An Integrative Framework for Ecosystem Services Research and Education across the LTER Network

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I. Introduction

The study of Ecosystem Goods and Services is now an established goal for both the international scientific community and the LTER Network. Simply put, ecosystem goods and services are the benefits people obtain either directly or indirectly from functioning ecological systems. While this concept is easily grasped on the surface, it is no small task to put the idea into practice. Better understanding of ecosystem goods and services will require both increased knowledge and understanding of the complex ecological systems that deliver specific goods and services and fuller appreciation of the different ways that goods and services are valued by humans.

The study of ecosystem services has been recognized as a useful synthetic research concept for two fundamental reasons. First, it links human and ecological systems together in a viable theoretical framework that has been tried and tested within the international scientific peer community. Second, the concept is relatively easily understood by non-scientist collaborators who work with LTER sites, thereby allowing scientists to address concerns in the communities where they work.

The challenge is that ecosystem service analysis still remains relatively removed from everyday research practice at individual LTER sites and has not yet been effectively linked to network-level research agendas.

From April 27-29, 2005 an interdisciplinary team of scientists and collaborators representing five LTER sites (BES, CAP, CWT, FCE, KBS) met in Burlington, VT to develop a clear and concise strategic plan for integrating ecosystem service research within the LTER network. We designed the plan to (a) foster and promote the use of network-level synthesis science in developing greater understanding of the valuation and management of ecosystem services, and (b) explore how those services are currently being delivered by a range of ecological systems represented across the network. Our goal was to focus attention on the topic of ecosystem services and begin the process of laying out a common, integrative framework for ecosystem service research that could generate research proposals as well as enthusiasm and excitement within the LTER community of scientists.

This document represents a strategic roadmap for carrying out ecosystem service analysis in the LTER network. First, we present for consideration a new framework for Ecosystem Service Assessment and Research. Second, we discuss potential modifications to network-level organizational structure to actively support ecosystem service research. Third, we develop a brief case study showing how ecosystem services research might look, on the ground, for the Florida Coastal Everglades. In so doing, the document helps satisfy LTER planning goals for advancing synthesis research and education.

II. Ecosystem Service Assessment and Research Framework

There is no one single category that captures the diversity of what a fully functioning ecological system provides to humans. Rather, researchers in the field now recognize that ecosystem services occur at multiple scales and can affect people in very different ways--from climate regulation and carbon sequestration at the global scale, to water supply at the regional scale, to soil formation and timber provision at the local scale. At the same time, the widespread adoption of the ecosystem service concept is also due to its clarity and simplicity—it is something that an international audience of experts and laypersons alike can understand and relate to. The Millennium Ecosystem Assessment Conceptual Framework (2003) provides a useful way of grouping ecosystem services into four basic categories based on their functional characteristics:

1. *Regulating Services*: ecosystems regulate essential ecological processes and life support systems through bio-geochemical cycles and other biospheric processes. These include things like climate regulation, disturbance moderation and waste treatment.
2. *Provisioning Services:* ecosystems supply a large variety of ecosystem goods and other services for human consumption, ranging from food and raw materials to energy resources and genetic material.
3. *Cultural Services:* ecosystems provide an essential 'reference function' and contribute to the maintenance of human health and well being by providing spiritual fulfillment, historic integrity, recreation and aesthetics.
4. *Supporting Services:* ecosystems provide a range of services that are necessary for the production of the other three service categories. These include nutrient cycling, soil formation and soil retention.

In the same manner, not all strategies for assessing ecosystem goods and services will be equally adapted to answer the research questions that we inevitably want to ask. To help make sense of this, we have turned to a well known ski-slope typology—the green circle, blue square, black diamond—that tells any international ski adventurer, wherever they are in the world, what level of difficulty he or she is about to face when approaching new terrain:

Level 1

Level 2

Level 3

When approaching the new terrain of assessing and evaluating ecosystem services, an interdisciplinary team of LTER scientists will inevitably encounter a complex array of different theories, methods and approaches from *both* the biophysical and socioeconomic sciences that must be sorted out to succeed. As the science of ecosystem service evaluation is still evolving, there are many approaches that can be used and no one way can yet be said to be the 'right way'.

To promote greater integration and collaboration, we propose the following framework to help newly formed interdisciplinary teams within the LTER network begin to make sense of the different options that are available to them when they seek to evaluate ecosystem goods and services at individual sites and across the network. While the list is certainly not exhaustive, it does give the reader a broad sense of the increasing levels of difficulty and associated levels of investment that will be needed to increase knowledge and understanding of both the complex ecological systems that deliver goods and services and the different ways that goods and services are valued by humans.

LTER Ecosystem Service Assessment and Research

Level 1 Analysis

- Relies on data sources collected for purposes other than the evaluation of ecosystem services at a specific LTER site
- Relies on short-term site level input of expertise both external and internal to each LTER site
- Likely to be broad scale and shorter-term (e.g., snapshot inventories generated by an interdisciplinary team).

Potential Types of Products

- Rapid ecosystem service Inventory
- Economic values for ecosystem services drawn from existing economic literature
- Identification of broad linkages and trajectories among ecosystem services and underlying biogepophysical conditions
- One-shot educational and public relations materials

Level 2 Analysis

- Relies on both secondary data sources and limited primary data acquisition
- Uses 'off-the-shelf' models to partially customize findings, notably valuation results (e.g., using "benefit functions" or meta-models)
- Likely to be medium-term (e.g., PhD student or post-doc research projects)

Potential Types of Products

- Conduct quantitative meta analysis of pre-existing valuation studies
- Create a new LTER Network ecosystem services database

- Estimate generalizable economic valuation functions for ecosystem services that might be transferred across sites
- Initiate semester or year-long research projects for students

Level 3 Analysis

- Relies on primary data acquisition
- Long standing collaborative relationships and co-learning between interdisciplinary teams within and across sites
- Entails collaborative design of bioeconomic models of ecosystem function, services & nodes of human intervention
- Likely to focus on long-term results (e.g., multiple assessments over time)

Potential Types of Products

- Primary non-market valuation analyses
- New dynamic ecological-economic models
- New market mechanisms (e.g., payment for environmental services schemes)
- Design ecosystem service delivery targets in policy and decision making
- Establish long-term educational monitoring projects

III. Case Study: the Florida Coastal Site (FCE) LTER

We describe next the results of a collaborative, interdisciplinary 'thought experiment' in which our team sketched out an ecosystem service assessment as it might be applied to a participating LTER site, using the approaches described above.

Site background

The Florida Coastal Everglades LTER Program (FCE) is investigating how changes in freshwater flow affect estuarine ecotone productivity. The FCE program is encompassed by Everglades National Park. This entire landscape is oligotrophic, and the limiting nutrient—phosphorus—is supplied by the ocean rather than by upstream runoff. Restoration of the Everglades is anticipated to transform this wetland landscape from an "altered system" to a "designed system". Everglades Restoration will increase freshwater flow over the next several decades. The problem is in defining what is "in balance" because estuarine dynamics will be driven by freshwater increase as well as by sea level rise and the natural disturbance regime in southern Florida.

As the human population in south Florida continues to grow, the reliable supply of clean and reasonably priced fresh water is becoming increasingly important. At present, the shallow Biscayne aquifer provides water to roughly 95% of the 6 million people in south Florida. This aquifer is largely recharged by the Everglades. Risks to the Everglades and uncertainty about the outcome of its restoration—or rehabilitation—thus directly translate into future risks to south Florida's water supply and its economic sustainability.

Critical Ecosystem Services at FCE

The interdisciplinary team was able to rapidly identify the following ecosystem services that would form the basis for an ecosystem service assessment at the FCE site.

Supporting Services
- Water Supply
- Water Regulation

Regulating Services
- Disturbance Mitigation--Flood Control, Fire Control, & Hurricane Surge
- Soil Loss/Soil Retention
- Invasive species control
- Habitat Refugium
  - Tree Islands
  - White Stork
- Nutrient Regulation
- Climate and Gas Regulation
  - Regional Precipitation

Cultural Services
- Aesthetics
- Recreation (tourism, Recreation Fishing).
- Spiritual

Provisioning Services
- Food
- Fish
- Consumptive Use of Fresh Water

The key ecosystem service of interest in the FCE case is *water supply*. Because the Everglades is a large wetland system immediately adjacent to human populations, *water regulation* (i.e. flood protection) is a secondary service. Excessive extraction of fresh water by the growing human population risks the provision of this water by the Everglades, as extraction threatens to dry up the system and encourages saltwater intrusion into the Biscayne aquifer. The Everglades is an extensive landscape and provides important *climate and gas regulation* services. Coastal mangroves provide the important secondary service of *disturbance regulation* by ameliorating the effects of hurricanes on coastal communities while also enhancing fisheries services by providing habitat for fish and shellfish. The unassuming natural beauty and rich cultural history of the Everglades are associated with several secondary ecosystem services, including *aesthetics*, *recreation*, and *spiritual* services.

Because Everglades wetlands are naturally oligotrophic, they are largely incapable of providing *waste assimilation* services. In fact, waste assimilation services are highly risky, since any attempts to increase these services could endanger the system itself and other services. Attempts to increase the *food* or *raw materials* services would require further conversion of wetlands for human uses, which would diminish other services. From a decision-making perspective,

there are clearly tradeoffs between the different types of services that will be provided by a functioning Everglades system.

Ecosystem Service Assessment at FCE

Using this list of ecosystem services as a baseline, the team then applied the proposed typology for ecosystem service assessment and research to the FCE site. Our goal was to generate a list of data needs and potential methods for research that could realistically be applied to studying the state of the identified ecosystem services at the site.

Faced with the challenge of conducting ecosystem service analysis at a new site, the team decided to break the problem down into three synergistic tasks each one dealing with a complimentary aspect of ecosystem service analysis: valuation, decision making and biogeophysical processes. Below, we present for each task, the list of data to be used in analyses at each level, from Level 1 to Level 3, depending on the availability of time and resources and on the level of acceptable error for the assessment. At each level, the data listed would be integrated across task groups to provide increasingly complex measures of the state of ecosystem services and to model increasingly complex scenarios of future change in service delivery.

FCE Valuation Assessment

Level 1 Analysis

1. Find existing environmental valuation studies that have been done in the Everglades on specific ecosystem services of interest.
2. Locate and collect valuation studies that have been done elsewhere in similar ecosystems for benefit transfer
3. Collect existing market data for home and land sales and transactions
4. Collect existing tax data: “Everglades Restoration Fee”

Level 2 Analysis

1. Conduct a limited set of one-time primary valuation studies within the FCE ecosystem
2. Identify empirical valuation functions that have been estimated in the economic literature and employ them in a value function transfer with supplemental socioeconomic data collected in the decision making assessment
3. Create and implement a strategy for collecting long-term restoration expenditure data for the Everglades restoration program

Level 3 Analysis

1. Conduct extensive long-term primary valuation studies focused on marginal changes within the FCE ecosystem
2. Experiment with new markets for ecosystem services like water supply

3. Develop dynamic integrated ecological-economic models for the FCE system

FCE Decision Making Assessment

Level 1 Analysis

1. Stakeholder analysis to Identify which government agencies, private interests, NGOs, and community groups use and regulate different ecosystem services
2. Examine existing laws and regulations for communities that affect or are affected by, the Everglades system

Level 2 Analysis

1. Characterize existing decision-making interactions among different types of organizations and stakeholders
2. Characterize tools and strategies used by different organizations and stakeholders, including zoning, permits, and so on (restrictive and incentive-based)
3. Conduct network analysis of interactions and power relationships among organizations and stakeholders

Level 3 Analysis

1. Characterize decision-making feedbacks between organizations and changes in ecosystem services.
2. Develop historic, current and future scenario models of feedbacks between organizations, stakeholders and ecosystem services.
3. Identify synergisms and vulnerability interactions in the decision-making / ecosystem service environment
4. Design new policy incentives to induce improved ecosystem stewardship.

FCE Biogeophysical Assessment

Level 1 Analysis

Conduct correlative analyses using data already collected by FCE LTER:

1. Geohydrology data and water budgets
2. Soil transmissivity
3. Core vegetation data
4. Wildlife populations
5. Fishery populations
6. Topography
7. Groundwater table levels
8. Meteorology data
9. Human demographic data

 **Level 2 Analysis**

1. Measure vegetation-wildlife community interactions within the Everglades system
2. Model interactions and future change scenarios (e.g. wildlife populations changes with altered vegetation structure)
3. Model dynamic landscape changes over time

 **Level 3 Analysis**

1. Analyze complex structure and function relationships
2. Dynamically model complex scenarios (e.g. changing structure-function relationships over time)
3. Gather disturbance/natural hazard data and integrate with other models

IV. Potential Modification of LTER Organizational Structure to address Ecosystem Services

Currently, the LTER network does not have an organizational structure that explicitly supports ecosystem services research within or across individual sites at any level of analysis. This is problematic because without institutional support, we do not believe that the concept alone, while compelling, will be enough to carry the drive forward to achieve the scientific innovations that are now possible.

While the ecosystem service concept has been embraced enthusiastically by the LTER scientific community, we believe that a few small organizational changes within the network itself would yield significant marginal benefits by fostering and promoting the future study of ecosystem goods and services within the network.

Specific ideas generated by the working group for implementation within the LTER network include:

1. **Establish a new "Ecosystem Services Ad Hoc Committee" to:**
    a. Provide research consistency across sites
    b. Provide Local LTER teams with mentoring and support
    c. Facilitate network-level research efforts
    d. Develop incentives to promote innovative research on ecosystem services across the network

2. **Encourage cross-site Teaching and Education**
    a. Create a standing "virtual community" focused on ecosystem service research using broad band internet technology and the LTER network web site

b. Facilitate cross-site collaborative course(s) at research institutions associated with the network. Such courses would be focused on ecosystem service assessment and analysis.
c. Establish new Research Assistantships focused on ecosystem services research—undergraduate and graduate
d. Establish new Postdoc positions at individual sites

IV. Summary

The LTER network is now well positioned to take a leadership role in the study of Ecosystem Services. The challenge is to take the concept from theory and translate it into everyday practice. To aid in this process, we have presented a strategic roadmap for carrying out ecosystem service analysis that could readily be implemented within the current structure of the LTER system. Viewed in this light, the concept of ecosystem goods and services offers a compelling foundation for network scientists to foster cutting edge synthesis science between participating sites and the interdisciplinary teams who operate within and beyond the network. We envision that the concept of ecosystem goods and services will provide a common foundation from which several synthetic and collaborative research projects might emerge. Our own effort, contained in this document, has revealed that both physical and social scientists can work together to develop ecosystem service related research projects that could support and sustain the synthesis research vision now being championed within the network.

Sources Cited:

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