 through 2007 with support from the National Science Foundation (NSF). Decadal reviews of LTER in 1990 and 2000 commissioned by NSF emphasized the need for interdisciplinary science, greater cross-site synthesis and the desire for a network-level research agenda. The purpose of the Planning Process was to develop the scientific basis and conceptual framework for network-level science that would facilitate synthesis and integration from the start. Many researchers from the biophysical and social sciences were involved in the process, which resulted in a conceptual framework for integrated, long-term, social-ecological research that has been widely embraced globally. Although the LTER Network did not get to implement its Network-level science initiative, the process demonstrated that LTER scientists could work together across sites to develop a research agenda essential for understanding how global environmental change will affect the dynamics of social-ecological systems during the Anthropocene.

Keywords LTER program · Long-term ecological research · Ecological strategic planning · Network science · National Science Foundation · Integrative science · Conceptual framework · Socio-ecological systems

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14.1 Introduction

The goal of this chapter is to provide some background and context for the Long-term Ecological Research (LTER) Planning Process, an NSF-funded activity that took place from 2004 through 2007. I want to emphasize that this chapter will contain a highly personal perspective on what happened and why. I will provide some background relevant to the start of the process, the overarching objectives of the process, a summary of the process itself, the ultimate outcomes and products, and their reception by NSF management and the broader scientific community. A lot of people put a lot of time and energy into this process over a 3 year time span, with some important, concrete outcomes for the LTER Network and beyond. Like the International Biological Program (IBP) that is widely but wrongly criticized for not achieving its primary goal of modeling net primary production globally (Golley 1993), we did not accomplish our overly ambitious goal of a establishing a new, long-term, cross-site, fully integrated, social-ecological research program. But also like the IBP, several long-lasting positive outcomes emerged from the planning process, including a new conceptual framework for social-ecological research, a new governance structure for the LTER Network, and an enhanced web portal to manage and deliver LTER data. Despite these important success stories, one might ask whether or not these outcomes were worth the time and money invested in the Planning Process? I will return to this nagging question under lessons learned at the end of the chapter.

14.2 Background and History

From September 1992 to February 2003 I was a Program Director in the Division of Environmental Biology (DEB) at the National Science Foundation (NSF). From 1995 to 2000 I served as the Program Director (PD) for LTER, before being reassigned to be the first PD for the National Ecological Observatory Network (NEON). Despite that administrative move, I remained actively engaged in LTER management, as well as a long-time researcher at the Konza Prairie LTER site in northeastern Kansas. In February 2003, I left NSF to take a faculty position at the University of New Mexico and to become the lead Principal Investigator on the Sevilleta LTER program. On one of my last days as a Program Director at NSF, I was having a meeting with Dr. Joann Roskoski who was the Deputy Assistant Director for Biological Sciences (BIO) at the time. During that meeting, much to my great surprise and pleasure, she said, "we need to find a way to get more money to LTER." LTER was on her mind because the program had just been through the 20-year review (Krishtalka 2002) commissioned by the BIO Directorate. That review called for more resources, as well as a greater emphasis on synthesis research and cross-site coordination.

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In the early years of LTER, staff at NSF realized that LTER would not be successful or justifiable from an agency standpoint without the program acting more like a network. As was typical of NSF through much of the evolution of the LTER Program, managers at NSF would identify what they considered to be an important direction (e.g., act like a network, or develop a data management system) for LTER to move and then ask the scientists to figure out how to make it happen. These mandates often, but not always, came with extra resources. Indeed, the LTER Network Office was conceived early on as a facility to support and encourage network-level activities, such as annual meetings among the site PIs to promote collaboration. The first "LTER All Scientists Meeting" occurred in 1985 hosted by the University of Minnesota and since then these meetings have been held approximately every 3 years. Thus, network integration and coordination were goals from the start of the LTER Network (LTER Network Office 1989), but it was not always clear how to achieve these goals given how the Network was established through multiple competitions for site-based science.

The need for cross-site and synthesis activities was further reinforced by the LTER Ten Year Review (Risser 1993) which concluded that although, "…intersite comparisons have been conducted…the power of the network of coordinated research sites has not yet been fully realized." The LTER Twenty Year Review continued that theme (Krishtalka 2002) noting that, "…missing is a clear exposition of what synthesis science LTER should accomplish - what should the scientific focus, niche and priorities of the LTER program be for the next decade? Despite…accomplishments, some of the critical recommendations of the Ten-Year Review for LTER science have yet to be fully realized. The transition from individual site-based research and science projects to a broader, more integrative research platform has not been sufficient to address large-scale, interdisciplinary environmental issues."

Synthesis can be achieved in two ways. The first is to integrate across disciplines within a site. Long-term, integrated, site-based research was and still is the essential ingredient in LTER science. Indeed, most sites have a long history of blending biophysical perspectives from the start, and the addition of urban sites provided yet another level of integration that included the social, behavioral and economic sciences. Cross-site synthesis, on the other hand, was slower to materialize within LTER, increasing gradually as the LTER Network matured (Johnson et al. 2010). In some cases, multi-site research projects were generated externally, with funding provided by various programs in the Division of Environmental Biology (DEB) (e.g., LIDET, Gholz et al. 2000; Parton et al. 2007), and others were established through two NSF-sponsored LTER cross-site competitions open to researchers within and outside the LTER Network. Both competitions included funds contributed by other programs in DEB and Biological Oceanography in the Directorate for Geosciences. Cross-site competitions were designed to generate multi-site LTER research, as well as to attract non-LTER scientists to work at LTER sites and to facilitate research between LTER and non-LTER sites. Although these competitions were popular, because of constant budget constraints, no permanent internal funds were earmarked to keep them going.

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In the mid-1990s, while James Gosz was DEB Division Director, NSF received an unexpected budget windfall from which DEB held a competition within the LTER Network to expand site based research regionally and to increase disciplinary breadth. The North Temperate Lakes (NTL) and Coweeta (CWT) LTER sites were selected following peer review to receive budget increases from ~$560,000 per year (the Network standard at the time) to $1,000,000 per year. The ultimate plan was to repeat this competition periodically so that more sites could expand their research programs. In truth, the budget windfall was intended for other federal agencies (NASA, USDA, Department of Energy), not NSF. This funding bonanza occurred because NSF had room in its budget request for additional global change research funds through its annual request to Congress. These funds were directed to NSF by the Office of Management and Budget with the intention of NSF participating in a cross-site competition for global change research. As a consequence, rather than continuing to expand LTER site science, most of these funds were used for NSF's contribution to the Terrestrial Ecology and Global Change interagency competition, known as TECO. That effectively ended the plan to use these funds to expand the scale and scope of sites in the LTER Network.

As the LTER Network grew, there was a clear need for a governance structure to promote cross-site interactions. The Coordinating Committee (CC) meeting initially served in that capacity. Starting in the mid-1990s research symposia at the CC meetings were used to explore interconnections among LTER sites. For example, one highly successful CC workshop hosted by Dave Tilman (Cedar Creek LTER) resulted in an LTER working group led by Bob Waide and Mike Willig and supported by the National Center for Ecological Analysis and Synthesis (NCEAS). That working group resulted in several impactful cross-site publications (e.g., Waide et al. 1999; Dodson et al. 2000; Gough et al. 2000; Gross et al. 2000; Mittelbach et al. 2001). This was one of the first of numerous cross-site efforts, many of which were funded by resources provided through NCEAS and, more often, the LTER Network Office.

In fact, the LTER strategic planning at the time of the Twenty-Year Review identified the third decade of LTER science as one of cross-site research and synthesis that would lead to a better understanding of complex environmental problems and result in knowledge that serves science and society. Despite the increase in synthesis and cross-site research that had occurred by that time, most such activities were *ad hoc*, somewhat idiosyncratic, and relatively uncoordinated, thus preventing the LTER Network from achieving its full potential. This deficiency called for a coordinated, organized approach to Network-level science, collaboration and synthesis driven from the bottom-up by the LTER research community. Network level science to address Ecological Grand Challenges, a list of urgent research priorities identified by the National Research Council (National Research Council 2001), was incorporated into the LTER Network's vision, mission, and scientific priorities. In addition, Network-level science required improvements in governance and organizational structure, infrastructure needs, advanced informatics and integration with education and policy initiatives all built around a strong science-driven research agenda.

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In addition to cross-site research, the LTER Network formed a partnership with Oxford University Press to publish site-based (e.g., Knapp et al. 1998; Bowman and Seastedt 2001; Magnuson et al. 2005; Havstadt et al. 2006; Chapin et al. 2000; Lauenroth and Burke 2008; Brokaw et al. 2012; Hobbie and Kling 2014; Swank and Webster 2014; Hamilton et al. 2015; Childers et al. 2019), methods-oriented (e.g., Robertson et al. 1999; Greenland et al. 2003; Fahey and Knapp 2007), and topical (e.g., Greenland et al. 2003; Shachak et al. 2004; Redman and Foster 2008; Willig and Walker 2016) synthesis volumes. The complete list of LTER books can be found at https://lternet.edu/books/. These syntheses provided a means to summarize years of site-based research, and they promoted standardized measurement and analysis protocols both across the Network and for ecological research in general. Finally, the triennial LTER All Scientist Meetings (ASM) increasingly acted as a catalyst for cross-site synthesis and coordination both nationally and internationally. Activities at the ASM led to proposals submitted to the LTER Network Office, and again several of these LNO funded meetings resulted in important publications (e.g., Redman et al. 2004; Suding et al. 2005; Peters et al. 2008; Fountain et al. 2012; Robertson et al. 2012; Bestelmeyer et al. 2012; Alber et al. 2013; Hallett et al. 2014; Kaushal et al. 2014; Smith et al. 2015). Thus, interest in synthesis was growing within and across the network. Like most syntheses, integration across LTER sites was often challenging because of variable time frames, and different methods and measurements across systems. What was needed was a framework for integrated LTER science that would enable synthesis from the start.

The organization of the LTER network certainly facilitated communication and interactions, but it was not well-suited to conduct and coordinate network-level science. For many years, the primary form of governance for the LTER Network included an Executive Committee (EC) and the Coordinating Committee (CC). As noted earlier, the CC was made up of all the lead PIs as well as individuals representing information managers and the graduate students, whereas the EC was an elected subset of CC members. Essentially, the EC was the "business" arm of the LTER Network, including interacting with NSF staffers from time to time. The role of the CC was not particularly clear because early on there were no LTER Network bylaws in place that specified its role in network governance, nor was there any explicit mechanism to promote cross-site research.

14.3 The Planning Process

At the time I moved to UNM in March 2003, the Chair of the EC/CC was James Gosz, former PI of the Sevilleta LTER and a Professor in the UNM Biology Department. The LTER Network Office with Bob Waide as Executive Director was also located at UNM. As Chair, Gosz was notified by Henry Gholz, LTER Program Director at NSF, to prepare a proposal that would lead to a forward looking research plan for Network-level science. This plan was to build off recommendations of the Twenty-Year Review. The science should be built around the Environmental Grand

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Challenges recently defined by the National Research Council (2001), as well as the recommendations of the Ecological Society of America (ESA) Visions Committee (Palmer et al. 2004; 2005). The Visions Committee was established by ESA to update the highly successful Sustainable Biosphere Initiative (Lubchenco et al. 1991) that included a forward looking research and education agenda for ecology. In addition, the LTER Planning Process needed to walk a fine line between integrating with existing networks, including the development of the National Ecological Observatory Network (NEON) (National Research Council 2003), while also clearly differentiating LTER from NEON. To fulfill this agenda, I worked with Gosz and Waide to design a bottom-up planning process that would gather input from a wide-ranging group of scientists from both within and outside of the LTER network. Our goal was to generate a scientifically-based action plan for network-level, integrative, long-term, social-ecological research, to recruit more scientists to the LTER Network, and to justify increased funding that would be needed to implement this plan.

The Planning Process had three specific objectives. The first was to develop a plan for LTER network-level science, technology, and training by (1) developing a new initiative in long-term thematic, regional, and network-scale science; (2) increasing cyberinfrastructure and technical expertise at each site; (3) embedding graduate and undergraduate training into Network-level science and synthesis; and (4) integrating LTER and non-LTER sites and networks into a comprehensive international network of networks for ecological research. We also believed that the governance structure of the LTER Network needed to change to accommodate this new vision for LTER. Therefore, the second objective of the planning process was to explore alternative governance, planning and evaluation structures for managing LTER Network-level science. The new model required a governance structure to serve and support a more highly coordinated scientific network, one that included (1) a structure for network-wide science planning and evaluation, (2) a process for seamless integration of new sites and collaborative networks, and (3) an implementation plan to achieve these objectives.

The third objective for the planning process was to envision a much more ambitious plan for education, training, outreach, and knowledge exchange activities to link LTER science with application needs. Specifically, this objective included (1) establishing priority areas and key targets for education and outreach activities, (2) exploring mechanisms to facilitate collaborative science, (3) enhancing the participation of groups underrepresented in the discipline, and (4) developing skills and mechanisms for better exchange of knowledge among scientists, policymakers, and resource managers.

These were ambitious objectives that would require substantial increases in resources for the LTER Network. We did not want existing LTER research funds to be shifted to our new agenda. Instead, our goal was to build off the existing strengths of the LTER Network by enhancing research activities at each site through a new set of activities that would be layered on to existing research programs, but one that would be more fully integrated across sites from the start. Funds for the planning process came largely from the Directorates for Biological Sciences, Geosciences,

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and Social, Behavioral and Economic Sciences (SBE). SBE at the time was providing some of the funding for the urban LTER sites in Baltimore and Phoenix, with the hope that social sciences could be integrated into other LTER sites. Also, there was a growing movement in the research community globally for conceptual and empirical research on social-ecological systems (Haberl et al. 2006; Haberl et al. 2007). Thus, the planning process began.

The planning process was organized by a Science Task Force made up of the Planning Grant PIs – Jim Gosz (LTER Network Chair), Scott Collins (Sevilleta LTER), Dan Childers (Florida Coastal Everglades LTER), Barbara Benson (North Temperate Lakes LTER Information Manager representative), Alison Whitmer (Santa Barbara Channel LTER and Education and Outreach representative), along with Bob Waide (LTER Network Office) (Fig. 14.1). Input was also provided by the LTER National Advisory Board (NAB), an advisory committee specific to the

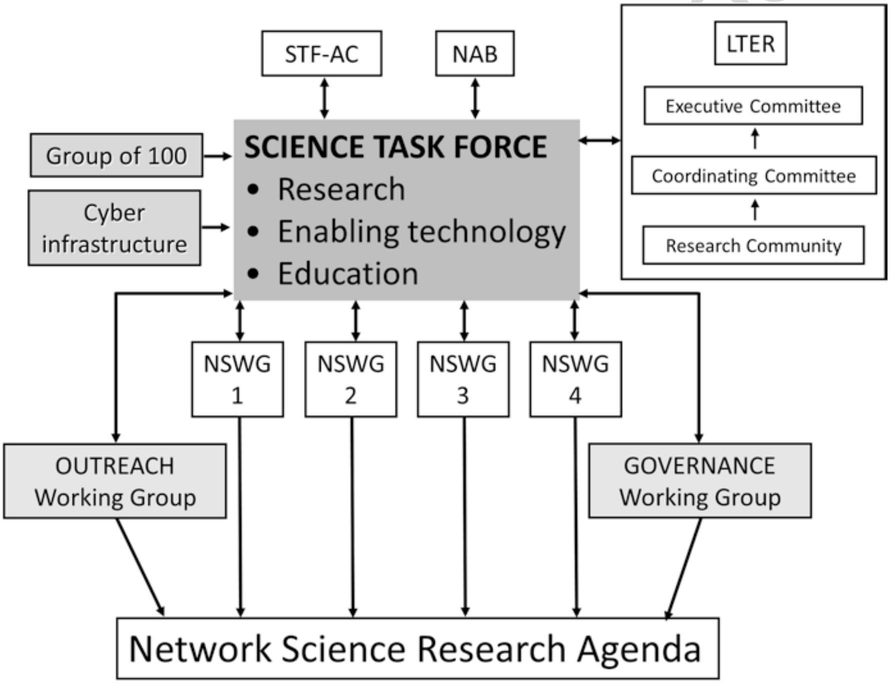

Fig. 14.1 A schematic overview of the LTER Planning Process that occurred from 2004–2007. The goal was to generate network-level science with input from as many participants and disciplines as possible. The Science Task Force was comprised of the Principal Investigators on the proposal to NSF that funded the process. The process started with a meeting of 100 participants from a wide range of disciplines to build a new research agenda based on the existing strengths of the LTER Network. Following the meeting of 100, four thematic working groups (NSWG 1-4) were formed to develop more focused activities. Researchers at All Scientists Meetings, the Coordinating Committee, and Advisory Committees (e.g., NAB – National Advisory Board; STF-AC – Scientific Task Force Advisory Committee) also provided input and guidance throughout the planning process

planning process (STF-AC) along with input from the broader LTER Network via the Executive Committee, Coordinating Committee and All Scientist Meetings. The goal was to start broad and then to narrow both the focus and the scientific team tasked with organizing the planning process. Shortly after the process got started, Jim Gosz retired from University of New Mexico, leaving me to take over as PI of the planning award.

The first step in the process began with the Meeting of 100, which was to be broadly inclusive, involving a number of social scientists (anthropologists, sociologists, economists, geographers) as well as biophysical scientists from within and outside the LTER Network. At one point during the initial Meeting of 100, I said to one of the resource economists at the workshop that we needed more sociologists at the next meeting, to which he replied, “oh, we don’t need any more of those.” I invited more sociologists anyway. The purpose of the Meeting of 100 was to focus the research themes, which ultimately resulted in four Network Science Working Groups (NSWGs). The themes for the four NSWGs were organized somewhat hierarchically (Fig. 14.2): at the broadest scale was climate variability and climate change. Embedded in that was coupled natural-human systems, which encompassed altered biogeochemical cycles and altered biotic structure. These themes were considered to represent the existing strengths of the LTER Network and provided a sound foundation for initiating network-level science. What followed was a series

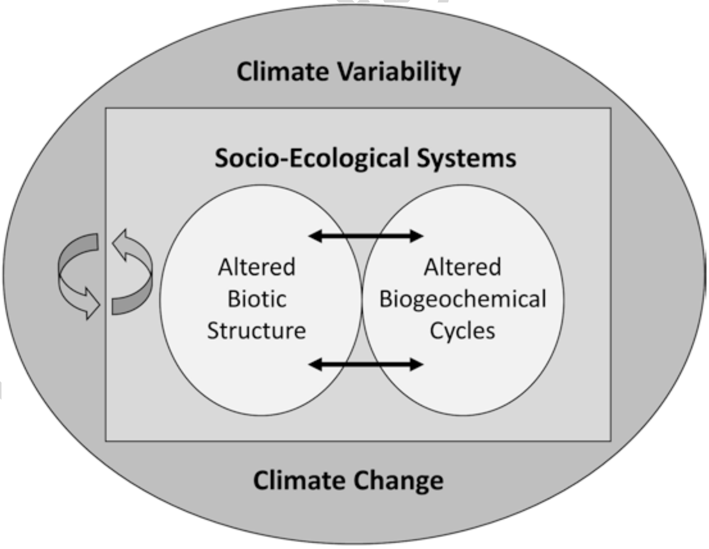

Fig. 14.2 A hierarchical schematic of the key strengths of the LTER Network research., which were the focus of four Network Science Working Groups. Altered biological structure and altered biogeochemical cycles were nested within social-ecological systems, all of which are affected by climate change. These research domains and their interactions are built around Environmental Grand Research Challenges (NRC 2001) and formed the basis of the expanded LTER Network research agenda

of meetings by Network Science Working Groups to fine tune their conceptual frameworks and research questions, and implementation plans. At the same time the Governance, Education and Outreach, and Cyberinfrastructure working groups also met to develop their ambitious plans for expanding the scale and scope of the LTER Network. Working Group meetings were often co-located to facilitate interaction and communication among all participants.

The input from Network Science Working Groups was then handed off to a Conference Committee, a smaller working group drawn from members of the NSWGs. It was the task of the Conference Committee to build the overarching scientific framework for network-level, integrated science based on the following premises. First, human activities are changing the abundance of key resources and other ecosystem drivers globally, such as elevated atmospheric CO_2, increased rates of nitrogen deposition, altered precipitation regimes and more extreme precipitation events, and sea level rise (Vitousek et al. 1997; Chapin et al. 2000). These changes can be classified as either *pulses* (e.g., discrete events, like wildfire) or *presses* (e.g., gradual increases in mean annual temperature) (e.g., Ives and Carpenter 2007; Smith et al. 2009). Many species traits (e.g., C_4 photosynthesis) result from evolutionary selection for scarce resources (e.g, atmospheric CO_2 concentrations, inorganic nitrogen) (Galloway et al. 2008; Edwards et al. 2010). Changes in resource availability or environmental drivers have significant consequences for species interactions, community structure and ecosystem functioning (Tilman et al. 2014; Komatsu et al. 2019; Clark et al. 2019). Moreover, human social systems are also spatially and temporally dynamic, and also respond to [and cause] pulse and press events (Grimm et al. 2017; Ripplinger et al. 2016). Social system drivers and dynamics (tax laws, regulations, preferences, behaviors) directly affect ecological processes (Millennium Ecosystem Assessment 2003; Carpenter et al. 2009; Larson et al. 2017), and changes in ecological processes have feedbacks that affect human social systems (Pace et al. 2015).

The conference committee determined that the overarching question for network-level science was, "How do changing climate, biogeochemical cycles, and biotic structure affect ecosystem services and dynamics with feedbacks to human behavior?" The infamous loop diagram (Fig. 14.3; Collins et al. 2011) was conceptualized to address this question, and to provide a common framework for site-based social-ecological research that could also facilitate cross-site integration. This loop diagram has four main components: biophysical systems and social systems that are linked explicitly via ecosystem services and press-pulse dynamics. Each of the major linkages is associated with a general question (see caption) that can be adapted for site based-applications.

The loop diagram had several important attributes for cross-site social-ecological research. This research agenda was designed to address *societally relevant* questions at regional and national scales. The process was *multivariate*. Cross-site research would expand beyond univariate-based understanding to study interactive effects of multiple stressors at multiple sites over long time frames and could identify commonalities in ecosystem and social system responses. The work was explicitly *interdisciplinary* and potentially *transdisciplinary*. Historically, people were

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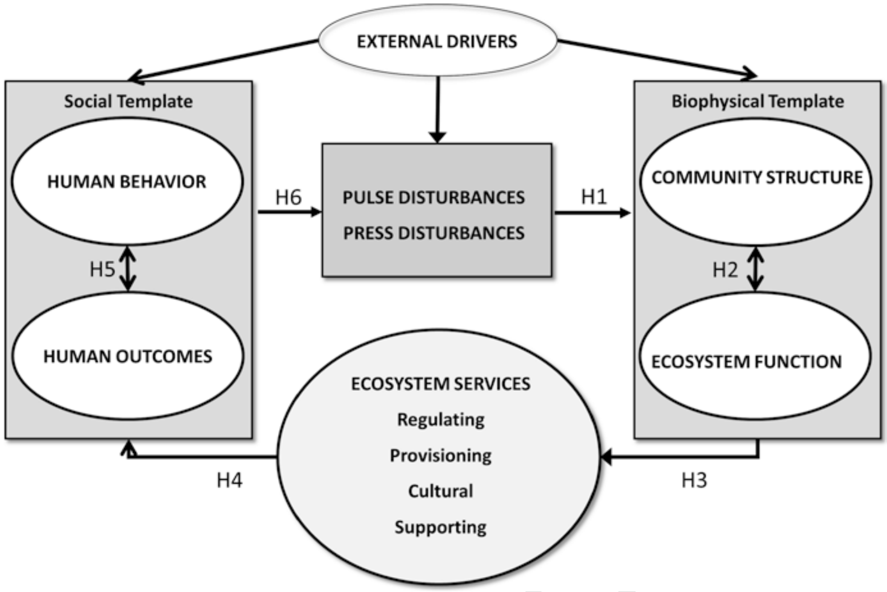

Fig. 14.3 The components of press-pulse dynamics that formed the basis for long-term, Network-level, social-ecological research. Each set of arrows in the diagram was associated with a generic hypothesis (H1-H6) that could be modified and applied to specific contexts. H1 – long-term press disturbances and short-term pulse disturbances interact to alter ecosystem structure and function; H2 – biotic structure is both a cause and a consequence of ecological fluxes of energy and matter; H3 – altered ecosystem dynamics negatively affect most ecosystem services; H4 – changes in vital ecosystem services alter human outcomes; H5 – changes in human outcomes, such as quality of life or perceptions, affect human behavior; H6 – predictable and unpredictable human behavioral responses influence the frequency, magnitude, or form of press and pulse disturbance regimes across ecosystems. (Modified from Collins et al. 2011)

typically viewed by ecologists as drivers of change, less frequently as response variables, but rarely as participatory actors as part of a research agenda, the goal of transdisciplinary science. The loop could be entered at any point, meaning projects could start with the social science drivers in some cases and the biophysical drivers in others. The conceptual framework facilitated research across sites and habitats. Multiple-site research would help to identify the most important underlying processes through a combination of observation, modeling and experimentation. The process would Integrate education and outreach. Social-ecological research is participatory and thus requires full participation by citizens, educators, and policymakers.

Throughout the planning process we were well aware that the new and expanded research agenda for the LTER Network was not going to come cheap. At the same time, we hoped to expand this research agenda well beyond LTER. Quite simply the LTER Network was asking for a lot more money for the LTER Network, which seemed far too self-serving. Requesting large sums of new money just for this new agenda was unlikely to gain much support from NSF Program Directors or the broader scientific community. As a consequence, we put together a funding initiative directed at NSF, Integrated Science for Society and the Environment (ISSE; Collins et al. 2007), to justify a substantial increase in research funds that would be distributed across at least three research Directorates and multiple programs (Fig. 14.4). Therefore, when we approached NSF with our new plan for network-level science, we would also provide a scientifically based justification for a funding initiative that would broadly benefit and further integrate the biophysical and social sciences.

14.4 Outcomes of the Planning Process

It is safe to say that not all LTER scientists were enthusiastic about the goals of the planning process. The members of the Science Task Force did their best to communicate plans and progress to NSF and the LTER Network along the way. One All Scientists Meeting (2006) was dedicated to the planning process, many site scientists were involved in working groups throughout the process, and we regularly reported on progress at annual Science Council meetings and to the LTER Executive Board. Nevertheless, a few PIs felt that an unwanted research agenda was being forced on them. Others argued that human impacts were not that important at their sites, so they were concerned they would be punished for not being more engaged in social-ecological research. Still others just wanted more money for what they were already doing, which was simply not going to happen. And yet most sites and PIs fully embraced the planning process and the organizing framework, incorporating the loop diagram into their renewal proposals, with various degrees of success.

The planning process ran from 2004 to 2007. A lot can happen within a funding agency over a 3 year time span. In fact, during this period, Dr. Mary Clutter, Assistant Director (AD) for Biological Sciences, retired. Dr. Clutter was a strong supporter of the LTER Network and considered LTER to be one of the flagship programs in the Directorate. Dr. Clutter had been the AD since 1988. She was replaced by a series of rotators, all of whom had different interests and priorities. The BIO Directorate at NSF has a history of insularity from the research community. Although BIO occasionally reached out to the community (i.e., regarding the need for the national center to promote ecological synthesis), unlike other Directorates, BIO rarely sought advice about potential research-oriented funding initiatives from the community of active research scientists. But with new leadership, we hoped that the culture within BIO might have changed, and that the new management would be receptive to the social-ecological integration inherent in ISSE.

We were wrong. There was considerable skepticism expressed about ISSE and the plans for an expanded research agenda for the LTER Network. Although we regularly briefed NSF management on our progress and goals throughout the

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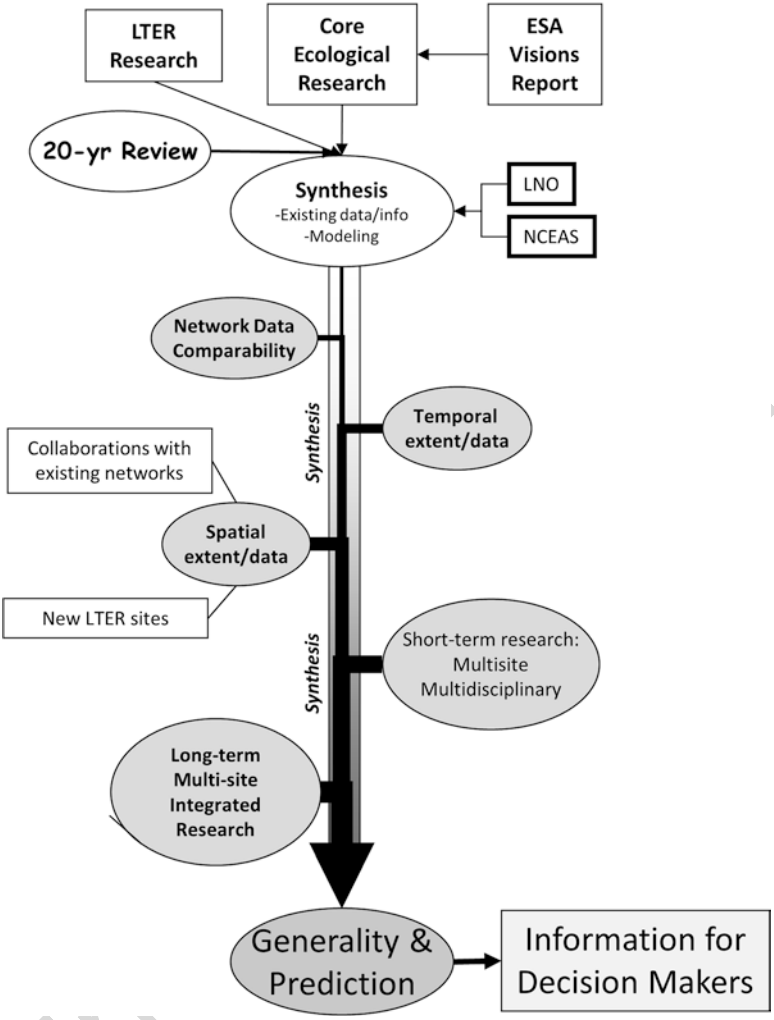

Fig. 14.4 Integrated Science for Society and the Environment (ISSE) was built around the premise that our ability to tackle challenging environmental problems and generate synthesis research over space, time, and disciplines is limited by impediments to data integration, the need for increased spatial coverage and additional long-term measurements, and coordinated, cross-disciplinary research which fully integrates social, geophysical, and ecological sciences. ISSE incorporated ideas from on-going LTER research programs, decadal reviews, and the Ecological Society of America's Visions Report (Palmer et al. 2004, 2005). Thus, ISSE recommended enhanced resources for existing as well as new funding opportunities for individual investigator and team-based long-term research, along with more resources for interdisciplinary research, more opportunities for synthesis of existing research, and a new network-scale, interdisciplinary, long-term research program for LTER. *LNO* LTER Network Office, *NCEAS* National Center for Ecological Analysis and Synthesis

planning process, they were, in fact, completely unprepared for our initiative. Instead, Directorate-level management claimed that they were expecting a "strategic plan" for LTER, not a new research agenda. There is no mention of a strategic plan in the proposal that funded the planning process. At no time during the planning process or during our meetings with BIO Directorate management did the notion of a strategic plan come up. Instead of discussing the merits of our proposed research initiative, we were told to go back to the drawing board and develop a strategic implementation plan (SIP) for LTER. SIPs are the formal structure used by, for example, Science and Technology Centers funded by NSF. They include timelines, goals, how and when funds will be allocated. It is inappropriate to call for a SIP when no funds have been appropriated, because quite simply it is impossible to strategically implement funds you do not have.

Nevertheless, the LTER Network leadership developed an unfunded SIP as requested, which directly resulted in next to nothing. Essentially, the Directorate was not interested in our initiative nor did they have any intention of expanding and enhancing LTER science. The strategic plan and SIP felt very much like a make work program while BIO management pursued other priorities, especially NEON. Not surprisingly, we received more favorable receptions in other Directorates at NSF (GEO, SBE), which were more open to community input than BIO was. We were also invited to present ISSE to staff at USDA, NASA and on the Hill, and to other research networks (e.g., Consortium of Universities for the Advancement of Hydrologic Science; International LTER) where the initiative was well-received.

Despite our reception by the BIO Directorate staff, there were certainly some successes that emerged from the planning process. The Governance Working Group (GWG), led by Dr. Ann Zimmerman from the University of Michigan, and John Magnuson (North Temperate Lakes LTER) provided one of the most enduring outcomes of the Planning Process. They noted that the management structure and organization of LTER at the time was inadequate regardless of the plan to expand to network level science. Many lead PIs were avoiding the annual Coordinating Committee meetings because there was very little meaningful action and science at those meetings. The GWG proposed a new structure in which an Executive Board (EB) would conduct the day-to-day business of the Network. It would be made up of representatives from one third of the sites (hopefully the lead PI) and each representative would serve a 3 year term. That way, all sites would have representation on the EB every 9 years or so, and all sites would contribute to Network governance. The Chair of the EB would be elected and could serve at most two consecutive 3 year terms, assuring regular changes in Network-level leadership. The Coordinating Committee of lead PIs would then become the Science Council (SC) and the annual Science Council Meetings would focus on science and synthesis. These recommendations from the GWG, among others, were quickly adopted and implemented by the LTER Network, and they definitely led to re-engagement of PIs in network-level management through the EB, and participation in Science Council meetings, which now have an explicit science theme for synthesis each year.

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The loop diagram was another success. The science behind it and the general framework, known as "press-pulse dynamics" or PPD was published in *Frontiers in Ecology and the Environment* (Collins et al. 2011). As of 1 April 2020, that paper has been cited 488 times according to Google Scholar. The framework has been widely referenced and incorporated into long-term social-ecological research programs, especially in Europe. I think that suggests that the intellectual contribution of the PPD was novel, important and useful. It would have provided a solid foundation for long-term, Network-level, integrated research. In that regard, I would also like to think that ISSE and the loop diagram provided some impetus to the US Forest Service in their efforts to establish Urban Long-term Research areas (ULTRAs), which required a strong integration of social and biophysical sciences. In addition to the *Frontiers* paper, we generated a second paper on the Hierarchical Response Framework (HRF), also built on press-pulse interactions that was published in *Ecology* (Smith et al. 2009) and as of 1 April 2020 has been cited 384 times. The HRF focuses on how global change presses, in particular, are driving long-term ecosystem dynamics, and how these presses can interact with pulse disturbances as a potential drivers of state changes in ecological systems (e.g., Ratajczak et al. 2017).

An important obligation of long-term research, in general, and the LTER Network specifically, is a secure and perpetual data management system that facilitates data discovery, re-use and synthesis. For decades NSF pushed LTER to not only manage the data that were being collected, but to make those data and the metadata that describe the data freely available, discoverable and usable by anyone within or outside the Network, ideally through a single data portal. At the time most LTER data were accessed through websites hosted by individual LTER sites, which was highly inefficient for drawing together disparate datasets for cross-site synthesis. The Planning Process ended as the country was entering the 2008 financial crisis. To jumpstart the economy and preserve jobs, Congress passed the American Recovery and Reinvestment Act (ARRA), which allocated $787 billion for increased spending on education, health care, infrastructure and the energy sector. As part of ARRA, NSF received a one-time infusion of $1 billion to fund "shovel ready" research projects. Because NSF forced the LTER Network to develop a very detailed SIP, including plans for an advanced information management system to support synthesis, the LTER Network Office was poised to receive ARRA funding through NSF. The LNO then submitted a proposal for ARRA funding to support the development of PASTA (Provenance Aware Synthesis Tracking Architecture). Essentially, PASTA is a "one stop shop" for uploading, managing and discovering LTER data and metadata. ARRA funds were also used to complete the LTER Network Information System Data Portal, which provides public access to all open LTER data sets in PASTA. So, the benefits of the planning process allowed the LTER Network to achieve one of its long-standing goals, the development and implementation of an advanced information management system to facilitate data management, access and synthesis.

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14.5 Lessons Learned

What are the lessons that were learned through the Planning Process and through our interactions with NSF? At the beginning of this chapter, I posed the question, “Despite some clear success stories, one might ask whether or not the benefits of the Planning Process were worth the costs in time and money? Although we did not achieve our highly ambitious over-arching goal of establishing a long-term, multi-site, social-ecological research program within the LTER Network, solid research, management and infrastructure outcomes emerged from the planning process. In retrospect it seems as though staff at NSF had no intention of following through on our agenda and I remain deeply disappointed in how the BIO Directorate management dealt with our plan. Perhaps we were both naïve and too ambitious, and we certainly irritated BIO management by proposing a broadly based funding initiative let alone an expanded LTER research agenda.

These factors were further complicated by changes in NSF staff from the Assistant Director down to the LTER Program Director, individuals with dramatically different priorities than those who were in place when we started the Planning Process. Despite these roadblocks, we did everything we said we would in the funded planning proposal. Of significance, we clearly demonstrated that we could conceptualize and potentially carry out network-level, interdisciplinary science, which continues to be an aspirational goal for LTER in addition to maintaining and strengthening site-based, long-term research. Social-ecological research remains a solid core activity at a number of LTER sites. As we enter the Anthropocene, more and more interdisciplinary science will be needed to understand the dynamics of ecosystems increasingly influenced by human activities and decision making. I think the planning process has demonstrated that the LTER Network is ready, willing and able to lead such an important, vital and forward-looking research agenda.

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