Healthy Ecosystems Grants 1 Final Report

Project Title: Advancing Optimization of Ecosystem Services to Inform Management and Restoration of the Gulf of Mexico
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Awardee: Stanford University
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- Christine Shepard, The Nature Conservancy
- Spencer Wood, Stanford University

I. ORIGINAL PROJECT SUMMARY (from proposal)

This project will significantly advance the application of ecosystem service science to strategic management and planning in the Gulf of Mexico. New policies place a strong emphasis on planning processes that work across sectors and political jurisdictions to provide the greatest returns for people and nature. While collective understanding of relationships between healthy ecosystems and people is growing, governments and non-governmental organizations lack the science and models to translate these ideas into practical guidance for specific locations. This project will develop and implement, within a pilot planning process in the Gulf, a science-based approach to prioritize restoration projects that maximize delivery of services to people. Results will reveal potential tradeoffs between different services given investment priorities and community vulnerabilities. By accounting for a changing climate and its effects on ecosystems and the services they provide, together with other external drivers, this project will identify the best places to enhance resilience in a region affected by oil and gas extraction and exploration.

The project objectives are to (1) develop a multi-objective optimization framework for prioritizing conservation and restoration of coastal environments given a suite of activities including coastal development, fisheries, oil and gas exploration, and marine transportation, (2) connect models of ecosystem service provision to community benefits from these services and vulnerability to change to

produce an integrated analysis of ecosystem services under multiple prioritization schemes for a pilot site
(3) develop and test the optimization framework and models within a stakeholder engagement process where officials are prioritizing projects to meet multiple ecosystem service objectives.

These objectives respond to the RFA by advancing knowledge of ecosystem services in relation to offshore and coastal energy production and by accelerating informed management and restoration of the Gulf. The new optimization framework will prioritize coastal and marine services using models that account for relationships between biophysical attributes of the environment and human well-being. By working within a planning process in the Gulf, scientific outputs will be positioned to inform decisions about which projects to select to meet the needs of local communities, while preventing unintended consequences that could undermine efforts to enhance coastal resilience. Collection of local social and environmental data will facilitate the development of first generation models for ecosystem services in the Gulf that can be used as the basis for future science and management.

Relevance to the Gulf Research Program: Project results will further the Gulf Research program's three goals by advancing the science to understand better how diverse activities, including offshore oil and gas development, influence the structure of ecosystems and the broad range of services they provide to people. The optimization framework and models will explicitly connect the function of the Gulf and outer shelf areas with the well-being of human communities and produce practical information that will allow decision-makers to foster environmental protection. Over the long-term, the hope is that results from this project will lead to enhanced resilience of the Gulf's social-ecological system and optimal delivery of benefits people depend upon.

II. PROJECT RESULTS

Accomplishments
Problem: Disasters such as the Deepwater Horizon (DWH) explosion and Hurricane Katrina highlighted how healthy ecosystems in the Gulf of Mexico (GOM) provide multiple benefits to people and the negative consequences for communities when these ecosystems are degraded or lost. State, county and local government agencies, non-governmental organizations and industry representatives are making decisions now about where to invest in development, conservation and restoration projects to rebuild the region’s economic and social vitality. Yet they lack the science and tools necessary to transparently and credibly translate a growing understanding of relationships between ecosystems and human wellbeing into practical applications for management and restoration. A key need to inform strategic decisions is a science-based approach to prioritize the most beneficial restoration and conservation projects across the GOM to maximize delivery of services to people.

Studies: To advance the scientific basis for ecosystem management in the GOM, we (1) scoped management opportunities within which to develop and apply ecosystem service models to inform conservation and restoration priorities, 2) connected models of service provisioning to social data concerning community benefits and vulnerability, (3) developed a multi-objective optimization framework for prioritizing conservation and restoration of coastal environments based on delivery of ecosystem services, (4) conducted a pilot analysis to test the framework for prioritizing projects to meet a suite of ecosystem service objectives.

Results: Our work produced four main results. First, we produced an analysis of both near- and long-term opportunities to develop, and test the utility of, the multi-objective optimization framework for informing restoration and conservation decisions. Through meetings and conversations with representatives from US federal agencies (e.g., NOAA, EPA, USFWS, Restoration Council), NGOs such as TNC and Restore America's Estuaries, and consultants such as Abt Associates, we identified a suite of management decisions requiring social and ecological information to prioritize funding. We identified the decision timeline, key institutions involved, and restoration/conservation goals (including focal ecosystem services). We also included restoration funding cycles not explicitly tied to DHW. Through this scoping exercise, we identified the Gulf Coastal Ecosystem Restoration Council's funded priorities list (FPL) as one near-term process that could potentially benefit from the multi-objective optimization framework. The Council revised its Comprehensive Plan in December 2016 and anticipates releasing the next FPL within a few years. As a federal agency they are interested in incorporating ecosystem services in their decision-making (OMB Management Memorandum 16-01. October 2015). Further opportunities to apply the framework exist within the NFWF Gulf Environmental Benefit Fund, NOAA's Coastal Restoration grants and the NRDA process associated with the DWH disaster.

Second, we advanced models of ecosystem service provisioning for coastal protection and recreation by connecting them to social data in order to estimate how changes in natural and built environments affect community benefits and/or vulnerability. To accomplish this, we reviewed the literature on social vulnerability to coastal hazards. We found a limited number of studies that combine coastal hazard modeling, natural and nature-based features, and data on social vulnerability (beyond population) to understand human dependence on ecosystems for risk reduction (Arkema et al. forthcoming 2017 in Living Shorelines, Arkema et al. in press Annals of the New York Academy of Sciences). Lack of integration among disciplines is problematic because understanding the societal benefit of a management action requires quantifying how change in ecosystem structure and function will affect particularly vulnerable groups of people (Table 1, Arkema et al. in press). Differences in access to resources, power, capacity, and information are major elements driving disparities in disaster response, including preparedness, evacuation, damage, and recovery. We leveraged existing social vulnerability indices (e.g., SoVI) that incorporate census-based demographic information that reflects the drivers above and combined these data with outputs from the supply steps from our coastal hazard model to understand where socially vulnerable communities would be most likely to benefit from policies and management decisions that sustain ecosystems. To extend the results of the recreation model to understand community benefits we used information on tourism expenditures and livelihoods dependent on the tourism industry from the different states in our pilot area of interest (Hawthorne et al. in prep, see below).

Third, we produced a multi-objective optimization framework for prioritizing conservation and restoration of coastal environments. We incorporated recreation and coastal protection services, which are common objectives in the GOM, but the framework allows the addition of more objectives. The framework consists of two components, a scenario processor and a mixed integer programming (MIP) optimizer. The scenario processor allows the user to provide baseline input data for the ecosystem service models and a scenario shapefile that contains locations and descriptions of a set of potential projects. The scenario processor iterates through the potential projects, using the ecosystem service models to estimate each project's marginal benefits. The marginal benefits are calculated as the difference between baseline results and the results with a single project implemented. The MIP optimizer allows the user to define decision parameters like weights on different objectives (i.e., weighting coastal protection as more important than recreation benefits), constraints (i.e., overall budget) or ecosystem service targets, and whether to generate single solutions or trade-off surfaces.

Fourth, we produced a pilot analysis for Mississippi, Alabama, and Florida using the multi-objective optimization framework and the DWH Tracker (http://www.dwhprojecttracker.org/) to address three questions we heard from decision-makers during our scoping (first result). 1) Where should investments in restoration and conservation be made to achieve the best return on coastal protection, tourism and the combined ecosystem services? 2) What is the estimated outcome of approved projects (DWH tracker) on coastal protection and tourism? 3) How do the approved projects align with areas the framework suggests for investment and are there gaps to be targeted in future proposals? Our outputs include a series of maps (investment portfolios) and trade-off curves that show where to invest in conservation and restoration of oyster reefs, seagrass, saltmarsh etc. to achieve coastal protection and tourism benefits and the marginal benefits of the projects in the DWH Tracker (Hawthorn et al. in prep for Conservation Letters).

Initial Outcomes

Implication of project results for current and future work of the project team: The project results have several important implications for the future work of the project team. First, the multi-objective optimization framework and extension of ecosystem service models to beneficiaries provides the project team with the core research and analytical platform to advance our work with partners in the GOM and beyond. The framework we have developed through this work will allow us to work with our partners to ask, where should we fund and/or engage in a suite of activities (e.g., conservation, restoration, development related activities) to achieve multiple ecological and social goals. It provides the foundation upon which to build out further functionality to analyze more habitats, actions (beyond conservation and restoration to include development etc.), and ecosystem service objectives.

Second, the pilot analysis revealed limitations in the information being tracked about each proposed and approved project and showed this is a major barrier to using a science-based approach and ecosystem service models to inform restoration decisions. In particular, by testing our framework using the Deepwater Horizon (DWH) Project Tracker, we learned that only a subset of the projects delineate the spatial footprint of proposed activities and anticipated outcomes. Filling this data gap is an opportunity to improve the flow of science-based information into the restoration decision-making. To address this issue we focused our analysis on those projects and cases that included information on the spatial footprint. We then classified the remainder of the projects in terms of what kind of information would be needed to specify the footprint (Hawthorne et al. in prep). In some cases, the necessary information included providing a polygon with the spatial footprint of the proposed activities. In other cases, it included providing spatial coordinates of a bounding box for the activities and anticipated outcomes. We are now working on several quantitative approaches for using our multi-objective optimization framework WITHIN a particular project area to provide information about the best place to target specific actions. We imagine this kind of an analysis supporting conversations between entities proposing projects and decision-makers charged with dispersing funds during the course of the proposal process. Such an approach could increase the transparency and efficiency of the funding process by iterating the flow of information among scientists, stakeholders and policy-makers to achieve social and ecological outcomes.

Third, the results of this project also helped us identify new opportunities for funding and collaboration. We submitted a proposal in response to the NOAA Restore Act Science program call for decision-support tools in collaboration with staff at the Gulf Coast Ecosystem Restoration Council. Working closely with Council staff to understand their information needs revealed an unexpected outcome. They are particularly interested in the intermediate results from our analysis, rather than a final output that combines results for all objectives and all activities. These conversations with the Restore Council staff shifted the focus of our future research to understanding and modeling the components of this analysis that can most easily be fed into their decision-making process, rather than assuming the kinds of information most relevant to decision-makers (see below for further discussion).

Implication of project results for research or practice of others: We anticipate several implications from our results for the research and practice by others. First, we hope that by pointing out the disconnect between social, physical and ecosystem scientists working on coastal hazards that this will help to foster more interdisciplinary scholarship (Arkema et al. in press Annals of New York Academy of Sciences). Second, our approach of developing and testing the model using a pilot analysis for the GOM and the DWH Tracker, and engaging closely with various federal agencies and NGOs, has the potential to advance specification of project location during the restoration decision-making process. Ultimately, this could lead to new tracking of restoration project data during the proposal phase, funding approval phase, and ultimately project implementation phase. Third, we anticipate continuing to advance the multi-objective optimization framework to include more ecosystem related objectives coastal protection and recreation to include, for example, habitat for fish, fisheries and livelihoods. By continuing to advance the framework, and by confronting it with the reality of actual decision-making processes, we anticipate that federal, state and local governments, NGOs and other stakeholders become better able to incorporate multiple objectives in a science-based approach by screening projects and identify gaps in proposed projects to elicit new proposals to achieve multiple objectives.

Our results advance the utility of ecosystem services information for management and restoration of the GOM. The results of the multi-objective optimization framework help to highlight restoration and conservation projects that will bolster ecosystems while delivering ecosystem services that benefit the economy and society by accounting for relationships between biophysical attributes of the environment and human well-being (e.g., protection from storms and livelihoods from the nature-based tourism industry). Our results suggest that accounting for multiple objectives that matter to people may shift restoration priorities. Funding projects that matter to people is important for achieving the mandates of certain federal agencies and also for ensuring project sustainability and longevity by incorporating the needs of local communities. Furthermore, because we developed and tested the framework using a pilot analysis for Mississippi, Alabama and Florida, and actual projects logged in the DWH Project Tracker, our outputs are positioned to inform decisions about which projects to select to meet the economic needs of local communities, while preventing unintended consequences that could undermine efforts to enhance, for example, coastal resilience. Our collection and synthesis of local social and environmental data facilitate future modeling of ecosystem services in the GOM that can be used as the basis for advancing science and management.

Unexpected Results

We experienced two main unexpected results. First, we had hoped to develop the multi-objective optimization framework within an on-going decision-making process. But we discovered the best opportunities to influence restoration and conservation decision making in the GOM, would require a longer engagement period than the 1-year timeline of this project and further funding to support more in-depth stakeholder elicitation and outreach. Instead, we decided to scope a suite of potential opportunities and to identify several for which we would pursue further funding to work with end-users, while taking the time to develop the deep relationships (among academics and practitioners) needed to apply, test and iterate on the multi-objective optimization framework to inform decision-making. As a result of conversations we had during the scoping phase we were able to then conduct a pilot analysis designed to specifically test the societal/scientific questions we heard from decision-makers that they face in their work related to prioritizing investments in coastal habitats.

Second, as we briefly described in the Initial Outcomes section (above), we learned through scoping various opportunities to inform restoration decision-making, that the outputs from our analysis most useful for informing decisions were actually several types of "intermediate" outputs, rather than a final result from the optimization analysis combining all habitats, activities and objectives (services). Often times academic scientists think that a "final answer" will be most helpful for decision-makers. However, because management decisions are rarely, if ever, made solely based on science, final outputs are in reality often less useful. A final summary output may mask critical steps in the analysis and skip over opportunities for decision-makers to understand, interpret and use the data created in each step of the analysis. By highlighting and communicating the "intermediate" results of our optimization analysis, we realized we can better build the capacity of staff at various NGOs and federal agencies in the GOM to understand and incorporate information about ecosystem services and community benefits from coastal habitats in to their prioritization of restoration and conservation projects.

Project Relevance

Researchers, community leaders, state government officials and federal government officials would all be interested in the results of our project. Researchers would be interested in the extension of the biophysical outputs from the ecosystem service models to incorporate community benefits and vulnerability because understanding the connections between ecosystems and well-being is an active area of research. Further, they would be interested in a multi-objective optimization framework for coastal and marine ecosystem services because thus far optimization of ecosystem services to achieve social and ecological goals has been more prevalent in terrestrial/freshwater systems

State and federal government officials would be particularly interested in our results because these entities are charged with fielding proposals for investments in conservation and restoration. In the GOM state and federal governments are receiving massive numbers of proposals and have expressed interest in as science-based approach to help them screen projects gainst shared ecological and social objectives for coastal habitat restoration and conservation

In addition to the above reasons, community leaders would be interested in the results of the project because using information about ecosystem services to inform coastal habitat restoration and conservation brings in social considerations which in the past have received less attention than ecological outcomes and goals. This could shift their thinking in terms of what projects to propose and where to target enhance human well-being. Further, by articulating social as well as ecological goals and outcomes, community leaders may be able to create more community buy in and ensure the longevity of the project. Our results could also help to make the process of proposing projects and applying for funding from the state and federal agencies more transparent and efficient for community leaders by suggesting some additional data and information that could be brought to bear on the proposed location of the projects.

Education and Training

Number of students, postdoctoral scholars, or educational components involved in the project:

- Undergraduate students: 0
- Graduate students: 0
- Postdoctoral scholars: 0
- Other educational components: 2

The "other education components" included in our project were two staff from the Gulf Coast Ecosystem Restoration Council. Funding from the NAS Innovation Grant supported a portion of the salary for Stanford researchers to engage with staff from the Gulf Coast Ecosystem Restoration Council at three educational events. These events were the Annual Natural Capital Symposium and Training at Stanford University in March 2016 and two workshops at the National Center for Ecological Analysis and Synthesis at UC Santa Barbara on coastal habitat restoration for social and ecological outcomes in May 2016 and January 2017. These events provided an opportunity to build the capacity of Restoration Council staff to use an ecosystem services approach to inform conservation and restoration decisions by sharing the goals, approaches and results from this project. These meetings and workshops also offered an opportunity to elicit feedback from endusers on our optimization framework, ecosystem service models and tools.

III. DATA AND INFORMATION PRODUCTS

This project produced data and information products of the following types:

- Data
- Scholarly publications, reports or monographs, workshop summary or conference proceedgins
- Models and simulations
- Software packages, digital tools, or other interactive media

Data

See attached Data Report.

Information Products

Citations for project publications, reports and monographs, and workshop and conference proceedings:

Arkema, K.K., S.B. Scyphers, and C. Shepard. Forthcoming March 9, 2017. Living shorelines for people and nature. In Bilkovic, D.M., M. Mitchell, J.D Toft, and M. La Peyre, eds., Living

Shorelines: The Science and Management of Nature-based Coastal Protection. CRC Press. https://www.crcpress.com/Living-Shorelines-The-Science-and-Management-of-Nature-Based-Coastal-Protection/Bilkovic-Mitchell-Peyre-Toft/p/book/9781498740029

Arkema, Katie K., Robert Griffin, Sergio Maldonado, Jessica Silver, Jenny Suckale, Anne Guerry. In press. Linking social, ecological and physical science to advance natural and nature-based protection for coastal communities. Annals of the New York Academy of Sciences. Issue: Year in Ecology and Conservation Biology.

Shepard, Christine. Building Coastal Resilience in the Gulf of Mexico: New and Emerging Science and Tools. Restore America's Estuaries 8th National Summit on Coastal and Estuarine Restoration and 25th Biennial Meeting of The Coastal Society. Our Coasts, Our Future, Our Choice. New Orleans, LA. December 10-15, 2016

Hawthorne, P., K. Arkema, J. Silver, S. Wood, C. Shepard. Prioritizing investments in restoration and conservation to achieve social and ecological goals in the Gulf of Mexico. In preparation for submission to Conservation Letters.

Curricula, GIS applications, models or simulations, software packages or digital tools, or other interactive media: See attached Information Products Report

Relevant Metadata Records:
N/A

Additional documentation to describe information products:
Both software and source code ("Project processor" and "Restoration Opportunities Optimization Tool") are (will be) accompanied by documentation that describes what they do, and the inputs and configuration files needed to run them. This documentation is (will be) included with the source downloads in the corresponding repositories.

Other activities to ensure access to information products:
In conjunction with the anticipated publication of our in prep paper Hawthorn et al., we intend to communicate broadly about the results of this project beyond our collaborators at the TNC Gulf of Mexico program and beyond the Gulf Coast Ecosystem Restoration Council staff. In particular, we will post links to the published paper (in prep for submission to Conservation Letters), the data (to be housed on Dryad), and the code (housed in bitbucket) on our website naturalcapitalproject.org and through online media sites such as Cool Green Science http://blog.nature.org/science/

Data Report										
DataType	**DigitalResourceType**	**Title**	**FileName**	**Creators**	**PointofContact**	**PublicationYear**	**RepositoryName**	**DOIorPersistentURL**	**Keywords**	**Publications**
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_DWH_saltmarshRES.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_DWH_saltmarshCON.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_DWH_oysterRES.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_DWH_oysterCON.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_DWH_seagrassRES.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_DWH_seagrassCON.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_saltmarshRES.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
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Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_seagrassRES.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Ecosystem service marginal values	gulf_results_seagrassCON.shp	Hawthorne, Peter, University of MN, Natural Capital Project	Hawthorne, Peter, hawt0010@umn.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Habitat Suitability Index - Seagrass	GulfHSI_Seagrass.shp	Silver, Jess. Natural Capital Project, Stanford University.	jess.silver@stanford.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	Habitat Suitability Index - Marsh	GulfHSI_Marsh.shp	Silver, Jess. Natural Capital Project, Stanford University.	jess.silver@stanford.edu	2017				
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	InVEST Coastal Vulnerability (CV) Model output	GulfCVmodel_outputs.shp	Silver, Jess. Natural Capital Project, Stanford University.	jess.silver@stanford.edu	2017				
Social/Cultural	Geospatial (vector, raster, or gridded)	InVEST CV Model Input - Social Vulnerability Index (SoVI) for the U.S. Coastal States based on the 2010 Census Tracts	Gulf_SoVI.shp	Created by Emrich, Chris. Hazards and Vulnerability Research Institute (HVRI), University of South Carolina, Modified by Silver, Jess	jess.silver@stanford.edu	2014				
Social/Cultural	Geospatial (vector, raster, or gridded)	InVEST CV Model Input - Dasymetrically mapped ACS population data from 2006-2010 Census Block Groups	Gulf_Population.tif	Created Verutes, Gregg. Natural Capital Project, Stanford University based on the American Community Survery 5-year estimates	jess.silver@stanford.edu	2013				
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV & Rec Model Input - Coastal habitats (coastal forest, aquatic bed and marsh) extracted from the U.S. Fish and Wildlife National Wetlands Inventory	CoastalForest.shp, AquaticBed.shp, Marsh.shp	Dataset created by U.S. Fish and Wildlife (Barrios, Jose - Southeast Region Wetlands Coordinator), Modified by Silver, Jess	jess.silver@stanford.edu	last updated 2017				

Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV & Rec Model Input - Coastal habitat (woody wetlands) extracted from the U.S.G.S. National Land Cover Dataset	CoastalForest.shp	Dataset created by Multi-Resolution Land Characteristics Consortium (MRLC) project of the U .S. Geological Survey, Modified by Silver, Jess	jess.silver@stanford.edu	2011 edition (first published 2001)					
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV & Rec Model Input - Coastal habitat (dunes) extracted from the U.S.G.S. Coastal Classification Mapping Project	Dune.shp	Dataset created by Guannel, Greg of The Natural Capital Project, Stanford Univeristy based on the U.S.G.S. Coastal Classification Mapping Project	jess.silver@stanford.edu	1998 & 2000					
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV & Rec Model Input - Coastal habitat (seagrass) coverage for AL, MS and FL compiled from numerous sources	Seagrass.shp	Statewide datasets created by the Mobile Bay Estuary Program (AL), The Nature Conservancy's Northern Gulf of Mexico EcoRegion Program (MS), the Florida Fish and Wildlife Commission and Fish and Wildlife Research Inst (FL)	jess.silver@stanford.edu	2009 (AL), 2000 (MS), 2001-02 & 2006 (FL)					
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV & Rec Model Input - Coastal habitat (oyster reef) coverage for AL, MS and FL compiled from numerous sources	OysterReef.shp	Statewide datasets created by the Alabama Dept. of Conservation Marine Resources Division (AL), Mississippi Dept. of Marine Resources (MS), and Florida Fish and Wildlife Conservation Commission - Fish and Wildlife Research Institute (FL)	jess.silver@stanford.edu	1995 (AL), 2010 (MS), 2011 (FL)					
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV Model Input - Shoreline Geomorphology Layer created from NOAA's Office of Response and Restoration Environmental Sensitivity Index (ESI) Maps	Geomorphology.shp	Created by Guannel, Greg, Natural Capital Project, Stanford University based on the NOAA ORR ESI dataset	jess.silver@stanford.edu	2013					
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST CV Model Input - Wind and Wave data from the US Army Corps of Engineers' Wave Information Studies Wave Model for the Gulf of Mexico	WIS_Pts_ClimateForcing.shp	Created by the USACE, modified by Guannel, Greg Natural Capital Project, Stanford University	jess.silver@stanford.edu	2010					
Earth and Environmental Sciences	Geospatial (vector, raster, or gridded)	InVEST Recreation and Tourism (Rec) Model output - photo user days	GulfRecmodel_pud_results.shp	Silver, Jess. Natural Capital Project, Stanford University.	jess.silver@stanford.edu	2017					
Earth and Environmental Sciences	Text	InVEST Recreation and Tourism Model output - regression coefficients	GulfRecmodel_regression_coefficients_5km.txt	Silver, Jess. Natural Capital Project, Stanford University.	jess.silver@stanford.edu	2017					
Geospatial	Geospatial (vector, raster, or gridded)	InVEST Rec Model input - Developed land extracted from the U.S.G.S. National Land Cover Dataset	Development.tif	Dataset created by Multi-Resolution Land Characteristics Consortium (MRLC) project of the U .S. Geological Survey, Modified by Silver, Jess	jess.silver@stanford.edu	2011 edition (first published 2001)					
Geospatial	Geospatial (vector, raster, or gridded)	InVEST Rec Model input - location of boat ramps and marinas from AL, MS and FL	Marinas_and_Boatramps.shp	Dataset created Toft, T. for NOAA's Gulf of Mexico Data Atlas	jess.silver@stanford.edu	2013					
Ecological/Biological	Geospatial (vector, raster, or gridded)	InVEST Rec Model input - Beaches extracted from the U.S.G.S. National Land Cover Dataset	Beaches.shp	Dataset created by Multi-Resolution Land Characteristics Consortium (MRLC) project of the U .S. Geological Survey, Modified by Silver, Jess	jess.silver@stanford.edu	2011 edition (first published 2001)					

Geospatial	Geospatial (vector, raster, or gridded)	InVEST Rec Model input - Industrial and Military land uses extracted from Open Street Maps database	Industrial.shp, Military.shp	Dataset created by OpenStreetMap, Modifier by Fisher, Dave of The Natural Capital Project, Stanford University	jess.silver@stanford.edu	updated 2017				
Geospatial	Geospatial (vector, raster, or gridded)	InVEST Rec Model input - Beach Access Points (FL only)	Beach_Access.shp	Dataset created by the Florida Fish and Wildlife Commission and Fish and Wildlife Research Inst.	jess.silver@stanford.edu	updated 2017				
Geospatial	Geospatial (vector, raster, or gridded)	InVEST Rec Model input - Large Cities (>10,000)	Cities.shp	Dataset created by the National Atlast of the United States, Modified by Silver, Jess of The Natural Capital Project, Stanford University	jess.silver@stanford.edu	2014				
Economic	Text	InVEST Rec Model input - Vistation and expenditure information for Mississippi	Visit Mississippi, Travel and Tourism Economic Contribution Report	Report prepared by Van Hyning, Tom, Visit Mississippi Research Program	jess.silver@stanford.edu	2010, 2012, 2015				
Economic	Text	InVEST Rec Model input - Vistation and expenditure information for Alabama	Sweet Home Alabama, Travel Economic Impact 2015	Report prepared by the Alabama Tourism Department	jess.silver@stanford.edu	2015				
Economic	Text	InVEST Rec Model input - Vistation and expenditure information for Florida	The Heart of Florida's Emerald Coasta, 2012 Tourism Statistics	Report prepared by EmeraldCoastFL.com	jess.silver@stanford.edu	2012				

Information Products Report									
InfoProductType	**DigitalResourceType**	**Title**	**FileName**	**Creators**	**PublicationYear**	**Publisher**	**RepositoryName**	**DOIorPersistentURL**	**DatasetReference**
Models and Simulations	Software and Source Code	Project processor	project_processory.py	Hawthorne, Peter	2017		bitbucket.com/phawthorne	Note that the source code will be posted on bitbucket within the year	
Models and Simulations	Software and Source Code	Restoration Opportunities Optimization Tool	root_mip.py	Hawthorne, Peter	2017		bitbucket.com/phawthorne	Note that the source code will be posted on bitbucket within the year	