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Review

Valuing Ecosystem Services for Coastal Wetland Protection and Restoration: Progress and Challenges

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Abstract: Coastal wetlands, such as marshes, mangroves and forested swamps, are in decline globally. Although considerable progress has been made in quantifying and valuing some of the key ecosystem goods and services provided by these habitats, fundamental challenges remain. The biggest challenge is inadequate knowledge to link changes in ecosystem structure and function to the production of valuable goods and services. Another problem is that very few ecosystem services are marketed. This review discusses recent advances in overcoming these challenges. To illustrate key valuation issues, the paper introduces three case studies from the US Gulf Coast state of Louisiana: quantifying ecosystem services and the 2012 Master Plan for coastal Louisiana; valuing storm protection by marsh in southeast Louisiana; and oil spills and the Natural Resource Damage Assessment approach to wetland compensation in lieu of restoration. The paper concludes with some final remarks on the state of coastal wetland valuation for protection and restoration.

Keywords: coastal wetlands; ecosystem services; economic valuation; Gulf Coast; Louisiana

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1. Introduction

Coastal zones make up just 4% of the Earth's total land area and 11% of the world's oceans, yet they contain more than one third of the world's population and account for 90% of marine fisheries catch [1]. Coastal human population densities are nearly three times that of inland areas, and they are increasing exponentially [2]. The long-term sustainability of these populations is dependent on many important coastal ecosystems and the critical services they provide, such as storm buffering, fisheries production, and enhanced water quality.

In coastal areas, many wetlands are found in estuaries, which are bodies of water and their surrounding coastal habitats typically found where rivers meet the sea. The wetland habitats associated with the brackish water of estuaries include salt marshes, mangroves and forested swamps. However, human activities are now threatening many of the world's remaining coastal wetlands and the benefits they provide [2–5]. Their decline is intense and increasing worldwide, with 50% of marshes and 35% of mangroves either lost or degraded [5–7].

The global loss of coastal wetlands affects at least three critical ecosystem services: the number of viable (non-collapsed) fisheries; the provision of nursery and breeding habitats for near-shore commercial and recreational fisheries; and filtering and detoxification services provided by suspension feeders, submerged vegetation, and wetlands [3,8]. Loss of filtering services is also linked to declining water quality and the increasing occurrence of harmful algal blooms, fish kills, shellfish and beach closures, and oxygen depletion. The decline in biodiversity and ecosystem functions in coastal wetlands may have contributed to biological invasions and *vice versa*. Increasingly, the loss or change of vegetation in coastal ecosystems has affected these systems' ability to protect against shore erosion, coastal flooding and storm events [9,10].

Such widespread and rapid transformation of coastal wetlands and their services suggests that it is important to understand further what is at stake in terms of critical benefits and values. The purpose of this paper is to review some key areas of progress in such analysis, as well as the key challenges that still need to be addressed. This review consists of two parts. The next section provides a summary and overview of valuation studies of coastal wetland ecosystem goods and services. The subsequent section illustrates some of the progress and challenges in applying valuation by reviewing the outcomes of three case studies from the US Gulf Coast state of Louisiana: quantifying ecosystem services and the 2012 Master Plan for coastal Louisiana; valuing storm protection by marsh in southeast Louisiana; and oil spills and the Natural Resource Damage Assessment approach to wetland compensation in lieu of restoration. The paper concludes with some final remarks on the state of coastal wetland valuation for protection and restoration.

2. Valuing Coastal Wetland Ecosystem Goods and Services

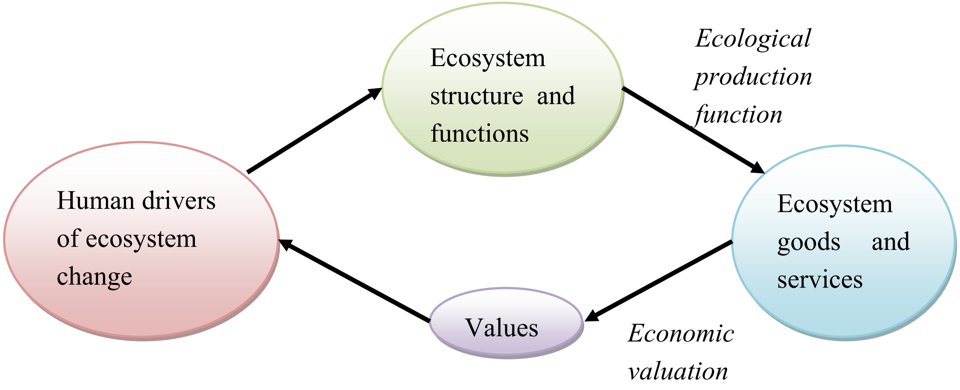
In identifying the ecosystem services provided by natural environments, a common practice is to adopt the broad definition of the Millennium Ecosystem Assessment that "ecosystem services are the benefits people obtain from ecosystems" [1]. Although this definition has been interpreted in different ways, a consensus is emerging on what ecosystem services are and how they arise from ecological processes and functions.

First, a wide range of valuable goods and services to humans arise in myriad ways via the structure and functions of an ecosystem. For example, some of the living organisms found in an ecosystem might be harvested or hunted for food, collected for raw materials or simply valued because they are esthetically pleasing. Some of the ecosystem functions, such as nutrient and water cycling, can also benefit humans through purifying water, controlling floods, recharging aquifers, reducing pollution, or simply by providing more pleasing environments for recreation. These various benefits provided by an ecosystem via its structure and functions are what is meant by *ecosystem services*.

Second, although they are the source of ecosystem services, the structure and functions of an ecosystem are not synonymous with such services. Ecosystem structure and functions describe the components of an ecosystem and its biophysical relationship regardless of whether or not humans benefit from them. In contrast, as stated by [11], "ecosystem services are the direct or indirect contributions that ecosystems make to the well-being of human populations". Quantifying these contributions, or "benefits", in terms of human welfare is often referred to as *valuing ecosystem services*.

Figure 1 summarizes why quantifying and valuing ecosystem services is important for policy and management decisions, such as coastal wetland protection and restoration. Human drivers of ecosystem change, such as pollution, resource exploitation, land conversion, species introductions and habitat fragmentation, affect the structure and functioning of ecosystems. Assessing and quantifying this impact is important, as it alters the ecological production of ecosystem goods and services that benefit humans. The role of economic valuation is to measure explicitly gains in losses in human welfare from these changes. These values can then be used to guide the necessary changes in policies and environmental management to control the human drivers of ecosystem change.

Figure 1. The key steps in quantifying and valuing ecosystem services. Adapted from Figures 1–3 in [12].



The biggest challenge to quantifying and valuing ecosystem services is inadequate knowledge to link changes in ecosystem structure and function to the production of valuable goods and services [12–16]. This is certainly true for the various marsh, mangrove and swamp forest habitats. For these systems, how we quantify and value ecosystem goods and services can impact significantly our approach to coastal wetland protection and restoration. Yet, we often do not know how variation in ecosystem structure, functions and processes give rise to the change in an ecosystem good or service, although we are starting to learn about some of these impacts. For example, in the case of coastal wetlands, the change could be in the spatial area or quality of a particular type of wetland, such as a mangrove, marsh vegetation or swamp forest. The subsequent loss of habitat and vegetation may not only influence shellfish and other species that depend on the habitat but also reduce protection of shorelines and control of erosion. In addition, the loss of important wetland breeding and nursery habitat may influence a variety of valuable goods and services provided in neighboring marine systems, such as commercial or recreational fisheries. Alternatively, changes in coastal habitat could be due to variation in the flow of water, energy or nutrients through the system, such as the variability in tidal surges due to coastal storm events or the influx of organic waste from onshore pollution, or the impacts of oil spills and other human-induced hazards.

Another problem encountered in quantifying and valuing ecosystem services is that very few are marketed. Some of the products provided by coastal wetlands, such as raw materials, food and fish harvests, are bought and sold in markets. Given that the price and quantities of these marketed products are easy to observe, there are numerous ways to estimate the contribution of the environmental input to this production [16–18]. However, many other key services of coastal wetland habitats do not lead to observable marketed outputs. These include many services arising from ecosystem processes and functions that benefit human beings largely without any additional input from them, such as coastal protection, nutrient cycling, erosion control, water purification and carbon sequestration. In recent years, substantial progress has been made by economists working with ecologists and other natural scientists in applying environmental valuation methodologies to assess the welfare contribution of these services [11–15].

Table 1 provides some examples of how specific coastal wetland goods and services are linked to the ecological structure and functions underlying each service. It also cites, where possible, economic studies that have estimated the values arising from the good or service. The list of 80 valuation estimates included in Table 1 is only representative of the literature on economic valuation of coastal wetland goods and services; nevertheless, the table gives an indication of the range of valuation estimates available for specific goods and services, and is thus instructive.

For example, the estimates summarized in Table 1 are drawn from a wide range of studies from around the world, which is encouraging. However, the table also indicates that valuation studies have largely focused on only a few ecosystem goods and services, such as recreation, coastal habitat-fishery linkages, raw materials and food production, and water purification. In recent years, there have also been a growing number of estimates of the storm protection service of coastal wetlands. But for a number of important services very few or no valuation studies exist. In other words, despite the recent progress in valuing coastal wetland goods and services, the current state of valuation is not significantly improved from a mid-2000 review of valuation estimates for coastal and marine environments in the United States [19]. According to this review, with the exception of recreational fishing, the coastal and marine valuation literature is generally insufficient to support effective policy-making, as most coastal habitats such as wetlands have not been well studied, key values have not been estimated, geographical coverage is incomplete, and the application of methodologies is uneven [19].

Yet, the good news is that progress is being made in quantifying and valuing coastal wetland goods and services, and as more valuation estimates are generated, we are improving our understanding of the structure and function of coastal wetland habitats that provide such benefits. We are also starting to learn more about what ecological and economic data and analyses are required to estimate how these habitats yield various benefits. In addition, as we gain more experience with quantifying and valuing coastal wetland goods and services, we are beginning to appreciate how such analyses can improve coastal management decisions. However, it is also clear that some approaches and methods to assessing ecosystem goods and services need to be improved. To further illustrate these issues, the next section reviews three case studies from the US Gulf Coast state of Louisiana that discusses further the progress and challenges in applying valuation for specific coastal protection and restoration management issues.

Table 1. Examples of coastal wetland services and valuation estimates.

Ecosystem structure and function	**Ecosystem goods and services**	**Valuation examples (80 estimates total)**
Attenuates and/or dissipates waves, buffers wind	Coastal protection from storms	12 estimates
Provides sediment stabilization and soil retention	Erosion control	4 estimates
Water flow regulation and control	Flood protection	2 estimates
Provides nutrient and pollution uptake, as well as retention, particle deposition, and clean water	Water purification and supply	7 estimates
Generates biogeochemical activity, sedimentation, biological productivity	Carbon sequestration	4 estimates
Climate regulation and stabilization	Maintenance of temperature, precipitation	0 estimates
Generates biological productivity and diversity	Raw materials and food	7 estimates
Provides suitable reproductive habitat and nursery grounds, sheltered living space	Maintains fishing, hunting and foraging activities	20 estimates
Provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	Tourism, recreation, education, and research	21 estimates
Provides unique and aesthetic landscape of cultural, historic or spiritual meaning	Culture, spiritual and religious benefits, existence and bequest values	3 estimates

Note: A list of the studies providing these estimates is available from the author upon request.

3. Case Studies

3.1. Quantifying Ecosystem Services and the 2012 Master Plan for Coastal Louisiana

Over recent decades, considerable coastal wetland loss has occurred in the United States, with the most significant declines occurring along the Gulf Coast [20–22]. These historic trends in Gulf Coast wetlands result from flooding from storms in the Gulf, sea level rise, flooding from rivers, natural land subsidence, and human-related activities, such as drainage, filling, canal dredging for navigation, construction of levees and other flood control structures, and coastal development [23,24].

The most dramatic coastal wetland changes have occurred in Louisiana. The state still contains about 40% of the wetlands of the lower 48 United States, but has historically accounted for about 80% of total US wetland losses [20–22]. From 1932 to 2000, Louisiana lost about 4900 km^2 of coastal lands, primarily marshes. In 2005, Hurricanes Katrina and Rita may have caused another 520 km^2 to disappear. It is estimated that Louisiana continues to lose about 6500 ha of wetlands annually, and about 90% of the total coastal marsh loss in the lower 48 United States each year [25,26].

Since Hurricanes Katrina and Rita in 2005, ambitious plans have been put forward for restoring wetlands along the U.S. Gulf Coast as natural protection barriers against future hurricane damages [23,24,26–28]. For example, the President's Gulf Coast Ecosystem Restoration Task Force recommends extensive wetland restoration, given that the "Gulf's wetlands provide a natural flood attenuation function, which may reduce the impacts of flooding associated with storms" [28]. The 2012 Master Plan for the Louisiana Coast proposes to build 1412 to 2225 km^2 of new land, much of it restored marsh, over the next 50 years to provide storm protection and other ecosystem benefits [26]. Dedicated dredging on the Barataria Basin Landbridge in Louisiana has already created 4.9 km^2 of intertidal marsh and nourished an additional 6.4 km of marsh in 2010, at a total cost of $36.3 million [26].

The assessment of coastal ecosystem services was a major feature of the wetland restoration plans put forward by the 2012 Master Plan for the Louisiana Coast. Without wetland restoration, Louisiana will likely lose another 4548 km^2 of marsh and other coastal land over the next 50 years [26]. Yet, halting wetland loss and investing in restoring wetlands is expensive, and it may be difficult to prevent net wetland decline for Louisiana. Recent estimates show that even an investment of $25 billion over 50 years still results in a loss of 585 km^2 of wetlands [26]. Although the 2012 Master Plan was unable to estimate explicitly the values gained from such a 50-year investment for Louisiana, quantification of coastal wetland services played an important role in formulating the Plan and the selection of the 109 recommended protection and restoration projects.

A total of 248 restoration projects were individually evaluated in terms of their effects on 14 ecosystem services over a 50-year period. The analysis of ecosystem services did not rely on direct quantification of the 14 ecosystem services but instead focused on proxy characteristics of the coast, such as provision of habitat (*i.e.*, habitat suitability indices) and other factors that can support these services. Table 2 lists the coastal ecosystem “services” analyzed in the Master Plan and summarizes how the proxies for each service were quantified in the analysis. Not only were these various metrics used to evaluate an individual project’s effect on ecosystem services, but also to examine the collective coast wide effect of groups of projects on those services.

As indicated in Table 2, quantification of ecosystem services by a habitat suitability index and other ecological factors that may support each service can lead to some confusion. For example, for specific species that are harvested for commercial or recreational purposes, such as alligator, crawfish, oysters, shrimp and other fisheries, the habitat suitability index approach may work reasonably well to estimate changes in the biological populations of these valuable species. However, difficulties arise for using habitat suitability indices as a proxy for quantifying other species, such as waterfowl and other coastal wildlife, as it is unclear what the ultimate benefit to humans of having higher or less abundance of these species might be. Similarly, quantifying nutrient uptake, carbon sequestration, freshwater availability and storm surge/wave attenuation does not provide a good indication of how these various ecological functions may translate into valuable benefits to humans in coastal areas.

Despite the limitation of the quantification approach to ecosystem services outlined in Table 2, the ecosystem services analysis conducted by the 2012 Master Plan does provide some insight into how the Plan’s projects may affect these various services. Although the location of the services along the Louisiana coast may shift with the implementation of the Master Plan, the selected projects are likely to provide larger benefits from increases in alligator, freshwater fisheries and waterfowl habitat, while coastal wildlife, shrimp and saltwater fishery habitats are likely to stay at current levels [26]. There may be a 10%–20% decrease in suitable habitat for oysters, but many coastal areas will also experience increase in salinity levels that will enhance oyster cultivation. Freshwater availability could increase by 40%, and there will be significant increases in carbon sequestration and nutrient uptake. Nature-based tourism and suitable agricultural land will also rise slightly. Finally, the Plan also analyzed how the various ecosystem service impacts of projects may vary over the 50-year time horizon, with differing climate change and sea level rise scenarios.

Table 2. Quantification of coastal ecosystem services in the 2012 Louisiana Master Plan. Source: [26].

Ecosystem service	Quantification approach
Alligator	Estimated habitat suitability index based on how different combinations of water, vegetation and land characteristics support alligator habitat
Crawfish (wild caught)	Estimated habitat suitability index based on how different combinations of water, vegetation and land characteristics support crawfish habitat
Oysters	Changes in oyster habitat were predicted through a habitat suitability model that accounted for land change, water, and bottom characteristics.
Shrimp (white and brown)	Habitat suitability models were developed for juvenile brown shrimp and juvenile white shrimp to predict changes in habitat based on water and vegetation characteristics.
Saltwater fisheries	A habitat suitability model for juvenile speckled trout was used to reflect changes to saltwater fisheries, based on water and vegetation characteristics.
Freshwater fisheries	A habitat suitability model for largemouth bass was developed, which incorporated changes in water and submerged aquatic vegetation characteristics.
Waterfowl	A combination of habitat suitability models for mottled duck, gadwall, and green winged teal was used to estimate waterfowl habitat changes based on predicted changes to water, vegetation and land characteristics.
Other coastal wildlife	Habitat suitability models for muskrat, river otter, and roseate spoonbill were developed based on water, vegetation, and land characteristics.
Nature-based tourism	A model was developed to estimate the potential for nature-based tourism, which measured human access to high quality habitats for wildlife near coastal tourism centers, such as barrier islands and wildlife management areas. The species used to describe this service included: alligator, roseate spoonbill, river otter, muskrat, neotropical migrants, and waterfowl.
Support for agriculture and aquaculture	A model was developed that evaluated salinity characteristics and frequency of flooding in upland areas. This index includes lands that are in production for rice, sugarcane, cattle, farmed crawfish, and other agricultural and aquaculture activities.
Nutrient uptake	A model was developed to predict effects on nitrogen removal in open water, sediment, and wetlands.
Carbon sequestration	A wetland morphology model was used to estimate effects on carbon storage potential, which allows for variation in carbon storage with the type of wetland, the acreage, and the annual vertical accretion of soil.
Freshwater availability	A suitability model was developed to evaluate salinities in close proximity to strategic assets or populated areas.
Storm surge/wave attenuation	Estimated the effects of storm surge and waves on coastal communities, based on the location and amount of land in proximity to population centers, type of vegetation, and land elevation

3.2. Valuing Storm Protection by Marsh in Southeast Louisiana

Field studies indicate that coastal marsh vegetation significantly impacts wave attenuation, as measured by reductions in wave height per unit distance across a wetland [10,29,30]. Such evidence is often cited to support marsh restoration globally for the purpose of protecting low-lying coastal communities and property from hurricanes and storms [6,24,26–28]. For example, global assessments of coastal wetland loss in temperate zones urge marsh restoration as a priority in protecting coastlines [6,31,32]. In Europe, the building of coastal defenses has accelerated marsh loss, thus increasing the vulnerability of coastal populations and property to storms [32]. And, as the previous section indicated, plans for wetland restoration along the US Gulf Coast have stepped up in the aftermath of the 2005 Hurricanes Katrina and Rita [24,26–28]. Despite this interest in the protection provided by coastal wetlands, there have been few economic valuations of the storm protection service of coastlines dominated by temperate marshes [33,34]. This case study summarizes one such analysis [35], and the valuation approach it had to adopt in estimating storm protection values for marsh in southeast Louisiana.

One of the main challenges is that determining the value of the storm protection service of wetlands requires consideration of the varying hydrodynamic properties of storm surges as well as the effects of differing wetland landscape and vegetation conditions across coastal systems. Although previous studies for temperate coastal wetlands have lacked such data [33,34], recent storm surge models developed for southern Louisiana show how the attenuation of surge by wetlands is affected by the bottom friction caused by vegetation, the surrounding coastal landscape, and the strength and duration of the storm forcing [36–39]. Barbier *et al.* [35] show how the hydrodynamic outputs from these models can be used to estimate the storm protection benefits of wetlands to southeastern Louisiana, which includes greater New Orleans. Once the various influences of wetland landscape and vegetation on storm surge are determined, they can be applied to estimate the effects of wetlands on damage from flooding, based on standard modeling approaches that relate property damages to the flood depth caused by surges [40–44]. As damage estimates for Hurricane Katrina and other storms indicate, the most important flooding impact caused by hurricane storm surges along many temperate coastlines is to residential property [40,43,45]. The results of the analysis by Barbier *et al.* [35] show that wetland continuity and vegetation roughness measured along a coastal transect are effective in reducing hurricane storm surge levels and thus demonstrate how wetland conditions can cause a significant reduction in property damage.

The storm surge transect analysis was performed along a selected location in the Caernarvon Basin in southern Louisiana east of New Orleans. Along the transect, 12 locations were selected where time-dependent storm surge data for each storm are available from storm model simulations. The analysis was based on storm surge simulations for four hypothetical hurricanes traversing the Caernarvon Basin transect. Surge attenuation was then defined as the maximum reduction in storm surge per unit distance along each of the eleven transect segments defined by the 12 locations. The average length of each transect segment was approximately 6 km.

Figure 2 depicts how the surge attenuation function for the four storms we analyzed is affected by both the presence of wetlands (W_L) and their roughness (W_R). The maximum surge attenuation associated with each storm clearly increases as the wetland-water ratio progresses from zero (open water) to one (solid marsh) and as roughness imposed by vegetation increases from 0.02 (no vegetation) to 0.045 (high and stiff vegetation).

Barbier *et al.* [35] estimated the elasticities, or percentage change effects, of the impact of wetland continuity and roughness on the maximum surge for each of the four storms as they traverse the eleven segments. The estimated elasticities are indicated in Table 3. A 1% increase in the wetland-water ratio along each segment will reduce storm surge by 8.4% to 11.2%. A 1% increase in wetland roughness caused by wetland vegetation will decrease storm surge by 15.4% to 28.1%. These estimates suggest that storm surge will be reduced by 1 m per 9.4 to 12.6 km of additional wetlands along the transect we analyzed.

Figure 2. Attenuation (A_S) of storm surge (S) as a function of (**a**) wetland continuity (W_L); and (**b**) wetland vegetation roughness (W_R) along a storm track segment of distance (x) in m for four hurricanes in the Caernarvon Basin of southeast Louisiana. Source: [35].

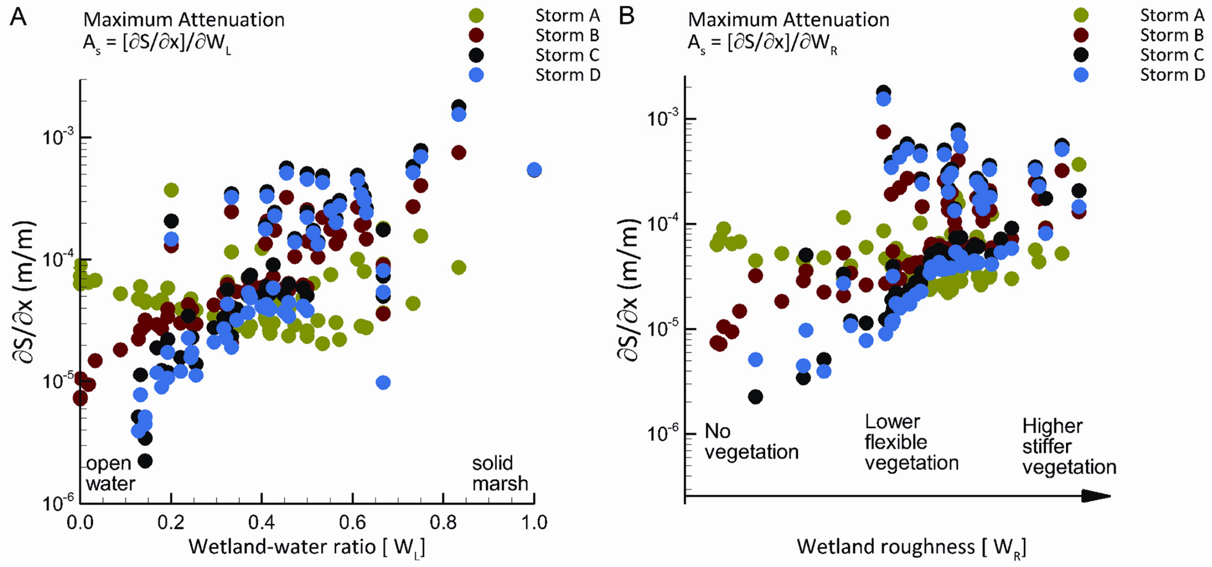


Table 3 also shows our corresponding estimates of the marginal value of an increase in wetland continuity and vegetation roughness in terms of reducing residential property damage from storm surge floods. A 0.1 increase in the wetland-water ratio per m along the transect (W_L) will reduce flood damages by $99 to $133 for the average SPU, and a 0.001 increase in bottom friction through changes in wetland vegetation (W_R) will reduce damages by $24 to $43. If such increases in wetland continuity and roughness can be extended across the landscape then damages can be further reduced. For example, an equivalent marginal increase in wetland continuity over approximately 6 km (the average length of one of our transect segments) would lower residential property flood damages by $592,000 to $792,100 for the average SPU, whereas the marginal increase in bottom friction over 6 km would reduce flood damages by $141,000 to $258,000 for the average SPU (see Table 3). Given the mean residential property value of $170,701 per SPU, these latter values of a marginal change in wetland continuity and vegetation roughness are equivalent to saving three to five and one to two properties per storm, respectively.

Coastal wetlands globally are considered important for a wide range of ecosystem services, such as providing habitats in support of fish and other wildlife, recreation, carbon sequestration, water purification and controlling erosion (See Table 1). But, as this case study of southeastern Louisiana shows, the value of temperate wetlands in protecting coastal property from storm surges may prove to be the most significant benefit. This study also develops a novel methodology for incorporating the influence of wetland characteristics on surge attenuation into modeling and estimating the economic value of wetlands in reducing expected property damages from hurricane storm surge. This approach could be easily tested, adapted and extended to include additional sea-to-coast transects, either in southern Louisiana or other coastal areas of the Gulf of Mexico. It would also be relevant for valuing the storm protection services of other estuarine and coastal habitats, such as mangroves, sea grass beds, coral reefs and sand dunes. As better information is gained from hurricane and other tropical storm surge models, it would also be possible to improve on estimations of the distribution of expected coastal flood damages related to the distribution of storm events. Such improvements in the methodology could greatly enhance future studies of the economic value of coastal wetlands in protecting property and lives.

Table 3. Estimated storm surge impacts and marginal values of changes in wetland continuity (W_L) and vegetation roughness (W_R) Source: [35].

Estimated wetland impacts on attenuating maximum storm surge levels (S)		**Estimated marginal values of wetlands in terms of avoiding damages to residential property**	
Change in W_L and W_R	Change in storm surge	Change in W_L and W_R	Marginal value
1% change in W_L per segment	−8.4% to −11.2%	0.1 increase in W_L per m	\$99.29 to \$132.87
1% change in W_R per segment	−15.4% to −28.1%	0.001 increase in W_R per m	\$23.72 to \$43.24
9.4 to 12.6 km change in W_L	−1 m	0.1 increase in W_L per segment	\$591,886 to \$792,082
		0.001 increase in W_R per segment	\$141,399 to \$257,762

Notes: W_L is represented by the wetland/water ratio ranging from open water ($W_L = 0$) to solid marsh ($W_L = 1$); W_R is represented by Manning's n for bottom friction caused by degree of wetland vegetation ranging from no vegetation ($W_R = 0.02$) to high density vegetation ($W_R = 0.045$); Mean maximum surge level (S) is 2.302 m; Mean wetland/water ratio (W_L) is 0.408; Mean Manning's n (W_R) is 0.032; Mean transect segment length (x) is 5961 m.

3.3. Oil Spills and the NRDA Approach to Wetland Compensation

The 1990 Oil Pollution Act (OPA) makes parties releasing oil into the environment liable not only for the cost of cleaning up those releases but also for monetary compensation for injury (damages) to natural resources caused by the releases. The OPA was enacted in response to the 1989 *Exxon Valdez* oil spill and a spate of similar incidents in U.S. coastal waters [46]. The OPA authorizes public trustees, which can include federal and state governments and some Native American tribes, to seek recovery of all natural resource damages arising from an oil spill. Serving as the trustee for all coastal and marine resources, the National Oceanic and Atmospheric Administration ("NOAA") is the main agency responsible for assessing the effects of any spill, through a process known as Natural Resource Damage Assessment (NRDA). The NRDA approach has been used most recently in determining compensation in the US Gulf Coast, with respect to the 2010 *Deepwater Horizon* platform fire and resulting oil spill.

The main method of assessment in the NRDA is *habitat equivalency analysis* (HEA), which is based on the principle that the public can be compensated for past losses of habitat resources through habitat replacement projects providing additional resources of the same type. This principle is implemented through quantifying the *interim* losses in natural resource services arising from damages to a coastal and marine resource, such as a wetland, and then estimating the scale of compensatory restoration required to offset these service losses. In the case of a wetland damaged by an oil spill, an HEA would not necessarily estimate or value the damages to the wetlands or its services; instead, "it calculates the natural resource service losses in discounted term and then determines the scale of restoration projects needed to provide equal natural resource service gains in the future in discounted terms, thereby fully compensating the public for the natural resource injuries" [47]. Determining the amount of compensation or replacement wetland habitat required is therefore critical to the HEA, although the scale of this compensation will depend on whether or not primary restoration of the damaged wetland takes place. Moreover, compensatory restoration may not necessarily take place at the primary restoration site; in other words, it may involve the creation, restoration, or enhancement of wetlands in a site nearby and equivalent to the original wetlands damaged by the spill.

Barbier [23] discusses the pros and cons of HEA from both an ecological and economic perspective. The HEA approach places restoration at the beginning of the NRDA process, which may expedite both restoration and compensation and avoids protracted and costly litigation as well as the need for expensive valuation studies. In addition, by guaranteeing funds for compensatory restoration, the HEA ensures financing of wetland restoration and enhancement projects. However, the HEA can misrepresent complex ecological services of wetlands, produce misleading estimates of the costs and benefits of wetland restoration, and in some cases, over-supply some wetland services in the long run.

Figure 3 illustrates the differences between the economic valuation and HEA approaches to compensation and restoration. For example, suppose an offshore oil spill occurs in time T_0 and damages a coastal wetland ecosystem. Before the incident occurs, the wetland provides a range of valuable services, including wildlife viewing and recreational benefits, a nursery and breeding habitat for offshore commercial and recreational fishing, and storm protection and flood control for shoreline properties. Assuming some common metric for measuring these services, the baseline level of services before the oil spill is S_0, as indicated in the upper diagram of Figure 1. If the wetland is allowed to recover naturally, then eventually, in some future time T_N, the full level of ecosystem services will be restored. The *interim* losses will be areas A plus B in the upper diagram. However, if primary restoration activities take place starting at time T_1, then wetland recovery will occur much faster, and full services will be restored at T_P. The amount of *interim* services lost would be equal to area A only. Under the monetary compensation approach, the full damages assessed would be the monetary value of the *interim* services lost plus the costs of primary restoration. That is, compensation would equal the present value in *dollars* of the loss in *interim* services from time T_0 to T_P (*i.e.*, area A) plus the present value *dollar* cost of the primary restoration undertaken from time T_1 to T_P.

The bottom diagram of Figure 3 illustrates the HEA approach. At some time T_2 after the initial oil spill incident, a new wetland is created at a nearby site to provide the same type of services lost as in the damaged wetland. Creating a new wetland at this site is assumed to be cost effective; that is, there is no other comparable site for creating the same level of wetland services at a lower cost. Compensatory restoration occurs at this site not only until time T_3, when the created wetland delivers a full amount of services S_C, but until time T_C, when the total amount of created wetland services, areas C plus D, compensate completely for the *interim* loss of services in the original oil-damaged wetlands (*i.e.*, area A).

In other words, compensatory restoration occurs until the ecosystem service losses from the spill equal the service gains from the newly created wetland. No monetary valuation of these services is necessary, however. The scale of the newly created wetland project is chosen to ensure that the present value in *ecosystem service units* gained from compensatory restoration from time T_2 to T_C (*i.e.*, areas C plus D) is sufficient to offset the present value in *ecosystem service units* lost as the oil-damaged wetland recovers from time T_0 to T_P (*i.e.*, area A). Compensation is then sought from the responsible party for the present value monetary costs of the project that creates the new wetland at the nearby site. Or, as an alternative to submitting a damage claim for the costs of the compensating wetland project, the responsible parties may agree to undertake this project, subject to performance criteria established by the trustees.

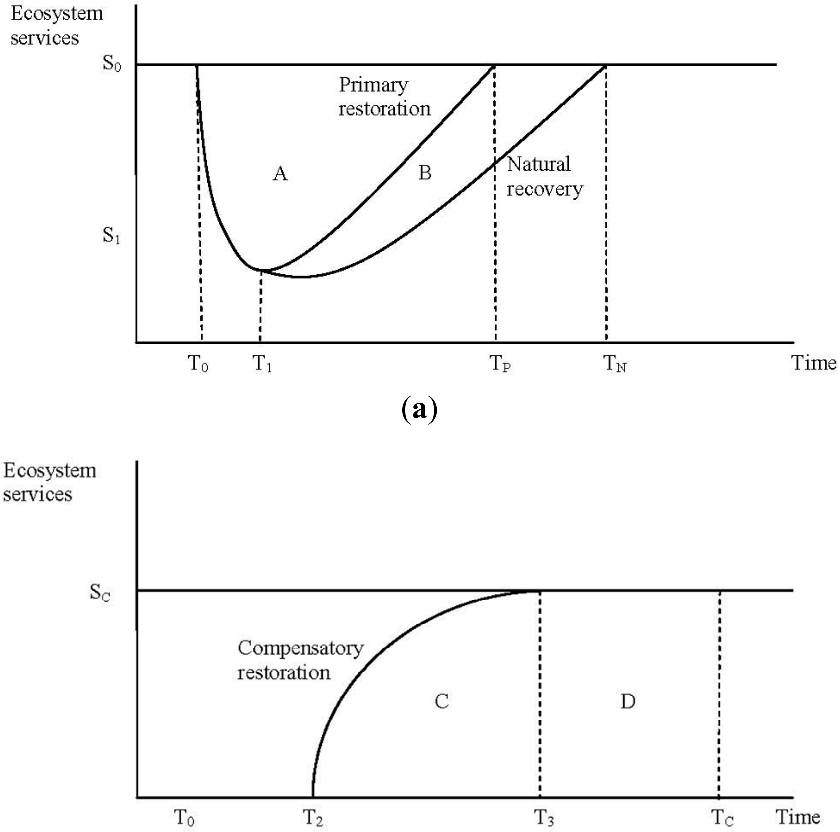
The HEA approach to coastal wetland restoration and compensation was applied to a major oil spill incident in the Gulf of Mexico in the case of the Texaco oil pipeline rupture on 16 May 1997, that discharged 6561 barrels of crude oil into Lake Barre, Louisiana [48,49]. The spill resulted in slick and oil sheen damage to over 1740 ha of estuarine salt marshes in the vicinity, although more than 95% of the affected area suffered only limited service losses with full recovery occurring after four months. NOAA decided that salt marsh creation and/or enhancement was the appropriate restoration to compensate for the *interim* marsh, aquatic fauna, and bird damages caused by the spill, and HEA was used for the assessment. The selected compensatory restoration project for the Lake Barre incident was planting salt marsh vegetation on newly deposited dredged materials on the nearby East Timbalier Island. The HEA concluded that planting 7 ha of new salt marsh on the barrier island would compensate the public for marsh, aquatic fauna, and bird interim losses [48]. In addition, the planted marsh would create another 16 ha through vegetative spreading, eventually yielding a total new marsh area of around 23.5 ha [49]. Texaco agreed to undertake the planting project on East Timbalier Island as compensation for the oil spill damages.

Proponents of HEA suggest that it has several advantages over the conventional monetary compensation approach to assessing natural resource damages [48,50–52]. First, the HEA focuses the NRDA on the goal of resource restoration from the beginning of the assessment process, which may result in expediting both restoration and compensation. In addition, since both trustees and the responsible parties for an oil spill have an opportunity to agree to a settlement, HEA avoids protracted and costly litigation to recover damages. By recovering the costs of compensatory restoration, the HEA ensures that enough money is collected to implement the proposed habitat creation or enhancement projects. For example, using the monetary compensation approach, damage assessment of the 1989 *World Prodigy* oil tanker spill off the coast of Rhode Island did eventually produce a settlement, but restoration projects did not begin until 1996. In contrast, the Lake Barre oil pipeline rupture occurred in May 1997, the HEA commenced immediately afterwards, and the marsh creation project began in the summer of 2000 [48]. In addition, as the damages collected from the responsible parties are for the costs of restoration and not for the value of the *interim* losses to impacted resources and habitats, the HEA avoids the need to conduct economic valuation studies of these services.

However, to implement this compensatory restoration approach, an HEA often makes a number of simplifications, such as assuming a preference for compensation with the same services that were damaged, a fixed proportion of habitat services to habitat value, and a constant real value of services over time [53,54]. HEA also requires that complex ecological services be expressed in terms of a single metric and that any ongoing impacts of a damaging effect can be estimated reliably over time [47]. These simplifying assumptions can be especially problematic if the value of the lost *interim* services changes significantly over time, which is likely to occur if the period of recovery is long [55].

The HEA could also lead to the over-supply of some wetland services in the long run [50]. Recreation, wildlife viewing, and other services may be used to full capacity before a coastal wetland is damaged by an oil spill incident. In Figure 3, the baseline level of supply S_0 basically satisfies the demand for these services. Creation of a new wetland at an alternative site may compensate for the *interim* loss of these services from the damaged wetland, but when the latter is eventually restored, both the original and compensatory habitat will offer the same set of services. If the demand for recreation, wildlife viewing, and other services does not change, then there will be excess supply.

Figure 3. Primary and compensatory restoration of an oil-damaged coastal wetland. Source: (**a**) Damaged wetland site; (**b**) Compensatory wetland site [23].



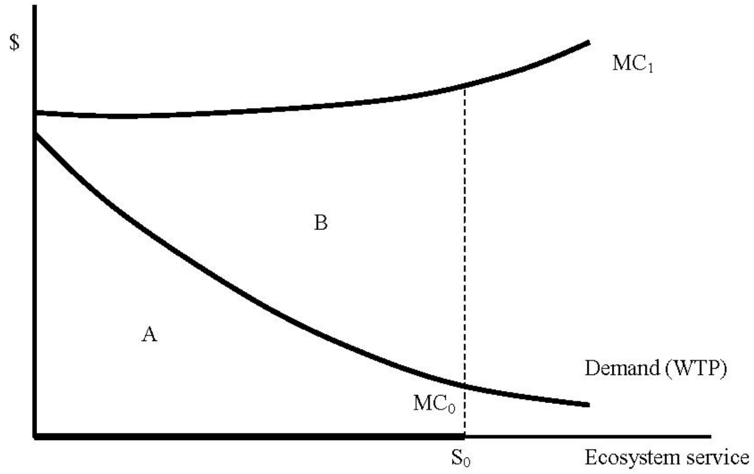
(**a**)

(**b**)

Perhaps the main criticism of an HEA is that it may not provide an accurate reflection of the actual costs and benefits of compensatory restoration. That is, "by avoiding money in the estimation of preferences, there is no way to judge whether costs are disproportionately high relative to benefits" [55]. This problem may arise because an HEA is based on a *replacement cost* approach to valuation. This method is frequently used in circumstances where an ecological service is unique to a specific ecosystem and is difficult to value, so that the cost of replacing the service or treating the damages arising from the loss of the service is estimated instead. However, economists urge caution in using the replacement cost approach as it has a tendency to overestimate values [16–18,23,56]. This method can provide a reliable valuation estimation for an ecological service, but only if the following conditions are met: (1) the considered alternative provides the same services; (2) the considered alternative is the least-cost alternative; (3) there is substantial evidence that society would demand the service if the least-cost alternative provides it [56]. In the case of the HEA, the first two criteria can be met, but the third is more difficult to determine. The result can lead to disproportionately high costs as compared to the benefits gained from compensatory restoration.

Figure 4 illustrates this potential inaccuracy in the HEA approach. Before it was damaged by an oil spill, the original coastal wetland provided a range of ecosystem services (e.g., recreation, habitat support for offshore fisheries, and storm protection). As depicted in the diagram, the baseline level of each ecosystem service supplied by the wetland before the spill is S_0. However, as the wetland provided this service "free" without any human inputs, the marginal cost of this service, MC_0, corresponds to the horizontal axis. The willingness to pay (WTP) for all those who benefit from this service is the downward-sloping demand curve. Thus, the total net benefits, measured in monetary terms, of the baseline level of service S_0 is area *A* in Figure 4. In comparison, the creation of a compensatory wetland at a nearby site to provide the same baseline level of ecosystem service is not costless. As indicated in the figure, the marginal costs of creating the new wetland is MC_1, and the total cost of this compensatory habitat up to S_0 is areas *A* plus *B*. Thus, the "replacement cost" of compensatory restoration clearly exceeds the benefits of the ecosystem service provided. If the cost of creating the new wetland is used as the basis for compensation for the *interim* loss in baseline services S_0 as a result of the oil spill, then these damages to the original wetland are overestimated. Moreover, unless an estimate is made of the value of the *interim* loss of wetland services (*i.e.*, area *A*), it is impossible to determine how much the compensatory restoration replacement cost approach overestimates these foregone benefits.

Figure 4. Benefits and costs of compensatory restoration of a coastal wetland. Source: [23].



4. Conclusions

A comprehensive review of non-market values estimates for US coastal and marine environments suggested that our knowledge of key habitat values was insufficient to support effective policy-making and management [19]. As this paper has indicated, in recent years there has been substantial progress in valuing a wide range of goods and services provided by coastal wetlands. One positive outcome is the growing number of studies around the world that are attempting to improve upon estimates of the storm protection service of mangroves and marshes (See Table 1). As the case study of southeastern Louisiana illustrates (see Section 3.2), the value of temperate wetlands in protecting coastal property from storm surges may prove to be one the most significant benefits of coastal wetlands.

Valuation can identify tradeoffs, including the costs and benefits of various coastal management options, and contribute to assessing management effectiveness. Improving our methods of estimating key coastal wetland goods and services, and expanding the geographic coverage of wetland valuation studies, will be essential for ameliorating the current and rapid decline in key global coastal wetland habitats. Perhaps one way of accelerating the progress in valuation is to focus future studies on the management of coastal "hotspots", as these are the regions where valuing coastal wetland goods and services may have the most immediate and needed impact on policy [4].

However, to assist coastal management and policy, quantitative assessment need not always require valuation of ecosystem benefits. As discussed in Section 3.1, the ecosystem services analysis conducted by the 2012 Master Plan for the Louisiana coast involved only indirect quantification of these services through proxy characteristics, such as habitat suitability indices and other measures (see Table 2). Although there were considerable limitations to this approach, the ecosystem service metrics did provide some guidance about the shift in key coastal habitats and services as a result of the Master Plan's proposed projects. In contrast, there may be more serious concerns about the economic and ecological implications of the habitat equivalency analysis used in a NRDA for an oil spill and other coastal hazards (see Section 3.3).

If employed properly, quantifying and in some cases valuing coastal wetland goods and services will aid decision-making by policymakers and local communities with respect to the protection and restoration of coastal habitats. Continued progress in valuing the various benefits provided by coastal wetlands will be essential to this task.

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Conflict of Interest

The author declares no conflict of interest.

References

1. Millennium Ecosystem Assessment (MEA). *Ecosystems and Human Well-Being: Current State and Trend*; Island Press: Washington, DC, USA, 2005.
2. United Nations Environment Programme (UNEP). *Marine and Coastal Ecosystems and Human Well-Being: A Synthesis Report Based on the Findings of the Millennium Ecosystem Assessment*; UNEP: Nairobi, Kenya, 2006.
3. Lotze, H.K.; Lenihan, H.S.; Bourque, B.J.; Bradbury, R.H.; Cooke, R.G.; Kay, M.C.; Kidwell, S.M.; Kirby, M.X.; Peterson, C.H.; Jackson, J.B.C. Depletion, degradation and recovery potential of estuaries and coastal seas. *Science* **2006**, *312*, 1806–1809.
4. Newton, A.; Carruthers, T.J.B.; Icely, J. The coastal syndromes and hotspots on the coast. *Estuar. Coast. Shelf Sci.* **2012**, *96*, 39–47.

5. Valiela, I.; Kinney, E.; Culbertson, J.; Peacock, E.; Smith, S. Global Losses of Mangroves and Salt Marshes. In *Global Loss of Coastal Habitats: Rates, Causes and Consequences*; Duarte, C.M, Ed.; Fundación BBVA: Bilbao, Spain, 2009; pp. 109–142.
6. Valiela, I.; Bowen, J.L.; York, J.K. Mangrove forests: One of the world's threatened major tropical environments. *BioScience* **2001**, *51*, 807–815.
7. Food and Agricultural Organization (FAO) of the United Nations. *The world's Mangroves 1980–2005*; FAO: Rome, Italy, 2007.
8. Worm, B.; Barbier, E.B.; Beaumont, N.; Duffy, J.E.; Folke, C.; Halpern, B.S.; Jackson, J.B.C. Lotze, H.K.; Micheli, F.; Palumbi, S.R; *et al*. Impacts of biodiversity loss on ocean ecosystem services. *Science* **2006**, *314*, 787–790.
9. Alongi, D.M. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuar. Coast. Shelf Sci.* **2008**, *76*, 1–13.
10. Koch, E.W.; Barbier, E.B.; Silliman, B.R.; Reed, D.J.; Perillo, G.M.E.; Hacker, S.D.; Granek, E.F.; Primavera, J.H.; Muthiga, N.; Polasky, S.; *et al*. Non-linearity in ecosystem services: Temporal and spatial variability in coastal protection. *Front. Ecol. Environ.* **2009**, *7*, 29–37.
11. Environmental Protection Agency (EPA). *Valuing the Protection of Ecological Systems and Services*; EPA: Washington, DC, USA, 2009.
12. National Research Council (NRC). *Valuing Ecosystem Services*: *Toward Better Environmental Decision Making*; The National Academies Press: Washington, DC, USA, 2005.
13. Barbier, E.B. *Capitalizing on Nature*: *Ecosystems as Natural Assets*; Cambridge University Press: Cambridge, UK, 2011.
14. Barbier, E.B.; Hacker, S.D.; Kennedy, C.J.; Koch, E.W.; Stier, A.C.; Silliman, B.R. The value of estuarine and coastal ecosystem services. *Ecol. Monogr.* **2011**, *81*,169–183.
15. Polasky, S.; Segerson, K. Integrating ecology and economics in the study of ecosystem services: Some lessons learned. *Annu. Rev. Resour. Econ.* **2009**, *1*, 409–434.
16. Barbier, E.B. Valuing ecosystems as productive inputs. *Econ. Policy* **2007**, *22*, 177–229.
17. Freeman, A.M., III. *The Measurement of Environmental and Resource Values*: *Theory and Methods*, 2nd ed.; Resources for the Future: Washington, DC, USA, 2003.
18. McConnell, K.E.; Bockstael, N.E. Valuing the Environment as a Factor of Production. In *Handbook of Environmental Economics*; Mäler, K.G., Vincent, J.R, Eds.; Elsevier: Amsterdam, the Netherlands, 2005; pp. 621–669.
19. Pendleton, L.; Atiyah, P.; Moorthy, A. Is the non-market literature adequate to support coastal and marine management. *Ocean Coast. Manag.***2007**, *50*, 363–378.
20. Dahl, T.E.; Johnson, C.E. *Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's*; U.S. Department of the Interior, Fish and Wildlife Service: Washington, DC, USA, 1991.
21. Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States, 1986 to 1997*; U.S. Department of the Interior, Fish and Wildlife Service: Washington, DC, USA, 2000.
22. Stedmand, S.M.; Dahl, T.E. *Status and Trends of Wetlands in the Coastal Watersheds of the Eastern United States, 1998 to 2004*; National Oceanic and Atmospheric Administration, National Marine Fisheries Service and U.S. Department of the Interior, Fish and Wildlife Service: Washington, DC, USA, 2008.

23. Barbier, E.B. Coastal wetland restoration and the *Deepwater Horizon* oil spill. *Vanderbilt Law Rev.* **2011**, *64*, 1821–1849.
24. Day, J.W., Jr.; Boesch, D.F.; Clairain, E.J.; Kemp, G.P.; Laska, S.B.; Mitsch, W.J.; Orth, K.; Mashriqui, H.; Reed, D.R.; Shabman, L.; *et al*. Restoration of the Mississippi Delta: Lessons from hurricanes Katrina and Rita. *Science* **2007**, *315*, 1679–1684.
25. Corn, M.L.; Copeland, C. *The Deepwater Horizon Oil Spill: Coastal Wetland and Wildlife Impacts and Response*; CRS Report 7-5700; Congressional Research Service: Washington, DC, USA, 2010.
26. Coastal Protection & Restoration Authority (CPRA) of Louisiana. *Louisiana's Comprehensive Master Plan for a Sustainable Coast*; Office of Coastal Protection and Restoration: Baton Rouge, LA, USA, 2012.
27. Twilley, R.R. *Coastal Wetlands & Global Climate Change: Gulf Coast Wetland Sustainability in a Changing Climate*; Pew Center on Global Climate: Arlington, VA, USA, 2007.
28. Gulf Coast Ecosystem Recovery Task Force. *Gulf of Mexico Regional Ecosystem Restoration Strategy*; Gulf Coast Ecosystem Recovery Task Force: Washington, DC, USA, 2011.
29. Gedan, K.B.; Kirwan, M.J.; Wolanski, E.; Barbier, E.B.; Silliman, B.R. The present and future role of coastal vegetation in protecting shorelines: Answering recent challenges to the paradigm. *Clim. Change* **2011**, *106*, 7–29.
30. Shephard, C.C.; Crain, C.M.; Beck, M.W. The protective role of coastal marshes: A systematic review and meta-analysis. *PLoS One* **2012**, *6*, e27374.
31. Erwin, K.L. Wetlands and global climate change: The role of wetland restoration in a changing world. *Wetl. Ecol. Manag.* **2009**, *17*, 71–84.
32. Airoldi, L; Beck, M.W. Loss, status and trends for coastal marine habitats of Europe. *Oceanogr. Mar. Biol.* **2007**, *45*, 345–405.
33. Farber, S. The value of coastal wetlands for protection of property against hurricane damage. *J. Environ. Econ. Manag.* **1987**, *14*, 143–151.
34. Costanza, R.; Pérez-Maqueo, O.; Martinez, M.L.; Sutton, P.; Anderson, S.J.; Mulder, K. The value of coastal wetlands for hurricane protection. *AMBIO* **2008**, *37*, 241–248.
35. Barbier, E.B.; Georgiou, I.Y.; Enchelmeyer, B.; Reed, D.J. The value of wetlands in protecting southeast Louisiana from hurricane storm surges. *PLoS One* **2013**, *8*, e58715.
36. Loder, N.M.; Irish, J.L.; Cialone, M.A.; Wamsley, T.V. Sensitivity of hurricane surge to morphological parameters of coastal wetlands. *Estuar. Coast. Shelf Sci.* **2009**, *84*, 625–636.
37. Wamsley, T.V.; Cialone, M.A.; Smith, J.M.; Atkinson, J.H.; Rosati, J.D. The potential of wetlands in reducing storm surge. *Ocean Eng.* **2010**, *37*, 59–68.
38. Resio, D.T.; Westerink, J.J. Hurricanes and the physics of surges. *Phys. Today* **2008**, *61*, 33–38.
39. Westerink, J.J.; Luetich, R.A.; Feyen, J.C.; Atkinson, J.H.; Dawson, C.; Roberts, H.J.; Powell, M.D.; Dunion, J.P.; Kubatko, E.J.; Pourtaheret, H. A basin to channel-scale unstructured grid hurricane storm surge model applied to southern Louisiana. *Mon. Weather Rev.* **2008**, *136*, 833–864.
40. Merz, B.; Kreibich, H.; Schwarze, R.; Thieken, A. Review article: Assessment of economic flood damage. *Nat. Hazard Earth Sys.* **2010**, *10*, 1697–1724.
41. Burrus, R.T.; Dumas, C.F.; Graham, J.E. The cost of coastal storm surge damage reduction. *Cost Eng.* **2001**, *43*, 38–44.

42. Dutta, D; Herath, S; Musiake, K. A mathematical model for flood loss estimation. *J. Hydrol.* **2003**, *277*, 24–49.
43. Pistrika, A.K.; Jonkman, S.N. Damage to residential buildings due to flooding of New Orleans after hurricane Katrina. *Nat. Hazards* **2009**, *54*, 413–434.
44. US Army Corps of Engineers (USACE). *Catalog of Residential Depth-Damage Functions Used by the Army Corps of Engineers in Flood Damage Estimation*; USACE: Washington, DC, USA, 2006.
45. Vigdor, J. The economic aftermath of Hurricane Katrina. *J. Econ. Perspect.* **2008**, *22*, 135–154.
46. Ofiara, D.D. Natural resource damage assessments in the United States: Rules and procedures for compensation from spills of hazardous substances and oil in waterways under US jurisdiction. *Mar. Pollut. Bull.* **2002**, *44*, 96–110.
47. Dunford, R.W.; Ginn, T.C.; Desvousges, W.H. The use of habitat equivalency analysis in natural resource damage assessments. *Ecol. Econ.* **2004**, *48*, 49–70.
48. Burlington, L.B. An update on implementation of natural resource damage assessment and restoration under OPA. *Spill Sci. Technol. B.* **2002**, *7*, 23–29.
49. Penn, T.; Tomasi, T. Calculating resource restoration for an oil discharge in Lake Barre, Louisiana, USA. *Environ. Manag.* **2002**, *29*, 691–702.
50. Jones, C.A.; Pease, K.A. Restoration-based compensation measures in natural resource liability statutes. *Contemp. Econ. Policy* **1997**, *15*, 111–122.
51. Thur, S.M. Refining the use of habitat equivalency analysis. *Environ. Manag.* **2007**, *40*, 161–170.
52. Zafonte, M.; Hampton, S. Exploring welfare implications of resource equivalency analysis in natural resource damage assessments. *Ecol. Econ.* **2007**, *61*, 134–145.
53. Mazotta, M.J.; Opaluch, J.J.; Grigalunas, T.A. Natural resource damage assessment: The role of resource restoration. *Nat. Resour. J.* **1994**, *34*, 153–178.
54. Unsworth, R.E.; Bishop, R.C. Assessing natural resource damages using environmental annuities. *Ecol. Econ.* **1994**, *11*, 35–41.
55. Flores, N.E.; Thacher, J. Money, who needs it? Natural resource damage assessment. *Contemp. Econ. Policy* **2002**, *20*, 171–178.
56. Shabman, L.A.; Batie, S.S. Economic value of natural coastal wetlands: A critique. *Coast. Zone Manage. J.* **1978**, *4*, 231–247.