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The Costs of Obtaining Environmental Outcomes through Coastal Habitat Restoration

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Abstract

Studies examining the costs of coastal habitat restoration have focused on the cost per acre of restoration or on cost efficiency of various restoration methods. On the other hand, studies examining the benefits of restoration have focused on various ecosystem services that more directly affect welfare including amenity value, storm protection, nutrient retention and biodiversity. We examine a set of 133 Gulf of Mexico coastal habitat restoration projects to estimate the cost of obtaining average annual habitat units (AAHUs), a measure which captures the quantity and, importantly, quality of habitat restored, which is one of the more direct ecosystem service benefits from coastal restoration. AAHUs are the environmental outcome considered during the assessment of proposed projects by decision-makers and therefore are a potential measurement unit that can more closely link costs and benefits of restoration.

Introduction

Coastal habitat in the Gulf of Mexico has been degrading for decades (Brown et al., 2011). Habitat such as barrier islands, wetlands, and oyster reefs provide ecosystem services that include the protection of the coast from storms, coastal fisheries support, and wildlife habitat (CPRA, 2012). While considerable coastal wetland loss has occurred throughout the United States, the loss has been most significant along the Gulf of Mexico coast and in Louisiana in particular (Barbier, 2013). The Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority (1998) projected loss of more than 630,000 coastal acres from Louisiana alone by 2050, even after accounting for current restoration projects. The Coastal Protection and Restoration Authority of Louisiana (2012) suggests that 1,750 square miles of additional coastal land are at risk of being lost over the next 50 years. The loss of habitat along the Gulf of Mexico coast is caused by both natural processes such as hurricanes and rising sea levels, and by human activity such as coastline construction and alteration of waterways (Morton, 2003).

CPRA refers to the coastal land loss as a “crisis” and numerous agencies, corporations, businesses, non-profit groups, and coalitions are involved in the restoration of the Louisiana Gulf Coast. Federal agencies include the United States Department of Agriculture, National Fish and Wildlife Service, United States Environmental Protection Agency, and the Department of Interior. More regional organizations including the Barataria-Terrebonne National Estuary Program, Lake Pontchartrain Basin Foundation, and the Gulf of Mexico Alliance plan, fund, and construct coastal restoration projects along the United States Gulf Coast (CWWPRA, 2017). That so many entities from the federal to local level have a vested interest in coastal habitat loss in Louisiana is a testament to its perceived ecological and economic importance.

The Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) is federal legislation enacted in 1990 whose primary purpose is to implement coastal wetland restoration projects in Louisiana. Its goal is to “provide for the long-term conservation of wetlands and dependent fish and wildlife populations with cost-effective plans for creating, restoring, protecting, or enhancing coastal wetlands” (CWPPRA, 2017). CWPPRA projects are coordinated by a joint effort between the Louisiana State Government, New Orleans District of US Army Corps of Engineers, Region 6 of Environmental Protection Agency, U.S. Fish & Wildlife Service, Natural Resource Conservation Service of Louisiana, and the National Oceanic and Atmospheric Administration. Two-hundred-ten coastal restoration or protection projects have been authorized since 1990 and these projects have managed to care for roughly 111,000 acres of land across the coast of Louisiana (U.S. Fish and Wildlife Service, 2017). Annual funding allocated to coastal habitat restoration projects varies between $30 million and $80 million annually (CWPPRA).

From an economic point of view, optimal investment in coastal habitat restoration entails a comparison of the benefits of restoration to its costs in present value terms. One of the challenges for policy-makers, however, is that coastal habitat consists of complex ecosystems providing a wide array of benefits. Brander et al. (2006) and Barbier, each of which reviews the economic non-market valuation literature on ecosystem services provided by wetlands and other coastal habitat, find that benefits typically examined in these studies include amenity value, biodiversity, hunting and fishing support, water quality support, water flow regulation, nutrient retention, climate regulation, and flood and storm protection, among others. In a study of the Gulf of Mexico coast specifically, Interis and Petrolia (2016) estimate the value of storm protection, water quality improvement, fisheries support, and wading bird habitat benefits of restoring oyster reefs, salt marsh, and mangroves in Louisiana and Alabama. Petrolia, Interis, and Hwang (2014) estimate the value of wildlife habitat, storm surge protection, and commercial fisheries benefits of restoring land lost in a major estuary in Louisiana. The benefits estimates from restoration are sizable in both these studies. The economic impacts supported by Gulf coastal habitat are also large. The seafood industry brings in roughly 20% of all harvested seafood in the United States (U.S. Fish and Wildlife Service). With a $2 billion profit in the forest industry, as well as many other benefits, the Louisiana Gulf coast holds significant economic value to the United States (Coreil, 1995).

In this article, we examine the relationship between investment in habitat restoration and environmental outcomes in coastal Louisiana. The purpose is to determine the environmental outcomes that can be expected from a given level of investment in coastal restoration projects (and which may also vary according to location and the type of restoration undertaken), outcomes which in turn fit into the benefit-cost comparison of an economically holistic coastal habitat restoration policy. We examine 133 habitat restoration projects along the Louisiana Gulf Coast, the data for which come from CWPPRA project lists available online. The primary environmental outcome measure we examine is Average Annual Habitat Units (AAHUs), which is the environmental impact measure actually used to assess these projects when they are under consideration for funding. AAHUs are modeled to be a function of the type of habitat restored, the ecological basin, the number of months of project construction, and total cost of the restoration project. Whereas the benefits of coastal habitat restoration are complex and varied as described above, our focus is on AAHUs for their policy relevance. Determining the relationship between investment and physical environmental outcomes is a necessary step for decision-makers to be able to compare the costs and benefits of various coastal restoration projects. In particular, our analysis helps decision-makers understand what environmental outcomes to expect from a given investment. Furthermore, whereas the studies cited above focus on the benefits of habitat restoration entirely in isolation from the costs of restoration, our study creates a link between the two because not only are AAHUs the environmental outcome considered by decision-makers but its embodiment of habitat quality relates to ecosystem services generally considered to be more directly relevant to public welfare.

Existing studies have examined the costs of Gulf coastal habitat restoration in various frameworks. Ogg (2012) summarizes from previous studies the costs per acre of restoring wetlands and oyster reefs, finding values between $265 and $14800 per acre, depending upon the habitat type and restoration method. Caffey, Wang, and Petrolia (2014) estimate the costs of various restoration projects as a function of production attributes and then estimate the stream of benefits (measured in dollars) that would be necessary to break even on the investment. Milano (1999) evaluate the cost effectiveness of ten coastal restoration projects in Florida. The most closely related study to ours is that of Aust (2006). She regresses the log of AAHU per dollar of investment (her chosen measure of cost-effectiveness of the projects) for a set of Gulf restoration projects on, among other variables, the project basin, sponsoring agency, and restoration type. Given the dependent variable of AAHU per dollar, her focus is on identifying cost-effective combinations of independent variables—that is, answering the question of, given that policy-makers are going to restore the Gulf coast, what is the least-cost way to do it?

Our primary contribution to the literature is that, whereas previous studies of the costs of habitat restoration in the Gulf have examined simple average costs per unit area of restoration or how to design a most cost effective project given that one will be implemented, we are the first to attempt to answer the question of what environmental outcomes a policy-maker can expect to obtain from a given dollar investment in a Gulf habitat restoration project. We model AAHU as a function of, among other variables, project cost. Unlike the examination of the cost-effectiveness of a given project, which determines the least-cost way to obtain an objective given that restoration will be undertaken, our framing of the issue fits within the broader economic objective of benefit-cost analysis to determine whether restoration should be undertaken in the first place. To truly understand whether the benefits of a project outweigh its costs, our model specifies the environmental impact of interest (average annual habitat units, AAHUs) as a function of, among other variables, investment in the project. When combined with future studies estimating the economic benefits of AAHUs, our results help constitute a complete picture of the benefits and costs of Gulf coastal habitat restoration. We find that a 1 percent increase in investment yields a 0.41% increase in AAHUs. We also estimate a model with acres restored as the dependent variable and find that a 1 percent increase in investment yields a 0.45% increase in acres restored. Other factors affecting environmental outputs of projects include whether the project has been completed, the time of project approval, and project and basin types.

Data

The data pertaining to the restoration projects are gathered by the agencies that form the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) and are maintained on the CWPPRA website. These agencies include the Louisiana State Government, the New Orleans District of the U.S. Army Corps of Engineers, Environmental Protection Agency Region 6, U.S. Fish and Wildlife Service, Natural Resource Conservation Service Louisiana, and the National Oceanic and Atmospheric Administration. From the CWWPRA website, we tabulated data on 200 coastal restoration or protection projects using the General Project Fact Sheet and Project Manager's Technical Fact Sheet available for each project, and the Wetland Value Assessment on the website. The General Project Fact Sheet for a given project contains the status, location, anticipated problems, restoration strategy, and progress to date. The project status section includes short descriptions of the project including its approval date, location and area (size), and project priority list (PPL) number which is a ranking of projects into groups according to their priority level. The PPL values range from 1 to 25, which refer to projects being approved in 1991 (first priority at the time of initial assessment) to 2015. A project with a project priority number of 3, for example, refers to a project receiving approval in 1994 (1991+3). The Project Manager's Technical Fact Sheet contains more specific information including the date of project design completion, date of construction completion, whether a project is active, complete, or becomes deauthorized, and the costs of the project. Following Caffey, Wang, and Petrolia, we use the U.S. Army Corps of Engineers Civil Works Construction Cost Index System to adjust each project's total cost corresponding to its priority list year to 2017 dollars. Information relating to the type of restoration (e.g. barrier island restoration, vegetative planting, etc.) and the number of Average Annual Habitat Units (AAHUs) and acres restored from each project are found on the Wetlands Value Assessment section of the CWPPRA website.

Average Annual Habitat Units capture information related to both the quantity and the quality of the land restored or protected from a given project (Aust). First, various experts calculate a Suitability Index, which assesses the quality of a unit of restored land for habitat for 32 common species including estuarine fish and shellfish, freshwater fish, birds, reptiles and amphibians, and mammals. CWPPRA then multiplies this value by the quantity of land the project will restore to calculate the Average Annual Habitat Units of the project. Importantly, AAHUs have never been the environmental outcome whose value has been estimated in any benefits estimation study we know of. However, we choose AAHUs as the environmental outcome of interest because it is the primary environmental project attribute used by CWPPRA in assessing proposed Gulf restoration projects. CWPPRA projects are developed with planned maintenance of the project for 20 years after project construction, so it is assumed the AAHUs do not diminish over at least that 20 year period.

Table 1. Variable Descriptive Statistics (N = 133).

Variable	Count	Mean	Std Dev	Min	Max
AAHUs	--	331.72	441.51	9	2992.85
Acres	--	6922.75	16479.66	77	140380
Total project cost (2017 $US millions)	--	17.16	19.47	0.61	126.04
Project priority list (1991=1, 2015=25)	--	10.71	7.49	1	25
Duration of project construction (months)	--	21.30	27.80	0.13	162
Construction is complete[a]	87	--	--	0	1
Basin					
Atchafalaya	2	--	--	0	1
Barataria	31	--	--	0	1
Breton Sound	4	--	--	0	1
Calcasieu/Sabine	21	--	--	0	1
Mermentau	13	--	--	0	1
Mississippi River Delta	3	--	--	0	1
Pontchartrain	17	--	--	0	1
Teche/Vermillion	13	--	--	0	1
Terrebonne	27	--	--	0	1
Multiple basins	2	--	--	0	1
Project Type					
Barrier island restoration	13	--	--	0	1
Dredged material/Marsh creation	46	--	--	0	1
Freshwater diversion	4	--	--	0	1
Herbivory control	1	--	--	0	1
Hydrologic restoration	25	--	--	0	1
Outfall management	3	--	--	0	1
Sediment diversion	3	--	--	0	1
Sediment and nutrient trapping	4	--	--	0	1
Shoreline protection	31	--	--	0	1
Vegetative planting	3	--	--	0	1

[a] Based on 105 projects without missing values.

Table 1 contains descriptive statistics and a description of each variables included in the model for our sample. AAHUs range from 9 to 2993, with an average of 332. The mean project cost is around $17 million and ranges from $610,000 to $126 million. The average construction phase of a project is 21 months and the construction phase of 65% of the projects (87 total) are complete (though the monitoring and maintenance phases generally last 20 years after completion). The Louisiana coast contains nine different basins. Most projects in the sample are in the Barataria, Calcaseiu/Sabine, or Terrebonne basins, and there are couple projects that span multiple basins. Each CWPPRA restoration project falls into one of ten primary designated restoration methods. Most projects in our sample involve dredged material or marsh creation, hydrologic restoration, or shoreline protection.

Of the 200 total projects for which we had data, 31 projects were omitted because they lacked values for AAHUs or acres restored (these were small-scale technology "demonstration" projects), and 34 deauthorized projects, one additional project with missing cost data, and one additional project whose AAHU value was an extreme outlier (4912, with the next highest being just below 3000) were omitted. These 67 omissions left us with 133 usable observations included in the analysis.

Model and Results

Our primary focus is on a model with AAHUs as the dependent variable, but we also estimate a model with acres restored as the dependent variable. In each model, the environmental outcome is modeled as a function of other project attributes listed in table 1 using ordinary least squares regression. To allow for changing returns to investment we also include the natural logarithm of the project cost, and to allow for the marginal effect of project cost to vary between projects whose constructions phases are complete or incomplete, we interact the cost terms with a corresponding dummy variable. The duration of a project's construction phase is also interacted with the dummy for projects whose construction is complete. To avoid dropping 28 projects with missing values for the construction duration, these terms include only projects without missing values. Also, to allow for a nonlinear time trend, we include the square of the project priority list number.

The regression results for our two models—one each with AAHU and acres restored as the dependent variable—are presented in table 2. Notice that each of the models contains the log of the respective dependent variable. Originally we modeled the left-hand side to be simply AAHU, but we found strong evidence of heteroscedasticity (Breusch-Pagan Chi-square(1), $p<0.001$). Conducting a Box-Cox grid search over exponents of the dependent variable in the set $\{-1, -0.5, 0, 0.5, 1\}$ indicated an optimal lambda of 0 (i.e. the log of AAHU). Taking the natural logarithm of AAHU corrected the heteroscedasticity ($p=0.49$). Similarly for the model with acres restored as the dependent variable, leaving the dependent variable simply as acres yielded strong heteroscedasticity ($p<0.001$) and a grid search over the same set of lambda values indicated an optimal lambda of 0. While taking the log of acres restored helped correct somewhat for heteroscedasticity, it could not be rejected at the 5% level ($p=0.027$). We used the *boxcox* command in Stata 15 to find an estimated optimal lambda of -0.10. Using that value corrected the heteroscedasticity even better ($p=0.30$) and its results are qualitatively identical to those in table 2, but we present the model taking only the natural logarithm of acres restored for its ease of interpreting the marginal effects.

Table 2. Regression Results.

Dependent variable:	ln(AAHU)			ln(acres restored)		
N = 133	Beta		St. Err.	Beta		St. Err.
Total project cost * complete	0.000		0.010	-0.017		0.012
Total project cost * not complete	0.017		0.030	0.020		0.037
Ln(total project cost) * complete	0.409	**	0.183	0.454	*	0.230
Ln(total project cost) * not complete	-0.215		0.383	-0.173		0.481
(Construction is) complete	-1.426	**	0.632	-0.696		0.794
Construction duration * complete	0.001		0.004	0.005		0.005
Construction duration * not complete	-0.003		0.007	0.003		0.009
Project priority list	-0.138	***	0.048	-0.097		0.060
Project priority list squared	0.004	**	0.002	0.003		0.002
Basin[a]						
Atchafalaya	0.629		0.643	-0.621		0.807
Barataria	-0.020		0.255	-0.833	**	0.320
Breton Sound	-0.572		0.547	-0.573		0.687
Calcasieu/Sabine	0.481	*	0.284	0.102		0.357
Mermentau	0.097		0.325	-0.564		0.409
Mississippi River	-0.120		0.805	-0.168		1.011
Pontchartrain	0.130		0.300	-1.042	***	0.377
Teche/Vermillion	-0.261		0.347	-1.081	**	0.437
Multiple Basins	-0.236		1.155	1.349		1.452
Project Type[b]						
Barrier island restoration	0.118		0.334	-0.344		0.419
Dredged material/Marsh creation	0.464		0.283	-0.134		0.355
Freshwater diversion	1.784	***	0.481	1.932	***	0.604
Herbivory control	3.201	**	1.442	2.025		1.812
Hydrologic restoration	1.072	***	0.243	1.947	***	0.305
Outfall management	1.873	***	0.574	2.903	***	0.722
Sediment diversion	1.533	*	0.813	0.614		1.022
Sediment & nutrient trapping	1.201	**	0.499	1.213	*	0.626
Vegetative planting	1.201	*	0.722	0.232		0.907
Intercept	5.823	***	0.620	8.006	***	0.779
Adj. R-Square	0.310			0.545		
F(27, 105)	3.20***			6.84***		

*,**,*** indicate significance at the 10%, 5%, and 1% levels.

[a] The omitted basin is Terrebonne.

[b] The omitted project type is shoreline protection.

Our primary interest is in the cost variables in table 2 and there are two related key findings. First, project cost—which we interpret as investment in the project—affects the environmental outcome only through the logarithm of cost, not through cost directly. The parameter on the logarithm of cost is significant and positive in each model, indicating that a 1 percent increase in investment in a project increases AAHUs by 0.41% and acres restored by 0.45%. Second, investment has a significant effect on the environmental outcome only for projects whose construction phase is complete. Project costs, AAHUs, and acres restored are updated continually as a project progresses through its various implementation phases, so the non-significance of costs for incomplete projects may be indicative of inherent uncertainty about their outcomes until construction is completed.

The parameter on the dummy variable for whether a project's construction phase is complete is negative in both models but significant only in the model with AAHUs as the dependent variable, which could indicate undue optimism in predicting AAHUs before construction of the project is complete. The construction duration itself does not have any significant effect on environmental outcomes for either complete or incomplete projects.

There is a time trend in the AAHU model as measured by the parameters on the project priority list variables. The semi-elasticity of AAHUs with respect to the project priority list value is -0.138 + 2*0.004*PPL. This equation would indicate a negative effect of the PPL on AAHUs for projects approved prior to 2008 (which corresponds to project priority list 18), and a positive effect for projects approved in 2008 or later. A possible explanation for this result might be that decision-makers became better over time at identifying projects that would yield greater environmental impacts or that technological advancements helped increase environmental outcomes.

The parameters on the dummy variables for each basin should all be interpreted relative to the omitted basin of Terrebonne, and the parameters on the dummy variables for each project type should be interpreted relative to the omitted project restoration type of shoreline protection. Given our primary interest in determining the environmental outcome decision-makers might expect from a given investment in a coastal restoration project, we hypothesized that the marginal effect of investment might vary across basins or across project types. We therefore created interactions between project costs and basins and between project costs and project types. None of these interactions were remotely significant, however. Of course, we have few observations for several basins and several project types and non-significance might be expected for these, but neither do we find significance for any basin or project type with a decent number of observations (e.g. 31 projects in the Barataria basin or 46 dredged material/marsh creation projects).

Except for the parameter on the log of project cost for complete projects, only some of the basin and project type dummy variables have a significant effect on acres restored in the second model. Even the parameter on the log of project cost is significant only at the 10% level, and there is no significant marginal effect of whether a project's construction phase is complete or of the time of project approval.

Conclusion, Implications, and Future Work

Gulf of Mexico coastal habitat restoration projects can take on many forms, using a wide variety of methods and technologies, and have a wide range of associated costs. Given the amount of investment that has already occurred to restore habitat along the coast in Louisiana and elsewhere, it is clear that there is a great perceived value in such restoration. From an economic point of view, a proposed restoration project is a good idea if its benefits outweigh its costs and our study contributes to the cost side of this comparison. Of course, coastal restoration generally results in several different types of benefits including erosion control, storm protection, and land and sea animal habitat. Our outcome of interest in this study are a measure of animal habitat quality and quantity known as Average Annual Habitat Units (AAHU), and we also estimate a model with acres restored as the dependent variable. While not exhaustive of the possible benefits resulting from coastal restoration projects, these two measures are readily available for coastal restoration projects in the CWPPRA online database. They are also related to benefits, the values of which have been estimated in the non-market environmental valuation literature, though the value of AAHUs has not been previously estimated directly.

We find, by analyzing data from 133 restoration projects from the CWPPRA database, that project investment has non-linear marginal effects on AAHUs and on acres restored. A 1% increase in investment is estimated to yield a 0.41% increase in AAHUs and a 0.45% investment in acres restored for projects whose construction phase is complete. There was a negative time trend on AAHUs for projects approved prior to 2008.

How are these findings useful? First, they provide an easy way for decision-makers to assess what levels of environmental outcomes they might expect from a given investment in coastal restoration. This is important in the broader scheme of the allocation of public funds among many competing potential uses. Second, they provide a step towards a broader benefit-cost analysis of coastal restoration. However, to complete the benefit-cost analysis the benefits and the costs must be estimated over the same units. No study we know of, for example, has yet estimated the value of the benefits from AAHUs. Instead, related benefits of restoration including amenity value, biodiversity, water quality, and flood and storm protection have been estimated. While certainly insightful, these benefits do not appear to be of primary interest to decision-makers, at least as indicated by concrete measures used in project assessment. And while, for example, AAHUs are likely related to biodiversity or other measures of habitat quality, these links between the environmental outcomes on which decision-makers are basing decisions and environmental outcomes economists are valuing need to be more explicit and direct. Of course, even if future researchers estimate the monetized value of AAHUs, which likely provide both use and non-use values, there is still the possibility that the costs of obtaining AAHUs exceed their benefits. At least, however, a more direct comparison of the benefits and costs of a consistent environmental outcome of interest will be possible.

Besides the aforementioned caveat that our environmental outcomes of interest do not account for all the different types of benefits resulting from Gulf of Mexico coastal habitat restoration, another limitation of our study is that we have used only CWPPRA projects, which are geographically limited to the coast of Louisiana. Our model may not fit well for projects in other coastal states. Furthermore, we are of course limited by data available on these projects. We would welcome the diligent collection of additional measures related to restoration projects and environmental outcomes, likely determined by ecologists and other environmental scientists.

Barbier suggests that our knowledge base from the existing literature is generally insufficient for effective coastal habitat policy design. We would emphasize that one particular shortfall is the discrepancy between environmental outcomes measured and considered at the time of project assessment and the environmental outcomes examined in the non-market valuation literature, and their associated benefits and costs. In this study, we've attempted to partially address this discrepancy.

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