

# **A Heuristic Framework for Evaluating Ecosystem Services in Coastal and Marine Environments: Marine InVEST**

Mark Plummer, Micah Effron, and Howard Townsend



FEDERAL AGENCY EXPLORATIONS AND APPLICATIONS: CASE 2  
National Oceanic and Atmospheric Administration

**A Heuristic Framework for Evaluating Ecosystem Services  
in Coastal and Marine Environments: Marine InVEST**

Mark Plummer, National Oceanic and Atmospheric Administration  
Micah Effron, National Oceanic and Atmospheric Administration  
Howard Townsend, National Oceanic and Atmospheric Administration

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The National Center for Ecological Synthesis

The National Socio-Environmental Synthesis Center

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## About This Document

This case is part of the Federal Resource Management and Ecosystem Services (FRMES) Guidebook created by the [National Ecosystem Services Partnership \(NESP\)](#). NESP, housed at the [Nicholas Institute for Environmental Policy Solutions](#), seeks to enhance collaboration within the ecosystem services community and to strengthen coordination of policy implementation and research at the national level. The FRMES Guidebook represents a collaborative effort by federal agencies and outside experts to develop a credible and feasible approach to incorporating ecosystem services into the decision-making processes of federal agencies.

Cases are written and approved by the author(s)' agency, but they have not been peer reviewed. They describe the decision-making context within which that agency is considering or testing an ecosystem services management framework, and they present approaches or innovations that the agency is using to incorporate ecosystem services into its planning and decision-making processes. Cases informed development of the FRMES Guidebook and could be of value to others embarking on ecosystem services planning and management efforts.

To read other federal agency explorations and applications of an ecosystem services management framework, visit [www.nespguidebook.com](http://www.nespguidebook.com).

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# **A Heuristic Framework for Evaluating Ecosystem Services in Coastal and Marine Environments: Marine InVEST**

## **Project Overview**

Many scientific diagnoses of declining marine species and habitats and of recreational use patterns along U.S. coasts point to upland and freshwater sources of imperilment. A growing number of scientists argue that the best hope for protecting marine resources for multiple uses is to consider larger-scale processes, including activities that take place on land, when designing management strategies. But how inclusion of land- and water-use practices in strategies to sustain coastal marine resources affects management outcomes is poorly understood. The goal of this research is to assess the importance of including these practices in the management of coastal marine resources, using an ecosystem services framework. An ecosystem services framework provides a clear and novel path forward—one that integrates ecological processes with socioeconomic behavior and values.

The specific objectives of the research are to develop a set of linked watershed-marine models with ecosystem service outputs to evaluate management strategies for coastal resources and to apply those models to three case studies: Puget Sound, Galveston Bay, and Chesapeake Bay. In each case, we compare the strength and influence of watershed activities on key ecosystem services and ask how outcomes of marine resource management strategies are affected by including coastal watershed processes. We also explore a limited set of climate change scenarios. We estimate ecosystem services and their values using production function approaches, focusing on how changes in system function driven by land use management and climate change lead to changes in the provisioning of food from selected fisheries. Future work may extend this analysis to aquaculture, recreation, and coastal protection.

## **Project Description**

This project originated from staff-led interest. Staff recognized that many diagnoses of declining marine species and habitats along U.S. coasts point to upland and freshwater stressors; however, few studies have examined how and whether activities on land affect marine resources, and few management efforts have used quantitative linkages between land use management and marine resources to inform decision making. Similarly, although the effects of climate change on coastal systems are fairly well quantified, few studies have explored how alternative land- and water-use management strategies and climate scenarios will likely influence the delivery of marine ecosystem services. Although NOAA may have no direct connection with the development and implementation of these management strategies, it can provide scientific support to state and other agencies that are responsible for land- and water-use policies.

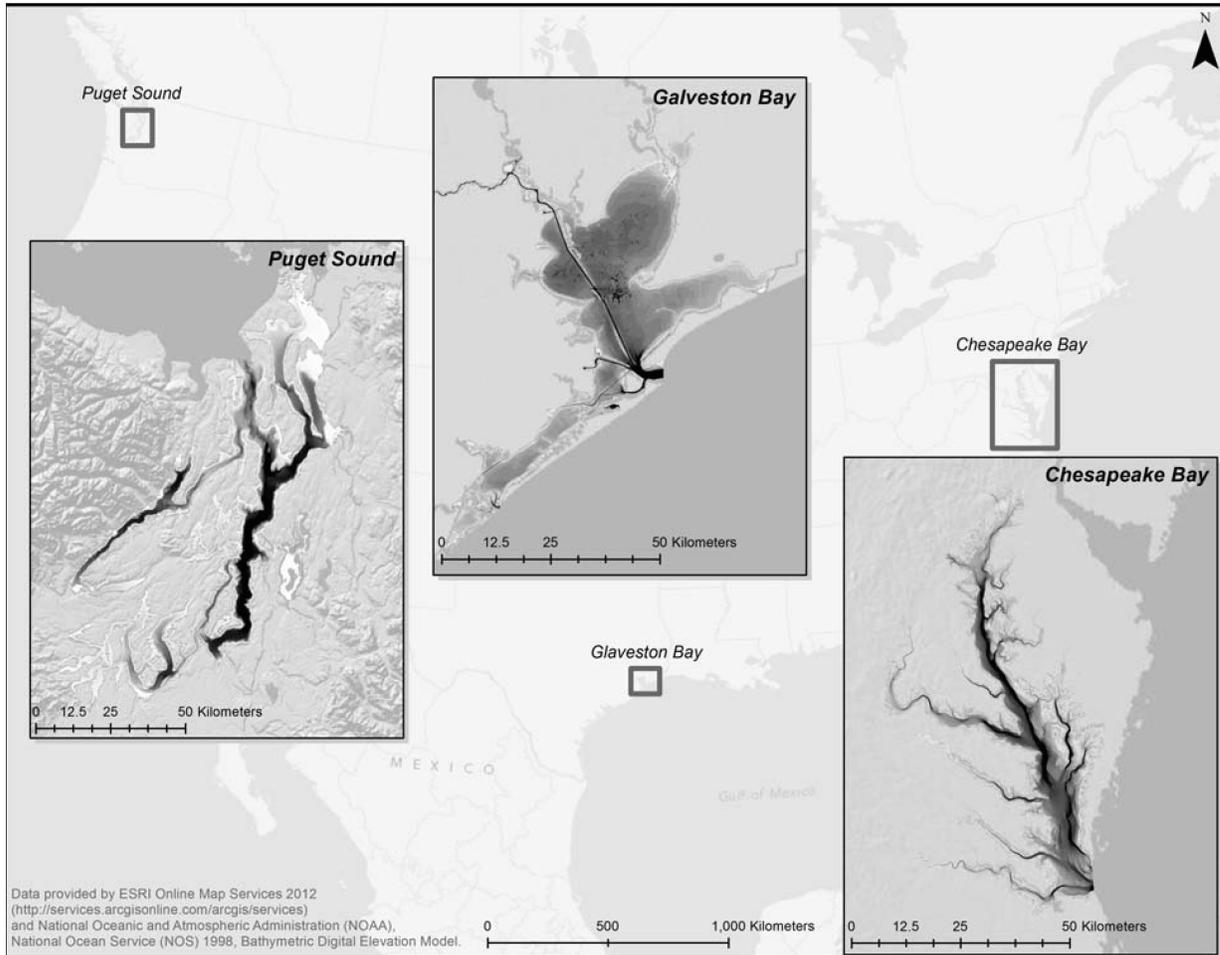
NOAA/NMFS scientists from the Northwest Fisheries Science Center, Southeast Fisheries Science Center–Galveston Laboratory, and Habitat Conservation Division/Chesapeake Bay Program teamed with scientists from the Natural Capital project (a partnership of Stanford University, the University of Minnesota, The Nature Conservancy, and the World Wildlife Fund) to develop a proposal for funding for the project.<sup>1</sup> The proposal was to develop a set of linked watershed-marine models using an ecosystem services framework to evaluate the effects of management and climate change on ecosystem service outputs. We chose three locations for conducting the analysis: Puget Sound, Galveston Bay, and Chesapeake Bay (Figure 1). We chose these locations on the basis of similarities in important

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<sup>1</sup> <http://www.naturalcapitalproject.org>.

ecosystem services (commercial and recreational shellfish harvests) and the availability of NOAA/NMFS staff in each location.

**Figure 1. Project Locations.**



Source: Carey et al. (2013).

The decision to pursue this project was based on no particular NOAA/NMFS (National Marine Fisheries Service) planning or regulatory decision-making processes. Instead, staff viewed the project as an important scientific contribution that could inform and support both such processes and state agency efforts to manage coastal resources. (State fisheries management agencies were not partners in the proposal but were involved on a voluntary basis, providing data on harvest, landings, and licensing.) We did not intend the project to be immediately integrated into a particular agency process; therefore, we did not consider programmatic and implementation responsibility for utilizing project results. If the project were implemented on an operational basis, participation by state fisheries management agencies as well as local land use management/planning agencies would be needed.

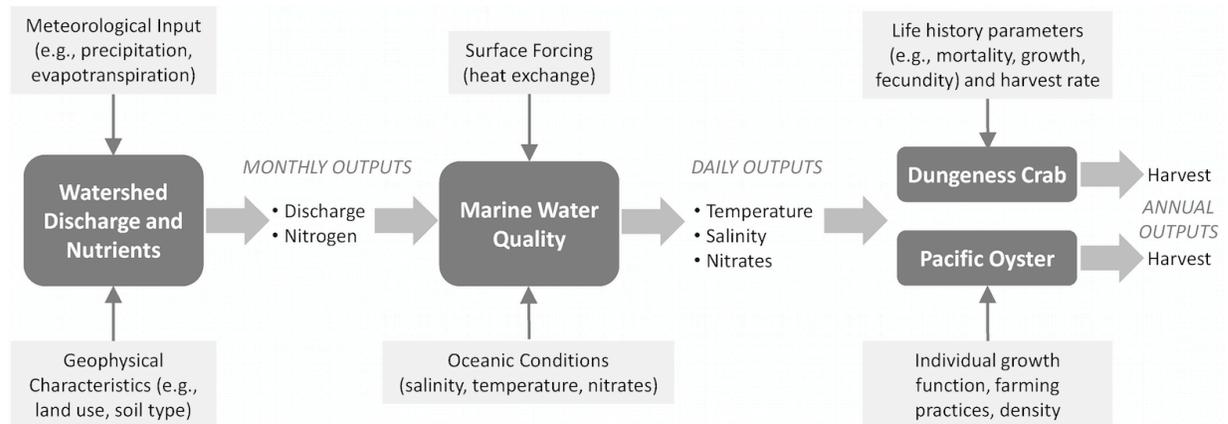
In April 2010, we were awarded funding through the Comparative Analysis of Marine Ecosystem Organization (CAMEO) program, a joint program with NOAA/NMFS and The National Science Foundation to hire post-doctoral researchers and contractors to develop linked watershed-marine

ecosystem service models to evaluate coastal management.<sup>2</sup> In addition to the CAMEO funding, which ended in 2012, the project utilized federal staff scientists. Because these staff scientists and their partner scientists at the Natural Capital Project were familiar with scientific literature on ecosystem services and had experience in constructing and using models of ecosystem services supply and demand, they needed no training in conducting ecosystem services analysis.

We first developed and applied our framework to fisheries and aquaculture management in the Hood Canal of Puget Sound. To illustrate the influence of watershed processes on marine ecosystem services provided by the Hood Canal, we modeled the sensitivities of Dungeness crab and Pacific oyster harvests to changes in land use and large-scale ocean and climate drivers. For land use, we evaluated a scenario of possible land cover changes that was previously generated as part of a project to envision possible futures in Puget Sound (Bolte and Vache 2010). Land cover categories included developed, forest, grasslands, planted and cultivated, and wetland land covers, all of which could be affected by land use decisions or restoration and conservation decisions.

The final ecosystem goods and services evaluated were crab and oyster biomasses available for commercial and recreational harvest. The team developed or re-parameterized simple process models to link the land use changes and climate change to (1) watershed discharge and nutrients, (2) marine water quality, (3) Dungeness crab populations available for harvest, and (4) Pacific oyster populations available for harvest (Figure 2). The existing models used in the analysis were drawn from the InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) and Marine InVEST toolbox.

**Figure 2. Conceptual Diagram of Watershed Marine Model Linkages.**



Source: Toft et al. (2013).

Note: Primary inputs and outputs of each model and temporal resolution of outputs are noted.

For ecosystem services values, the gross commercial value of oyster and crab harvest was measured as the net present value of the biomass based on ex-vessel prices. The recreational value of crabs was measured as willingness to pay for recreational fishing opportunities (as estimated by travel costs).

Because the initial application of the framework was on watershed-marine linkages for a limited set of ecosystem services, we have not yet explored the issue of trade-offs among the full set of ecosystem services covered by the InVEST models. Moreover, because the project has not been implemented on an operational basis, we have neither identified nor developed governance and management structures for evaluating trade-offs and conflicts between land use planning and fisheries management.

<sup>2</sup> <http://cameo.noaa.gov>.

We have published some of these models, which were applied to fisheries and aquaculture management in the Hood Canal of Puget Sound (Toft et al. 2013). We have also explored some of the research questions in the context of loop analysis in all three locations (Puget Sound, Galveston Bay, and Chesapeake Bay) (Carey et al. 2013). A broader framework is under development, pending funding, for the Rappahannock River, Chesapeake Bay, and Galveston Bay.

### **Decision Context**

Holistic ecosystem approaches to marine and coastal management can greatly improve our ability to predict the consequences of management decisions in a complex physical and political environment. Demonstrating the benefits of ecosystem-based management (EBM) approaches can promote cooperation among the various local, state, and federal agencies responsible for stewardship of natural resources. However, implementing ecosystem-based management across vast land and seascapes presents a major challenge. Coordination and collaboration across jurisdictional boundaries is impeded by agencies' differing legislative mandates, priorities, operational processes, and organizational cultures.

As NOAA works with the fisheries management councils to shift from single-species management to an EBM approach, it is crucial that we develop a better understanding of “where marine resource managers should target watershed-based pressures, and under what conditions near-shore strategies are sufficient to protect or recover recreationally, commercially, and culturally important marine species” (Toft et al. 2013). This project, which experiments with a modeling approach to investigate the water quality impacts, under different climate scenarios, of land-based runoff on wild and farmed shellfish, helps advance the emerging science of spatially explicit, production function-based ecosystem services assessments. It has several potential management applications:

- The project shows that shellfish, for the most part, responded positively to increased sources of land-based runoff, but several ecological processes that likely would have had a negative impact on shellfish were not modeled. Thus, land-sea linkages that may affect fisheries should be further investigated. Gaining a better understanding of even the rough magnitude of the potential impacts of specific ecological processes on fisheries would help NOAA determine where to target its mitigation efforts.
- The project demonstrates the importance—and challenge—of attempting to account for all relevant ecological relationships that, taken together, deliver benefits to society. A modeling approach that fails to account for ecological processes on land that affect marine systems or that fails to include a subset of processes within a given system may lead decision makers astray. This point highlights the particular importance of investigating and explicitly stating the uncertainty associated with ecosystem services assessments.
- The project reveals how an ecosystem services framework highlights the need for better integration both within and among natural resources management organizations. Land-based sources of water pollution affect not only fisheries but also other services that NOAA is concerned with, such as beach recreation and protection of threatened and endangered species, not to mention services under the purview of other agencies (e.g., drinking water under the purview of the U.S. Environmental Protection Agency). Therefore, an ecosystem services framework reveals the benefits of collaboration and potential synergies that might otherwise be overlooked.

In summary, this project emphasizes that the ecosystem services framework has much to offer, but that its full potential cannot be realized until methodological, political, legal, and institutional barriers are overcome. The integrated nature of this framework stands in stark contrast to the silo management approach that often characterizes natural resources management in the United States. NOAA is eager to

engage its partners in efforts to tackle management problems from the more holistic perspective that the ecosystem services framework offers.

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***Cover photo: National Oceanic and Atmospheric Administration***

***About the Authors***

**Mark Plummer** joined the Northwest Fisheries Science Center in 2002. He is studying methods for assessing the cost-effectiveness of salmon conservation actions and examining methods for valuing ecological goods and services for Puget Sound.

**Micah Efron** is a social scientist specializing in ecosystem services science and policy. He started at NOAA as a Knauss Marine Policy Fellow in 2012. He has also worked on a variety of marine conservation projects around the world, including socioeconomic fieldwork with fishing communities in Sierra Leone and Kenya.

**Howard Townsend** leads the NOAA Chesapeake Bay Office (NCBO) modeling team, which supports holistic, ecosystem-based fisheries management by developing and implementing ecosystem models and other analytical tools. He also provides administrative coordination of NCBO programs at the Cooperative Oxford Laboratory.

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### **About the National Ecosystem Services Partnership**

The National Ecosystem Services Partnership (NESP) engages both public and private individuals and organizations to enhance collaboration within the ecosystem services community and to strengthen coordination of policy and market implementation and research at the national level. The partnership is an initiative of Duke University's Nicholas Institute for Environmental Policy Solutions and was developed with support from the U.S. Environmental Protection Agency and with donations of expertise and time from many public and private institutions. The partnership is led by Lydia Olander, director of the Ecosystem Services Program at the Nicholas Institute, and draws on the expertise of federal agency staff, academics, NGO leaders, and ecosystem services management practitioners.

### **About the Nicholas Institute for Environmental Policy Solutions**

Established in 2005, the Nicholas Institute for Environmental Policy Solutions at Duke University improves environmental policymaking worldwide through objective, fact-based research in the areas of climate change, the economics of limiting carbon pollution, emerging environmental markets, oceans governance and coastal management, and freshwater management. The Nicholas Institute is part of Duke University and its wider community of world-class scholars. This unique resource allows the Nicholas Institute's team of economists, scientists, lawyers, and policy experts not only to deliver timely, credible analyses to a wide variety of decision makers, but also to convene decision makers to reach a shared understanding of this century's most pressing environmental problems.

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For more information, please contact:

Lydia Olander  
E-mail: [Lydia.olander@duke.edu](mailto:Lydia.olander@duke.edu)  
Phone: 919-613-9713  
Web: <http://bit.ly/1zCpSnt>

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