

Values at the Land-Sea Interface: Mapping Ecosystem Services in the Coastal Environment

LISA M. WEDDING, PH.D., SARAH M. REITER, M.SC./J.D., GREGORY M. VERUTES, M.SC., ERIC HARTGE, M.SC., GREG GUANNEL, PH.D., AND LAURA H. GOOD, PH.D.

ABSTRACT

While climate impacts are increasing (e.g., rising seas, increasing storm damage) so too is the desire to protect natural systems and capitalize on their protective benefits and other services. Linking ecosystem services science through mapping efforts can help students learn methods for including the value of nature in climate adaptation decisions. This hands-on lab activity was developed to introduce students to the theory and application of ecosystem service valuation and mapping at the land-sea interface. By working with case study data from British Columbia, students learn to apply ecosystem service concepts and easy-to-use, open-source software to answer engaging questions within a real-world policy and planning context.

DEVELOPMENT OF AN ECOSYSTEM SERVICE MAPPING ACTIVITY

Ecosystem Services are the stream of vital benefits flowing from natural capital to people. Examples of service flows that are vital to humanity include the production of goods (e.g., food from fisheries that depend on nursery habitat) and services (e.g., coastal protection from dune or wetland habitats). Coastal habitats provide one of many ecosystem services by reducing impacts from storms and increase resilience in coastal areas. However, with ever increasing human pressure on ecosystems, we need ways to identify, map, and place value on where natural habitats provide the greatest benefits to coastal communities in order to prioritize adaptation planning efforts that protect or restore those critical natural habitats. To support decision-makers in their efforts to



The dune habitat surrounding Doran Beach in Sonoma County provides the ecosystem service of coastal protection. Courtesy of Eric Hartge

manage coastal resources in a changing climate, the Natural Capital Project and the Stanford Center for Ocean Solutions have engaged in several case studies to embed ecosystem service science in practice (Verutes and Rosenthal 2014; Langridge et al. 2014; Reiter et al. 2015; Wedding et al. 2016). We developed this lab to foster skills-based learning in a cross-cutting exercise that provides learning outcomes with both scientific methods and policy implications.

We developed this lab for a graduate level course at the University of California at Santa Barbara (UCSB) during Fall 2015. The Bren School at UCSB emphasizes in their mission statement the importance of understanding environmental issues and solutions by exposing students to the theoretical and analytical approaches of several disciplines. To support the training of research scientists and environmental-management professionals, the Bren School invited us to co-create a new and unique curriculum in support of their mission (ESM 296-4F: Advanced Special Topics in Geographic Information Systems). This lab was later adapted for a graduate-level marine geography course at San Francisco State University during Fall 2016. This activity demonstrates both the challenge of integrating ecosystem service assessment and mapping, and the opportunity to place value on our natural habitat in a real-world planning context. Students will learn how coastal planning decisions can have alternative outcomes for people and the environment. The activity, detailed here, is highly transferrable to a variety of audiences, both student and professional, and opens the opportunity to engage students in some of the more human-related Ocean Literacy Principles and fundamental concepts (listing follows).

ACTIVITY: Coastal Vulnerability Modeling

BACKGROUND

Extreme weather, sea-level rise, and degraded coastal ecosystems are placing people and property at greater risk of damage from coastal hazards. Marine and coastal habitats work as buffers from storms and floods, reducing the need and investment costs in types of 'hard' shore protection such as riprap, levees, and bulkheads. Coastal habitats include oyster reefs, coral reefs, marshes, dunes, seagrass, and kelp forests. These habitats all play different roles in reducing risk from coastal hazards as well as providing many other auxiliary benefits, such as carbon sequestration, opportunities for recreation, and nursery habitat for fisheries. In order to place value on the goods and services from natural coastal habitats—and thus evaluate the benefits from ecosystem services—we can map the location of both habitat and human population.

In this lab, we will use InVEST (Integrated Valuation of Environmental Services and Tradeoffs) Coastal Vulnerability Model, which is a suite of software models created by the [Natural Capital Project](#) used to map and value the goods and services from natural capital (e.g., earth's lands, waters, and their biodiversity). InVEST is a free and open-source suite of software models that are spatially-explicit. Students will work within a decision context in British Columbia to assess where investments in habitat conservation and restoration will be most effective for reducing risk of coastal communities and properties to sea-level rise and storms. Using InVEST in an iterative process, students will create new scenarios based on the information revealed by the models until suitable solutions are identified (e.g., under varying sea-level rise scenarios and planning time horizons).

OVERVIEW

This exercise will guide students through coastal vulnerability modeling on the west coast of Vancouver Island (WCVI) as a case study location. Students will examine the role of habitat in providing protection from coastal hazards and learn how to place value on their protective benefits. A scenario-based exercise will call on students to create a coastal vulnerability map for different planning and time horizons. Ultimately, students will be able to role play the engagement of coastal managers with this information to support the assessment of hazard risk to people, property, and infrastructure in British Columbia. Students work in groups to explore and communicate impacts associated with climate change under three time horizons. By empowering emerging ocean leaders with the skills to engage decision-makers about these challenges associated with climate impacts, students will apply the scientific and policy principles. To culminate, students will be asked to reflect on their experience of applying best available science to a management context.

TOPIC

Environmental Studies—Climate Change Adaptation
Coastal hazards
Coastal management
Geographic Information Systems (GIS)

LEVEL

Community college, undergraduate or graduate students in environmental/marine sciences, resource management, or policy. Could also be adapted for high school earth science, grades 11-12, including AP classes.



Students learning how to map and place value on coastal habitat during a coastal vulnerability lab. Courtesy of Chris Anderson

ALIGNMENT WITH OCEAN LITERACY PRINCIPLES

1. *The Earth has one big ocean with many features:* Fundamental concept h.
5. *The ocean supports a great diversity of life and ecosystem:* Fundamental concept h.
6. *The ocean and humans are inextricably interconnected:* Fundamental concepts b, d, f, g
7. *The ocean is largely unexplored:* Fundamental concepts b, c, d, e, f (*Ocean Literacy*, 2013)

CLASS SIZE

Designed for ~15-20 students, 4-5 groups of 3-4 students, depending on number of instructors and teaching assistants.

FOCUS QUESTIONS

- What are the natural habitats that provide an ecosystem service of coastal protection?
- Where is the coast most exposed to hazards associated with impacts from climate change?
- Where is the risk reduction provided by coastal habitats greatest?

- How does coastal exposure change under different planning horizons and sea-level rise scenarios?
- How would you best convey this information to a coastal manager?

TEACHING OBJECTIVES

- Encourage student interest and awareness in the role, and impact of climate change in preparedness planning
- Increase student understanding of how science and policy interact in coastal management
- Raise student awareness of GIS and spatial approaches to environmental decision making
- Increase student knowledge regarding scenario-based approaches to management
- Increase student awareness of the complexity of environmental problem solving and coastal management



Surfer's Beach, San Mateo County
February 26, 2016; Photo: E. Hartge



Surfer's Beach, San Mateo County
January 19, 2017; Photo: E. Hartge

Surfer's Beach in San Mateo County is one of many examples that portray active coastal adaptation decision making that impacts our relationship with the coastline. Courtesy of Eric Hartge.

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LEARNING OBJECTIVES

Upon successful completion of this exercise, students will be able to:

- Define ecosystem service assessment and natural capital
- Demonstrate a proficiency in using a spatial analysis tool such as InVEST
- Develop spatial questions and map products to address management problems
- Engage in role play with small groups to practice collaborative decision making

MATERIALS

- Ecosystem Service Mapping Presentation & Script
- InVEST software
- Exercise data sets
- Computers with access to internet
- GIS software, if available but not mandatory
- Reflection Exercise

All teaching materials can be downloaded from:
<https://oceansolutions.stanford.edu/lesson-plan-and-materials-coastal-vulnerability-modeling>

TEACHING TIME

- 2–3 hours

ACTIVITY ARRANGEMENT

- Classroom arranged into table clusters or u-shape format to encourage student-centered discussion and group collaboration.
- Students are assigned to small breakout groups for lab exercise and discussion. Breakout groups should contain no more than four students.

KEYWORDS

Ecosystem services, natural capital, coastal habitat, climate adaptation planning, ocean/coastal management, geographic information systems (GIS), spatial approach, ecosystem service mapping, climate change, environmental decision making.

PROCEDURE

Engage

1. Prior to class, students should watch a Stanford Center for Ocean Solutions [5 minute video on Series of Solutions](#). This is the first episode of the four-part Series of Solutions that highlights the valuable role that nature provides in protecting coastal communities; and follows the story of an intern as she discovers how her ecology background can directly inform coastal policy.

In addition, students should read [Coastal habitats shield people and property from sea-level rise and storms](#). Arkema, Katie K.; Greg Guannel; Gregory Verutes; Spencer A. Wood; Anne Guerry; Mary Ruckelshaus; Peter Kareiva; Martin Lacayo; Jessica M. Silver. *Nature Climate Change*. October 2013, Vol 3, pp 913-918.

Recommended time allotment: 20 minutes

2. When class begins, introduce the activity and goals. Explain to students they will be working towards answering the following questions:
 - What are the natural habitats that provide an ecosystem service of coastal protection?
 - Where is the coast most exposed to hazards associated with impacts from climate change?
 - Where is the risk reduction provided by coastal habitats greatest?
 - How does coastal exposure change under different planning horizons and sea-level rise scenarios?
 - How would you best convey this information to a coastal manager?

Recommended time allotment: 10 minutes

3. Start class in one of two ways, by 1.) having students listen to ecosystem service assessment presentation by instructor; or 2.) encouraging students to review the [presentation](#) and notes in groups and summarizing the key points.

Recommended time allotment: 20 minutes.

Explore and Explain

4. As a class, and using students' notes from the presentation, break students into small groups and have them work through the [lab materials](#) together.

"You have been tasked by a coastal management agency to assess where investments in habitat conservation and restoration will be most effective for reducing risk of coastal communities and properties to storms and sea-level rise. Use results from the InVEST Coastal vulnerability model to answer the questions below."

1. *Along the west coast of Vancouver Island, where are the most exposed areas to coastal hazards? (Hint: this is just biophysical exposure and does not include social vulnerability.)*

2. *Where is the risk reduction provided by coastal habitats greatest? This will be supported by visualizing 1.) a coastal exposure map with the presence of habitats; and 2.) a coastal exposure map without habitats.*
3. *Where would habitat restoration lead to the greatest risk reduction?*

Recommended time allotment: 60 minutes

Synthesis and Reflection

Lead a synthesis of the findings and reflection on being placed in a coastal management position and applying science to a real-world context using questions from the reflection exercise. Discuss overlapping challenges linking ecosystem service mapping and assessment within a policy context.

5. Have each group work through the reflection questions below and prepare to present to the class (may be useful to use white board/flip charts/post it notes). Groups will describe their reflections in the context of the following questions:
 1. *What did you learn about coastal vulnerability analysis?*
 2. *What did you learn about the role of coastal habitat on the west coast of Vancouver Island?*
 3. *Was the coastal exposure map sufficient for deciding the best location(s) for habitat restoration?*
 4. *How did your group come to consensus on the priority areas for habitat restoration?*
 5. *What coastal location would you apply this analytical approach to in the future?*

Recommended time allotment: 30 minutes

ASSESSMENT OPPORTUNITIES

The reflection exercise can serve as an assessment of whether the lab activity met the learning objectives overall. An individual written reflection could be added post-class to provide further insight in to individual progress.

EXTENSION ACTIVITIES

Have students research the natural habitats in their local area and consider the ecosystem services these provide. Students could also review the coastal resilience approach to mapping and climate adaptation planning on <http://coastalresilience.org/> with a focus on their local area.

CONNECTIONS TO OTHER SUBJECTS

- Environmental law and policy
- Geography

ADDITIONAL RESOURCES

- www.naturalcapital.org
- www.esri.com/
- <http://coastalresilience.org/>

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LISA WEDDING, PH.D., is an Early Career Science Fellow at the Stanford Center for Ocean Solutions. Lisa is engaged in spatial modeling efforts to identify coastal exposure and the role that habitat can play in protecting coastal communities from climate change impacts along the California central coast. She holds a Ph.D. in geography, with a specialization in marine landscape ecology from the University of Hawaii at Manoa.

SARAH M. REITER, M.SC./J.D., is a Professor (Summer/Adjunct Faculty) at Vermont Law School (VLS), where she teaches Ocean and Coastal Law and Environmental Dispute Resolution. She also works with the next generation of environmental lawyers as the Associate Director of Career Services at VLS. Her peer-reviewed interdisciplinary research is published in *Science* and *Stanford's Environmental Law Journal*. Sarah holds a Bachelor of Science in Oceanography from the U. S. Naval Academy, a M.Sc. in Environmental Studies from the College of Charleston, and a J.D. from Vermont Law School.

GREG VERUTES, M.SC., is a coastal geographer, blending the fields of conservation and technology. He builds simple tools to communicate sustainability science using storytelling, serious games, and data visualization. Gregg received his Master of Science from San Diego State University and Bachelor of Science in Policy Analysis and Management from Cornell University.

ERIC HARTGE, M.SC., is the Research Development Manager with the Stanford Center for Ocean Solutions. His current work focuses on incorporating best available ecosystem services science into climate adaptation planning in coastal California. Eric holds a Master of Science in Environmental Sciences and Policy from Johns Hopkins University and a Bachelor of Science in Marine Biology from the College of Charleston.

GREG GUANNEL, PH.D., is part of the University of Virgin Islands. Guannel's research involves the incorporation of natural habitat in the modeling of nearshore hydrodynamics as well as short- and long-term shoreline change. Greg received his Civil Engineer degree from Ecole Supérieure des Travaux Publics in Paris, France, his Master of Science in Ocean Engineering from Texas A&M University, and his Ph.D. in Civil Engineering from Oregon State University.

LAURA H. GOOD, PH.D., is the Science Education and Outreach Coordinator at California State University, Monterey Bay where she manages several university outreach programs for emerging marine researchers, and supports the development of STEM student success and STEM diversity initiatives in the College of Science. Laura's background is in marine science, environmental education, and free-choice learning. She is interested in marine education, scientist engagement in education and outreach, sociocultural learning theory, and professional development practices. Laura holds a Bachelor of Science in Ocean Science from the University of Plymouth (UK), a Master of Science in Marine Resource Management, and Ph.D. in Science Education from Oregon State University.