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Integrating Social Science into the Long-Term Ecological Research (LTER) Network: Social Dimensions of Ecological Change and Ecological Dimensions of Social Change

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Abstract

The integration of the social sciences into long-term ecological research is an urgent priority. To address this need, a group of social, earth, and life scientists associated with the National Science Foundation's (NSF) Long-Term Ecological Research (LTER) Network have articulated a conceptual framework for understanding the human dimensions of ecological change for the LTER Network. This framework explicitly advocates that what is often divided into "natural" and human systems be considered a single, complex social-ecological system (SES). In this paper, we propose a list of core social science research areas, concepts, and questions; identify the need for multiscale investigatory frameworks crucial for implementing integrated research; and suggest practical approaches for integration. In sum, this paper is a general outline for empirical and cross-site research projects where investigators agree that bringing together social, biological, and earth scientists can lead to synthetic approaches and a unified understanding of the mechanisms regulating SES. Although the motivation for this goal is specific to the LTER Network and similar projects, we believe that the issues and ideas presented here are widely applicable to other interdisciplinary SES studies.

Key words: Social-ecological systems; integration; interdisciplinary; long-term ecological research; Baltimore; Phoenix; LTER; multi-scale; urban ecology; social patterns and processes.

Introduction

In pursuit of a thorough, scientific understanding of the world around us, ecologists and social scientists have worked within their academic disciplines to develop a wide range of empirical studies, methods, and models to identify key drivers, processes, and controls that regulate human behavior and interactions with the environment. However, most researchers have pursued answers to fundamental questions about pattern and process in the ecological and human world from within the boundaries of one discipline or another, neglecting the relationships between ecological and social systems.

It is no longer tenable to study ecological and social systems in isolation from one another (Low and others 1999; Redman 1999a; Kinzig 2001; Gunderson and Holling 2002). Humans are an integral part of virtually all ecosystems (McDonnell and Pickett 1993; Vitousek and others 1997). Almost all human activity has potential relevance to global environments (NRC 1999), and biogeophysi-

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cal contexts strongly condition human decisions (Diamond 1997). Although it is not novel to recognize the interconnectedness of humans and the environment (Marsh 1864; Thomas 1956; Turner and others 1990), there is an urgent need to construct new approaches that emphasize an integrative framework equipped with comprehensive models, reinforcing methods, and complementary data (Michener and others 2001; van der Leeuw and Redman 2002). In 2002, the National Science Foundation (NSF) released its 20-year review of the Long-Term Ecological Research (LTER) program, which calls on LTER participants to collaborate with social scientists in a mutual effect to increase the understanding of the interrelationships and reciprocal impacts of natural ecosystems and human systems with the aim of better informing environmental policy (NSF 2002).

LTER-based research and education combine long-term analysis of site-specific ecological phenomena with general systems theory and cross-site comparisons across diverse ecosystems (NSF 2002), and LTER scientists have long fostered interdisciplinary collaborations. The first LTER projects were established in 1980; they now include over 1,100 scientists and students and 24 different projects located in diverse biomes. All LTER sites are dedicated to documenting, analyzing, and understanding ecological processes and patterns operating over long time scales and broad spatial scales. Since its inception in 1980, the LTER Network has promoted synthesis and comparative research across sites and ecosystems (Callahan 1984; Franklin and others 1990; NSF 2002).

Having made significant strides in integrating a variety of biological and physical approaches into their research, LTER scientists met in Madison, Wisconsin, in 1998 and voted to create a committee to examine ways to integrate social science into LTER investigations. Two years later, LTER scientists, along with their colleagues from other large interdisciplinary projects funded by the NSF, came together in Tempe, Arizona, and later at subsequent meetings and symposia to promote a broader discussion and receive input from within the LTER Network.

Through these gatherings, a consensus emerged concerning many aspects of integrated social-ecological systems (SES) research. For instance, a task force of ecologists had defined and implemented a core set of biogeophysical concepts to understand the long-term dynamics of ecosystems within the LTER Network (http://www.iternet.edu.research). We agreed that a core set of social patterns and processes analogous to the ecological core areas would aid greatly in integrating social science into LTER research. Although several social core areas were identified "a strong theoretical basis or research agenda for coupling natural and human systems across the LTER program to enhance an understanding of both" had not yet emerged (NSF 2002). However, the momentum was growing.

Building upon ideas generated at meetings, workshops, and symposia of ecologists and social scientists, we argue here that LTER scientists should give serious consideration to the following issues: social science research areas that are applicable to the LTER Network; the unique aspects of human perspectives and their role in social-ecological research; the need to develop multiscale investigatory frameworks for implementing of integrated research projects; innovative ways of linking the social and ecological domains; and practical approaches to cross-disciplinary integration. Consistent with the NSF's goals for LTER research, this paper serves as a general outline for the creation of empirical and cross-site research projects that would bring together social, biological, and earth scientists and lead to synthetic approaches and a unified understanding of the mechanisms regulating SES. Although the motivation for this work is specific to the LTER Network and similar projects, we believe that the issues and ideas presented here are widely applicable to other interdisciplinary SES studies.

Social Patterns and Processes: Proposed Core Areas for the Study of Social-Ecological Systems

A central goal for ecologists, especially those in the LTER Network, has been the development of a better understanding of the long-term dynamics of ecological systems. Although approaches, ecosystem types, and disciplinary expertise differ among sites, conceptual similarities override differences. In their common commitment to understanding long-term ecological dynamics, for example, most LTER have traditionally recognized two distinct classes of variables that drive ecosystems. The first and better-studied class includes ecological drivers, such as geologic setting, climate and its variation, patterns of primary productivity, hydrologic processes, and other biogeophysical factors. Investigating how these drivers interact with ecological processes to produce long-term dynamics has been at the heart of most LTER programs. The second, less-studied class of variables includes drivers directly associated with human activities, such as land-use change, the

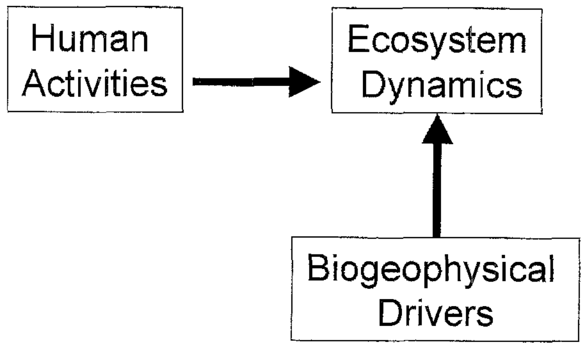

Figure 1. Traditional conceptual framework for ecosystem studies.

introduction of exotic species, and the use of resources (Russell 1993; Likens 1991). The simplified model in Figure 1 defines the intellectual arena within which most ecologists have worked to this point. Although it is effective in many respects, we find this approach incomplete.

This model is significant for including both ecological and social processes, yet it ignores important interactions and feedbacks that influence long-term ecosystem dynamics. For example, an activity such as land-use change, traditionally seen as a "human" driver, should be viewed as the result of more fundamental patterns and processes (Pickett 1993; Agarwal and others 2001; Lambin and others 2001). Because many of these missing feedback mechanisms relate to social sciences, contributions from these disciplines would greatly enhance our understanding of the overall dynamics of SES.

Although incorporating existing social science frameworks into the best of ecological theory is a good starting point, what is ultimately needed is a new integrative ecology that explicitly incorporates human decisions, cultural institutions, and economic systems (Grimm and others 2000; Michener and others 2001; Pickett and others 2001). An integrative ecology would draw from and combine ideas extant in the social science literature that have focused on a human–ecosystem framework, as practiced in sociology (Duncan 1961, 1964; Burch and DeLuca 1984; Field and Burch 1988; Machlis and others 1997) and anthropology (Vayda 1969; Watson and Watson 1969; Kottak 1999; Scoones 1999), as well as in ecology's patch-dynamics approach (Grove and Burch 1997; Pickett and others 1997; Wu and David 2002). The synthesis proposed here is, in essence, a combination of ecosystem and landscape approaches (Allen and Hoekstra 1992; Grove 1999). Authors of previous descriptions in the literature have used the term "human ecosystem" however, we prefer to use the term "social-ecological system," so as to emphasize the coequal interaction of the forces acting in these two domains. We build our view upon ideas contained in earlier works by Machlis and others (1997) and Burch and De Luca (1984). In this expanded view, what we call the SES is defined as:

1. a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;
2. a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;
3. a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and
4. a perpetually dynamic, complex system with continuous adaptation (Burch and DeLuca 1984; Machlis and others 1997).

Although the social system is integrated within the SES, researchers still need to recognize that the social system itself comprises:

1. social institutions: collective solutions to universal and particular social challenges;
2. social cycles; temporal patterns for allocating human activity; and
3. social order: cultural patterns for organizing interactions among people and groups (Burch and DeLuca 1984; Machlis and others 1997).

We must further acknowledge that the human component is complex and cannot be treated as an organism with consistent reactions to external stimuli. Humans (both as individuals and as groups) are self-aware, capable of learning quickly, able to convey meaning through the symbolic realm and to engage in extensive networks of rapid communication. Humans are also part of a larger political economy in which social inequality operates, natural resources are valued, individuals react to perceived risks, and institutions emerge to address persistent and novel problems. Understanding the contingent, contextual basis of human action is important, but we also need to work in a generalizing framework to advance our integrative goal.

An essential step in developing a powerful, integrated framework for the study of SES is to acknowledge that social and ecological systems share common properties, including resilience and complexity (Levin 1999; Gunderson and Holling 2002), that are linked through feedback relationships. For instance, social and ecological systems have varying structural complexities that change over time and

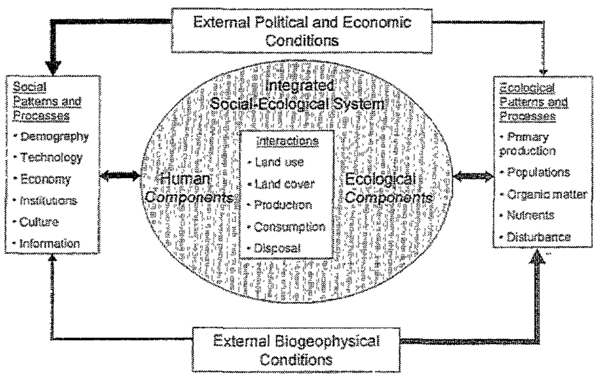

Figure 2. Conceptual framework for long-term investigations of social-ecological systems (SES).

space. Describing this social and ecological organization depends on understanding types and rates of change, scale(s) of phenomena, strengths of linkages, boundary conditions, and threshold values (Carpenter and others 1999). To advance our goal of integration, we have adopted some concepts from the Resilience Alliance, an international consortium of institutions that is attempting to forge an integrative approach to building adaptive capacity for sustainable futures (www.resalliance.org). By connecting theory development with regional case studies, the Alliance strives to provide novel solutions to managing resilience and coping with change, uncertainty, and surprise in complex SES. Starting from the complex, adaptive-systems approach exemplified by the Alliance, we propose an integrated framework that attempts to incorporate the range of interacting forces at any point in time and explicitly states that what is often divided into separate "natural" and human spheres be conceptualized as a single, complex SES (Figure 2).

Disciplinary training and traditional research design often treat elements of social and ecological systems as distinct entities although we recognize the pragmatic basis of these distinctions, we believe that, to promote interdisciplinary research and integrated interpretations, we must stress the linkages in the framework. To emphasize linkages, we focus on the *interactions* at the interface of the system's social and ecological components. We define these interactions as the specific activities that mediate between the social and ecological elements of the broader SES, including:

1. land-use decisions, especially those relating to the built environment;
2. changes in land cover, land surface, and biodiversity;
3. production systems;
4. consumption patterns; and
5. disposal networks.

Although these activities can take place on their own, they are strongly interdependent. We are sure that there are other points of articulation, but these activities are a good starting point for monitoring complex system interactions, because both ecologists and social scientists in our workshops and meetings have identified them as prominent and practical areas to monitor in LTER studies.

Once we have identified a set of specific interactions, the next step is to develop what we, and others, call *patterns and processes,* which define and act upon SES and the interactions that we choose to monitor. For conceptual convenience, we divide them into the following two categories: (a) those patterns and processes that primarily fit within traditional studies of ecology, and (b) those that fit within traditional studies of social sciences. We acknowledge the push and pull of social and ecological forces in each pattern and process but, as a first step, and to facilitate the application of this approach in the context of practical research, our framework separates the two forces.

The *ecological patterns and processes* include, but are not limited to, five general biogeophysical core areas (http://www.lternet.edu) that have guided LTER research since its inception:

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; and
5. patterns and frequency of site disturbances.

By broadly defining these ecological core areas and acknowledging that there are more elements that could be monitored, we think that most ecologists would agree that these areas describe the central biogeophysical processes that underlie any ecosystem.

To address the social realm, one approach would be to examine the human aspects of these five ecological patterns and processes. However, we propose a comparable list of broadly defined *social patterns and processes* (Figure 2) as a practical basis for integrating social, behavioral, and economic information into long-term ecological research. This list can be used to gain a better understanding of the long-term dynamics of SES and to serve, along with the ecological list, as a checklist to orient team collaborations. The proposed social patterns and processes include, but are not limited to:

1. demography: the growth, size, composition, distribution, and movement of human populations;
2. technological change: the accumulated store of cultural knowledge about how to adapt to, use, and act on the biophysical environment and its material resources to satisfy human needs and wants;
3. economic growth: the sets of institutional arrangements through which goods and services are produced and distributed;
4. political and social institutions: enduring sets of ideas about how to accomplish goals recognized as important in a society. For instance, most societies have some form of family, religious, economic, educational, health, and political institutions that characterize its way of life;
5. culture: culturally determined attitudes, beliefs, and values that purport to characterize aspects of collective reality, sentiments, and preferences of various groups at different scales, times, and places; and
6. knowledge and information exchange: the genetic and cultural communication of instructions, data, ideas, and so on.

This list takes as its starting point the National Research Council's (NRC) report on Global Environmental Change (NRC 1992), with one important change: We added *knowledge and information exchange,* in recognition of its great and growing importance in society (Berkes and Folke 1998). We expect that aspects of the last three proposed areas—institutions, culture, and knowledge—will be more difficult for our biologically trained colleagues to incorporate into their research; however, it is important to include these areas in SES research because all choices are not equally available but are conditioned by what we "know" and "value" (Ostrom 1999; Berkes and Folke 2002; van der Leeuw and Aschan-Leygonie unpublished). In fact, what we currently know and how we perceive the system constrain aspects of all core areas. Although we are interested in all of the features of these core areas, we are especially concerned with their influence on the accessibility and use of ecosystem goods and services (Costanza and others 1997), the maintenance of biodiversity and habitat quality (Dasgupta and others 2000), and the overall resilience of SES (Folke and others 2002). Another important consideration is the need to characterize the social core areas with explicit reference to scale, location, and history as we do the ecological core areas (Wilbanks and Kates 1999).

By distinguishing "external" biogeophysical, political, and economic conditions in the schematic framework shown in Figure 2, we are denoting that, in each case in which the framework is used, it is useful to separate factors that are closely and reciprocally related from those that may be important but act primarily in a single direction, as inputs to the system. For example, in most cases, microclimatic changes that relate to local land-cover changes are integral parts of SES (inside the oval in Figure 2), but global climate patterns or large-scale landforms are viewed as external conditions (inputs). This heuristic distinction allows us to set our approach in motion by focusing investigations on factors intimately related to system operation. We recognize that the allocation of factors to external versus internal realms will be specific to each application and may change over time or as more data are collected. Not only are the arrows from the external conditions to the patterns and processes one-way, they are drawn to indicate that political and economic conditions have a greater influence on social patterns and processes, whereas biogeophysical conditions have a greater influence on ecological patterns and processes. We recognize the danger of oversimplification; nevertheless, we are confident that proper ordering of dominant relationships will contribute to an efficient use of the approach.

Applying this SES framework to a research context involves data collection to illuminate the framework's three components (Figure 2):

1. collecting background information on "external" biogeophysical, political, and economic *conditions* that set the stage;
2. describing and monitoring changes in both ecological and social *patterns and processes* that drive the system; and
3. investigating the nature of and monitoring changes in the *interactions* resulting from the operation of the patterns and processes.

Human Perspective on Social-Ecological Systems

All research, whether on SES or other subjects, should respond to specific research questions, proceed from a fundamental understanding of the relevant disciplines, and recognize the human perspectives through which we view the research. Without undermining the scientific rigor of our approach, we, as responsible members of society, must also relate our scientific understanding of SES to societal concerns (Bazzaz and others 1998;

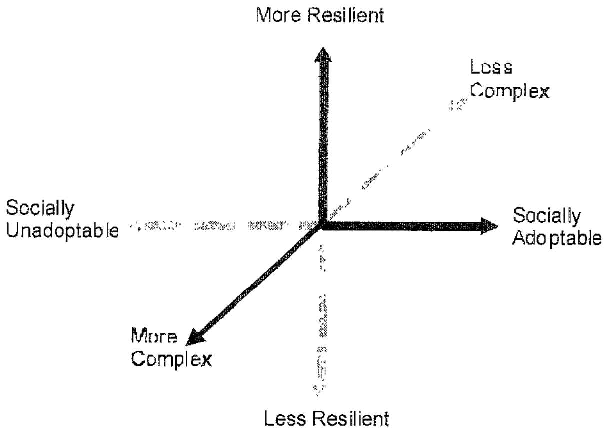

Figure 3. Parameters of social-ecological systems (SES).

Holling and others 2002). Figure 3 and the following discussion suggest an approach to evaluating the human perspective with respect to three fundamental parameters of ecosystem structure and function: resilience, complexity, and social acceptability.

Relative changes in an SES's resilience and complexity are fundamental to the system and to understanding the sustainability of that system (Gunderson and Holling 2002; Scheffer and others 2001). Change should be assumed to be neither continuous nor chaotic, but rather to occur in response to the interaction between fast and slow variables. These changes cannot be assumed to be linear and translate cleanly over space and time. For example, we conceptualize a more intricate and integrated cycle of land use within a SES that includes human land-use change affecting landscapes, altered landscapes affecting ecological processes, both affecting the ways in which humans monitor and respond to their surroundings, and human responses engendering further cycles of change (Grove and others 2002; Redman and others 2002).

From a human perspective, another fundamental parameter is the determination of whether the system is socially or, in the terms of Firey 1960 "socially adoptable." This difficult-to-measure variable is essential to many behaviors, from land-management decisions to attitudes in the scientific community, yet it is seldom examined or even recognized in ecosystem analysis. As scientists, we are directly concerned with how specific forces affect the complexity and resiliency of the system, but we must also seek to understand what interactions might lead the system to shift to a new sector within Figure 3 and accept the fact that some resource regimes will not be "valued by a given population in terms of their own system of activities" at a given place and a given time (Firey 1960). It is certainly possible for a highly resilient system to not be socially acceptable, and history has also shown us that some socially admirable societies did not prove to have long-term resilience (Redman 1999b). Our point here is that, given the pervasive influence of humans on SES behavior, a system can move among only four of the eight sectors of Figure 3 (those that are socially acceptable), even though biophysical factors would differentially allow systems to exist in the other four sectors. Application of this perspective to SES studies is further complicated by the reality that the human participants in the system may have varying views of system acceptability and differ in their ability to implement those viewpoints, depending on their relative power and access. Clearly, we need a better understanding of what governs these patterns over time and under differing circumstances. The following section describes how we might gain a further understanding of the changes that may affect the resiliency, complexity, SES resource activities, and social acceptability of SES over time.

Linking Patterns and Processes from Social and Ecological Core Areas

While we keep in mind the interrelations in Figure 2 and the parameters in Figure 3, the next step in linking patterns and processes from social and ecological core areas is to pose the following questions: How did the SES develop into its current state, how does it operate in the present, and how will it change in the future?

These questions focus on such fundamental aspects of the system as the nature of feedback linkages, rates of change, system components, and specifics of resource use and production. Four subsidiary questions allow us to narrow our inquiry:

1. How have past ecological systems and social patterns conditioned current options through legacies and boundary conditions?
2. How do current characteristics of ecological systems in the region under study influence the emerging social patterns and processes?
3. How do current social patterns and processes influence the use and management of ecological resources?
4. How have these interactions changed over time, and what does this mean for future possible states of the SES?

These subquestions will help to guide our inquiry toward the fundamental aspects of system history, composition, and operation. They also lead us to a perspective that not only includes humans as part of the system but acknowledges that humans are explicitly concerned with operating the system and its content at any point in time. It is key that one not approach the system, or these questions about the system, from two different perspectives, each reflecting disciplinary points of view. Rather, a synthetic approach that expands on traditional views must be negotiated. For most social scientists, this imperative will lead to an increased emphasis on the flows of energy, matter, and organisms in the system; for ecologists, information flow and decision making may take on greater relevance. For these reasons, we recommend that research designs include the five "interactions" at the center of Figure 2, rather than limiting their investigations to monitoring the two sets of "patterns and processes" at either side. As a synthetic approach emerges, the next step is to identify useful investigatory approaches and tools that can accommodate the complexity of SES.

A Focus on Multiscale Approaches

The physical, biological, and social sciences are all struggling with issues of organizational, temporal, and spatial scales, as well as trying to establish the best frameworks for collecting, analyzing, and interrelating data at multiple scales. These issues inform many elements of research, from sampling design, to data analysis, modeling, and interpretation of results. In a "human" sense, levels of organization can range from individuals to groups of increasingly large size until they encompass global networks. We must also be concerned with varying temporal scales, so that we can understand processes acting with great rapidity as well as those operating over long time spans. For example, social and ecological processes may share similar scales in some cases, as in decisions about a stand of trees; whereas these processes may occur across multiple scales in other cases, such as a forest fire that impacts the SES in diverse ways. Further, ecological and social processes may not operate at the same scale(s), and linkages may have to connect across scales, such as a river watershed that encompasses multiple property owners and political jurisdictions. It is possible that these types of cross-scale "mismatches" are responsible for many SES vulnerabilities that could lead to system breakdowns (Folke and others 2002). Finally, it is unknown whether theories that explain processes at one scale can be used to explain those at other scales; scaling up from small to large may not be a process of simple aggregation. Thus, fundamental research paradigms may need to be rethought, and substantial basic research may be required to provide the empirical framework for the research proposed here.

We will need to develop and refine a number of capabilities for a multiscale approach. These include the ability to determine how:

1. optimal scale(s) and resolution(s) for specific questions can be determined;
2. time lags, nonlinear relationships, and defining events affect the responses among social and ecological processes;
3. spatial characteristics of certain phenomena, such as shape, adjacency and matrix, affect social and ecological processes;
4. boundary or threshold conditions relative to space and time affect social and ecological processes;
5. large-scale data can be used to explain small-scale behavior and small-scale data can be used to explain processes at larger scales; and
6. data associated with one unit of analysis can be dis/aggregated to another unit, (for example, from census tracts to watersheds).

This multiscale approach requires new investigatory strategies and data protocols. For instance, it may be necessary to collect and analyze data at an "optimal" scale as well as at scales above and scales below. Hence, some analyses should proceed at the scale that appears to be most sensitive to the question being asked while additional data collecting is pursued to maintain the possibility that cross-scale interactions that might be key in driving the process will be discovered. In response to this challenge, several LTER have adopted a hierarchical patch-dynamic approach for modeling their sites (Wu and Levin 1994; Wu and Loucks 1995; Pickett and others 1997). As an example, landscape metrics, patch-scale dynamics, and whole-system parameters can be investigated in an effort to characterize the structure of the SES (Jenerette and Wu 2001). Although we expect many aspects of the SES to be connected in a hierarchical fashion, we must also recognize that processes and patterns may operate within different frameworks. The recognition of the complexity of investigating an SES demands a reformulation of research strategies and methods with the same concern for interdisciplinary integration and multiple perspectives that we call for in our conceptual approach. As multiscale techniques are further developed, we can use these new methods as practical tools to integrate data drawn from different disciplines.

PRACTICAL APPROACHES TO INTEGRATION

The general framework, core areas, and investigatory tools we have identified provide a focus for integration, but real-world success requires practical ways of encouraging scientists from distinct disciplines and with different perspectives to collaborate. Most scientists agree that interdisciplinary collaboration is essential to studying an SES effectively, yet our academic training and administrative barriers make that goal difficult to accomplish (van der Leeuw and Redman 2002). Hence, we must seek practical ways to lower the barriers.

Varying strategies, tools, and data-based approaches have already proven useful in bringing people together. For example, Geographic Information Systems (GIS) and even simple maps can be effective in promoting integrated thinking on social-ecological processes. Remotely sensed data can be integrated with this effort or used alone (NRC 1998). Such a focus on "place-based" research will build a common desire to understand a locality or landscape from as many perspectives as necessary, leading to a greater willingness to collaborate.

Similarly, simple models can be used as heuristic devices to articulate linkages, highlight diverse inputs, and test collaborative theories with data (Carpenter and others 1999). Modeling and graphic approaches are particularly important because of the need to work with multiple scales. Work at multiple scales, in turn, reinforces the need to consider the linkages among theoretical approaches at different scales and to examine the projected relationships among physical, biological, and social variables. Further, this approach requires that data be collected with complementary protocols in order to measure action-and-response relationships, as well as feedbacks among social and ecological processes.

There are several other conditions and methods that promote collaboration and integrated approaches. First, we have found in our research that historical analyses provide a conducive environment for researchers who focus on the functioning of contemporary systems to work together in understanding "why" and "how" social-ecological processes have operated to produce present-day patterns (van der Leeuw 1998; Pickett and others 1999; Foster and others 2002). The time spent in collaborating on background issues helps to build trust among researchers—an intangible but crucial and constructive element of integrated research. Second, programmatically defined core research areas, such as the two sets of patterns and processes (Figure 2) recommended for the LTER Network, provide a foundation for identifying and prioritizing research questions. To engage people from large and disparate programs, it may be necessary to begin with distinct projects and then reformulate the research strategy to include joint ventures as data accumulate and the benefits of collaborating to obtain the most effective solutions to the problems become apparent. Third, cross-site studies help us to share expertise and perspectives that can ultimately be applied to integrated research. Investigations that require the implementation of comparable strategies and protocols often guide the researcher toward issues of general significance that will stimulate the interest of scientists trained in social , life, or earth sciences (Redman and others 2002). Interestingly, comparative, generalizing investigations may also highlight the distinctive aspects and processes that characterize the individual sites.

CONCLUSION

In this paper, we have strived to identify the relevant core areas, concepts, and questions, while emphasizing the need for multiscale frameworks and practical approaches to incorporating social science into long-term ecological research. The path that we propose is consistent with the approach to long-term ecological research that NSF and LTER Network identified 20 years ago—an approach that is still valid today (Callahan 1984; Franklin and others 1990; NSF 2002). This approach:

1. addresses both societal concerns and scientific questions about processes that change over the long term;
2. compares results among many sites;
3. moves beyond inventories and description toward explanations and projections; and
4. promotes core areas that orient research toward hypothesis formulation, resolution, and theory building.

Interdisciplinary long-term studies of SES stand at a critical juncture. There is tremendous interest in their potential, yet real-world barriers continue to hinder progress toward their implementation. Based on previous meetings and workshops, we undertook a plan of action. The first step was to bring together social, biological, and earth scientists to formulate a framework and various strategies that would lead to a better understanding of the mechanisms underlying the operation of SES. Next, funding was obtained from the NSF's Biocomplexity in the Environment competition to conduct four focused workshops designed to encourage cross-site projects that integrate social science into long-term ecological research. Finally, as a result of these workshops, numerous initiatives were set in motion, one of which led to six LTER sites receiving funding for a project entitled "Agrarian Landscapes in Transition: A Cross-Scale Approach" (http://ces.asu.edu/agtrans). It is hoped that this and subsequent collaborations will serve as models for the integration of social scientific approaches into programs that have heretofore been conducted primarily according to the methodology of the life and earth sciences, programs and vice versa. It is further hoped that these collaborations will identify and promote practical approaches to integrative research.

In the preceding pages, we have reviewed the efforts of members of the LTER Network to infuse social scientific perspectives into their research agenda. These efforts, of course, are only part of the much larger task of forging an alliance among earth, life, and social scientists that would lead to a better understanding of the operation of the world around us and to insights that promote biodiversity, aid in the maintenance of ecosystem function, and enhance the quality of human life. Specific suggestions were made that we believe would accelerate this process. To wit, we identified a set of social patterns and processes for LTER scientists to pursue, described a suite of interactions on which both ecological and social researchers could focus their efforts, and presented a reconsideration of research strategies that would allow for multiscale and cross-scale data collection and analysis. The true value of these approaches will be measured by the quality and usefulness of the results of new empirical studies.

The scope of this challenge should not be underestimated. As new approaches and applications are developed, they must capture the interest of all the parties involved. The participating scientists must conclude that the integrative results are more complete, interesting, and useful than would be the case if they had remained within the boundaries of their own disciplines. We are confident that, through a refined focus on empirical and comparative studies, a broad-based interdisciplinary understanding of SES will ultimately emerge.

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