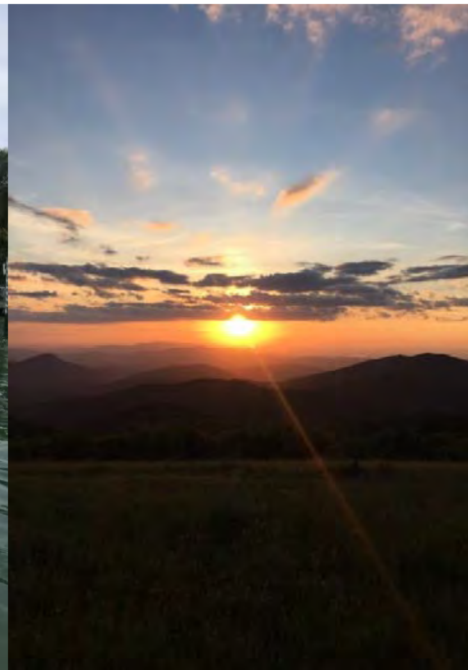
EPA
United States
Environmental Protection Agency

EPA/600/R-18/189
June 2018
http://www.epa.gov/si


FY 16 Output SHC 2.61 Ecosystem Goods and Services Production and Benefit Functions Case Studies Report

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS RESEARCH LABORATORY
GULF ECOLOGY DIVISION

Project Overview

Background

In the complex arena of sustainability, where the costs of failure can be high and stakeholders have multiple and sometimes conflicting interests, communities need measurement tools to characterize their current state, develop meaningful goals and quantifiable objectives for the future, understand the consequences of alternative investment strategies, track their progress, and confirm that their investments are yielding the intended results. The Sustainable and Healthy Communities (SHC) Research Program outlines the U.S. Environmental Protection Agency's (EPA) Office of Research and Development's (ORD) role in achieving U.S. EPA's objectives for cleaning up communities, making a visible difference in communities, and working toward a sustainable future. It was developed with considerable input and support from partners within U.S. EPA Program and Regional offices, as well as from outside stakeholders such as community leaders, other federal agencies, nonprofit organizations, and colleagues across the scientific community. It includes research and development to generate and provide access to environmental science on health, well-being, and the environment, and to place that science in the context of the critical decisions facing communities (Figure 1). Ecosystem services research under ORD's SHC Research Program addresses: (1) how to estimate current production of ecosystem goods and services, given the type and condition of ecosystems; (2) how ecosystem services contribute to human health and well-being; and (3) how the production and benefits of these ecosystem services may be reduced or augmented under various decision scenarios and in response to regional conditions.

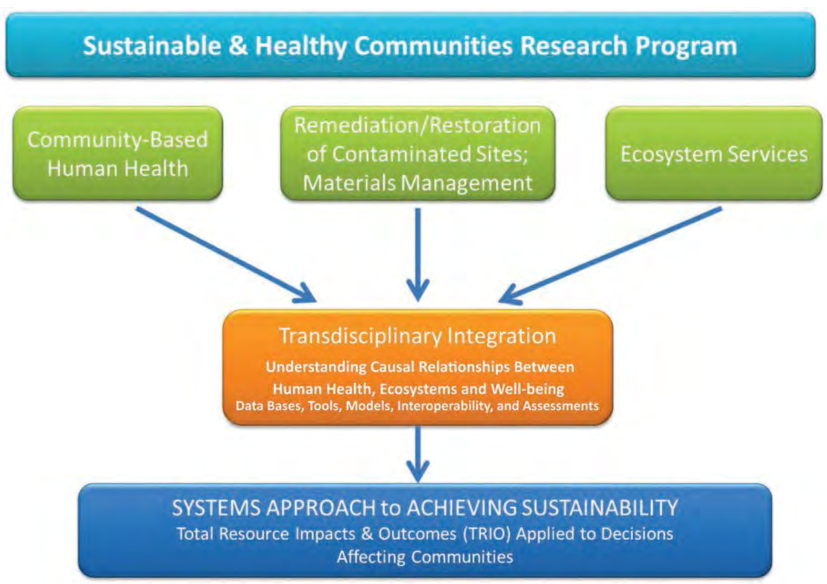


Figure 1 – The SHC research and development program conceptual model (Plan Years 2016-2019). U.S. EPA (2015).

Research and development conducted under the Sustainable and Healthy Communities Research Program is intended to inform and empower decision-makers to equitably weigh and integrate human health, socio-economic, environmental, and ecological factors to foster sustainability in the built and natural environments. The primary focus of SHC is on developing tools and approaches to help local decision-makers understand the effects of alternative policies and actions on sustainability. The SHC Project 2.61 Community- Based Final Ecosystem Goods and Services uses scientific knowledge of ecosystem services, economics, and human health to promote community well-being and maintain or restore high environmental quality. Research in SHC 2.61 focuses on: 1) the specification, classification, measurement, and modeling of final ecosystem goods and services (FEGS; those ecosystem goods and services that people directly use, enjoy, or otherwise benefit from; Boyd and Banzhaf 2007); 2) linkages of delivery of FEGS to beneficiaries within communities (including to members of vulnerable populations); 3) measurement of the benefits of FEGS with particular attention to human health and well-being endpoints; 4) examination of the effects of stressors on the production and delivery of FEGS; and 5) linkages of this research to EnviroAtlas and other decision support tools. The SHC Project 2.61 involves the development and integration of these research elements, in part, through the utilization of coordinated case studies for conducting research to help inform communities about making decisions with sustainable outcomes, and assess the transferability of FEGS-based decision support tools to other locations.

Project Goals and Research

The overall structure for the SHC 2.61 Project is outlined in Figure 2. Practical applications of incorporating ecosystem services science into community sustainability activities requires an evaluation of the decision context for that particular activity. Clarifying the decision context is critical to bring focus to a problem and define the scope of information that will be needed. Establishing ecosystem services concepts within a decision context is thus a crucial step that helps both scientists and stakeholders to identify and prioritize the information necessary to support decision making. Examples of community issues for which ecosystem services assessments were performed include watershed management, climate resiliency, development of resource sustainability plans, water quality regulation, and land use-development.

Outlining the Decision Context Helps

- Frame the problem
- Bring clarity to the scope and bounds of decision making capabilities
- Prioritize information needs
- Focus on, and more effectively evaluate, the most relevant potential tradeoffs

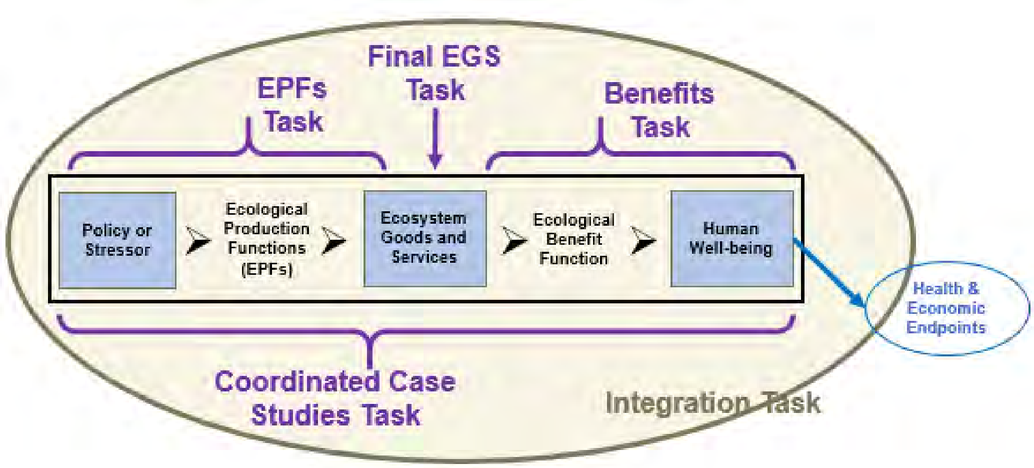


Figure 2 – SHC 2.61 Project Structure showing integration of ecosystem services related research across the Project.

The structure of SHC 2.61 (Figure 2) allows for the decision context to be articulated at multiple parts of the process, whether setting the stage for characterizing the actions/decisions, shaping the types of beneficiaries, and thus the relevant final ecosystem goods and services metrics to be studied, or understanding the human health and well-being endpoints that ecosystem services assessments can help inform at a given case study location.

Research activities across five Tasks in SHC 2.61 have been completed to accomplish the goals related to the FY 16 Output for this Project:

SHC 2.61 Community-Based Final Ecosystem Goods and Services Tasks

2.61.1 Integration, Synthesis and Strategic Communication

2.61.2 Final Ecosystem Goods and Services

2.61.3 Ecological Production Functions for Quantifying Final Ecosystem Goods and Services

2.61.4 National and Community Benefits of Final Ecosystem Goods and Services

2.61.5 Coordinated Case Studies

2.61.1 Integration, Synthesis and Strategic Communication (Matthew Harwell NHEERL/GED)

The scope of the **Integration, Synthesis, and Strategic Communication (ISSC) Task** includes the facilitation, internal coordination, and external dissemination of results of original research that utilize connections between community decisions, stressors, production functions, FEGS, and benefits.

2.61.2 Final Ecosystem Goods and Services (Paul Ringold NHEERL/WED)

Final ecosystem goods and services, or FEGS, are aspects of ecosystems that directly affect human well-being. The scope of the **Final Ecosystem Goods and Services (FEGS) Task** includes: identification of metrics and indicators of FEGS for multiple environmental classes and individual communities; identification of a FEGS approach that supports a complete national FEGS system; and the development and testing of methods for transferring metrics and indicators of FEGS among places and ecosystems.

2.61.3 Ecological Production Functions for Quantifying Final Ecosystem Goods and Services (Randall Bruins, retired NERL/SED)

Ecological production functions, or EPFs, are mathematical representations (i.e., models) of the production of ecosystem goods and services. The scope of the **Ecological Production Functions for Quantifying Final Ecosystem Goods and Services (EPF) Task** is to: develop approaches and tools for helping communities find or develop the ecological production functions (and associated data) needed to inform their decisions; provide an overview of existing and needed EPFs; and further develop, adapt, and utilize an existing online EcoService Models Library to address the needs of Coordinated Case Studies and other aspects of the Project.

2.61.4 National and Community Benefits of Final Ecosystem Goods and Services (John M. Johnston NERL/CED)

The scope of the **National and Community Benefits of Final Ecosystem Goods and Services (Benefits) Task** focuses on how the benefits of FEGS are delivered to different populations through: supporting primary and secondary benefits studies involving community-based preferences and values for natural resources; identification of opportunities in the Coordinated Case Studies Task to conduct quantitative modeling of FEGS and their benefits to human health outcomes; and providing a beneficiary perspective on advancing Eco-Health relationships.

2.61.5 Coordinated Case Studies (Richard Fulford NHEERL/GED)

The scope of the **Coordinated Case Studies (CCS) Task** is to develop approaches and test the utility of FEGS concepts within community-level structured decision making. This will be done through a national coordinated study designed to address how transferable a FEGS approach to decision support is across different water resources and climate change related issues and different community types. The work is conducted across a series of community-based case studies sharing several common elements: a set of methods to identify decision contexts, metrics, and indicators of FEGS for relevant beneficiaries; models to estimate production of those FEGS, including the impacts of stressors; and resulting benefits to human health and well-being. This task also tests the utility of decision support tools for facilitating these methods across community types and decision contexts. The five case study locations are San Juan, Puerto Rico, Great Lakes Region, Coastal Gulf of Mexico, Pacific Northwest, and Southern Plains Watersheds.

Output Description

This SHC 2.61.1 Output report (*Ecosystems Goods and Services Production and Benefit Functions Case Studies Report*) describes the U.S. EPA's Office of Research and Development's (ORD) research to incorporate the sustainability of final ecosystem goods and services (FEGS) production and benefits into community-scale decision making at several study sites around the U.S. This Output report discusses research in this Project that demonstrates the importance of articulating the decision contexts, the utility of decision support tools, the types of ecosystem service metrics examined, the types of ecological modeling of FEGS production examined, human benefits endpoints and estimation, and the utilization of these suites of tools and approaches by communities. This report summarizes how community-based studies have previously utilized ecosystem services to inform aspects of their decision making, to identify best practices that may be transferred to other communities, and to identify gaps in those practices that need to be addressed. This report builds upon a SHC 2.61.5 Coordinated Case Studies Task FY 16 Product (*Lessons Learned in Applying Ecosystem Goods and Services to Community Decision Making*) and other deliverables in SHC 2.61 covering work through FY 16.

Agency Relevance

This Output report, and the SHC 2.61 research upon which it is based, was developed for U.S. EPA Regional Offices (Table 1), Office of Water, Office of Air and Radiation, and the Office of Land and Emergency Management to support their efforts to help communities across the U.S. develop sustainable practices for their environments, economies, and the well-being of their citizens. Other notable U.S. EPA Program Offices that have significant interest/roles in ecosystem services research include the Office of Policy, Center for Environmental Economics, Office of Sustainable Communities, Office of International and Tribal Affairs, and the Office of Enforcement and Compliance Assurance. Additionally, this report is intended to inform colleagues involved with ecosystem services science within the U.S. EPA Office of Research and Development.

Table 1. Locations of SHC 2.61 ecosystem service studies cited in this report across the U.S. EPA Regional offices.

	Lessons Learned Report (2016)	Cooter et al. (2017)	Bruins et al. (2016)	Jewhurst and Mazzotta (2016)	Fulford et al. (2015)	Bradley et al. (2016)	Angradi et al. (2015)	Fulford et al. (2016)	Lewis et al. (2016)	Superfund (2017)
Region 1	✓				✓					
Region 2	✓	✓		✓	✓	✓				
Region 3	✓	✓			✓					
Region 4	✓	✓			✓			✓	✓	
Region 5	✓	✓			✓		✓			
Region 6	✓	✓			✓			✓		
Region 7	✓	✓								
Region 8		✓								
Region 9					✓	**relevant**				
Region 10	✓				✓					
National Relevance	✓	✓	✓	✓				✓		✓

Conceptual Framework

The conceptual framework for SHC 2.61 focuses on the process of informing decision making through the use of ecological production functions (EPFs), final ecosystem goods and services (FEGS), and indicators of human health and well-being. The elements of the proposed conceptual model shown in Figure 3 (e.g., stakeholder engagement/decision context, FEGS, EPFs, and measures of benefit) represent efforts to support community-level decision making incorporating quantitative information on the production and benefits of ecosystem goods and services. This conceptual model identifies critical linkages among the respective elements that brings about a novel integration of science and policy to yield highly effective measures of decision outcomes. Place-based studies provide an opportunity to explore the application of this conceptual model. The key science produced in SHC 2.61 in FY 16, and summarized in this report, are mapped onto the elements of the conceptual model in Figure 3.

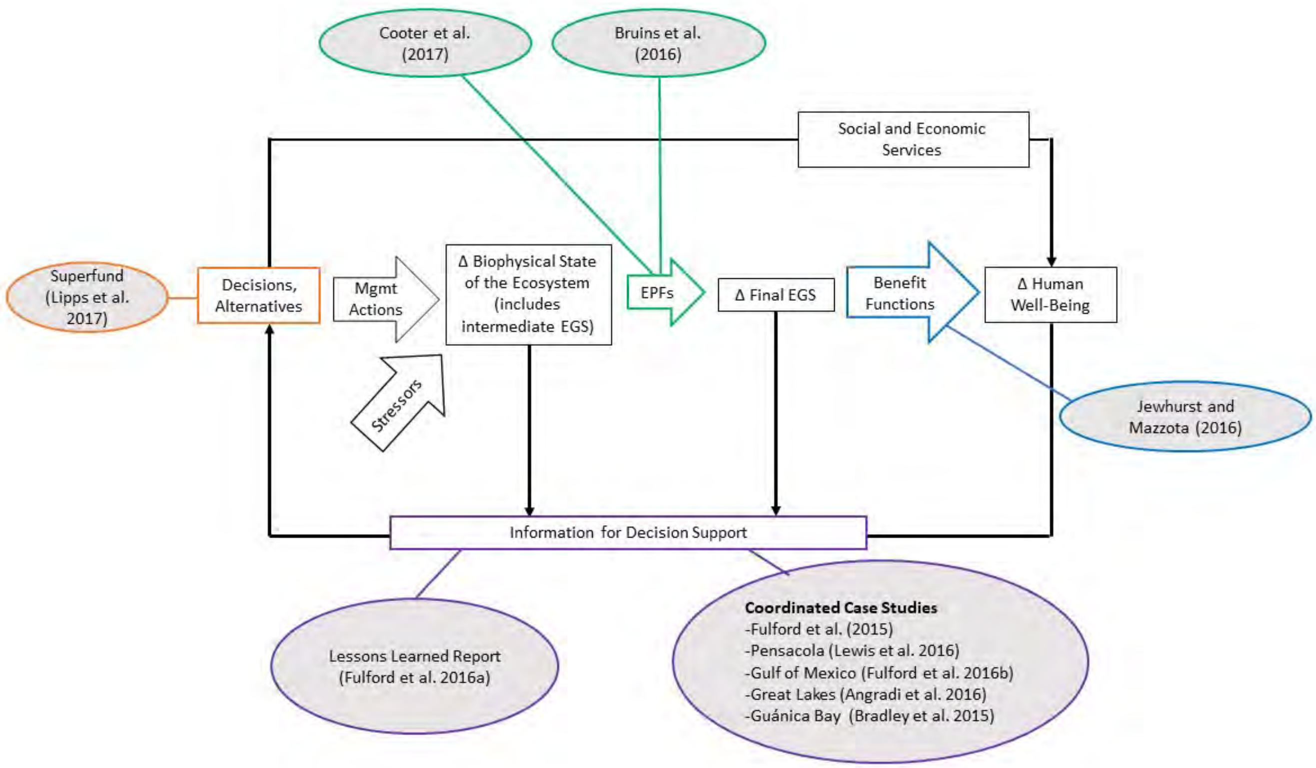
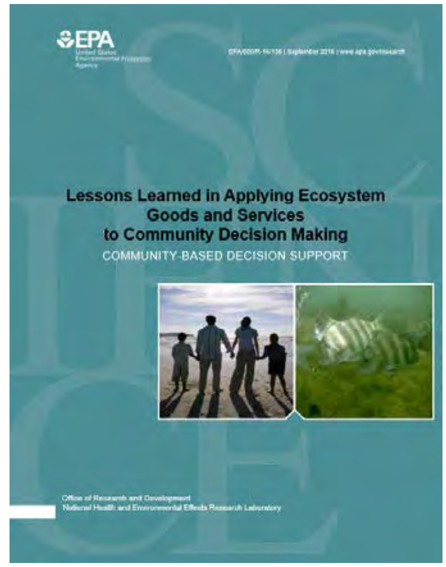


Figure 3 – The conceptual framework for SHC 2.61 focuses on the process of informing decision making through the use of ecological production functions, ecosystem goods and services, and indicators of human well-being. Recent (FY 16) SHC 2.61 research products described in this report are mapped onto elements of the conceptual model (colored ovals around the perimeter).

Contributions to Final Ecosystem Goods and Services Research

Task 2.61.1 Integration, Synthesis and Strategic Communication (ISSC)



Product Description

The synthesis report entitled *Lessons Learned in Applying Ecosystem Goods and Services to Community Decision Making* is the synthesis of recent place-based, community-scale ecosystem services studies conducted by EPA at 25 sites across the U.S.

Citation: Fulford, R.S., R. Bruins, T. Canfield, J.B. Handy, J.M. Johnston, P. Ringold, M. Russell, N. Seeteram, K. Winters, and S. Yee. 2016a. Lessons Learned in Applying Ecosystem Goods and Services to Community Decision Making. U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA/600/R-16/136.

Background

The U.S. EPA has been particularly active in developing research methods to incorporate ecosystem goods and services (EGS) into decision making to protect human health and the environment. The ecosystem goods and services concept has become increasingly valuable for identifying and evaluating important tradeoffs among diverse beneficiary groups and, by extension, has become a central element of decision-support for both public and private institutions. Fulford et al. (2016a) proposes a conceptual model of local decision making which is broken down into four key elements: stakeholder engagement/decision context, metrics and indicators of Final Ecosystem Good and Services (FEGS), Ecological Production Functions (EPFs), and measures of benefit (Figure 3). Place-based studies offer an opportunity to explore the conceptual model to real-world issues and are a link in U.S. EPA research into community-based decision support and the fostering of human and environmental health. Fulford et al. (2016a) describes results from 25 place-based studies (Figure 4) on how they have applied elements of EGS-based conceptual model for decision support.

Summary of Results

The Fulford et al. (2016a) report offers a complete conceptual model for an EGS approach at the community level that has been evaluated in the context of existing and previous place-based studies (PBS) with an eye towards how this model has been used, and what gaps exist that might be filled to increase its successful use in future PBS. The model provides linkages to each respective element that can bring integration of science and policy resulting in more effective decision outcomes. Each element represents significant efforts to support community-level decision making as evidenced by their successful use in one or more of the place-based studies.

In the case studies examined, environmental management decisions were often made with simple end goals in mind (e.g., economic development) that only encompassed the input from a small select group of professionals that drove the decisions on the basis of their expertise. Fulford et al. (2016a) recognize that stakeholders bring further understanding of actions and desired outcomes while science brings an understanding of how actions can translate to desired outcomes. As a result, common stakeholder engagement lessons were characterized. Future place-based studies will benefit from applying a structured decision-making approach to better integrate stakeholder priorities with data on ecosystem services and linked human welfare.

Each of the place-based studies characterized ecosystem goods and services at their sites, but few explicitly linked them directly to human use or benefit, which is the hallmark of the FEGS concept. Reliance on so-called "intermediate EGS", which support the production of FEGS but are not linked to human benefits, limited the capability of most of the PBS to estimate the value of changes to the production or availability of ecosystem services. A key recommendation of this study is that future PBS utilize FEGS concepts and metrics to facilitate linking changes of the environment to human well-being.

Place-based studies most frequently used multiple ecological production functions (EPFs; ecological models that estimate the availability or production of EGS) in a coordinated fashion (via linkage to one another or execution within decision-support tools) to estimate multiple EGS. Some EPFs that are useful for estimating EGS are simple models (e.g., five or fewer input variables), but most require linkage to more complex models for simulation of management alternatives. Fulford et al. (2016a) conclude that more work is needed to standardize EPFs for particular problems and effectively link EPF outputs to independently derived measures of human benefit. Further, the conceptual model proposed by Fulford et al. (2016a) (Figure 3) can be effective in overcoming challenges of matching EPFs to the decision context and use of short-term objectives as measures of benefits.

Stakeholder Engagement Conclusions

- Engage stakeholders and local decision-makers early in the process
- Take the time with stakeholders to formally define the decision context
- Use conceptual models and systems thinking to uncover unintended consequences
- Work with diverse groups of experts to integrate multidisciplinary sources of information

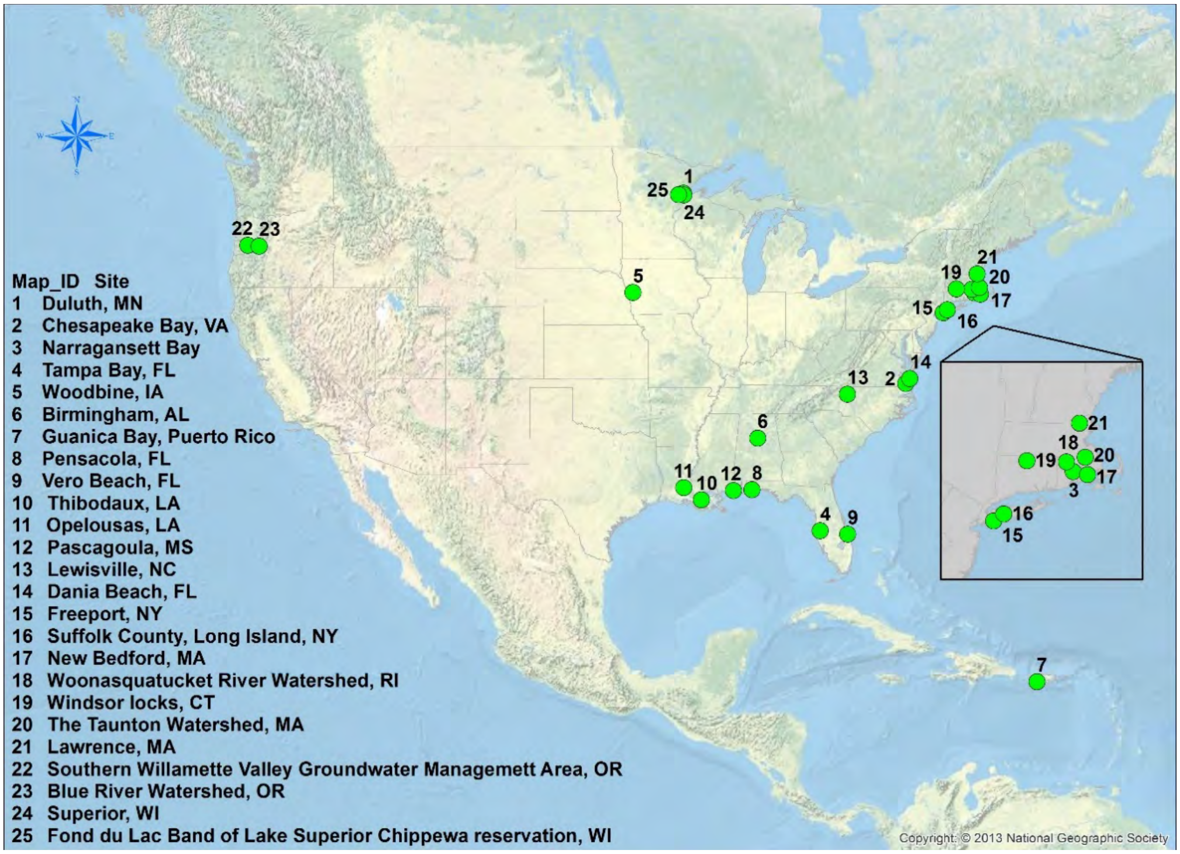


Figure 4 – Map showing locations and names for all the place-based studies participating in the information request on the use of an EGS approach from Fulford et al. (2016a).

The elements of the conceptual model (Figure 3) each represent significant efforts to support community-level decision making as evidenced by their successful use in one or more of the PBS examined by Fulford et al. (2016a). Stakeholders bring an understanding of both potential actions and the desired outcomes from those actions, and the conceptual model proposed in Fulford et al. (2016a) provides a defendable, robust approach for linking intentions to desired outcomes. Barriers to such an integration of science and policy include a lack of stakeholder involvement and understanding of an EGS approach, challenges of matching EPFs to the FEGS metrics of interest, use of inadequate short-term objectives as measures of benefit, and failure to integrate multiple issues into a common decision framework. An EGS-based conceptual model for decision support, such as the one proposed here, can overcome these challenges by linking the decision process together in a clear way. Place-based studies offer a rich opportunity to explore the application of this conceptual model to real-world issues and, as such, are a vital way to integrate EGS research in SHC 2.61 to community-based decision support to foster the sustainability of environment, economy, and human well-being.

2.61.3 Ecological Production Functions for Quantifying Final Ecosystem Goods and Services (EPF)


Annals of Agricultural & Crop Sciences

Austin Publishing Group

Exploring a United States Maize Cellulose Biofuel Scenario Using an Integrated Energy and Agricultural Markets Solution Approach

Abstract

Abbreviations and Acronyms

Introduction

Product Description

The manuscript entitled *Exploring a United States maize cellulose biofuel scenario using an integrated energy and agricultural markets solution approach* presents research on ecosystem services modeling to explore management solutions for Mid-western agricultural sources of excess nutrients, along with other non-point nutrient sources, can fuel hypoxia in the U.S. Northern Gulf of Mexico.

Citation: Cooter, E.J., R. Dodder, J. Bash, A. Elobeid, L. Ran, V. Benson, and D. Yang. 2017. Exploring a United States maize cellulose biofuel scenario using an integrated energy and agricultural markets solution approach. *Annals of Agricultural & Crop Sciences* 2(2).

Background

In recent years, there have been significant improvements in air, land, and water quality, yet because of complexity of the physical and chemical processes that operate across multiple media and a wide range of temporal and special scales, there are still serious air, land, and water pollution problems facing most communities in every state. These complex issues are further complicated by the diversity of interests among stakeholders, as well as potential multiple sources of contaminants which can be considerable distances from the location of adverse effects. A “one-biosphere” modeling approach integrates several multi-media modeling tools together to examine modeling scenarios to address management solutions for complex environmental challenges. The modeling framework includes the incorporation of the decision context, stakeholders, the environment itself, and the interaction of ecosystem and humans (through connecting ecological production functions all the way through to economic, social, health, and/or well-being human endpoints), similar to the FEGS causal conceptual framework (Figure 3) described in Fulford et al. (2016a).

Summary of Results

Cooter et al. (2017) demonstrates a one-biosphere modeling approach to evaluate alternative scenarios for managing nitrogen and phosphorus loading (e.g., EPF response variables) in the Mississippi River Basin as it relates to hypoxia impairment of the U.S. Northern Gulf of Mexico. Their scenario approach applies benefit endpoints for present and future agricultural and energy markets linked to nutrient fate and transport models in turn linked to coastal eutrophication models (i.e., EPFs) (Figure 5).

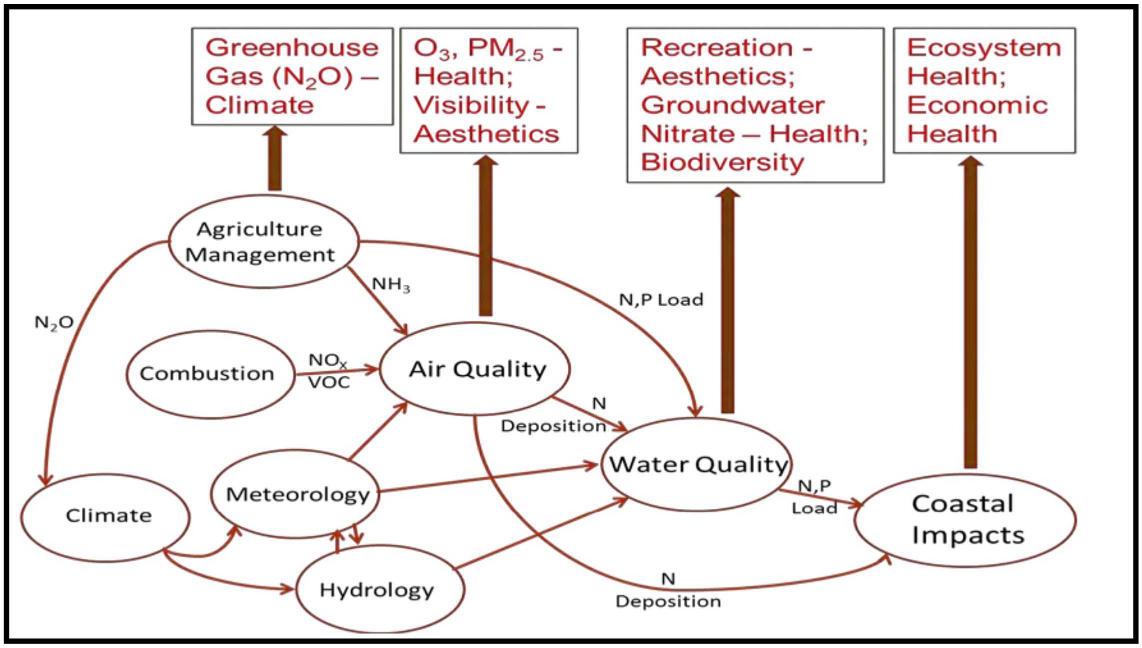


Figure 5 – A one-biosphere general framework to explore coastal zone eutrophication from Cooter et al. 2017 (diagram created by E. Cooter and used here with permission).

This demonstration of the one-biosphere approach utilized integrated markets modeling to bridge the gap between economic/societal actions and biogeophysical system responses. Models examined in the Cooter et al. (2017) study include atmospheric nutrient deposition (CMAQ; accessed 16 January 2018), agro-economic (Market Allocation Model; Lenox et al. 2013), and agro-ecosystem (EPIC; accessed 16 January 2018) models.

This application of the one-biosphere approach presented by Cooter et al. (2017) leverages a number of important research goals across the Air, Climate and Energy (ACE), Safe and Sustainable Water Resources (SSWR), and Sustainable and Healthy Communities (SHC) National Research Programs.

The one-biosphere approach requires the inclusion of stakeholder actions, reactions, and outcomes. This approach is in the beginning steps of developing process-based tools and methodologies capable of supporting environmental decision making.

2.61.3 Ecological Production Functions for Quantifying Final Ecosystem Goods and Services (EPF)


Special Series

Using Ecological Production Functions to Link Ecological Processes to Ecosystem Services

Product Description

The journal article entitled *Using ecological production functions to link ecological processes to ecosystem services* presents nine key attributes of ecological production functions that determine the utility and relevance of EPFs for decision making.

Citation: Bruins, R.J.F., T. Canfield, C. Duke, L. Kapustka, A. Nahlik, R. Schäfer. 2016. Using ecological production functions to link ecological processes to ecosystem services. *Integrated Environmental Assessment and Management* 13(1):52-61.

Background

Ecological production functions (EPFs) link ecosystems, stressors, and management actions to ecosystem service (ES) production. Though acknowledged as being essential to improve environmental management, relatively little attention has been directed toward the use of EPFs in ecological risk assessment. EPFs are operationally defined as usable expressions (i.e., models) of the processes by which ecosystems produce ecosystem services, often including external influences on those processes. This operational definition is an assumption that EPFs should be useful for decision making. Bruins et al. (2016) identify nine key (desirable) attributes of EPFs that determine the utility and relevance of EPFs for decision making. In general, EPFs can be a useful tool for framing current knowledge and fostering new research by highlighting knowledge gaps. As an example, Bruins et al. (2016) discuss both actual and idealized examples of their use to inform decision making related to pesticides.

Summary of Results

Ecosystem processes that represent final ES are directly used by human beneficiaries, and thus are most readily connected to human health and well-being. As a result, these often best serve the needs of decision makers. While qualitative descriptions of ES may suffice for some management decisions, semi-quantitative or quantitative ES are preferred where possible in the context of rational decision making on technical grounds.

EPF variables that are more descriptive of ecosystem processes can better capture ecosystem condition and can improve EPF accuracy as it informs impacts of decision alternatives. Likewise, models that examine ES must contain variables that can reflect the influence of stressor levels or potential management decisions.

Ecological processes that produce ES occur across markedly different scales of space and time having different rates and controlling feedbacks. The use of multiple, linked EPFs can illustrate trade-off complexity arising from differential ES responses across management scenarios.

Unless decision making occurs in areas that are already data-rich, or where new data can be acquired easily, EPFs have to perform using data of less than ideal resolution and quality. For practical reasons, therefore, EPF developers must make compromises among dynamism, scale optimization, and data requirements.

In decision-making situations, models are often used to address hypothetical scenarios (for example, projected future change, management alternatives) for which performance cannot be evaluated until after the fact. Therefore, the number of previous situations in which performance has been evaluated and the similarity of these situations to that facing the decision-maker could be considered as proxies of performance.

Ideally, potential end-users and all affected stakeholder groups would be consulted in model development, a process called participatory modeling. Regardless of model design, most useful models should have a user-friendly interface (accessible documentation), where all default initial values of variables and parameters that pertain to stakeholder interests should be accessible and modifiable.

Finally, developing models from scratch may not be feasible for most situations. While existing models have largely been developed for different purposes and may not meet the management requirements listed here, they often contain variables that relate to the ES approach. Importantly, user manuals, documentation, and access to code provide considerable transparency, offering users the ability to tailor their assessments to the particular features of their project.

Desired Attributes of Informative EPFs

- Estimate indicators of final ecosystem services
- Quantify ecosystem service outcomes
- Respond to ecosystem condition
- Respond to stressor levels or potential management scenarios
- Appropriately reflect ecological complexity
- Rely on data with broad coverage
- Are shown to perform well
- Are practical to use
- Are open and transparent

2.61.4 National and Community Benefits of Final Ecosystem Goods and Services (Benefits)


EPA

Economic Tools for Managing Nitrogen in Coastal Watersheds

Product Description

The report entitled *Economic Tools for Managing Nitrogen in Coastal Watersheds* examines several economic approaches for characterizing the benefits of the wetland ecosystem service of nitrogen load reduction.

Citation: Jewhurst, S., M. Mazzotta. 2016. Economic Tools for Managing Nitrogen in Coastal Watersheds. U.S. Environmental Protection Agency, EPA/600/R-16/036.

Background

Increasingly, community leaders wish to understand the economic value of ecosystem goods and services produced within their political domain so as to have an objective and relevant basis for assessing the costs and benefits of resource-use decisions. Additionally, the economic/monetary value of ecosystem goods and services are often easier to communicate to the general public than the environmental value alone. However, valuation of EGS can be challenging, and the success of incorporating EGS into community decision making requires practical approaches for assessing changes in their economic value due to changes in EGS quantity, quality, or production.

Jewhurst and Mazzotta (2016) provide information for watershed managers and community decision-makers on practical economic tools for managing nitrogen in coastal watersheds. In particular, they provide an overview of methods that can be applied to determine the most cost-effective means to reduce nitrogen pollution and to evaluate the economic benefits of improving the extent or condition of coastal ecosystems. The Jewhurst and Mazzotta report also summarize the needs of watershed managers for economists who may be interested in pursuing relevant research and analysis. The report provides an overview of approaches to economic analyses that can be used to answer a range of questions on watershed management, which could provide watershed managers with sound economic bases for evaluating ecosystem-change proposals (e.g., development, restoration, and remediation).

> *Economic values are an explicit way to evaluate, quantify and present the trade-offs that people are actually willing to make to protect or clean up the environment.*

Summary of Results

From a survey analysis, Jewhurst and Mazzotta (2016) conclude that watershed managers need proactive support from trained economists to achieve economic assessment goals. Based on the specific watershed management question, different economic methods may be used: cost-effectiveness analysis, economic contribution analysis, economic impact analysis, or economic benefits analysis. Each of these approaches are described by Jewhurst and Mazzotta (2016) along with the types of information needed and the utility of each method for different purposes. Additionally, the authors examine the challenges associated with the use of "total value" ecological economic studies (i.e., the value of an ecosystem estimated by monetizing the total flow of goods and services from that ecosystem). For example, substitution of one ecosystem type for another (e.g., due to development or restoration) or the reduction in the condition of an ecosystem will not likely result in a wholesale change in the quantity or production of the original system's EGS; hence most policy relevant changes to ecosystems would not be appropriately accounted for using value of the entire system. Consequently, the "total value" method is not generally recommended by economists for watershed management decisions.

In general, Jewhurst and Mazzotta (2016) conclude that watershed managers would benefit from better access to trained economists who understand their needs and can advise them in plain language about how to conduct valuation analyses. Consultation with economists who understand watershed management needs prior to commissioning economic analysis ensures adequate review of methods and promotes more accurate results. Watershed managers may also face restrictions on their access to critical data required for many of these analyses. Overall, data availability had a large influence on the scope and types of the economic analyses that could be conducted, and consequently, watershed managers should appreciate how data limitation affects the types of economic valuation assessments that they can achieve.

"**Direct use values** refer to ecosystem goods and services that are used directly by human beings. They include the value of *consumptive uses* such as harvesting of food products, timber for fuel or construction, and medicinal products and hunting of animals for consumption; and the value of *non-consumptive* uses such as the enjoyment of recreational and cultural activities that do not require harvesting of products. Direct use values are most often enjoyed by people visiting or residing in the ecosystem itself.

Indirect use values are derived from ecosystem services that provide benefits outside the ecosystem itself. Examples include natural water filtration which often benefits people far downstream, the storm protection function of mangrove forests which benefits coastal properties and infrastructure, and carbon sequestration which benefits the entire global community by abating climate change.

Option values are derived from preserving the option to use in the future ecosystem goods and services that may not be used at present, either by oneself (*option value*) or by others/heirs (*bequest value*). Provisioning, regulating, and cultural services may all form part of option value to the extent that they are not used now but may be used in the future.

Non-use values refer to the enjoyment people may experience simply by knowing that a resource exists even if they never expect to use that resource directly themselves. This kind of value is usually known as existence value (or, sometimes, passive use value)."

(Source: The World Bank, 2004, pp. 9 – 10)

2.61.5 Coordinated Case Studies


Ecological Indicators

Human well-being differs by community type: Toward reference points in a human well-being indicator useful for decision support

Product Description

The journal article entitled *Human well-being differs by community type: Toward reference points in a human well-being indicator useful for decision support* presents an approach for classifying communities based on the three sustainability pillars (social, economic, and environmental) for the coastal counties of the conterminous U.S.

Citation: Fulford, R.S., L.M. Smith, M. Harwell, D. Dantin, M. Russell, and J. Harvey. 2015. Human well-being differs by community type: Towards reference points in a human well-being indicator useful for decision support. *Ecological Indicators* 56:194-204.

Background

One way to examine sustainability is to measure net delivery of ecosystem goods and services (EGS) to human beneficiaries. Suites of indicators used to holistically measure human well-being (HWB) show promise as a synergistic measure of the outcome of net EGS production and delivery to humans (Smith et al. 2014). The challenge in applying HWB measures at the community level is in linking such a broad indicator to community specific issues and values as different communities have difference social, economic, and environmental dependencies. Fulford et al. (2015) present an EGS- based community classification system (CCS) to address whether a classification system is informative by asking whether HWBI type indicator values differ by community type as a potential measure of sustainability.

Summary of Results

Fulford et al. (2015) presents a community classification system (CCS) constructed from three sources of data intended to describe a community with respect to three pillars of sustainability (social, economic, and environmental). They analyze publicly available data for coastal communities in the contiguous United States (662 counties nationwide) to look at differences in their well-being to provide local well-being reference points informative for measuring changes in well-being.

Overall, 70 variables from existing national databases (covering the period from 2006-2010) were analyzed to examine the social (community social/demographic composition), economic (local employment dependencies), and environmental (ecological region data) pillars of sustainability.

Bayesian model analysis identified a total of eight primary groups for classification, delineating coastal counties first by population density, and then by resource dependence and socio-economic composition. While high population density was a general descriptor, additional delineation was realized with examination of economic dependence (as defined by employment information) and local resource dependence. Overall, differences in community type were strongly driven by economic and social dependence on local environmental resource issues either (through employment or land use) demonstrating a clear link between environmental service flows and human well-being.

Fulford et al. (2015) examine how HWB differs across different community types. Geographic differences in county-level HWB Index scores were observed in high population densities (high HWB scores and low dependence on local resources) compared to rural, high local dependence groups. Overall, U.S. coastal counties increase in HWB as they increase in population density and socio-economic diversity. More rural counties along the coast had higher scores for specific HWB domains (social cohesion and leisure time) suggesting there are elements of HWB that are not associated with high density. Two important conclusions arose from this research. First, community decision makers can use this type of community classification approach to identify baseline well-being from which to assess effects of potential management decisions. Second, trajectories of human well-being over time may change as a function of community dynamics so both need to be examined over time to inform community decision making.

Community Classification System Types for U.S. Coastal Counties (n=662)

1. Urban/suburban
2. Suburban, older citizens, working class
3. Rural, high local dependence, farther from coast
4. Rural, highest local dependence, high ethnic diversity
5. Rural, high local dependence, working class
6. Rural, higher local dependence, working class, farther from coast
7. Rural, central Florida, older citizens
8. Suburban, high throughput, north central U.S.

2.61.5 Coordinated Case Studies

2.61.5a Puerto Rico Case Study

Product Description

The EPA report entitled *Application of a Structured Decision Process for Informing Watershed Management Options in Guánica Bay, Puerto Rico* summarizes the results of community-based workshops examining the importance of ecosystem services to land-use decision making by multiple stakeholders in coffee-growing coastal watersheds of south-western Puerto Rico.

Citation: Bradley, P., W. Fisher, D. Dyson, S. Yee, J. Carriger, G. Gambirazzio, J. Bousquin, and E. Huertas. 2015. Application of a Structured Decision Process for Informing Watershed Management Options in Guánica Bay, Puerto Rico. U.S. Environmental Protection Agency, Office of Research and Development, Narragansett, RI, EPA/600/R-15/248.

Background

The importance of the overall decision context (i.e., defining what is the problem, issue, or reason for making a decision, in part, through the inclusion of ecosystem services science) is an important element throughout the structure of SHC 2.61 (see Figure 2). Ecosystem services science can be incorporated into decision making through a number of decision science approaches. Structured decision making (SDM) is an organized approach to allow stakeholders to share their perspectives and objectives regarding a given problem with a broader group, with the end goal of informing decision makers. It is particularly useful in complex decision situations.

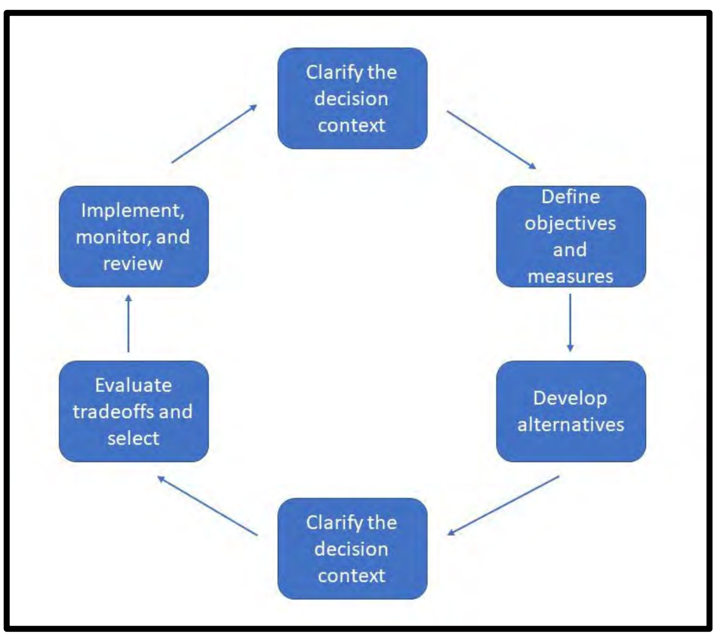


Figure 6 – The structured decision making (SDM) formal decision process steps; modified from Bradley et al. 2015.

SDM has six steps (Figure 6): 1) clarify the decision context; 2) define objectives and evaluation criteria; 3) develop alternatives; 4) estimate consequences; 5) evaluate trade-offs and select alternatives; and 6) implement, monitor, and review. Key to the SDM process is the engagement of stakeholders, experts, and decision-makers in a deliberative environment that deals rigorously with facts and values in decision making.

Summary of Results

Research under the SHC 2.61.5a *Ecosystem Services for San Juan, Puerto Rico* Task, involves the application of decision science and ecosystem services science to inform watershed management efforts for identifying and evaluating natural resource use alternatives in a collaborative manner that engages the interests of multiple stakeholders, and which results in a range of transparently-determined choices in a complex decision situation. Bradley et al. (2016) explore the use of SDM to address watershed land-use management issues in Guánica Bay, Puerto Rico through a series of workshops designed to examine fundamental goals and values of the community, and tradeoffs in coffee-growing practices and water runoff management as it related to reducing sediment runoff impacts to local coral reefs.

Advantages of Using Decision Science Approaches

- Guides information collection
- Increases stakeholder involvement
- Guides strategic thinking
- Improves communication
- Supports interconnecting decisions
- Facilitates creation and evaluation of management alternatives

In merging the two fields of ecosystem services and decision science, Bradley et al. (2016) expand on two important concepts: systems thinking and the use of decision frameworks. Systems thinking refers to a problem-solving approach focused on the importance of relationships and interactions among component parts of a system rather than focusing on those parts in isolation. Decision frameworks can represent any of a number of organizing/communicating approaches for characterizing complex environmental issues. Bradley et al. (2016) explore the development of a Drivers/Pressures/State/ Impacts/Responses (DPSIR) framework in their case study. They advance environmental assessments of coral reefs beyond ecological endpoints to include the social and economic values of stakeholders. Through facilitated workshops, they map stakeholder- and expert-identified ecological, economic, and social objectives associated with coral reef protection to corresponding ecosystem goods and services. Bradley et al. (2016) also translate their experience with Guánica Bay, Puerto Rico into lessons learned and provide generic guidance on the use of SDM processes depending on resources available (budgets/timelines) and different types of decision support tools for community engagement.

2.61.5 Coordinated Case Studies

2.61.5c Great Lakes Case Study


ARTICLE IN PRESS

Journal of Great Lakes Research

IAGLR

Mapping ecosystem service indicators in a Great Lakes estuarine Area of Concern

Product Description

The journal article entitled *Mapping ecosystem service indicators in a Great Lakes estuarine Area of Concern* presents an approach for quantifying the distribution and abundance of ecosystem goods and services, demonstrated in the St. Louis River (MN) Area-of-Concern (AOC) of Lake Superior.

Citation: Angradi, T.R., D.W. Bolgrien, J.L. Launspach, B.J. Bellinger, M.A. Starry, J.C. Hoffman, M.E. Sierszen, A.S. Trebitz, and T.P. Hollenhorst. 2016. Mapping ecosystem services of a Great Lakes estuary can support local decision-making. *Journal of Great Lakes Research* 42(3):717-727.

Background

There has long been a recognition among the ecosystems services community of practitioners regarding the importance of incorporating ecosystem services into the decision-making process. However, it has been only within the last decade or so that there has been a significant increase in the number of local-scale case studies (< 100 km^2 area) that have mapped final ecosystem services within the decision context of informing local management decisions. Recent research by the U.S. Environmental Protection Agency's Office of Research and Development has focused on advancing local-scale ecosystem services research with the intent of providing community decision makers with tools and information specifically for informing management tradeoffs and decisions.

Summary of Results

There are 27 Great Lakes coastal systems in the United States and Canada designated as Areas of Concern (AOC) because of legacy chemical contamination, degraded habitat, and non-point-source pollution. The impacts in these ecosystems diminish the benefits current and future human communities can receive from these ecosystems, but are the focus of ecosystem "remediation to restoration" (R2R) attention. In recognizing the limited scientific literature over the past decade in characterizing the ecosystem services in local-scale case studies (< 100 km^2 area), Angradi et al. (2016) explore mapping and enumeration of twenty-three final ecosystem services as they could potentially inform multiple management objectives, including restoration priorities, project siting, and defining engineering specifications in management decisions related to AOC restoration.

Angradi et al. (2016) anchor their ecosystem services assessments to the decision context to inform tradeoff analyses among management alternatives through the applicability of a final ecosystem service/management action matrix (e.g., Table 2).

Table 2. Hypothetical final ecosystem service/management action matrix examining potential effects of proposed management actions (right columns) on final ecosystem services (left column) in a given study area. Responses: 0 = no effect; + = more area of service created; -= areas of service lose; ? = response depends on context.

Management Action → Final Ecosystem Service ↓	Increased public access	Removal of contaminated sediments	Wetland habitat
Target Fish A	?	0	+
Power Boating/ Cruising Areas	+	?	?
Wave Attenuation Areas	0	-	+
Public Beaches	+	+	0

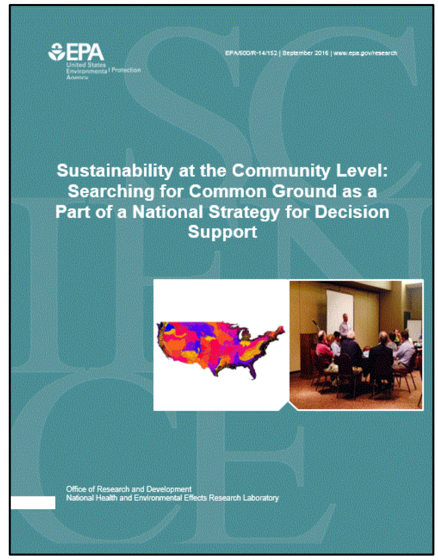
Angradi et al. (2016) also examine the importance of quantifying changes in final ecosystem services (e.g., acres of restored habitat) that can directly inform the existing restoration governance structure (i.e., the information is within the institutional capacity of local management agencies or AOC advisory groups to use). By examining ecosystem services research within an important decision context, Angradi et al. (2016) demonstrate how the overall goals of assessment of final ecosystem services in the Great Lakes can support decision making at the local scale.

The mapping approaches used in characterizing final ecosystem services indicators is within the institutional capacity of local management agencies. They are useful for designing and planning management actions, and for communicating the ecosystem service implications (i.e., tradeoffs) of management actions to beneficiaries and to policy makers.

2.61.5 Coordinated Case Studies

2.61.5d Gulf of Mexico Case Study

Product Description



The EPA report entitled *Sustainability at the Community Level: Searching for Common Ground as a Part of a National Strategy for Decision Support* examines analysis from multiple, community-based case study ecosystem services and decision science research activities.

Citation Fulford, R.S., M. Russell, J. Harvey, M. Harwell. 2016b. Sustainability at the Community Level: Searching for Common Ground as a Part of a National Strategy for Decision Support. U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA/600/R-16/152.

Background

One primary goal of U.S. EPA Office of Research and Development's Sustainable and Healthy Communities (SHC) research program is to support sustainable decision making at the community level, especially in providing scientifically sound and user-friendly guidance on the sustainability of current and projected activities to stakeholder groups at the community level, including planners, decision makers, and the general public. All communities have important differences in composition, priorities, and issues that create challenges for forging a coherent national strategy for decision support. Simply 'recreating the wheel' in each community is costly and inefficient, and an important goal is to explore the similarities among communities in key areas to produce a roadmap for comparability useful for informing local decision support in environmental planning and protection.

Community Based Decision Support

(CBDS) is a national scale issue in that the collective impacts of multiple local decisions can have large and pervasive results particularly in coastal areas. Treating all communities the same is risky because it allows for avoidable variability in community characteristics to bias the outcome, and it may be viewed as 'externally driven', which limits the acceptability of the support by stakeholders. In contrast, treating each community as totally unique is inefficient and ignores potentially valuable commonalities. As a result, decision support at the community level can have far-reaching implications for environmental quality and human health and well-being.

Sustainability indicators used by local communities often serve multiple purposes and are communicated in different ways. The research from Fulford et al. (2016b) focuses on four key areas for community sustainability comparison: community composition, stakeholder priorities, availability and quality of ecological resources, and measures of human well-being. First, the make-up of communities based on socio-demographic, economic, and ecological composition is examined. Second, the community priorities as reported by the stakeholders are considered. Third, a geographic information system (GIS) mapping approach is used to consider similarities and differences in the availability of important index ecosystem goods and services (EGS). Finally, similarities are explored in a measure of human well-being as an estimate of the impact of environmental decisions on overall quality of life. Combined, these four elements of comparison represent the major components of decision support from factors driving decision priorities, probable pathways for environmental impacts of decisions, and finally to probable impacts on beneficiaries.

Summary of Results

In this report, communities were compared based on four distinct metrics with the purpose of seeking common ground for defining and measuring sustainability at the local scale. An analytical community-classification system (CCS) was developed to delineate communities according to their environmental, social, and economic composition. Three CCS data types were used to examine the social, economic and environment pillars of sustainability: Social/Demographic composition; employment Location Quotient; and Ecoregion. The CCS was evaluated by combining it with the Human Well-Being Index (HWBI; Smith et al. 2014) and examining whether HWBI-type indicator values differ by community type as a measure of potential sustainability. Community type was found to be informative regarding the relative importance of elements of well-being. Overall, community well-being is a moving target and measuring human benefit is tied to tradeoffs in access to natural resources and most importantly changes across the rural to urban gradient. Therefore, a balance is proposed between subjective and objective criteria in measuring sustainability at the local level that may be best achieved through use of the weighted HWBI. The collective outcome of this report strongly supports exploration of a balanced approach for local decision support that begins with identification of community type and the calculation of weighted HWBI.

Fulford et al. (2016b) also examine two approaches for identifying and classifying community priorities. The first approach (direct stakeholder engagement) asked how a representative set of stakeholders in select communities defines their fundamental objectives. The second approach was a more objective examination of strategic planning documents based on the identification of keywords associated with pre-defined priority categories. The goal was to use stakeholder input to identify and rank community priorities in a useful and consistent manner. Examining community priorities benefited from combining the two approaches.

Based on a series of workshops in communities across the United States (Figure 7), Fulford et al. (2016b) develop four types of community sustainability indicators (Figure 8).

Figure 7 – Stakeholder workshops were held in four communities in the Gulf of Mexico coastal region to assess community priorities based on community type. Photo courtesy of U.S. EPA.

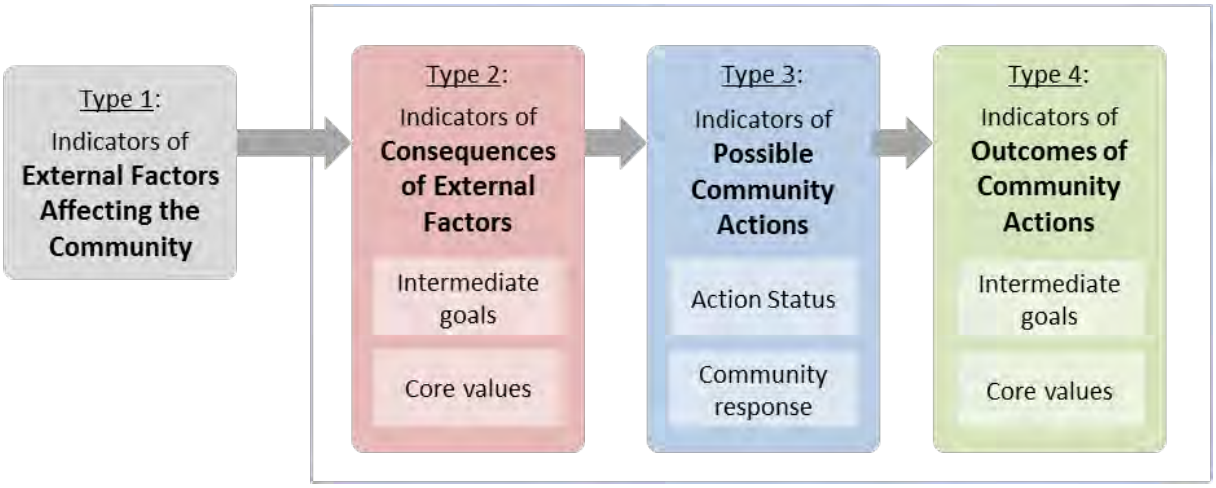


Figure 8 – Relationship between four types of EPA-identified community sustainability indicators from Fulford et al. (2016b).

These four types of community sustainability indicators focus information on core values, associated near- and long-term goals, and strategies for achieving those goals:

- **Indicators of external factors affecting the community** (measures of forces affecting community sustainability that are beyond a community's direct control)
- **Indicators of consequences of external factors** (measures of the effects of external factors on the ability of a community to sustain or achieve its goals)
- **Indicators of possible community actions** (measures of the status and immediate outcomes of community actions)
- **Indicators of the outcomes of community actions** (measures the effect of community actions on addressing those consequences)

By combining these four types of indicators, a community can assess threats, identify priorities, target actions, demonstrate accountability, monitor results, make informed mid-course corrections, and ultimately measure the impact of the actions in terms of the goals that matter most to the community.

The collective outcomes of the Fulford et al. (2016b) report strongly support exploration of a balanced approach for local decision support that begins with identification of community type and the calculation of weighted HWBI. Research questions remain about the optimal structure of the CCS and how well it can be applied in new communities.

This work supports new research and a Coordinated Case Study Task in SHC 2.61 that allows for examination of this approach to measuring sustainability in multiple communities, and at the national scale. Community-level decision support is a national scale issue and should be approached from that point of view. Doing so will maximize the impact of EPA-led efforts and can result in a more effective and accepted measure of community sustainability.

2.61.5 Coordinated Case Studies

2.61.5d Gulf of Mexico Case Study

Product Description:

The EPA report article entitled *Environmental Quality of the Pensacola Bay System: Retrospective Review for Future Resource Management and Rehabilitation* provides a summary of ecosystem condition assessments and ecosystem services in the watersheds of Pensacola Bay, Florida.

Citation: Lewis, M.A., J.T. Kirschenfeld, T. Goodhart. 2016. Environmental Quality of the Pensacola Bay System: Retrospective Review for Future Resource Management and Rehabilitation. U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA/600/R-16/169.

Background

Lewis et al. (2016) present an analysis of the environmental quality of Pensacola Bay, the fourth largest estuary in Florida (with a surface area of 373 km^2, 889 km of coastline and an approximate 18,000 km^2 watershed). In summarizing the scientific literature over the history of environmental condition assessments conducted in Pensacola Bay since the late 1600s, the authors note those environmental metrics which inform the estimation of ecosystem services for the bay. Using peer-reviewed published values, they present estimates of total non-habitat value for environmental goods and services of seagrass meadows, oyster reefs, and tidal wetlands and examine how habitat decline over the past half century has reduced these values. Lewis et al. (2016) uses a total value approach to highlight the importance of the environment to local decision makers as the region is examining how to best utilize funding for Gulf of Mexico restoration following the 2010 *Deepwater Horizon* oil spill.

Summary of Results

In the Pensacola Bay area, there are no locally validated models capable of predicting the effects of different levels of stressors on the economic value of the ecological services and goods produced by the ecosystem to inform scenario tradeoffs. In developing management recommendations for future cost-effective and science-based resource management, Lewis et al. (2016) examine data gaps and priorities among geographic locations, environmental parameters, stressor monitoring, and condition assessment needs. They conclude that long-term improvement in environmental condition in Pensacola Bay will be determined by conducting well-designed, goal orientated, financially supported studies, with accompanying public involvement and active management actions, as the Pensacola Bay system is a shared resource with multiple Federal, state, regional, and local jurisdictional organizations.

Highlights from other SHC 2.61 Ecosystem Services Science

Product Description:

The EPA Engineering Forum Issue Paper report entitled *Understanding Ecosystem Services at Superfund Cleanups* outlines how ecosystem service concepts and metrics could be used to support Superfund cleanup site management.

Citation: Lipps, J., M. Harwell, M. Kravitz, K. Lynch, M. Mahoney, C. Pachon, and B. Pluta. 2017. Understanding Ecosystem Services at Superfund Cleanups. U.S. Environmental Protection Agency, EPA/542/R-17/004.

EPA 542-R-17-004
August 2017

Engineering Forum Issue Paper

Agriculture-to-wetland project at the Lower Basin of Coeur d'Alene River Superfund site in northern Idaho. Photo Credit: Jewel Lipps

Ecosystem Services at Contaminated Site Cleanups

Contents

1. Purpose
2. Ecosystem Services
3. Considerations During Cleanup
4. Community Involvement
5. Ecosystem Services Evaluation Tools
6. Best Management Practices for Ecosystem Services
7. Summary
8. Acknowledgements
9. Notice and Disclaimer
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Appendix A. Ecosystem Services Evaluation Tools

The Technical Support Project (TSP) Engineering Forum issue papers provide information on remediation technologies or technical issues of interest. The information is not guidance or policy.

"Ecosystem goods and services are the many life-sustaining benefits we receive from nature—clean air and water, fertile soil for crop production, pollination, and flood control."

- U.S. Environmental Protection Agency, 2017
www.epa.gov/eco-research/ecosystem-services

1. Purpose

The U.S. Environmental Protection Agency (EPA) developed this issue paper to provide cleanup site teams with information about ecosystem services. These concepts and tools are useful in communicating the positive results of cleanup in addition to achieving the goals of cleanup. Information about ecosystem services may be considered in characterization of future land use options or design of a cleanup that is consistent with anticipated ecological reuse, depending on the regulatory authority of the cleanup program. This document does not provide guidance on how ecosystem services may or may not be factored into specific cleanup programs.

1

Background

In August 2016, the U.S. Environmental Protection Agency released an issue paper to help representatives from the Superfund program understand ecosystem services and their relevance to contaminated sites. In part as a response to the 2015 Executive Memorandum *Incorporating Ecosystem Services into Federal Decision Making*, the U.S. EPA Office of Superfund Remediation and Technology Innovation (OSTRI), the Technical Support Project Engineering Forum, the Ecological Risk Assessment Forum, and a 2015 Regional Sustainability and Environmental Sciences Ecosystem Services project team worked with Agency science, including science produced from the SHC 2.61 Community-Based Final Ecosystem Goods and Services Project. The science examined by the project team was used to outline how consideration of ecosystem services concepts during site cleanup is consistent with U.S. EPA's mission to protect human health and the environment with Superfund's goals of revitalization of contaminated lands. Overall, the evaluation of ecosystem services at Superfund sites has the capacity to inform multiple steps in the process (Figure 9) including the decision context, community/stakeholder engagement, and analyses of management alternatives through selection of best management practices for green remediation and ecological revitalization.

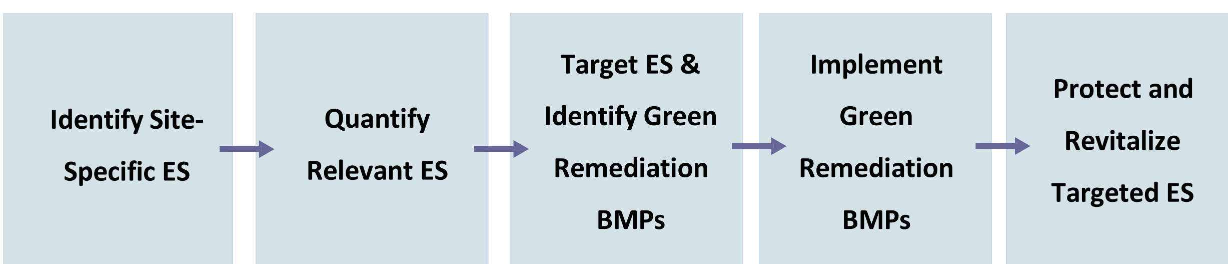

Figure 9 – A generic framework for examining ecosystem services (ES) in the Superfund process from Lipps et al. (2016). First, site specific ES are identified. The subset of ES relevant to the cleanup effort is then quantified. Targeted ES are then examined to identify approaches to mitigate impact on ES or improve ES. After Best Management Practice (BMP) implementation, the effect of cleanup actions on targeted ES are examined towards the goal of protecting and revitalizing ES at the site.

Summary of Results

This Engineering Forum Issue Paper articulates, using examples such as the Great Lakes Area of Concern, that by using ecosystem services characterizations as a tool, site teams are better positioned to develop approaches to avoid damage to sections of a site with high ecosystem services values, and to revitalize sections with low ecosystem services values. The issue paper describes the relationship between ecosystem services evaluation efforts and other environmental protection/cleanup concepts such as ecological risk assessments (ERA), ecological revitalization, natural resource damage assessments (NRDA), net environmental benefit analyses (NEBA), and applicable or relevant and appropriate requirements (ARARs). The authors also present a conceptual framework for consideration of ecosystem services endpoints into the cleanup process (Figure 9), and map an example for an ERA where the ERA assesses how contaminants affect relevant ecosystem services, while an ecosystem services evaluation examines how cleanup activities might impact or improve them. The Engineering Forum Issue Paper gives examples of best management practices (BMPs) that are commonly used to improve ecosystem services by using green remediation (Table 3).

Table 3. Example of green remediation BMPs which may be used for site assessment or remediation. From: Lipps et al. 2017.

	Example Greener Cleanup BMPs	Example Ecosystem Services		
		Habitat	*Erosion Control*	*Recreation*
Site Assessment Phase	Consider and document property characteristics such as habitat connectivity, topography and site access.	✓	✓	✓
Remedial Phase	Design works zones, traffic plans and construction phases to avoid habitat disruption.	✓	✓	✓
	Retain existing habitat and vegetation, especially habitats with high ES value and large trees.	✓	✓	✓
	Eradicate invasive plant species on site and use control measures to prevent invasion of non-native plants.	✓		
	Place mulch and metal grates over traffic corridor surfaces.		✓	
	Construct long-term ecological structural controls such as bio-swales and vegetated riprap.	✓	✓	
	Plant regionally native vegetation and pollinator habitats on bare soil and caps.	✓	✓	✓

Synthesis and Key Findings

Different elements of the conceptual model showed in Figure 3 are echoed throughout each of the studies described. These studies represent the critical linkages of science and policy needed to establish effective measures of decision outcomes of ecosystem services. Lipps et al. (2017) describes several tools that are examples needed to create effective measures of decision making. Understanding the complexity of stakeholder engagement and the decision-making process, Fulford et al. (2016a), Bruins et al. (2016), Fulford et al. (2015), Bradley et al. (2016), Fulford et al. (2016b), Angradi (2016) and Lipps et al. (2017) focus on strategies and approaches needed to accomplish these goals, including development and utilization of organized frameworks, decision strategies and mapping approaches. Lewis et al. (2016) focuses on identifying data gaps as an example of a specific case study assessment of ecosystem services, while Cooter et al. (2017) and Jewhurst and Mazzotta (2016) specialize in the quantitative and economic information of production and benefits in ecosystem goods and services.

The studies summarized in this report represent efforts to support community-level decision making by incorporating quantitative information on the production and benefits of ecosystem services. These efforts, mapped onto the conceptual model in Figure 3, look to clarify the decision context to help scientists and stakeholders identify and prioritize information needed for decisions-making.

Key Findings in this Output Synthesis Report

- Stakeholders bring further understanding of actions and desired outcomes while science brings an understanding of how actions can translate into desired outcomes
- Two important concepts, systems thinking and the use of decision frameworks, merge the fields of ecosystem, services and decision science
- Place-based studies are a vital way to integrate EGS research to community based decision support to foster the sustainability of the environment, economy, and human well-being
- Ecosystem processes that represent final ecosystem services are directly used by human beneficiaries and often best serve the needs of decision makers
- The use of multiple, linked ecological production functions can illustrate trade off complexity across management scenarios
- Trajectories of human well-being over time may change as a function of community dynamics so both need to be examined over time to inform community decision making
- Understanding and mapping the changes in final ecosystem services provides information that is within the institutional capacity of local management agencies for supporting decision making

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Acknowledgements

This Output report could not have been prepared without the support of the SHC 2.61 Integration, Synthesis and Strategic Communication Task Team for their valuable contributions. Additional report content contributions came from Jewel Lipps (Oak Ridge Institute for Science and Education Internship with OSRTI), and Ellen Cooter (ORD NERL). Tim Gleason and Jennifer Cashdollar served as additional reviewers for this report. Chloe Jackson provided valuable technical and editorial assistance. Photos on cover page courtesy of U.S. EPA.

Notice and Disclaimer

This is a contribution to the EPA ORD Sustainable and Healthy Communities Research Program.

The citation for this report is:
Harwell[1], M.C. and J.L. Molleda[2]. 2018. FY 16 Output SHC 2.61.1 Ecosystem Goods and Services Production and Benefits Case Studies Report. U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA/600/R-18/189.

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EPA/600/R-18/189