Estimating the Change in Ecosystem Service Values from Coastal Restoration

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Executive Summary

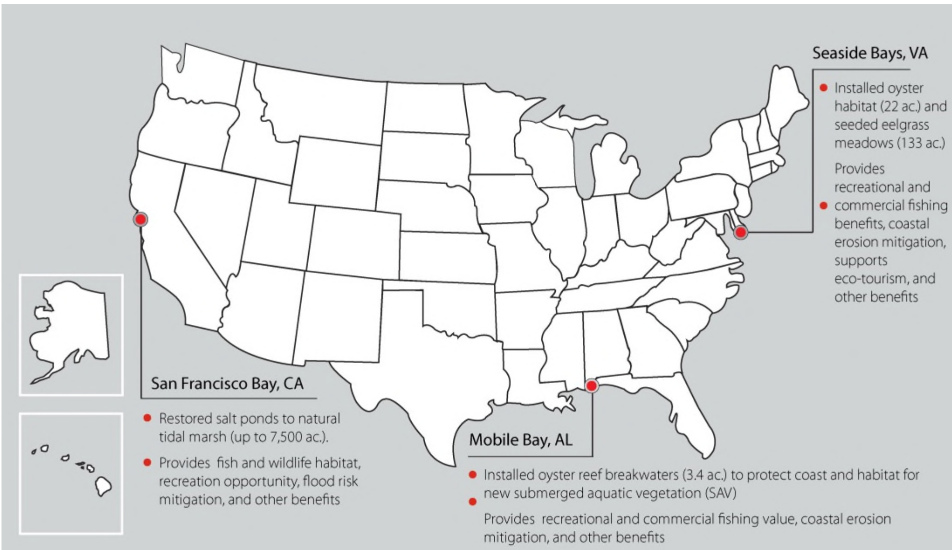
Introduction

Coastal ecosystems are highly productive, yet vulnerable, natural resources. Healthy tidal wetlands, salt marshes, submerged aquatic vegetation, oyster reefs, and other habitats provide vital goods and services, from fisheries production to recreation opportunities and wildlife habitat. These goods and services support the livelihoods, experiences, and resilience of coastal communities. Over the past century, however, human development pressures, natural disasters, and other factors have contributed to dramatic declines in the health and extent of the United States' wetlands, marshes, and submerged habitats. For example, while wetland loss rates are now slower than the historic rates of destruction during the 1950s-1970s, an estimated 62,300 acres of wetlands were lost in the conterminous United States between 2004 and 2009 (Dahl, 2011). The fundamental premise of coastal habitat restoration is to reverse the impacts of ecosystem stressors and return damaged habitats to a state that mirrors natural conditions. Resulting improvements to coastal environments include increased primary production, a more natural tidal pattern, better water quality, and larger fish and wildlife populations, among other outcomes. Restoration thus presents an opportunity to ensure the long-term health of coastal ecosystems. Because 39% of Americans live in coastal counties (NOAA/NOS, based on 2010 data), restoration is also an opportunity to ensure the vitality of coastal communities nation-wide.

Improved ecosystem conditions support economically valuable activity in coastal communities. Economists have demonstrated that improved habitats generate value for households and industry (Barbier et al., 2011). Restoration investments also generate short-term community benefits like job creation and regional economic activity (e.g., Edwards, Sutton-Grier, & Coyle, 2013; Mather Economics & The Walton Family Foundation, 2012; U.S. Fish and Wildlife Service, 2014). Despite research that shows the value of healthy ecosystems, and the clear need for restoration given ongoing and nation-wide coastal degradation, coastal restoration funding remains slim (Bagstad, Stapleton, & D'Agostino, 2007; Holl & Howarth, 2000). Slim funding reflects an apparent gap between scientific knowledge of the value of coastal ecosystems and consequent policy decisions to prioritize investments in coastal restoration (Barbier, 2013). Policies to address this gap may benefit from studies expressing the economic value of specific restoration projects and the tangible ecosystem services they generate (Aronson et al., 2010).

The purpose of this study is to help bridge the gap by assessing the potential economic value of long-lasting environmental benefits provided by recent coastal restoration projects (tidal marsh, eelgrass, and oyster reefs). The analysis demonstrates the value of restoration relative to the initial restoration investments, based on three projects designed to provide short-term economic stimulus under the American Recovery & Reinvestment Act: San Francisco Bay tidal marsh restoration, Virginia Seaside Bays oyster and eelgrass restoration, and Mobile Bay oyster reef breakwater installations (Exhibit 1).

Exhibit 1. Map of Case Study Sites.



Results of this study demonstrate that each project generates economic benefits by improving and enhancing a variety of ecosystem goods and services (e.g., enhanced flood protection, recreational amenities, commercial and recreational fishing). These benefits may produce long-term value in excess of the initial investment cost, as found for two of the three projects we analyzed in this study (Exhibit 2).

Exhibit 2 compares the estimated long-term ecosystem service benefits to construction spending and short-term economic output. The table reports NOAA/ARRA funds awarded for initial construction costs ("NOAA/ARRA Funding"), a separate study's (Coyle, 2013) estimates of the short-term economic activity following the dispersion of construction spending throughout the regional economy ("Economic Output"), and our estimates of the total present value (TPV) of each restored habitat's long-term ecosystem service provision ("Ecosystem Total Present Value"). Economic output and ecosystem TPV are complementary measures of value-added from the one-time spending on restoration. Economic output studies model the secondary spending which one-time restoration expenditures (e.g., laborer's wages and payments to materials suppliers) make possible by injecting new money into an economy (Edwards, et al., 2013). Because these effects eventually dissipate and are tied only to construction activity, they omit the value of services which the restored ecosystem provides.

Exhibit 2. Economic Benefits of Coastal Ecosystem Restoration at Three Sites ($2013).

	NOAA/ARRA Funding (1)	Economic Output (2)	Ecosystem TPV (3)	Ecosystem Benefit to Cost Ratio (4)
San Francisco Bay Salt Ponds	$8.27 million	$8.07 million	$6.89 - $220 million	0.8:1 to 27:1
Virginia Seaside Bays	$2.35 million	$2.57 million	$34.9 - $84.8 million	14:1 to 36:1
Mobile Bay, Alabama	$3.18 million	$3.46 million	$183,000 - $337,000	0.06:1 to 0.1:1

Sources: (1) NOAA; (2) Coyle (2013), a separate study not part of this analysis; (3) and (4) calculated over 40 years post-restoration, Abt Associates, Inc. (this analysis).

Notably, the upper bound estimates of ecosystem service benefits alone often far exceed construction costs. For example, two of the three ecosystem benefit-to-cost ratios indicate that, by enhancing and restoring ecosystems, restoration spending generates highly favorable gross returns. Short-term economic output, on the other hand, provides smaller return given the same construction cost. Not accounting for ecosystem benefits may, therefore, lead to incomplete conclusions about restoration benefit-to-cost ratios. Our study demonstrates that ecosystem service benefits are a potentially significant aspect of the restoration "story;" omitting their values may lead to inefficient allocation of restoration funds. By extension, coastal policy that accounts for ecosystem service benefits in addition to costs and short-term economic impact will represent a more complete picture, and may lead to greater support for coastal restoration investment.

Ecosystem service benefits, however, depend on site-specific factors such as ecosystem type, geographic location, baseline conditions, restoration success, and assumptions about the future duration of benefits. Across the three case study projects, we find that restoring habitats near socioeconomically-disadvantaged communities may also be able to provide environmental justice benefits. Because our analysis rests on accepted economic approaches and employs existing data, our analysis demonstrates a restoration valuation methodology that can be readily generalized and applied to other projects.

The remainder of this summary presents the case study projects, provides a synopsis of our valuation methods, and discusses the estimated economic value of benefits in context of coastal policy.

Methods

General Approach

Ecosystem goods and services produced by restored coastal habitats are inputs to economic activity and thus can offer real economic value to surrounding and distant communities. Coastal habitats *provide* society with directly consumable products (e.g., commercial fish harvests), support *cultural* activities (e.g., wildlife viewing and science education), and *regulate* and *support* the basic environmental processes (e.g., carbon sequestration and primary production) (Millenium Ecosystem Assessment, 2005).

We began this study by assessing the potentially-restored goods and services at each restoration site, and then used available monitoring data, environmental impact statements, and findings from prior ecological studies to estimate changes in ecosystem services at the site (Exhibit 3). The full effect of a restoration action may take decades to develop, but our case study projects were only very recently completed (less than five years prior to our study). To project long-term changes (and thus long-term economic benefits), we developed site-specific restoration trajectories to extrapolate available short-term restoration results over a 40-year period. Using available restoration site monitoring data, models and data from reference sites and scientific literature, we developed site-specific restoration trajectories. We next compared ecosystem service endpoints (i.e., vegetation density, oyster density, and others) before restoration to those throughout the restoration trajectory and used economic models to estimate the value of the change in services at each year. We discounted all values to present-day, for comparison to initial restoration investment.

We estimated economic values using a suite of market and nonmarket valuation approaches. For goods and services that are bought or traded in markets (e.g., increased fish catch), we used market-based approaches to estimate the value of these additional services. For nonmarket good and services, we used benefit transfer, a commonly-applied technique that involves adapting research found in the literature on the benefit value of similar projects and involving similar policy questions. Changes in individual households' willingness to pay (WTP) for goods and services served as our unit measure of non-market social benefits, such as aesthetic, recreational and non-use values.

Finally, because coastal managers may be concerned with making not only economically-defensible choices about restoration, but also about making choices that benefit a diversity of stakeholders, we conducted screening-level environmental justice analyses and identified the potential types of stakeholders who may benefit from a given coastal restoration investment. Our environmental justice analyses follow U.S. EPA guidelines (U.S. EPA, 2013b).

Exhibit 3. Summary of Ecosystem Service Valuation at Case Study Sites.

Benefit	Restoration Project: San Francisco	Restoration Project: Virginia Seaside Bays	Restoration Project: Mobile Bay
Aquatic Habitat			
Biodiversity	$	$	●
Threatened & Endangered Species	$	○	○
Commercial Fishing	$	$	$
Recreational Fishing	$	$	$
Subsistence and Artisanal Fisheries	●	●	●
Coastal Resiliency			
Erosion Mitigation	○	$	$
Flood Protection/ Storm Buffering	$	○	○
Life-Supporting Services			
Carbon Cycling	$	$	$
Nitrogen Cycling	○	$	$
Primary Production	$	$	○
Food Web Dynamics	$	$	$
Cultural Enhancements			
Bird Watching	$	●	○
Trail and Water Uses	●	●	○
Other Recreation	●	●	○
Existence/ Non-Use Values	$	$	●
Aesthetic Appreciation	$	●	○

○ = No change in the service/ Service is not relevant to the site.
● = Provides or enhances the service; effect is qualitatively assessed in this analysis.
$ = Provides or enhances the service; effect is quantified and monetized in this analysis.

Case Studies

Following the United States' recent economic recession, environmental agencies and other groups started to use coastal restoration to "… create work to support new jobs and provide income to local contractors and other industries" (U.S. Fish and Wildlife Service, 2014). In particular, using funds provided by the American Recovery and Reinvestment Act (ARRA), the National Oceanographic and Atmospheric Administration (NOAA) allocated in 2009, $167 million for 50 coastal and marine habitat restoration projects. These projects were targeted to create employment benefits in the short-term while achieving long-term environmental value. Subsequent research has demonstrated that the investments created an average of 17 jobs per $1 million invested (Edwards, et al., 2013).

We applied our ecological and economic assessment methods to three of the NOAA-ARRA projects. We selected these projects because they represent a variety of the United States' coastal ecosystems and surrounding communities, and maintained post-implementation habitat monitoring records that are needed for estimating changes in ecosystem service provision. At each site, we took into account key site-specific considerations, datasets, and valuation functions relevant to the individual project.

San Francisco Bay, California

Photo Courtesy of Doc Searls/Flickr

San Francisco Bay is the largest estuary on the Pacific coast of North America, yet more than 90 percent of its historic wetlands have been converted to agriculture, urbanization, and commercial salt production (Goals Project 1999). As part of regional efforts to reverse this habitat loss, federal, state, and local groups are engaged in collaborative efforts to convert South San Francisco Bay's salt production ponds back to their original state as ecologically- productive tidal marshes. Since 1994, federal and state agencies have purchased tracts of estuary baylands now totaling over 27,000 acres.

The current phase of tidal marsh restoration, funded in part by a $7.6 million NOAA-ARRA grant, is called the South San Francisco Bay Salt Pond Restoration Project (SBSPRP) and is designed to convert up to 7,500 acres of commercially-productive salt ponds to tidal marsh. Ecosystem monitoring shows that within just three years of commencing restoration activity at sites funded by the NOAA-ARRA program, individual restored ponds (approximately 1,513 acres) are beginning to provide vegetated marsh habitat and to support a different mix of bird, fish, and shellfish species, including threatened, endangered, and iconic species.

We applied a variety of ecosystem valuation approaches to estimate the total present value of the ecosystem service flow, using changes in salt marsh topography and plant density as indicators of wetland maturity and habitat quality. We estimated changes in total nonmarket value of the overall salt marsh habitat (including recreational use, biodiversity support, size of the project, and other features) using a benefit transfer from existing wetland valuation studies. In addition, we estimated the value of changes in specific ecosystem services provided by wetlands, including commercial and recreational fish populations, carbon sequestration, marginal changes in flood risk, etc.

Restoration Activity	Habitat Quality Indicators	Ecosystem Goods & Services (Summary)	Valuation Methods
Restored natural tidal influence to industrial salt ponds, reverting to original salt marsh habitat	• Presence of tidal influence • Marsh topography and sediment accumulation • Vegetation establishment and vegetation cover • Plant species mix	• Commercial seafood harvests Recreational fishing • Supporting services (primary production, food web effects, etc.) • Carbon cycling • Cultural benefits	• Function-based benefit transfer from studies and meta-analyses of total WTP • Trophic transfer models of fish production and market valuation

Seaside Bays of Virginia

Virginia's Seaside Bays include a variety of shallow coastal ecosystems, including submerged eelgrass meadows and oyster reefs. These habitats were once substantially present throughout the temperate zone and contributed important economic value. However, like many temperate estuaries of the United States, they experienced sharp declines in the last century due to habitat loss, natural disasters and over-harvesting.

With a $2.2 million NOAA-ARRA award, the project partners (including The Nature Conservancy, the Virginia Institute of Marine Science, Virginia Marine Resources Commission, and Virginia Coastal Zone Management Program) constructed functional oyster reefs at 14 sites; planted eelgrass seeds in the non-vegetated bottom of four bays; and deployed adult bay scallops as spawning stock in the restored eelgrass beds to support reintroduction of a self-sustaining bay scallop population.

Healthy, mature habitats are able to provide more and higher-quality services than partially-restored ecosystems. We used eelgrass shoot density and restored area as indicators of eelgrass habitat quality, and oyster population size, age structure, and reef area as indicators of oyster reef habitat quality. We separately estimated changes in total present value of goods and services from eelgrass and oyster reefs. For eelgrass, we estimated total nonmarket value of ecosystem services provided by eelgrass restoration using existing studies of households' willingness to pay to protect an eelgrass habitat similar to the case study (Johnston, Grigalunas, Opaluch, Mazzotta, & Diamantedes, 2002; Mazzotta, 1996). In addition, we estimated the value of eelgrass in protecting shorelines from coastal erosion. For oysters, we estimated individual values for increased carbon and nitrogen sequestration, market values for commercial fin fish landings, and recreational benefits of increased fin-fisheries at reefs (relative to bare sediment). The oyster reefs will be managed as sanctuaries with no oyster harvesting, but the reefs may provide non-monetizable value as "seed" (larval oyster) stock to nearby reefs.

Restoration Activity	Habitat Quality Indicators	Ecosystem Goods & Services (Summary)	Valuation Methods
• Constructed oyster reefs • Planted eelgrass meadows • Tested bay scallop spawning stock program at a demonstration site	• Oyster density and maturity at constructed reefs • Eelgrass coverage and shoot density • Scallops not quantifiable given available data	• Commercial seafood harvests • Recreational fishing • Supporting services (primary production, food web, etc.) • Carbon and nutrient cycling Cultural benefits	• Function-based benefit transfer from studies and meta-analyses of total WTP • Recreational travel cost models • Function-based benefit transfer from hedonic property value studies • Value transfer

Mobile Bay, Alabama

Mobile Bay, part of Alabama's Gulf Coast shoreline, is an estuary of national significance. It supports a diversity of nationally-important bird, fish, and wildlife species, and provides Fish and Wildlife Service-designated critical habitat areas for the piping plover (Mobile Bay National Estuary Program, 2008). However, changes in sedimentation patterns and salinity and increased use of shoreline armoring have altered wildlife habitats, exacerbated shoreline erosion, and reduced the Bay's resiliency during severe storms.

A $2.9 million grant from NOAA-ARRA to the Nature Conservancy (TNC) funded installation of "living shorelines" along several stretches of Mobile Bay coastline to provide oyster, other shellfish, and fin-fish habitats and create protective coastal breakwaters to provide shoreline stabilization and resiliency. In addition to enhancing the ecological health and resiliency of Mobile Bay marine habitats, the project was also designed to provide long-term fishery-related jobs for Mobile and Baldwin Counties. In total, 3.4 acres (1.6 miles) of oyster reef breakwaters were installed and now protect 31 acres of coastal habitat potentially suitable for new submerged aquatic vegetation (SAV) growth.

Oyster reef acreage served as this case study's habitat quality indicator. We estimated the value of increased ecosystem service flow based on several oyster reef functions: carbon and nitrogen sequestration, commercial and recreational fin fishery production, and coastal erosion mitigation. While this project is expected to produce ecosystem service benefits valued at lower than project cost, a variety of factors limited our ability to assess the full value of potential ecosystem services, including poor data availability. Further, natural environmental circumstances (e.g., hurricanes that amplified the effects of predation and poor water quality) dampened the pace of initial recovery at some sites.

Restoration Activity	Habitat Quality Indicators	Ecosystem Goods & Services (Summary)	Valuation Methods
• Constructed oyster reef shoreline breakwaters	• Oyster density and maturity at constructed reefs • Protected shoreline area	• Commercial seafood harvests • Recreational fishing • Supporting services (food web, etc.) • Carbon and nutrient cycling • Cultural benefits	• Function-based benefit transfer from studies and meta-analyses of total WTP • Fisheries production enhancement models and market valuation

Summary of Results

Among the many different types of benefits expected at each site, the three restoration projects will together help to enhance coastal biodiversity (all projects); protect threatened and endangered species (San Francisco Bay); provide nursery, habitat, and increased production of regionally-important fish and shellfish species targeted in commercial and recreational fisheries (all projects); provide nitrogen (Virginia Seaside) and carbon sequestration capacity (San Francisco Bay; Virginia Seaside); enhance opportunities for coastal recreation and tourism (all projects); and may provide real estate benefits by mitigating coastal erosion (Virginia Seaside; Mobile Bay) and providing marginal flood protection benefits to homes in coastal floodplains (San Francisco Bay).

Our report suggests that coastal improvements will generate substantial long-term economic value to coastal communities through improvements in ecosystem services. As described previously, these long-term ecosystem service benefits are separate from the short-term employment benefits that were a primary motivation of the ARRA program. However, our case studies show that restoration investment – in terms of initial construction costs – provides a variable return on investment. For every $1 invested in construction costs, the examined projects each produce between $0.06 and $36 in total long-term ecosystem service benefits. In other words, some, but not all, projects can be expected to demonstrate favorable benefit-to-cost ratios.

These ratios exclude any long-term operation and maintenance costs (i.e., maintaining existing levees in San Francisco Bay), and exclude both leverage and multiplier effects of the economic activity stemming from the improved ecosystem services. Leverage describes the additional coastal restoration resources obtained as new organizations provide funding and support to sustain or build on the initial restoration projects. Multiplier effects of economic activity capture the ripple effect of wages, subsequent purchases, and tax revenue generated by public and private spending on labor and construction costs of restoration.

Major Conclusions

We draw several major conclusions from comparative analysis across the three case studies:

Coastal habitat restoration enhances a wide range of valuable ecosystem goods and services. Restored salt marshes, sub-tidal meadows of eelgrass and other submerged aquatic vegetation, and oyster reefs provide fish and shellfish habitat and new recreational opportunities, protect coastal homes from shoreline erosion, mitigate climate change by storing carbon, enhance biodiversity, and help maintain coastal community character by supporting traditional and novel resource-dependent industries.

Coastal restoration investments can help address environmental injustices and support robust regional economies. Many people living in coastal communities will benefit from ecological improvements. However, coastal restoration can provide targeted benefits to some groups in particular, such as small businesses, resource-dependent industries, and traditionally under-privileged households. For example, when disadvantaged households stand to gain more from restoration than the average household within the community, restoration activity may help address environmental injustices (e.g., because a large portion of minority residents are employed in resource-dependent jobs that benefit from restoration, or because low income homeowners are less likely to purchase flood insurance coverage and thus benefit greatly from reduced flood risk). We observed this trend in two of the case studies we examined (Virginia Seaside; Mobile Bay).

Ecosystem service benefits are highly site-specific, but coastal resource planners can readily account for site features in the applied valuation of coastal resources. Accounting for a variety of project and site features is important, because no single feature guarantees success or value. While services valued on a per-area basis accrue approximately proportional to project size and quality (for example, Grabowski et al, 2010), synergistic effects from nearby ecological resources; the habitat's recovery pace; the type of services affected by restoration, and the characteristics of populations who benefit from restoration also contribute to coastal restoration values. Further, many service values are both non-linear and habitat-specific. For example, flood protection benefits do not scale linearly with project size: in the South San Francisco Bay case study, we account for flood protection values only after the project reaches a large size. Finally, projects like the Mobile Bay oyster reef restoration provide non-monetary benefits to society that should not be omitted during decision making, including benefits to infrastructure protection, "knowledge capital" generation, and employment.

A more comprehensive study would evaluate additional, previous, or ongoing coastal restoration projects to (1) provide a more robust assessment of the net benefits achieved by these types of projects and (2) help analysts better understand the factors leading to project success in terms of ecosystem benefit contribution. As part of a more comprehensive study, we recommend obtaining longer-term monitoring data at the projects we examined in this report to strengthen post-restoration evaluations and benefit assessments, particularly regarding the rate of accumulation and duration of benefits over time. Additionally, up-front restoration costs (e.g., Exhibit 2) at some projects may be followed by periodic maintenance costs that communities must incur to sustain restored ecosystems. As these costs become known, benefit to cost ratios could be adjusted to more completely reflect the long term. In general, by re-assessing project benefits as more data become available, we can better evaluate uncertainty in the current ecological and economic benefit projections.

Finally, extending the restoration valuation framework developed in this report to a wider variety of coastal restoration projects would broaden the understanding of how limited restoration resources could be more optimally distributed across potential projects. Enhanced understanding of restoration accomplishments across individual projects – especially if reported using consistent metrics that stakeholders respond to, such as the economic value of ecosystem improvements and returns on restoration investments – could promote greater allocation of funding to restoration overall.

Contents

List of Report Abbreviations

Acronym	Definition
ACR	Alabama Coastal Restoration
ARRA	American Recovery & Reinvestment Act
CZM	Coastal Zone Management office
EJ	Environmental justice
NOAA	National Oceanographic and Atmospheric Administration
SBSPRP	South San Francisco Bay Salt Pond Restoration Project
TNC	The Nature Conservancy
TPV	Total present value
VSBRP	Virginia Seaside Bays Restoration Project
WTP	Willingness to pay

1 Introduction

Coastal ecosystems are some of the United States' most important and vulnerable natural resources, including tidal wetlands, salt marshes, and adjacent marine ecosystems like submerged aquatic vegetation and oyster reefs. Impacts to coastal ecosystems occur due to a variety of reasons including filling, dewatering, poor water quality, sediment and nutrient runoff from development, industrial discharges, other land uses and overexploitation. Coastal ecosystem degradation and loss reduces or eliminates many vital ecological services that provide widespread ecological and economic benefits and/or employment for local communities.

Some of the more important services provided include:

- **Flood Protection:** Coastal wetlands protect upland areas from flooding due to sea level rise and storms, including protection of residential and commercial property.
- **Erosion Control:** Coastal wetlands can prevent coastline erosion due to their ability to absorb the energy created by ocean currents which would otherwise degrade a shoreline and associated development.
- **Wildlife Food & Habitat:** Eighty-five percent of the nation's waterfowl and migratory birds, and about 50 percent of the nation's endangered species depend on coastal wetlands. These animals and their habitat have recreational and commercial value to humans.
- **Commercial Fisheries:** Over 50 percent of commercial fish and shellfish species in the Southeastern United States rely on coastal wetlands.
- **Water Quality:** Wetlands filter chemicals and sediment out of water before it is discharged into the ocean
- **Recreation:** Recreational opportunities in coastal wetlands include canoeing and kayaking, wildlife viewing and photography, and recreational fishing and hunting.
- **Carbon Sequestration:** Certain coastal wetland ecosystems (such as salt marshes and mangroves) can sequester and store large amounts of carbon due to their rapid growth rates and slow decomposition rates.

In 2009, the National Oceanographic and Atmospheric Administration (NOAA), through the American Recovery and Reinvestment Act (ARRA), authorized allocation of $167 million in funds for coastal and marine habitat restoration. These ARRA funded projects were chosen partly to create short-term employment but also to provide potential long-term benefits to local and regional economies through the provision of market and non-market ecosystem services. In this report, Abt Associates assessed the long-term ecosystem and economic benefits of three coastal restoration projects partially or wholly funded through NOAA-ARRA.

2 San Francisco Bay Salt Ponds

2.1 Introduction

While wetland loss rates are now declining from historic rates of destruction in the 1950s-1970s, an estimated 62,300 acres of wetlands were lost in the conterminous United States between 2004 and 2009 (Dahl, 2011). To reverse losses of wetlands and other coastal ecosystem resources, active restoration projects are targeting these resources throughout the U.S.

San Francisco Bay is the largest estuary on the Pacific coast of North America, yet greater than 90 percent of its historic wetlands have been converted to agriculture, urbanization, and commercial salt production (Goals Project 1999). As part of regional efforts to reverse this habitat loss, federal, state, and local agencies and groups began a collaborative effort to restore salt production ponds in South San Francisco Bay to productive ecological habitats. Since 1994, federal and state agencies have purchased over 27,000 acres within the estuary. In the current phase of work, The California State Conservation Board, the U.S. Fish and Wildlife Service, the Hewlett, Packard, and Moore Foundations, and the Goldman Fund contributed approximately $100 million in total to purchase 16,500 acres of Cargill salt ponds and associated habitats in the South Bay[1]. The groups are now working towards achieving a 50-year regional plan designed to eventually convert 50 to 90% of the entire South Bay's former salt ponds or diked areas to tidal influence (EDAW, 2007; Goals Project, 1999), making the work the largest tidal marsh restoration effort in the western United States.

Box 1. South San Francisco Bay Salt Pond Restoration Project Goals

The goals of the project are to:

- Restore and enhance a mix of wetland habitats;
- Provide wildlife-oriented public access and recreation;
- Provide for flood management in the South Bay.

Source: www.southbayrestoration.org

The primary goal of restoring former salt-producing ponds to tidal wetlands is to provide ecosystem-based benefits, with a substantial focus on providing habitat for shorebirds, waterfowl, fish populations and other marsh dependent wildlife (Box 1). Thus, where possible, the tidal marsh restoration targets improvements to existing populations of threatened and endangered species like the federally- and state- endangered California clapper rail (*Rallus longirostris obsoletus*) and salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*). To maximize the benefit to the area's diverse biotic communities, and to achieve the broader suite of management objectives, South San Francisco Bay Salt Pond Restoration Project (SBSPRP) management team[2] has designed a series of salt pond conversion activities, each with different management objectives:

[1] http://www.southbayrestoration.org/faq/

[2] The collaborative management team includes the US Fish and Wildlife Service, the California Department of Fish and Wildlife, California State Coastal Conservancy, U.S. Geological Survey, National Oceanic and Atmospheric Administration, and other regional partners. A full list is available at http://www.southbayrestoration.org/partners/

- **Full breaching** of salt pond levees to tidal flow to create tidal wetlands in their place;
- **“Partial breaching”** and the placement of a water control structure to create ponds with muted tides that provide habitat for shorebirds and migratory waterfowl; and
- **Managing pond water levels** with water control structures to create deeper pond habitats for diving ducks (Hobbs and Moyne, 2012).

The SBSPRP restoration area includes a mosaic of former salt ponds and natural areas, which maximizes the creation of key habitats outlined in the Goals Project (1999). SBSPRP tidal marsh restoration activities are centered in 3 South Bay locations: Alviso Marsh Complex (AMC), Eden Landing (EL), and Ravenswood (Figure 2-1). In addition, restoration is also occurring on Middle Bair Island (MBI) although it is nominally outside of the designated SBSPRP area.

The exact cost of restoring acquired salt ponds depends on the level of construction work implemented in the coming decades, but is estimated to range from the low hundreds of millions to the high hundreds of millions (South Bay Salt Pond Restoration, 2013[3]). In 2009, ARRA funds totaling $7,620,943 were awarded to the California Coastal Conservancy for use in SBSPRP activities (NOAA 2012 Restoration Atlas). These funds were applied to a number of specific restoration activities during 2010-2011, as detailed in Table 2-1. ARRA-funded activities included breaching of existing levees to allow full or controlled tidal flushing of former salt ponds in the AMC and EL complexes, Phase 1 included fill and excavation to re-establish former tidal channels on MBI, and monitoring and herbicide control of invasive non-indigenous cordgrass (*Spartina alterntiflora*) species within the estuary.

The planned SBSPRP will substantially alter the structure and function of the South Bay marsh complex over the next 50 years. Not only will increased vegetation and improved water management provide higher-quality and more diverse habitats, but the overall project is facilitating improved access to and quality of water- and land-based recreation and improving many other activities, goods, and services valued by society over and above the simple existence of “better coastal habitat.” To illustrate societal benefits of the enhanced ecosystem services resulting from investing financial and other resources in coastal restoration, we linked changes in ecological features of the South Bay to changes in economic values, including the value of surrounding homes and the value of improved commercial and recreational fishery productivity.

We first analyzed ecological changes within the ARRA-funded portion of the project (AMC, EL, and MBI). A great advantage of this particular coastal restoration project is that scientific monitoring data are, although new, quite detailed and well-delineated. However, the ARRA-funded portion of the project is not occurring within a vacuum: its values are components of the much broader landscape-wide effort to restore much of the South Bay. We do not have data on the total cost of the past and future spending on the SBSPRP or ecological data to support quantification of individual benefit categories. However, it possible to estimate the approximate benefits gained from the overall project by extrapolating existing ecological data to the entire SBSPR area.

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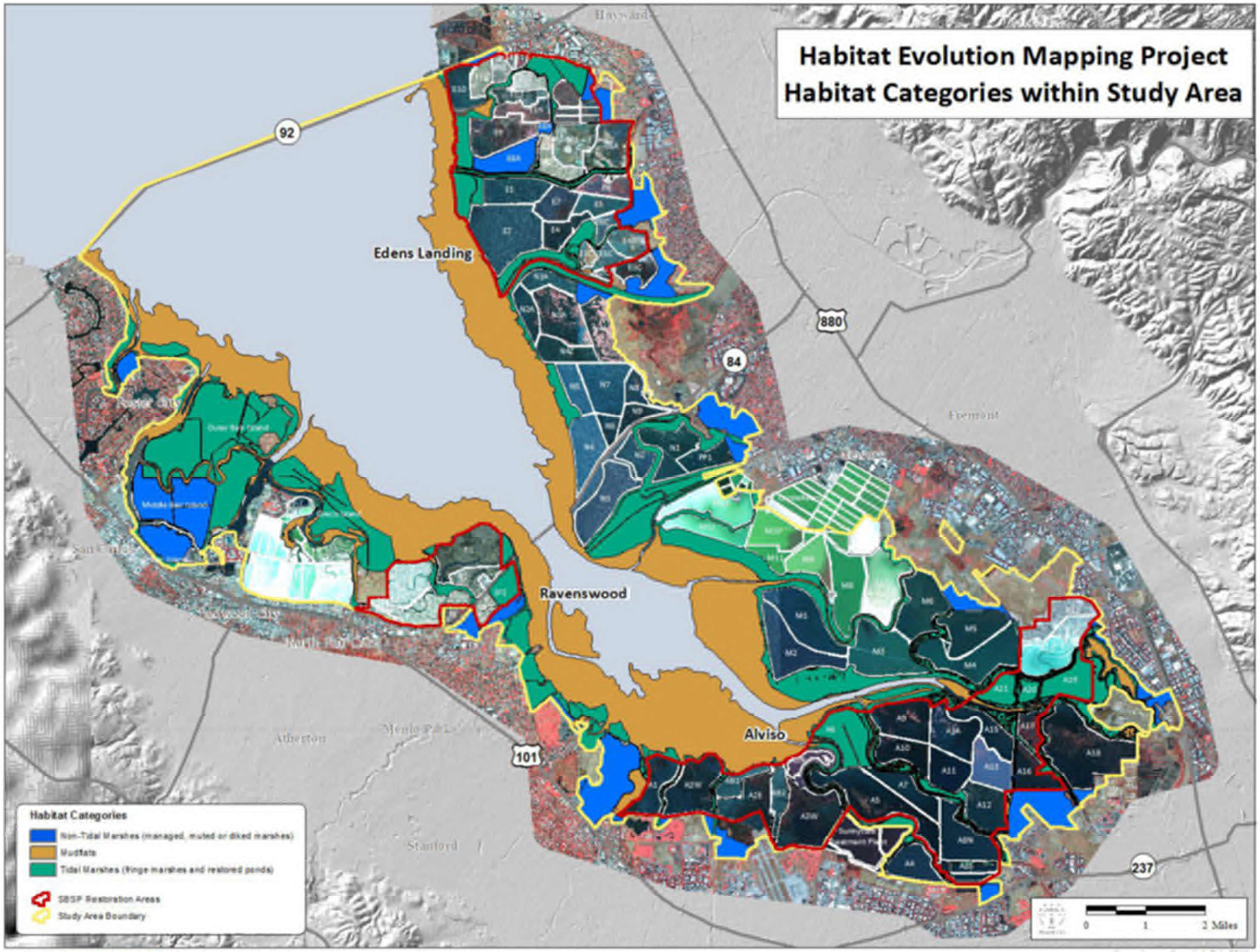
[3] http://www.southbayrestoration.org/FAQ.html

Box 2 summarizes results of our ecological and economic assessments. The remainder of this section describes our methods and findings in more detail.

Box 2. San Francisco Bay Restoration Benefits Summary

- Provides vegetated marsh habitat and enhances bird, fish, and shellfish species, including T&E and iconic species.
- ARRA-funded restoration expected to provide $3 to $9.6 million in annualized long-term ecosystem benefits.
- The local community, including low-income and minority households, also benefits from increased recreation opportunity and flood hazard reduction provided by the encompassing South Bay restoration effort.

Figure 2-1. South San Francisco Bay Salt Ponds Restoration Project Study Area.



Source: Habitat Evolution Mapping Project (2012).

Table 2-1. Summary of South Bay Salt Pond Restoration Projects Funded by ARRA.

Pond	Area (ac)	Restoration Action	Approx. Date of Action	Previous Habitat	Restoration Target Habitat
Alviso Marsh Complex[1]					
A6	332	Levees Breached	October 2010	Diked Salt Marsh	Tidal Marsh Wetland
A8	550	Tidal gate installed	Summer 2011	Seasonal High Salinity Pond	Seasonal (muted) Tidal Marsh Wetland
Eden Landing[1]					
E8A	241	Levees Breached	November 2011	High Salinity Pond	Tidal Marsh Wetland
E8X	31	Levees Breached	November 2011	Salt Pond	Tidal Marsh Wetland
E9	358	Levees Breached	November 2011	Salt Pond	Tidal Marsh Wetland
Middle Bair Island[2]					
MBI Restoration	571	Phase I work (excavation)	July to December 2011	Subsided Tidal Marsh	Tidal Marsh Wetland
MBI Enhancement	307	Phase I work (excavation)	July to December 2011	Subsided Tidal Marsh	Tidal Marsh Wetland
Invasive Spartina Control[3,4]					
2010 treated ac.	216	Invasive *Spartina* management	Growing seasons	Existing Tidal Marsh	Non-native *Spartina* species control
2011 treated ac.	145				
	2,751	**Total Area (ac) funded by NOAA-ARRA[5]**			

Notes:

(1): H. T. Harvey & Associates (2005). Area A8 was reported as both 407 and 550 ac; we used the latter which apparently includes both A8-north and A8-South.

(2): California Coastal Conservancy (2011).

(3): Grijalva & Kerr (2012)

(4): Hogle (2012)

(5): 2,751 ac. is based on the sum of detailed restoration plans and monitoring documents referenced in this table. If all of the proposed Middle Bair Island area (1,261; inclusive of the 878 ac. in this table) is included we estimate the total at 3,134 ac. The NOAA (2012) summary website provides an alternate total estimate of 3,358 acres across all sites. Because we could not verify NOAA's total estimate, we defuse totals based on published monitoring documents. The difference in Abt's compiled estimate and NOAA's total estimates is relatively small (7% of total area) and may reflect differences in proposed, versus actual, restoration activity.

2.2 Overall Ecological Resources and Restoration Effects

This section briefly summarizes the current condition of ecological resources of the SBSPRP sites and the expected, future conditions based on first-order restoration impacts (i.e., pre- vs. post-restoration). Re-opening closed salt ponds to tidal influence is expected to restore natural vegetation and associated habitats in individual areas of the South Bay. We characterized the ecological effects of restoration in terms of the following outcomes: (1) the amount and quality of wetland habitat; (2) abundance and diversity of fish and invertebrate communities; (3) effects on avian fauna; and (4) impacts on threatened and endangered species within South Bay.

Because many of the ARRA-funded sites are relatively early in the restoration trajectory (and thus monitoring data represent early, rather than final, characteristics of the restored areas), we first examined habitat restoration trajectories and current wetland status of similar sites that were restored earlier in the broader South Bay project (Appendix D). We also reviewed recent sediment measurement and habitat mapping conducted on representative sites in the current project. Based on this information, we estimated the time and habitat acreage for selected AMC and EL sites for the current year, 5-year, 10-year and 25-year periods (Section 2.2.a). While the ARRA-funded sites are part of a long-term (50 year) restoration plan, we expect the timeline for restoration of individual areas will be much quicker, including sediment accumulation to raise pond elevation and re-vegetation of the area to meet natural conditions (Section 2.2.a).

2.2.a Ecological Assessment of Wetland Habitat Restoration

Sediment Accumulation Trajectory

Opening ponds to tidal influence washes suspended solids in Bay and local tributary waters into the newly breached area. The sediment which accumulates on historically-subsided salt pans provides suitable substrate on which marsh vegetation can begin to regrow. Creation of good quality tidal marsh from the former salt ponds is dependent on flushing and surface elevation (Appendix D). Tidal marsh vegetation is highly sensitive to the frequency and duration of tidal inundation, which is directly affected by the marsh surface elevation relative to tides. Changes in elevation of 10 cm or less can lead to shifts in the dominant plant communities (Zedler & Callaway, 1999). As sediment and vegetation continue to accumulate, coastal sites typically evolve from subtidal mudflats to intertidal marsh as the average elevation increases and then levels off (Figure 2-2).

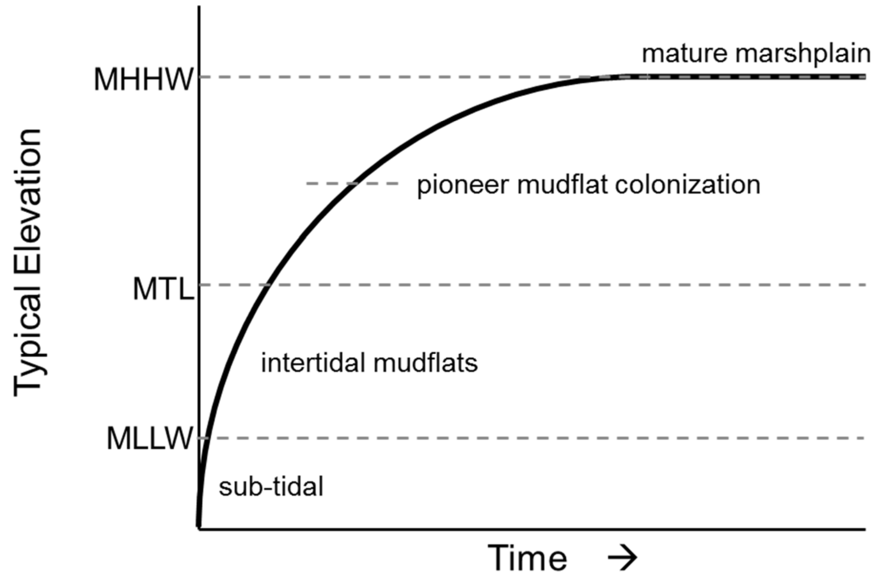


Figure 2-2. Marsh Development Trajectory as a Function of Surface Elevation.

Note: MHHW = mean higher high water; MTL = mean tidal level; and MLLW = mean lower low water.
Source: Williams & Orr (2002).

Vegetation Establishment and Habitat Quality

In addition to the total acres of wetlands restored to natural tides, wetland habitat *quality* also influences the value of ecological services provided. Although the SBSRP is expected to produce multiple and diverse habitat changes over time, we used the percent area covered by vegetation as the key indicator of wetland restoration quality.

Figure 2-3. Time Series of Aerial Photographs Showing Coastal Ecosystem Evolution from Commercial Salt Pond (Left) to Tidal Wetland (Center and Right Photographs).

Source: Image © Chris Benton.

To assess current and project future quality level of vegetated habitat in restored areas, we reviewed habit evolution (progress) documented at three restoration sites in South Bay completed before the ARRA-funded aspects (Appendix D). While these are informative, it is important to note that applications of "lessons learned" (e.g., place of inner diversion barriers) in more recent restoration projects have enhanced sediment accumulation and reduced internal scouring, thus speeding up the rate of bottom elevation rise and associated re-vegetation. We also reviewed qualitative descriptions of vegetation in the recently-breached ponds of interest (Brian Fulfrost and Associates, 2012; Phillip Williams and Associates, 2004) and prior studies of other tidal wetland restoration progress as benchmarks (Binard, Chiang, Rafferty, Greer, & Semion, 2008).

Based on these sources of information (Binard, et al., 2008; Phillip Williams and Associates, 2004) and best professional judgment, for the purpose of this analysis we assumed the following incremental vegetation cover at the three ARRA-funded sites over time: 15% cover at 2-3 years, 30% cover at 5 years, 60% cover at 10 years, 75% cover at 15 years, 90% at 20 years and approaching 100% at 25 years. We assumed that the initial establishment of cover by pioneering species would be rapid (after an initial lag time for adequate sediment accumulation to get above the MTL) but that rates of vegetation expansion would decline over time (similar to sediment deposition). We used these expected cover projections, together with current observations of the wetlands of interest, to estimate current and projected vegetation cover.

We reviewed the most current sediment accretion rates and vegetation data available for the restoration sites of interest (i.e., AMC and EL). For vegetation we used results of the recently completed Habit Evolution Monitoring Project (HEMP) (Appendix D) (Brian Fulfrost and Associates, 2012).

Based on several positive developments of wetland restoration at the site to date, we assumed percent habitat coverage at AMC and EL sites will continue to expand (Table 2-2) following the formulas discussed above. At the time of our report, ARRA funding at MBI had only been applied to preliminary Phase I (pre-breaching) work, so the 878 acres of planned restoration are not included in the ARRA-specific ecological or economic analyses. However, we expect that these areas will eventually also develop into good quality wetlands, similar to those found on Outer Bair Island. Thus, we include the MBI acreage in benefits analyses of the total SBSPRP activities in the South Bay, assuming an approximate lag time of 5 years.

Given the data and assumptions summarized above, we estimate current functional wetland habitat (i.e., 2013: restoration years 1-3) covers 227 ac of the South Bay ARRA-funded sites. We estimate ARRA-funded restoration will double the area to 454 ac within two years (restoration year 5) and eventually increase to about 1,531 acres in 25 years (Table 2-2). The increase in acreage would be accompanied by enhanced plant species diversity assuming the pattern and timing of plant colonization displayed in Muzzi Marsh (Appendix D). The colonization of Pacific cordgrass (*Spartina foliosa*) in the lower areas and pickleweed (*Salicornia*) on higher marsh plain would also greatly increase ecosystem primary production.

Studies indicate that primary production in the restored wetlands would rapidly increase (faster than vegetation diversity or coverage) such that within 10 years, biomass and carbon export rates should start to approach those of natural marshes (Brusati & Grosholz, 2006; Dame & Kenny, 1986). Other ecosystem functions such as support of biodiversity, denitrification and carbon sequestration should be commensurate with the relative vegetation cover and development of organic soils in the restored wetland.

We also examined the broader potential restoration scenario that includes activities completed throughout the matrix of ponds and wetlands across the entire South Bay area (of which the ARRA-funded SBSPRP is part). We projected future restoration of wetlands using a literature- suggested target of 7,500 acres (SBSPRP, 2012) using

GEIS Scenario B. This results in a 50:50 mixture of tidal wetlands to salt ponds.[4] After accounting for the 1,513 acres currently being restored in Ponds A6, A8; E8A, E8X, and E9 under ARRA, an additional 5,987 ac in wetlands are restored by considering the overall project (relative to the ARRA-funded estimates). For consistency with proposed timeline of the larger project, we assumed a 50- year restoration horizon, with the restoration acres distributed equally in 5 year increments of restoration (Table 2-3). In other words, restoration of 20% of the remaining acres is initiated every 5 years. Vegetation development on the restored acres follows the chronology described in Appendix D, and all restored wetlands are assumed fully-functioning 50 years after restoration began (in year 2060).

Ecological Summary

Based on review of the design and trajectory of ARRA-funded wetland restoration and activities at SBSPRP restoration sites and available data, we conclude the following about ARRA-funded restoration activity.

- Restoring tidal flushing by breaching and following expected patterns of re-vegetation shown in adjacent areas, tidal wetland habitat have increased by 195 acres and will eventually increase to 1,513 acres.
- Vegetation species diversity and habitat quality will increase rapidly with re-vegetation with most ecosystem functions and services being largely restored within 15-20 years.

These changes support biodiversity and wildlife habitat, increase denitrification and carbon sequestration capacity. Remaining sections of the South San Francisco Bay case study summarize estimated changes in populations of resident estuarine and visiting marine species, shorebird and migratory sea bird populations, and native, resident threatened and endangered species populations. In each section, we also present economic value estimates associated with the change in ecosystem goods and services provided as salt ponds are restored to functioning tidal wetlands.

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[4] 7,500 is about 50% of the total acreage of the existing 14,000+ acres of salt pond and wetlands the South Bay.

Table 2-2. Summary of SBSPRP - Estimated Potential Ecosystem Restoration Status of ARRA-Funded Sites.

Pond[1]	Total Area (ac)	Target Habitat	Estimated Wetland Acres[2] (% Restored) 0-3 years 10-15%	5 years 25-30%	10 years 60%	15 years 75%	20 Years 90%	25 Years 100%
Alviso Marsh Complex								
A6	332	Tidal Marsh Wetland	49.8	99.6	199.2	249.0	298.8	332.0
A8	550	Seasonal (muted) Tidal Marsh Wetland	82.5	165.0	330.0	412.5	495.0	550.0
Eden Landing								
E8A	241	Tidal Marsh Wetland	24.1	60.3	144.6	180.8	216.9	241.0
E8X	31	Tidal Marsh Wetland	3.1	7.8	18.6	23.3	27.9	31.0
E9	358	Tidal Marsh Wetland	35.8	89.5	214.8	268.5	322.2	358.0
		Total acres restored:	**195.3**	**422.1**	**907.8**	**1,134.8**	**1,361.7**	**1,513.0**

Notes:

(1) Pond numbers follow Harvey (2005).

(2) Restoration began in 2010 in AMC and 2011 in EL; this is reflected in the application of adjusted cover percentages in years 0-10; by 10 years it is assumed that the effect of a 1-year lag at EL will have a negligible effect on total restoration at all sites.

Table 2-3. Summary of SBSPRP - Estimated Potential Ecosystem Restoration Status of Overall South Bay Restoration with Targeted 50:50 Salt Pond to Wetland Habitat Mix.

Total Area	Phased Restoration Area	Restoration	Estimated Wetland Acres[1,2] 0-3 years	5 years	10 years	15 years	20 Years	25 Years	30 years	40 years	50 Years
Ponds A6, A8; E8A, E8X, E9											
1513		Tidal Marsh Wetland	195	422	908	1,135	1,362	1,513	1,513	1,513	1,513
Remaining South Bay Habitats											
5987	1,197.5	Restoration at year 5	0	180	359	718	898	1,078	1,197	1,197	1,197
	1,197.5	Restoration at year 10	0	0	180	359	718	898	1,078	1,197	1,197
	1,197.5	Restoration at year 15	0	0	0	180	359	718	898	1,197	1,197
	1,197.5	Restoration at year 20	0	0	0	0	180	359	718	1,078	1,197
	1,197.5	Restoration at year 25	0	0	0	0	0	180	359	898	1,197
		Total acres restored:	195	602	1,447	2,392	3,517	4,746	5,764	7,081	7,500

Notes:

(1): AMC and EL Ponds currently under restoration, refer to wetland acreages in Table 2-1.

(2): South Bay habitats are restored at 20% increments in years 5-25, restoration rate assumptions are the same as in Table 2-2.

2.2.b Economic Assessment and Valuation of Wetland Restoration Benefits

Ecosystem goods and services produced by restored coastal wetlands are inputs to economic activity and thus can offer real economic value to surrounding and distant communities. There are a number of ways in which society benefits from these and other improvements to ecosystem conditions (Figure 2-4). Restored wildlife habitat, for example, provides benefits well beyond the direct improvements to coastal marsh species populations. Recreational users in the San Francisco Bay area enjoy visiting areas that provide opportunity to view wildlife populations (Sokale & Trulio, 2013). Restored coastal wetlands also provide nursery grounds for recreationally commercially-valuable fish and shellfish species, increase carbon sequestration, may reduce coastal flood risk and improve other ecosystem services (Table 2-4). To estimate the long-term economic value of goods and services stemming from coastal restoration we used market and nonmarket valuation of approaches.

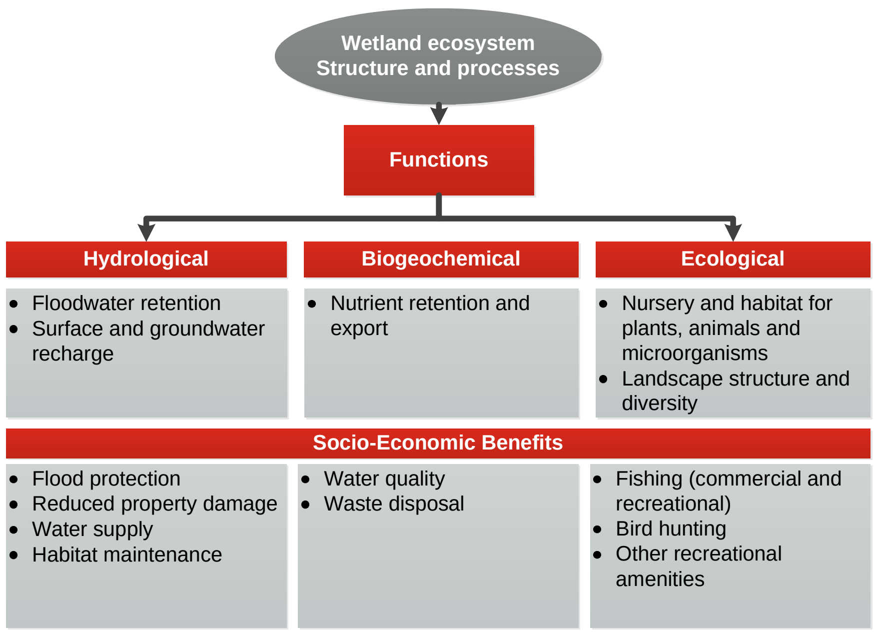

Figure 2-4. Wetland Ecosystem Functions and Their Derived Socio-Economic Benefits.

Source: Adapted from Brouwer et al. (1999).

In this section, we estimate social values for restored coastal habitats by comparing the economic value of the coastal areas in their baseline, un-restored state to their value as functioning tidal wetlands. This general approach is also applied to later case studies of restoration projects in Virginia (Section 3) and in Alabama (Section 4). In the case of South San Francisco Bay, the un-restored coastal salt ponds provided some baseline level of social benefit – for example, the salt ponds were economically productive in their historical industrial use as salt production facilities, and served (unintentionally) as migratory bird and brine shrimp habitat. Tidal wetlands offer a different mix of habitats than the salt ponds, and the purpose of this research is to examine the extent, timing and duration of economic benefits from restoring the wetland areas to their natural use. Converting salt ponds to wetlands provides increased habitat benefits, but incurs the cost of lost salt production value. In our analysis, we accounted only for the quality of the salt pond as habitat, but not for the lost economic value of salt production.

Table 2-4 characterizes the wetland goods and services enhanced by SBSPRP restoration. Each type of ecosystem service provided by restored coastal habitats falls into one of three general categories: provisioning (i.e., services that directly provide goods for economic consumption such as commercial fish harvesting), cultural (e.g., activities such as wildlife viewing and science education), and regulating (e.g., carbon sequestration and primary production). Changes in individual households' willingness to pay (WTP) are our unit measure of the social benefits from coastal habitats. Individual components of the total wetland value can be classified in a variety of ways (Champ, Boyle, & Brown, 2003; Freeman, 2003):

- **Market vs. non-market goods.** Some goods and services (e.g., commercially caught fish) can be bought and sold in traditional markets ("market goods") and thus can be valued using market price data and models. Other environmental amenities are not usually purchased in markets ("non-market goods"), and are more difficult to monetize. Non-market valuation techniques must be applied to reveal implicit prices of these goods based on individual's observed or reported behaviors. For example, the value of increased flood protection could be revealed by comparing housing prices across a flood zone boundary.
- **Use vs. non-use goods and services.** Some goods and services are valuable for their direct value to some human activity (goods with "use" value), such as the value of a day of recreational fishing or the value of a home located in an aesthetically-pleasing area. Others are valuable intrinsically and independently of any observable human use ("non-use" goods), such as a California resident's WTP to protect South Bay wetland habitats that she will never visit.

We refer to the combined social value of all restoration endpoints, including use and non-use benefits, as the "total economic value" of each habitat restoration project. Many benefits enumerated in Table 2-4 overlap in their value to society. For example, valuing both tidal wetland habitat and commercial fishery productivity may double-count the value of the wetland as a nursery ground for commercially-valuable species. In estimating the economic contribution of observed changes in ecosystem endpoints, we attempted to capture the total value of all restoration while avoiding double-counting. Our methods included first calculating the aggregate per-acre benefits of wetland restoration and then, where data were available, estimating the component part-worth of individual changes. Thus, the economic assessments presented in the remainder of this report should not necessarily be interpreted as "additive" (except where noted).

We used a suite of models and variety of monetization approaches to assess expected changes in ecosystem services over the restoration trajectory, comparing a consistent set of pre- and post-restoration conditions to estimate the economic value of the change in ecosystem services provided by the coastal resources associated with restoration (Table 2-5). The main component of our benefits analysis is based on the extent of ARRA-funded restoration, as we are able to support it with well-documented and detailed monitoring and assessment data. However, the project exists within context of a much larger restoration plan. Additionally, the larger scale of the overall project matrix may accomplish ecosystem benefits that the ARRA-funded portion would affect only negligibly. In particular, flood risk mitigation benefits are unlikely to be realized from the ARRA-funded portion alone, while restoration of tidal wetlands in the entire South Bay area may reduce flood risk to coastal communities. To estimate benefits of these services and to illustrate the returns to scale of multi-organization cooperative efforts, we also estimate changes in benefit categories using less-detailed data based solely on project acreage and estimated restoration trajectories.

All of our economic valuation methods employ benefit transfer, a commonly-applied technique that involves adapting research found in the available literature and conducted for one purpose, to another purpose, to address the policy questions at hand (Smith, Van Houtven, & Pattanayak, 2002; U.S. EPA, 2010; U.S. Office of Management and Budget, 2003). In developing benefit transfer approaches, we followed key steps for valuing effects of restoration on ecological services described in EPA's Guidelines for Economic Analysis, including: (1) describing the policy case, that is, the case for which value estimates are desired, (2) selection of the applicable studies from the available literature, and (3) transferring values.

We estimated benefits from the ARRA-funded portion and the entire South Bay restoration projects as follows:

- **ARRA-Funded Restoration:** Because not all ARRA-funded projects had commenced by the time of this report, we only examine the 1,513 acres of wetlands in the AMC and EL complexes which were restored in 2010/2011 (Table 2-1, excluding invasive species control projects), and assumed 15% of natural tidal wetland capacity had been achieved by 2013. We also assumed restoration progresses on a common trajectory across all sites at the rates listed for AMC and EL in Table 2-2, to reach a maximum of 100% natural wetland function at 25 years post-restoration. Following the standardized benefit estimation approach outlined in Appendix A, which facilitates consistent comparison of benefits estimates across all case studies in this report, we estimated benefits of the project assuming the restored wetlands provide 100% of services for 15 years after reaching maximum natural function. This brings the total benefit estimation period to 40 years, from 2010 to 2050.
- **Overall South Bay Restoration:** The conservative version of the broader SBSPRP includes plans designed to achieve a 50:50 mix of salt ponds and wetlands in the entire South Bay area within 50 years, converting approximately 7,500 ac of former salt ponds to wetlands by 2060. The total area of wetlands converted is, at 2060, achieved in total area and full ecological function at the end of the 50th year (Table 2-3). Given the broader project's focus on long-term maintenance of flood storage capacity for the South Bay region, we assume the restored wetlands will persist at their fully-functioning capacity for long thereafter. Given the type of services (e.g., flood benefits), length of time needed to achieve those services (50 years) and ultimate duration of the restored project, Abt Associates felt it is not appropriate to adjust benefits of the overall South Bay project to the 40-year timeline. For example, flood benefits are a discrete benefit unlikely to be achieved within 40 years, so linear approximations of partial benefits achieved on the ARRA time scale are not meaningful. To capture flood risk reduction benefits, however, we treat the overall South Bay project as a distinct case study that is not directly comparable to the smaller ARRA-funded work. In this case, we use a benefit accrual and annualization period of 100 years, capturing the 50-year project timeline (Table 2-3) plus 50 years of 100% wetland function and flood risk benefits.

Table 2-4. Ecosystem Services from Restored Coastal Wetlands in South San Francisco Bay.

Service Category	Ecosystem Services	Change as a Result of Restoration	Available Change Assessment Methods	Monetizable
Provisioning of "products obtained from ecosystems" (MEA, 2005)	Commercial seafood harvest	↑	Quantitative	Yes
	Recreational seafood harvest	↑	Quantitative	Yes
	Subsistence seafood harvests	↑	Qualitative	No, data not sufficient.
	Subsistence hunting harvests	↑	Qualitative	No, data not sufficient.
	Industrial Products – salt	↓	n/a (not a benefit)	n/a
Supporting ecosystem services "that are necessary for the production of all other ecosystem services" (MEA, 2005)	Primary production - vegetated habitat	↑	Quantitative	Yes
	Food web dynamics	↑	Qualitative	No, data not sufficient.
	Waste assimilation sinks	≈	n/a; No change to estimate	n/a
Regulating ecosystem processes and associated benefits.	Carbon and nutrient cycling	↑	Quantitative	Yes
	Flood Protection/ Storm Buffering	≈	Qualitative	Yes
	Sediment Stabilization	↑	Quantitative	Yes, indirectly
	Groundwater recharge/ quantity	≈	n/a	No, no change to monetize.
	Water quality	≈	Not Enough Information	n/a.
Cultural benefits that are "nonmaterial…and gained through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (MEA, 2005)	Recreation	↑	Quantifiable in baseline, but data support only qualitative analysis	TBA
	Aesthetic appreciation	↑	Qualitative	TBA
	Existence/ non-use values	↑	Quantitative; qualitative	Yes
	Information, science, education, and research	≈ or ↑	Qualitative	No, not monetizable.
	Biodiversity	↑	Quantitative	Yes
	Other cultural and spiritual factors	≈	Qualitative	No, not monetizable.

Table 2-5. Summary of Assumptions about Pre-Restoration Baseline Conditions and Anticipated Long-Term Post-Restoration Ecosystem Service Conditions.

Ecosystem Endpoint	Pre-Restoration Baseline	Post-Restoration
Commercial fishing	Salt ponds support brine shrimp and artisanal fishery, but no large commercial industry.	Wetland habitat (and salt pond-wetland matrix as a whole) contributes to increased productivity of commercial fisheries productivity and some brine shrimp.
Recreational fishing	Salt ponds do not support recreational fisheries.	Wetlands and wetland complex contributes to increased productivity of recreational fisheries.
Subsistence fishing	Salt ponds do not support subsistence fisheries.	Unknown but probable, since wetlands support recreationally- and commercially-valuable fish and shellfish populations.
Recreational hunting	Unknown but probable; bird hunting data are not tracked by local bird hunting groups.	Unknown but probable; bird hunting data are not tracked by local bird hunting groups.
Primary production	Salt ponds are un-vegetated.	Coastal wetland vegetation.
Food web dynamics	Highly saline; supports only salt-tolerant brine shrimp, but provides habitat for migratory birds.	Supports coastal wetland food web and maintains migratory bird habitat.
Carbon and nutrient cycling	Does not support.	Supports carbon and nutrient cycling.
Flood protection/ storm buffering	Outer bay levees provide storm buffering	Across entire South Bay, the cleared sloughs and ponds opened to tidal influence may together increase flood retention capacity locally.*
Recreation	Bird watching, bird hunting, outdoor recreation (walking, biking, etc.)	Provides increased access via new trails, improvements to visitor centers, and other recreational changes.*
Aesthetic appreciation	Salt pond matrix forms an aerial landscape of "myriad colors, textures, patterns and shapes."[1]	Individual restored ponds have increased vegetation, but the marsh-salt pond complex is still a diverse landscape.
Existence/ non-use values	Minimal, for a man-made landscape	May be higher than baseline, although it is included in the total value of restored wetland habitat. Quantifying a separate nonuse value is not feasible.
Information, science, education, and research	Visitor center, network of walking trails and boardwalks.	Increased areas open to recreation. Across entire South Bay, research projects and annual Science Symposia may increase regional knowledge capital.*
Biodiversity	Low levels of habitat and fish species diversity; some bird diversity.	Restored marsh habitats provide a greater plant and thus habitat diversity; bird and fish populations become more diverse as a result.

Notes: (1): Source: SBSPRP (2013). http://www.southbayrestoration.org/aroundtheweb/cris-benton/

(*) Denotes changes observed in context of the overall South Bay Restoration, but not in individual steps such as ARRA-funded portions.

2.2.c Values for Restored Tidal Wetlands – Total Value per Acre

As previously noted, SBSPRP has altered the characteristics of coastal wetlands in the South Bay. A variety of studies quantify WTP for wetlands based on their characteristics (e.g., Bauer, Cyr, & Swallow, 2004; Boyer & Polasky, 2004; Brouwer, et al., 1999; Opaluch, T. Grigalunas, M.J. Mazzotta, J. Diamantides, & Johnston, 1998; Woodward & Wui, 2001). Benefit transfer from these site-specific studies or meta-analyses allows us to estimate the total value of simultaneous changes in various wetland features. Given an appropriately specified transfer function, this approach can limit double-counting while capturing the change in value of multiple ecosystem services provided by tidal wetlands.

Household Values

The wetland valuation literature is large, with over 190 studies documenting WTP for wetlands around the world (Brander, Florax, & Vermaat, 2006). Despite this large body of knowledge, very few studies are similar to the coastal salt marsh context of the South San Francisco Bay. Additionally, the few identified studies that estimate WTP for wetlands in California considered inland wetlands, which have different ecological properties than coastal wetlands (Loomis, Hanemann, Kanninen, & Wegge, 1991). Because benefit transfer accuracy depends on a close match between original study site and policy site characteristics, including ecological changes, geographic location, uniqueness, demographic characteristics of the affected population and other considerations, we screened out studies that were not compatible with characteristics of the South Bay tidal wetlands. Ultimately, we selected two functions that provided the best match to the SBSPRP (Table 2-6):

- **Bauer et al. (2004)** present an original valuation function estimating Rhode Island residents' WTP for coastal wetland restoration in Rhode Island. While demographic and geographic differences between Rhode Island and California will likely result in some transfer error, Bauer et al.'s study is valuable because it estimates values for similar type of wetlands as are being restored in San Francisco. Coefficients in the valuation function allowed us to tailor estimates of total WTP per household based on the guidance from economic literature; available data on the South Bay site characteristics ; and best professional judgment

- **Brouwer et al. (1999)** present a meta-analysis of total WTP for wetlands with specific features, using studies from North America and Europe. While a meta-analysis that includes data from non-US sites implies a mismatch in policy conditions, it contains a dummy variable indicating the analyst's preference for US-based data. The function also allows us to examine changes in WTP based on changes in biodiversity, flood control, and other features not available in other studies (c.f., Opaluch, et al., 1998; Woodward & Wui, 2001). Like the approach used for Bauer (2004), we tailored annual per-household WTP based on the guidance from economic literature; available data on the South Bay site characteristics; and best professional judgment.

Appendix H details assumptions and data used in developing these benefits transfers.

Table 2-6. Transfer Functions Used in Calculating Total WTP for SBSPRP.

	Brouwer et al. (1999)	Bauer et al. (2004)
Study Description	Meta-analysis of wetland valuation studies including a diverse range of methodologies and broad geographical coverage	Contingent-choice survey designed to evaluate public preferences for wetland mitigation projects
Key Variables	• Payment vehicle, elicitation format and response rate in underlying studies • Location (North America vs. other countries) • Ecological function of valued wetland (biodiversity, flood control, water quality and quantity)	• Acres of restored salt marsh • Ecological improvements relative to other potential restoration projects. Separate variables for birds, fish, and shellfish. • Public access via viewing platform or trails
South San Francisco Bay Wetland Services Valued	• Flood control • Biodiversity supply • Controlled for, but not valued: Water generation; Water quality	• Size of wetland area restored • Presence of boardwalks and/or viewing towers • Endangered species • Preservation vs. restoration

First, we estimated per-household annual WTP for tidal wetland restoration in the South Bay by setting key variables to reflect findings from the ecological analysis (Appendix H). Estimating per-household WTP using Brouwer et al. (1999) did not require demographic information on the affected population, but we used average California population demographics (median income, educational attainment, and gender) to calibrate Bauer et al.'s (2004), transfer function. Next, we scaled per-household, per-year benefits from both functions to account for the size and the extent of ecological services provided by the restored area in a given year) and to the total number of households affected by restoration.

Benefitting Households

Households both nearby and distant from the South Bay may have use and non-use values for ecosystem services enhanced during coastal restoration. Data on the number of households that use (i.e., view, recreate in, fish in, receive flood protection benefits from, etc.) and do not use, but value (i.e., valuing the wetlands purely because they exist) these wetlands was unavailable. We used two findings from two existing studies to identify potential beneficiaries of the restoration projects (including users and non-users).

- Findings from an inland California wetland case study by Loomis (2000) show that WTP for wetland restoration decays with distance from the site. For example, households far beyond 100 miles are willing to pay approximately 60% of values that nearby households would pay.

- A trail user report for the Don Edwards National Wildlife Refuge, which overlaps the SBSPRP study area, indicates that recreational users of wetlands are primarily local residents who pass by the salt pond complex on their way to or from residences or work (Sokale & Trulio, 2013).

Assuming that both users and non-users of the tidal wetlands who live relatively close to the salt marsh complex are willing to pay 100% of the estimated total (use plus non-use) value for wetland restoration, we applied 100% of the predicted per-household WTP to the total number of households in three counties adjacent to the South San Francisco Bay: Alameda, Santa Clara, and San Mateo Counties (Decennial US Census, 2010). Based on the findings from Loomis (2000), we also applied 60% of per-household WTP for wetland restoration to the households in 16 additional counties whose border is within approximately 100 miles of the South San Francisco Bay (Decennial US Census, 2010). These households may value salt pond restoration even though they do not live in the project vicinity.

Benefit Annualization Assumptions

Benefits of coastal restoration will continue to accrue in both present and future years. To estimate the present value of future benefits from the ARRA project, we followed assumptions listed in Appendix A, using a total benefit period of 40 years. We also followed assumptions in Appendix A when estimating the present value of future benefits from the overall South Bay wetland restoration program, but use a total benefit period of 100 years to accommodate flood risk reductions. We used these same assumptions for all economic benefits categories.

Total Estimated Values

Assuming the restored wetlands persist indefinitely in the future, we estimate that the total nonmarket value of ARRA-funded salt pond restoration (1,513 ac) in South San Francisco Bay is between $3.0 million - $9.5 million per year when annualized over the 40-year timeframe (Table 2-7). The total present value (TPV) of these benefits is $68.9 - $220.3 million. Considering the 7,500 acre- salt ponds conversion (including the ARRA-funded portion), annualized benefits from the comprehensive project over a 100-year time frame are likely to range from $2.4 million to $10.5 million, with total present value of $77.3 - $331.4 million. Note that annualized values of the smaller and larger projects are not directly comparable, since they represent total benefits accrued over different time periods, and are annualized over different time periods.

Note that benefits of the overall project matrix are designed as an alternative representation of benefits, and should be neither added to nor directly compared to benefits from the ARRA-funded aspects alone.

Table 2-7. Total Economic Value of ARRA-Funded SBSPRP Wetland Restoration (2013$).

Study	Annual Per-Household WTP			Total Annualized Benefit[A]
	Baseline	Post-Restoration	Change	
Brouwer et al. (1999)	$2.63	$7.62	$4.99	$9,528,353
Bauer et al. (2004)	$33.17	$34.73	$1.56	$2,983,046

Notes: (A): Future annual benefits are calculated over a 40-year period at a 3% discount rate (Appendix A).
Source: Abt Associates benefit transfer analysis (2013).

Table 2-8. Total Economic Value of Overall South Bay Wetland Restoration (2013$).

Study	Annual Per-Household WTP			Total Annualized Benefit[B]
	Baseline	Post-Restoration	Change	
Brouwer et al. (1999)	$2.63	$9.32	$6.70[A]	$10,487,609
Bauer et al. (2004)	$157.09	$158.65	$1.56	$2,445,716

Notes:

(A): Post-restoration values differ across the ARRA- and overall-project scope for Brouwer et al. (1999) because flood protection benefits are only included in the latter, and for Bauer et al (2004) because WTP estimates are sensitive to the size of the restored area.

(B): Future annual benefits are calculated over a 100-year period at a 3% discount rate (Appendix A).

Source: Abt Associates benefit transfer analysis (2013).

Southwick Associates (2011) estimated that National Wildlife Refuge wetlands have a total economic value of $10,600/acre/year. Scaled up to the SBSPRP projects using the same time frames and annualization assumptions as before, a simplistic, third benefit transfer suggests restoration could provide an annualized value of $11.7 - $30.1 million per year (ARRA-funded and overall projects, respectively). Because this estimate is not calibrated to specific, observable changes in site conditions in the South San Francisco Bay, we present this static estimate of annualized value as a comparative measure alone. Further, because the entire south Bay is not designated as a National Wildlife Refuge, the Southwick Associates (2011) estimate would likely over-state the value of non-Refuge wetlands.

2.3 Fish Resources

San Francisco Bay, the largest estuary on the West Coast, is habitat for many fish species, including commercially important Pacific herring, popular sport fishes like striped bass, and less familiar species such as starry flounder, longfin smelt, and delta smelt (BI 2003). Marine species tend to use the Bay as spawning and nursery habitat while estuarine species reside in the Bay throughout their life cycle. While a few species are widely distributed over large areas many other species are unevenly distributed in the Bay, either concentrated in schools or confined to a few locations.

Some species are present in the Bay only during certain seasons. For example, anadromous species such as Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*) American shad (*Alosa* *sapidissima*), and white sturgeon (*Acipenser transmontanus*) use South Bay as a migratory pathway to spawning areas in the local tributary rivers (LifeSciences! Inc., 2003).

2.3.a Ecological Estimation

To estimate the changes in fish resources resulting from salt pond restoration, we focused on fish species that live in shallow, near shore habitats such as tidal marshes and adjacent sloughs at the restoration sites. There are sparse historic fishery data for these areas due to their history of commercial salt production and the difficulty of effective sampling (The Bay Institute, 2003).

Pre-restoration, South Bay salt ponds are characterized by elevated salinity and seasonal high water temperatures; compared to the adjacent tidal sloughs, these relatively harsh environmental conditions allow reduced (-50%) fish diversity (Mejia, Saiki, & Takekawa, 2008). The two pre-restoration study areas (Ponds A9-A13; A-15) (Lonzarich, 1989) and four restored South Bay wetlands adjacent to Alviso Marsh Complex and Eden's Landing (URS, 2008) exhibit low species diversity and evenness with high percentages of resident species that are particularly adapted to these environmental conditions, such as topsmelt. The post-restoration surveys indicated higher diversity (>H', more even representation of species (<D), and a smaller percentage of resident species, with associated larger percentages of seasonal and anadromous fish. We interpreted these trends as suggesting that the wetland restorations have led to greater exploitation of a wider gradient of habitats (particularly salinity gradients) by a more diverse group of fish, including some commercially sought-after species.

To compare between studies, we calculated the Shannon-Wiener[5] (H') and Simpson (D)[6] indices to assess, respectively, the diversity and dominance of species representation. We also calculated the % of the catch which was composed of Bay-resident[7] fish (The Bay Institute, 2003).

2.3.b Economic Valuation of Commercially- and Recreationally-Valuable Fish Populations

While very little commercial fishing is done within the boundaries of South San Francisco Bay, the region indirectly supports commercial fisheries by providing nursery habitat for game fish and their prey. Recreational fishing, on the other hand, has historically been a common and economically-valuable activity in the Bay region. In 2007, for example, sport-fishers caught over 327,000 fish in the Bay Estuary and in a neighboring area (Bodega Bay). Popular catch included jacksmelt, shiner perch, northern anchovy, pacific herring, striped bass, California halibut, and black perch. Based on the value of the fish caught, these fishing activities are worth between $65.5 million and $98.3 million in benefits to sport fishers (Battelle Memorial Institute, 2008).

Improved fish population changes (diversity and abundance) benefit local commercial and recreational fishermen and fish consumers in several ways. First, increased populations of wetland forage fish and invertebrates provide

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[5] The value of H' increases as both the species richness and the evenness of the community increase.

[6] The value of D is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species and values range from 0 to 1 (i.e., 100% same species).

[7] List of bay resident and seasonal species taken from San Francisco Fish Index (CDF&G 2001).

increased food for fish higher in the bay-wide food chain, providing indirect fisheries benefits. Second, wetlands also provide nursery habitat for commercially- and recreationally-valuable species, directly providing fisheries benefits.

While available monitoring data is not yet sufficient to rigorously quantify the extent of changes in commercial landings by species (Section 2.3.a), anecdotal stories suggest restoration activity will improve commercial, recreational, and subsistence fisheries in the South Bay (Box 3).

Box 3. Anecdotal Evidence of Changing Fisheries in South San Francisco Bay.

- Monitoring staff have observed new recreational fishing activity at the tidal mouth of breached ponds. The fishermen are believed to be waiting for sturgeon, a recreationally-valuable fish, as it hunts for forage fish leaving the breached wetlands on outgoing tides.
- Several small artisanal fishermen historically used the wetland complex for bay shrimp harvesting, and clearing sediment from tidal sloughs opens up new access to wetlands and bays. This increased access allows both recreational and artisanal fishermen to access fishery resources.

Source: Personal communication, Laura Valoppi (USGS)

Methods

Abt used a trophic transfer approach to approximate the potential commercial and recreational fishing benefits of SBSPRP because more exact methods of valuing benefits to recreational fishers or commercial producer’s surplus require more detailed quantitative data than is currently available. Trophic transfer approach is based on web connectivity between primary production, in this case primary production in wetland habitat, and the production of resident and transient fish (Kneib, 2003; McCay & Rowe, 2003). Abt recognizes that there are significant uncertainties associated with this approach. Nonetheless, it provides a simplified method to approximate potential commercial and recreational fishing benefits when fish sampling data is insufficient to support a more refined analysis.

Abt calculated fish production per acre of wetland habitat created by tracking biomass through four trophic levels as summarized in Figure 2-5. A trophic conversion occurs between each step due to losses of energy due to metabolic processes with only a fraction of production transferring to the subsequent level.

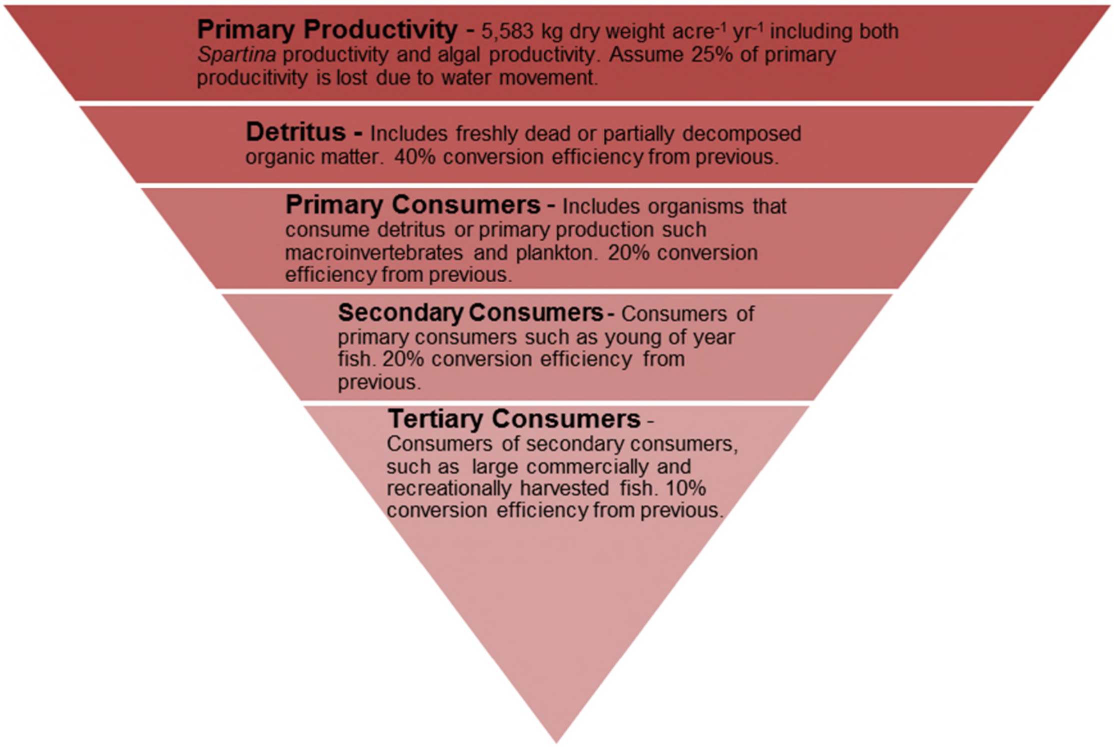

Figure 2-5: Trophic Transfer Calculation.

Inputs for this trophic analysis were drawn from EPA's habitat-based valuation approach for the proposed 316(b) rulemaking (U.S. EPA, 2011). Assuming that dry weight is 22% of wet weight, tertiary production is 30.5 kg wet weight per acre per year.

This analysis focuses on tertiary consumers because these species tend to comprise a vast majority of commercial and recreational benefits. Inputs for this trophic analysis were drawn from EPA's habitat-based valuation approach for the proposed 316(b) rulemaking (U.S. EPA, 2011). Assuming that dry weight is 22% of wet weight, tertiary production is 30.5 kg wet weight per acre per year. Because the precise mix of tertiary species enhanced is unknown, Abt calculated a range of benefits per acre of restored tidal marsh based on three illustrative species or groups of fish (henceforth, simply "fish"): the California halibut species, the striped bass species, and the group of fishes commonly known as "rockfish." In each case, benefits calculations incorporate fish-specific rates of growth, natural mortality, and fishing mortality. Commercial and recreational benefits are realized when this tertiary production is harvested either in the year of conversion or subsequent years as dictated by mortality rates.

Abt monetized changes in harvest following the approach used for EPA's proposed 316(b) rule (U.S. EPA, 2011):

- Harvest was allocated to commercial and recreational based the ratio of regional commercial and recreational harvest for the fish.

- The value of additional commercial harvest in each year of the analysis was calculated by multiplying additional harvest by the dockside price in California in 2012. Commercial benefits were calculated in terms of producer surplus, by multiplying dockside value by a specific net benefit ratio.
- The benefits of recreational harvest were calculated by multiplying the number of additional fish caught by the estimated (WTP per additional fish caught per trip).

Results

Total commercial and recreational fishery benefits for three illustrative California region fishes range from $21 to $27 per restored wetland acre per year (Table 2-9). Accounting for the size and acres and the trajectory of service improvements at the ARRA-funded site alone, total annualized fishery benefits would range from $23,332/year to $29,987/year. The estimated present value of these benefits ranges from $539,080 - $693,139. If considering the overall South San Francisco Bay project, annualized benefits of the entire project matrix could range from $94,783/year to $121,871/year. The estimated present value of these benefits ranges from $2.99 million to $3.85 million. As with the benefits per acre of wetlands, benefits of the overall project matrix should not be added or directly compared to benefits from the ARRA-funded aspects alone.

As mentioned, Abt considers this to be a rough approximation of potential fishing benefits of tidal marsh restoration. Additional site-specific data is necessary to conduct a more rigorous analysis.

Table 2-9. Annualized Commercial and Recreational Fish Production Benefits from Wetland Restoration (2013$).

Illustrative Species	Fishery Characterization	Annual productivity ($/acre/year)	ARRA Benefit Scenario[A]	SF Bay Benefit Scenario[B]
Halibut	30-year average lifespan. 86% recreational and 14% commercial.	$27.13	$29,987	$121,871
Rockfish	24-year average lifespan. 24% recreational and 76% commercial.	$23.78	$26,284	$106,822
Striped bass	9-year average lifespan. 100% recreational; 0% commercial.	$21.10	$23,322	$94,783

Notes:

(A): 1,513 ac. of new marsh created. Annualized benefits computed using a 3% discount rate over 40 years. (Appendix A)

(B): 7,200 ac. of new marsh created (50% restoration of entire South Bay by 50 years). Annualized benefits computed using a 3% discount rate over 100 years (Appendix A).

2.4 Avifauna in South Bay Wetland Restoration Sites

San Francisco Bay's historic importance to shorebird populations and as a migratory stopover on the Pacific Flyway has earned it the classification of "Hemispheric Importance" by the Western Hemisphere Shorebird Reserve Network (WHSRN 2009). SFB hosts an average of 67% of all shorebirds traveling along the west coast (Rowan, 2010). However, the loss of 80% of historical tidal salt marshes and 40% of intertidal mudflats in SFB over the last two centuries to human development pose significant challenges for maintaining this importance (Rowan, 2010). The South Bay region historically provided 75,000 acres of tidal wetlands, comprising nearly 30% of the estuary (Goals Project, 1999). Accordingly, the SBSPRP has sought through its restoration efforts "to optimize shorebird and waterfowl habitat functions" (Goals Project, 1999). In addition to providing nesting and migratory habitats for many species, the SBSPRP also looks to protect or enhance critical habitat for the threatened endemic clapper rail and snowy plover (see Section 2.5).

2.4.a Ecological Characterization of Avifauna in South Bay

A two year survey of all 53 of the SBSPRP ponds in AMC, EL, and Ravenswood complexes counted more than 1.75 million birds across 69 species (Takekawa, Athearn, Hattenbach, & Schultz, 2006). The species present in South Bay can be categorized into feeding/functional guilds including dabbling and diving ducks, eared grebes, piscivores, gulls, herons and egrets, shorebirds, and phalaropes (Takekawa, et al., 2006). Beyond its role as a migratory pathway, the array of habitat types in the South Bay provides for the diverse foraging and nesting needs of these various guilds. Commercially productive salt ponds are characterized by lower vegetative productivity and avian species diversity. Habitat restoration to tidal wetland habitat will likely improve overall avian abundance and diversity but it is recognized that these habitat changes may favor select guilds over others.

Since the wetland restoration conducted with ARRA funds are relatively recent, comprehensive post-restoration avian data and population trends are not yet available. Therefore, Abt developed its analysis to evaluate the potential effect of habitat restoration on avian populations in AMC Ponds A6 and A8 and EL Ponds E8A, E8X, and E9, on data from:

- Adjacent restored ponds that establish probable population trends.
- Baseline survey data of the specific ARRA-funded ponds and initial impression of avian population effects post inundation.
- Regional population trends, reflecting changes in diversity and abundance based on South Bay habitat transition.

Population and Species Diversity Trends

Pre-inundation, the Island Ponds avifauna were dominated by gulls (87% of the bird population) that used the site primarily for roosting between foraging visits to nearby landfills (Takekawa, et al., 2006). Post-restoration, once tidal fluctuations were in place, the guild composition during high tide remained similar to guild composition before breaching, although relative abundance changed. However, gull composition decreased by 20% of the total bird count while shorebird composition rose 22%, suggesting increasing use of exposed tidal flats for feeding by shorebirds. Overall counts of foraging rates rose 43% during high tides and 26% during low tides (Takekawa, et al., 2006). High-tide population counts were significantly greater in July and August of 2006 compared to the same months in 2005, probably due to increased shorebird foraging in the tidal flats exposed by levee breaching.

Although available data did not lend itself to specific population trend projections, Abt assumed a moderate increase in both total avian population and relative diversity following restoration efforts and habitat recovery. Generally, Takekawa (2006) suggests restoration could lead to increases in bird populations:

- a 20 to 45% increase in foraging birds;
- a potential range in annual water bird use from a 23% decrease to 213% increase in one restoration scenario; and,
- a 260% to 400% increase in species diversity from observational counts.

Avian population increases might easily be larger than representative habitat transitions would suggest, as habitat restoration in the South Bay has increasingly incorporated design elements such as networks of small nesting islands to enhance the nesting and foraging value of the restored habitat (Moskal, Takekawa, Smith, & Shaffer, 2013).

2.4.b Economic Values for Bird Watching and Hunting

Bird-watching is a common pastime in California. In 2006, 15% of all California residents participated in bird-watching at least once. Among these, 42% likely traveled over a mile from their home to bird watch. On average, these bird-watchers participated in the activity 14 days per year (Carver, 2009).[8] Birding is an especially common pastime in the Bay area; each year, over a million birds migrate along the Pacific Flyway, stopping to rest and feed in the San Francisco Bay (Battelle Memorial Institute, 2008). In the salt pond and wetland habitats of the Don Edwards National Wildlife Refuge, birders and hunters can expect to commonly or seasonally view 227 different bird species (US Fish & Wildlife Service, n.d.).

Figure 2-6. Seabirds in the south San Francisco Bay salt pond-wetland complex.

Source: High Country News.

In addition to bird watching, many people visit the Bay area to hunt waterfowl and some larger game such as wild pigs, elk, doves, coots, rabbits, quail, and other species (Battelle, 2008). In the nine counties surrounding the Bay Estuary, there were 1,786 dark goose hunters, 348 light goose hunters, and 7,213 duck hunters in 2006. Together, these hunters spent over 105,000 days hunting. Nationally, the average expenditure per waterfowl hunter is $541

[8] Nationally, Away-from home birders spent approximately $12 billion on bird-watching trips in 2006.

(Battelle Memorial Institute, 2008 based on data from US FWS, 2005). Applying this average to the Bay area, Battelle (2008) estimated that waterfowl hunting activities contribute $3.3 million to $4.1 million in expenditures and $5.5 million to $6.7 million in output to the local economy.

Initial restoration has already altered bird habitats enough such that short-term changes in bird populations, abundances and diversity have begun to dramatically shift (US Fish & Wildlife Service, n.d.). However, not enough data exist to reliably extrapolate the long-term effects of restoration on resident and migratory bird populations. As such, we did not monetize this benefit category aside from incorporating marginal values for increased biodiversity in the total WTP for wetland restoration (see Appendix H). Available wetland and bird valuation studies, however, indicate that social values for improving birds' habitat and population are likely to be significant.

- Loomis et al. (1991) estimate WTP for providing additional inland California wetland area to provide additional habitat for wetland birds. Their findings suggest that California residents are willing to pay $254 per year to increase the San Joaquin wetland area (which at the time of the study was limited by insufficient water supply and other factors) by 47%, with an associated 40% increase in wetland bird populations.

2.5 Threatened and Endangered Species

2.5.a Ecological Resources

Regional habitat restoration is also intended to benefit several federal and state-listed threatened and endangered (T&E) species, from the endemic clapper rail and salt marsh harvest mouse to the longfin smelt (Takekawa, et al., 2006). Overall, the SBSPRP will help the South Bay restore parts of the once ubiquitous tidal marshes, propelling higher productivity and greater species diversity (Sections 2.2 and Section 2.3). The effect of the conversion of salt ponds into tidal wetland habitat (either under "Alternative B" ratio of 50:50 wetlands to managed ponds or as "Alternative C" ratio of 90:10 wetlands to managed ponds) is expected to result in increases numbers of endangered Clapper Rail and Salt Marsh Harvest Mouse within the SBSPRP (Appendix G).

However, not all species may benefit equally. Although salt-production ponds are artificial and non-historic habitat for the region, federally-threatened snowy plovers that were displaced from beaches by coastal development have come to use them as nesting grounds. Accordingly, as tidal wetlands are restored, efforts are being made to mitigate the loss of these nesting sites.

No post-restoration studies are available quantifying changes to T&E populations in the ARRA-funded ponds. However, characterization of the trajectories of restoration habitats (Section 2.1.2) provides support for the value of the SBSPRP in protecting and/or enhancing federal- and state-listed T&E species.

Fish

Active salt ponds do not provide notable habitat for any endangered or threatened fish species (Mejia, et al., 2008). Restoration of salt ponds to tidal habitat has the potential to create additional foraging habitat for the federally-endangered chinook salmon, and additional nursery ponds for the federally-threatened steelhead trout

(Hobbs, Moyle, & Buckmaster, 2012). Post-restoration surveys of AMC revealed the presence of state-threatened longfin smelt (Hobbs, et al., 2012). The presence of longfin smelt in AMC was attributed in 2010 and 2011 to the rapid increase in mysid shrimp, an important prey source for the smelt which has been declining regionally (Hobbs, et al., 2012). The restored-ponds value may be even greater, as freshwater outflows make AMC a potentially important spawning ground for the longfin smelt (Hobbs, et al., 2012).

Birds

The federally- and state-endangered clapper rail will likely be one of the greatest beneficiaries of the SBSPRP. Once numbering in the tens of thousands, hunting, habitat fragmentation, and invasive predators and vegetation caused the total clapper rail population to decline to 1,400 individuals by the early 2000s, with 75% of the population in the South Bay (Pitkin & Wood, 2011; Takekawa et al., 2011). Clapper rails are particularly vulnerable given specialization to forage during low tides in tidal marshes (Takekawa, et al., 2011).

Quality habitat for self-sustaining populations of Clapper Rail includes large parcels of tidal marsh at least 100 hectares (250 acres) in size and a network of first order channels (PWA 2004). Restoration of large contiguous marshes, healthy stands of marsh vegetation, and a well-developed network of tidal channels at the bay edge, along with better control of predators (red fox and feral cats) should increase the number of nesting pairs of rails in the SBSPRP (Pitkin & Wood, 2011).

While the SBSPRP is beneficial for numerous T&E avian species in the South Bay like the clapper rail, the project is complicated by negative impacts on the threatened snowy plover that uses dry salt-pannes as an alternative nesting grounds. The historic decline of the federally-threatened snowy plover populations has been fueled by the loss of coastal beach nesting sites to human development. Snowy plover has been using dry salt-pannes as an alternative nesting grounds. Recent surveys have indicated progress towards the eventual recovery goal of 500 nesting pairs in the South Bay (Goals Project, 1999; Pitkin & Wood, 2011). As salt ponds are restored to tidal wetlands, there is concern that the loss of nesting grounds and potential displacement of gull populations into other snowy plover nesting sites may inhibit or reverse this gradual recovery. These trends, however, have not been realized in nesting surveys (Donehower, Tokatlian, Robinson-Nilsen, & Strong, 2013). Potential impacts to snowy plover populations can be further mitigated by active management which has created nesting islands in flooded ponds, distributed oyster shells to camouflage chicks, and curtailed nest predation through non-lethal gull hazing and the removal of adjacent predator perches (Donehower, et al., 2013).

Volunteer observational counts have been conducted in Hayward and Alameda counties through the PRBO and Avian Knowledge Network [AKN] (Avian Knowledge Network, 2013). In addition to the snowy plover and clapper rail, post-restoration sightings have occurred for osprey, peregrine falcons, brown pelicans, northern flicker, least tern, and the black rail. Although these observational counts are informal and unable to provide population trends, a simple count of the number of observations of T&E species at AMC or EL provides evidence for increased post-restoration use of these ponds by numerous T&E avian species (Figure 2-7).

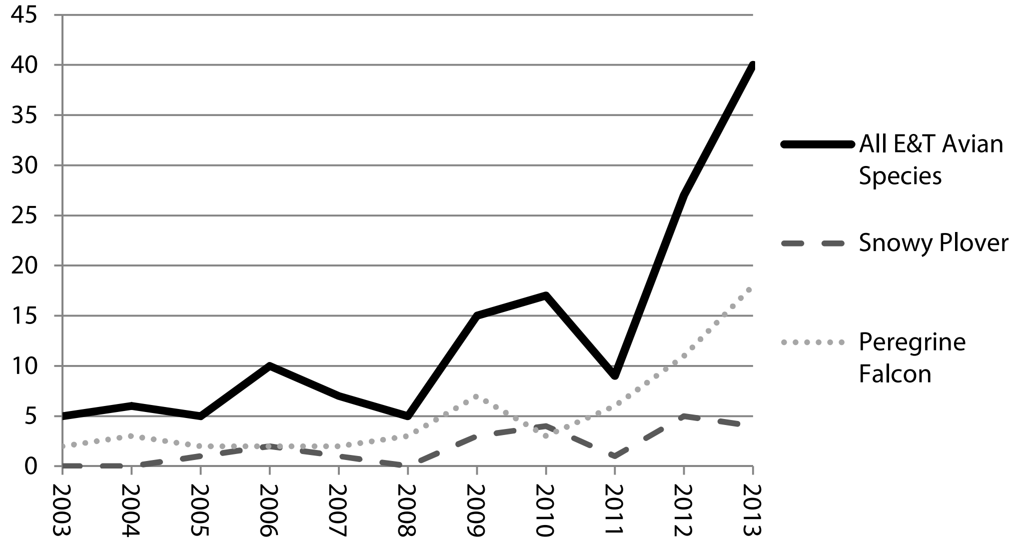

Figure 2-7. Observations of T&E Avian Species, at AMC and EL.

Note: Data are simple observational counts of avian species. "All T&E Avian Species" includes snowy plover, clapper rail, osprey, peregrine falcon, brown pelican, northern flicker, willow flycatcher, and black rail.
Source: Abt Analysis, data from Avian Knowledge Network (2007).

Salt-Marsh Harvest Mouse

The salt-marsh harvest mouse, an endemic, federal- and state-endangered marsh-obligate is expected to benefit from wetland restoration. Found only in the South Bay, the South Bay salt marsh harvest mouse population was only a few thousand in the early 1980s and has likely since continued its decline due to the fragmentation of its habitat and invasive predators (OPP 2010). Contiguous, vegetated space is critical to the survival of this species, and the SBSPRP will provide a significant step towards population recovery for the harvest mouse. As with the Clapper Rail, the control of access by predators (fox and feral cat) is also a key factor to increasing local mouse populations.

2.5.b Economic Values for Threatened and Endangered Species and Biodiversity

Existing salt ponds are characterized by low habitat diversity and low biodiversity—in other words, the habitat is relatively homogenous, and a relatively small number of species make up the total mix of species present. Restoring the South Bay salt ponds to tidal wetlands induces marshland and aquatic habitat changes that provide a greater diversity of habitats and water salinities. These changes allow a broader range of fish, bird, and other species to live in the wetland and upland areas, relative to salt ponds. Short-term monitoring data suggest that restored areas are supporting relatively more diverse groups of birds and fish (Sections 2.3 and 2.4). Many people enjoy knowing that habitats support biodiversity aside from any observable use they could gain from it. For example, some people enjoy knowing that an endangered species will continue to exist for future generations to enjoy ("bequest value"). Households both nearby and distant from the San Francisco Bay are likely to have "non-use values" for increased biodiversity and improved protection of T&E species. Specifically, resource valuation studies have shown that households are willing to pay more to protect or restore wetlands that support biodiversity as opposed to those which do not support it (Brouwer, et al., 1999). Brouwer et al. (1999) estimate that households are willing to pay an additional $3/year for wetlands that support biodiversity compared to wetlands that do not provide it. The increased biodiversity value is already included in our total economic value calculations (Table 2-7).

Resource valuation studies also indicate that people my hold significant values for preventing extension or increasing populations of T&E species. For example, Stanley (2005) estimated an average annual household WTP value of $25 for the preservation of the riverside fairy shrimp in Orange County CA. Based on the meta-analysis of 31 stated preference studies eliciting WTP for changes in T&E fish, bird, reptile, or mammal species populations (Richardson & Loomis, 2009), households are willing to pay, on average, $13 to $65 per year to protect individual bird species[9] like woodpeckers, owls, bald eagles, and cranes.

2.6 Valuation of Other Ecosystem Goods and Services

Ecosystem restoration in the South Bay area will improve several other goods and services related to wetland structure and quality, including flood mitigation, carbon sequestration, and recreational use.

2.6.a Flood Risk Reductions

The overall matrix of South Bay restoration activity will maintain bay-side levees, re-open previously closed areas to tidal influence, and increase the depth and capacity of tidal sloughs (channels) that connect the overall pond matrix to the bay. At the time of this report, a congressionally authorized group of Federal and State, and regional water management groups was developing a flood risk management plan for the Alviso area under various ecosystem restoration scenarios (South Bay Salt Pond Restoration Project, 2012). While the project is still under planning and evaluation, together the final suite of natural and man-made changes will generally maintain and may marginally increase the south Bay coastline's flood storage capacity and reduce risk of coastal or fluvial flooding (EIS, 2007).

After reviewing the project's Environmental Impact Statement and discussing expected changes with USGS staff (personal communication, Valoppi, 2013), Abt Associates believes these changes are unlikely to significantly alter the extent of coastal floodplains (such as the 100-year floodplain, commonly used in FEMA flood insurance calculations), but may marginally reduce coastal, tidal river and levee-related flood severity *within* that zone (EIS, 2007). Thus, there is a potential for portions of local communities to benefit from restoration-related flood risk reduction (Figure 2-8).

[9] Richardson & Loomis (2009) did not evaluate WTP for endangered clapper rail.

Note that SBSP flood benefits arise from the overall matrix of salt pond restoration activity, and do not stem from restoring the particular individual ponds funded under ARRA. Thus, we evaluated this benefit category only at the scale of the overall SBSPRP projects. While this means any flood benefits should not be compared directly to project costs for the ARRA-funded work, ARRA-funded work may contribute marginally to the overall benefit category.

We searched for quantitative details on the changes in the flood risk or geographic extent of flooding (EIS, 2007), but did not find detailed results. This data gap makes efforts to estimate and monetize flood management benefits somewhat speculative. We conducted a scoping test to roughly approximate the property value effects of a 1% change in flood risk. We assumed that while restoration activity is unlikely to change the extent of the floodplain (and thus, the number of houses affected by floods), houses currently within the floodplain may still experience “less than significant, but beneficial” changes in flooding (EIS, 2007) – we assume these very small benefits translate to reductions less than or equal to 1% of baseline flood risk.

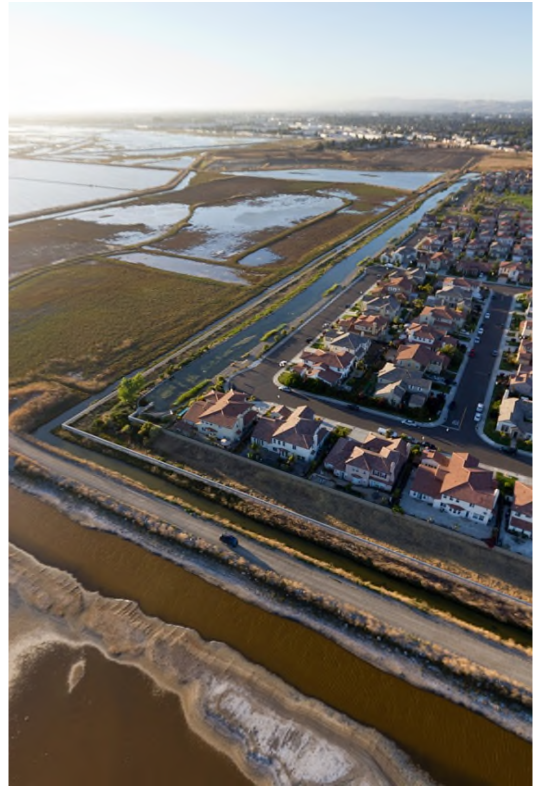

Figure 2-8. Coastal homes near the Eden Landing salt pond and marsh complex.

Source: Image © Chris Benton.

Methods

Available hedonic property valuation studies (Table 2-10) suggest a 1% reduction in flood risk translates to about 0.5% - 5% improvement in property values (e.g., Braden & Johnston, 2004; Daniel, Florax, & Rietveld, 2009). A one-percent reduction in flood risk is equivalent to removing properties from the 100 year flood plain. Although the Environmental Impact Statement (2007) prepared for the ARRA-funded portion of the south Bay restoration project does not suggest restoration will affect the extent of the 100-year floodplain, some studies suggest that even a less-than-1% reduction in flooding would result in a small increase in value. Furthermore, recent increases in flood insurance may translate in greater property value effects from marginally reducing flood risk. The SBSPRP is coordinated with, and complementary to, a separate shoreline study designed to manage flood risk in South Bay communities. Available resources suggest that state and federal funds may be leveraged to complete SBSPRP and flood risk reduction activities simultaneously, but available resources did not provide exact estimates of the resulting change in flood risk.

In this analysis, we illustrate the property value benefits of marginally reducing the frequency flooding (but not its spatial extent). We limited the analysis to flood zones south of the San Mateo Bridge because salt ponds/wetlands are generally limited to areas below the bridge, and South Bay restoration is unlikely to affect flooding throughout the encompassing San Francisco Bay.

Merging FEMA-designated flood zone[10] maps and US Census Data, we identified the number of households (Census 2010 block groups, US Decennial Census, 2010) and median home values (Census 2010 tracts, American Community Survey 2011, 5-year estimates) in areas at risk of inundation or shallow flooding by the 1-percent-annual-chance flood event. By including coastal flood hazard areas we also include homes subject to additional hazards due to storm-induced velocity wave action. Note that parts of western South Bay (Redwood City and San Mateo County) do not have any FEMA-listed flood zones; thus, the flood risk analysis is limited to Alameda and Santa Clara counties.

Table 2-10. Flood Risk Reduction Benefit Transfer Functions.

		% Change in Property Value from Reducing Flood Risk	
Study	**Study Description**	**Low Bound**	**High Bound**
Streiner & Loomis (1995)	Flood damage reduction, stream stabilization and re-vegetation, debris removal, improvements in fish habitat, and additional buffer land around the stream corridor all together affect mean residential property values. This also includes aesthetic, recreational, and educational features. As reported in Braden & Johnston (2004).	3%	5%
Braden & Johnston (2004)	Conducted a categorical synthesis of estimates reported in 6 studies. Properties that remain exposed to "frequent profound" flooding would gain the "low" benefit. Those which are removed from the 100-year flood plain and thus federal insurance would gain the "high" benefit. Values are converted to the percent change using an approximate housing value of $134,000.	≤ 2%	2.5% to 5%
Daniel et al. (2009)	Conducted a meta-analysis of 19 US-based studies of the property value effects of a change in flood risk. The value at left represents the one-time transaction price differential of reducing the probability of flood risk in a year by 1%. The authors note there may be a confounding effect of coastal amenity values and increased flood risk observed in the coastal zone, making the pure effect of flooding unclear.	0.60%	

[10] We limited FEMA designated areas to only coastal high hazard areas (V and VE) and special flood hazard areas not currently protected by a flood protection system. See: https://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations

Results

Results of the spatial flood zone analysis suggest approximately 32,902 households live in South Bay neighborhoods subject to 100-year flood risks (Table 2-11). Home values in these neighborhoods tend to be more valuable than average homes in Alameda and Santa Clara counties.

Table 2-11. Housing Characteristics of Flood-risk Neighborhoods in the South San Francisco Bay.

		Median Home Value (2013$)	
County	Households in floodplain	Block groups in floodplain	County-wide
Alameda	7,339	$568,740	$524,161
Santa Clara	25,563	$697,677	$660,428

Using block-group level median home values for block groups that intersect flood plain areas, the identified flood risk reduction benefit estimates shown in Table 2-10 suggest that small (i.e., <1%) reductions in flood severity or risk may provide benefits between $0.86 and $42.6 million in TPV, limited to two counties in the South Bay coastal and fluvial flood plains. The wide range in benefits estimates may be due to the differences in ecosystem services included in each estimate: Daniel et al. (2009) limit their analysis to only flood reduction values[11], while Streiner & Loomis (1995) also include co-benefits of flood reduction such as aesthetic, recreational, and educational features. Given the coarse nature of the flood risk reduction analysis and our underlying assumption that the restoration would affect flood risk for all properties in the flood plain, we suggest cautious interpretation of these results.

Table 2-12. Flood Risk Reduction Benefit Transfer Results (2013$).

Study	% Change In Property Value	TPV	Annualized Benefit[A]
Daniel et al. (2009)	0.60%	$857,300	$128,724
Braden & Johnston (2004)	2%	$27,971,756	$4,199,963
Streiner & Loomis (1995)	3%	$42,592,536	$6,395,276

Notes:

(A) Annualized benefit divides the per-household total benefit by the 3% discount rate to provide estimates of the annual value to homes each year in perpetuity, rather than the one-time benefit from selling a house for more money (Appendix I).

This table of final benefit estimates omits results based on Braden & Johnston's (2004) upper bound estimate because we do not expect restoration to effectively remove houses from current floodplain boundaries. These values also omit Streiner & Loomis' (1995) upper bound, since their benefits values also incorporate aesthetic, recreational and educational features of flood risk reductions and stream bank stabilization.

[11] Daniel et al. (2009) also note that coastal areas simultaneously have higher flood risk and more aesthetically-pleasing views. As such, one could consider estimates based on Daniel et al. (2009) as the net effect of coastal views and flood risk.

Comment on Changes in Flood Risk Over Time Due to Projected Sea Level Rise

We did not incorporate probable changes in flood risk due to climate-change-related sea level rise in the Bay area. However, if sea level rise occurs as projected, flood risk reduction benefits could be larger in the future (all else equal) as more homes are considered part of the 100-year floodplain.

Currently, an estimated 190 km^2 of coastal areas in the counties surrounding the south San Francisco Bay are at risk of inundation during extreme flood events – the rare "100-year storm" events that have a 1% chance of occurring each year (Table 2-13, Cal-Adapt, 2013[12]). Best available climate projections suggest that, with increasing sea level rise, by year 2100 these areas at risk may be 22% to 44% larger than present-day areas (Figure 2-9). Flooding in developed areas causes substantial material damage to property and infrastructure, and costs associated with lost property and disrupted productivity can be large. Thus, although extreme floods are unlikely to occur frequently, mitigation and protection measures to reduce coastal flood risk are economically valuable because they reduce the likelihood of large property losses (Daniel, et al., 2009).

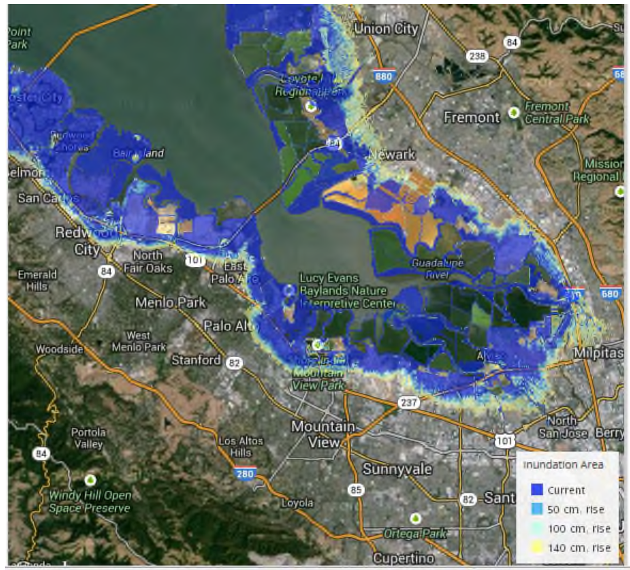

Figure 2-9. Map of South Bay areas threatened by flood risk in current (dark blue) and projected future scenarios of sea-level rise.

Source: Cal-Adapt (http://cal-adapt.org/sealevel/#), based on USGS flood maps.

Table 2-13. Extent of areas threatened by extreme coastal flooding in 2000 and 2100 (projected).

	Estimated km^2 in 2000	Estimated km^2 in 2100	Percent Change
San Mateo, Bay only	73.4	93.9	+22%
Santa Clara	39	57.5	+32%
Alameda	78.5	141.3	+44%

Source: Cal-Adapt: http://cal-adapt.org/sealevel/#. Extreme coastal flood risk includes areas that may be in threat of inundation during an extreme flood event (100 year flood), and values do not incorporate benefits from coastal flood protection structures including levees.

2.6.b Carbon Sequestration

Climate change is widely viewed to be a significant long-term threat to the global environment. Tidal wetlands can contribute to climate change mitigation by sequestering carbon—thereby preventing it from entering the

[12] http://cal-adapt.org/sealevel

atmosphere (Callaway, Borgnis, Turner, & Milan, 2012). As described by Callaway et al. (2012), "[wetlands] are particularly effective at doing this because of their high primary productivity, ongoing sediment deposition, and relatively low decomposition rates" (p. 1163). Long-term storage of carbon (e.g., 100 years) is of particular interest for climate changes mitigation, compared to carbon that is released in the shorter term through decomposition. SBSPRP will increase long-term carbon sequestration by increasing vegetation and, in the long term, creating highly productive tidal wetlands in place of barren salt production ponds.

Methods

Abt Associates estimated carbon sequestration for SBSPRP using a recent of study of carbon sequestration in San Francisco Bay Tidal Wetlands by Callaway et al. (2012). Callaway et al. estimate tidal salt and brackish wetlands sequester carbon at an average rate of 79.3 g C m^{-2} yr^{-1}, based on five sites in the estuary.[13] Abt applied this rate to the number of acres restored using NOAA-ARRA funds and adjusted annual sequestration capacity each year based on the restoration trajectory. We assumed zero net long-term sequestration in absence of restoration based on the presence of commercial salt ponds before restoration.

Abt then estimated the monetary value of carbon sequestered at the SBSPRP wetlands using the social cost of carbon as estimated by the U.S. Government's Interagency Working Group on Social Cost of Carbon (Interagency Working Group on the Social Cost of Carbon, 2013). "SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year" (Interagency Working Group on the Social Cost of Carbon, 2013, p.2). It reflects the value of the various effects of climate change, such as changes in net agricultural productivity, human health, property damages from increased flood risk, and effects to ecosystem services."[14]

Results

Using 3 percent average SCC values (Appendix B), Abt estimates an annualized TPV of $54,303/ year for the 1,513-acre restoration over 40 years (TPV is estimated at $1.8 million summed from 2010 through 2050). If considering a broader restoration project that achieves its target of a 50:50 mix of functioning wetlands and salt ponds in 50 years (7,500 acres restored), and benefits accrue at full value for 50 years thereafter, estimated annual carbon sequestration benefits occurring within the total 100-year period of 2010-2110 are $412,502 (TPV is estimated at $13.8 million).

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[13] This sequestration rate is based on ^{210}Pb dating. The study also analyzed carbon sequestration using Cs distributions for dating. Abt used the ^{210}Pb results for the analysis of SBSPRP because the authors recommend use of ^{210}Pb results (or other long-term dating methods) for analyzing carbon credits.

[14] Appendix B presents the Interagency Working Group's the SCC values. Abt converted published values from 2007$ to 2013$ using the GDP deflator. Abt also converted from "per metric ton of CO_2" to "per metric ton of C" by multiplying the annual values by 3.67, which is the molecular weight of CO_2 divided by the molecular weight of C (44/12). IWG reports SCC values in 5-year increments. Abt interpolated annual values within these periods and assumed SCC values remained constant at the 2050 value for all years beyond 2050, the final year reported by the Working Group.

2.6.c Other Recreational and Cultural Values in South San Francisco Bay

In the San Francisco Bay area, popular recreation activities include boating and sailing, hiking, kayaking, windsurfing, swimming, beach use, photography, surfing, scuba diving, and bicycling (Battelle, 2008). These activities confer sizeable benefits for the 15 million annual visitors to the Bay area as well as to local residents. Additionally, recreation in the area, especially by visitors, contributes billions of dollars to the local economy each year. The San Francisco Bay Restoration Authority (n.d.) estimates that Bay area tourism generates over $24 billion in spending each year, supporting over 178,000 jobs.[15]

The Don Edwards San Francisco National Wildlife Refuge is part of the SBSPRP area, encompassing 30,000 acres of open bay, salt pond, salt marsh, mudflat, upland and vernal pool habitats. The complex includes over 30 miles of boardwalks, viewing platforms and hiking trails from which users can view the various habitats. The refuge, which is located within 10 miles of 2 million area residents (Save the Bay, 2011), provides a variety of activities including hunting, fishing, interpretation, environmental education, wildlife observation, and wildlife photography (U.S. Fish and Wildlife Service, 2013). Between 2006 and 2008, the refuge drew over 800,000 visitors annually (U.S. Fish and Wildlife Service [USFWS], 2013), with residents accounting for 85% of the visits (Carver & Caudill, 2009).

Each year, there are over 3,900 hunting visits to the refuge and 3,700 fishing visits, with sport-fishers catching rays, leopard sharks, sand sharks, white sturgeon, striped bass, and shiner surfperch (USFWS, 2013). Wildlife observation is a very popular activity in the refuge as well, with nearly every visitor partaking in the activity. Environmental education is a high priority for the refuge; every year over 10,000 students visit the park to participate in field trips, summer camps, restoration courses, and other activities (USFWS, 2013).

SBSPRP funds (but not ARRA-allocated funds) are being used to complete structural improvements at visitor centers, provide additional recreational access points and trail segments, and allow for waterfowl hunting. These improvements are likely to make South Bay recreational trips more enjoyable for visitors and residents alike, translating to higher per-day values for recreation. Although improved recreational opportunities may lead to an increase in the number of visits to the South Bay recreational areas, existing data on baseline visitation rates in the general Bay area are not detailed enough for us to predict changes in the number of visits to the South Bay specifically.

Hiking, Bicycling and Other Recreation

The San Francisco Bay currently has rich recreational resources. For example, the Bay Trail is a planned recreational corridor that will encircle San Francisco and San Pablo Bays with over 500 miles of trails for bicycling

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[15] Carver & Caudill (2009) also estimated visitation's impact to the overall regional economy. Compared to the total economic value approach that we took in this report, regional economic impacts are an alternative, complementary way to describe monetary restoration outcomes: impact analysis examines the level of economic activity associated with wildlife recreation, but does not untangle the social well-being generated by restoration. Carver & Caudill (2009) write, "total expenditures were $16.0 million with residents accounting for 9.7 million or 61 percent of total expenditures. Expenditures on non-consumptive activities accounted for 98% of all expenditures, followed by hunting and fishing at 2 and less than 1 percent respectively … Final demand totaled $15.1 million with associated employment of 196 jobs, $8.3 million in employment income and $3.8 million in total tax revenue" (p. 338).

and hiking. Currently, over 310 miles of trails connect nearby communities to parks, open spaces, and agricultural areas all over the Bay area (San Francisco Bay Restoration Authority, n.d.). It is accessible within 5 miles of 54 cities that have a total population of 3.8 million people. Over 5.8 million people (75% of the area's population) live within 20 miles of the trail (Association of Bay Area Governments, 2005). According to the Association of Bay Governments (2005), the trail draws 37.9 million annual walking or biking trips that would have otherwise been driving trips. Visitors take approximately 16 million trips to Bay Trail segments in the three counties surrounding the South Bay salt pond complex (Table 2-14).

Table 2-14. Annual Trips Taken to San Francisco Bay Trail Segments in Counties Bordering the South San Francisco Bay Salt Pond Complex.

County	Trips per year (2005)
Alameda	11,977,267
Contra Costa	2,295,897
Santa Clara	3,801,137

Source: The Association of Bay Area Governments (2005).

Both the ARRA-funded portion of, and overall salt pond restoration project, will change the physical appearance of South Bay recreational sites. By maintaining levees, ARRA-funded and other project portions will provide new additional walking trails. Non-ARRA funds have recently been used to create 2.9 miles of new trails and create a kayak launch point at Eden Landing (South Bay Salt Pond Restoration Project, 2012). Furthermore, plans are in place to establish an interrelated trail system; provide viewing and interpretation opportunities and allow for waterfowl hunting (South Bay Salt Pond Restoration Project, 2012).

As the Bay Trail is expanded and improved through restoration, it will draw more visits and connect more people to Bay resources. It will serve an increasing population, as the Bay area population is expected to increase by 2 million people in the next 25 years (San Francisco Bay Restoration Authority, n.d.). It will also provide increased access to Bay-shore facilities for communities that currently lack adequate access, since currently these facilities are utilized primarily by wealthy white communities (Association of Bay Governments, 2005).

Based on Bauer et al. (2004), household's WTP for adding recreational amenities such as boardwalks and trails to the ARRA –funded salt marsh restoration projects is $ and $per site, respectively. Taken across the overall SBSPRP project (not just the ARRA-funded restoration), the average household would be WTP approximately $/year for the increased recreational opportunity provided by new trails and viewing platforms in the South Bay complex. The values of recreational amenities are already included in the total value or restored wetland habitat.

In addition to providing valuable recreational opportunities to residents and visitors in the Bay area, hiking opportunities provide sizeable economic impacts locally. The Association of Bay Governments (2005) conservatively assumed that trail users spend approximately $5 per trail visit on supplies, food, fuel, lodging, and other items, estimating the economic impact at approximately $190 million annually (including multiplier effects).

Other Activities

In addition to bird watching, fishing, hunting, bicycling, and hiking, many people visit the Bay area resources to simply observe wildlife. For example, close to 100% of visitors to the Don Edwards National Wildlife Refuge partake in some form of wildlife viewing during their visit (USFWS, 2013). Pendleton (2006) estimated that wildlife viewing trips in Alaska were worth $143 to $229 per person per day, while in the Florida Keys, they were worth $108. Boating is also popular. There are 40 marinas in the central Bay, with more than 11,000 boat slips (Battelle Memorial Institute, 2008).

2.7 Environmental Justice Analysis

All populations living in the communities surrounding the SBSPRP are expected to benefit from the ecological improvements enumerated in preceding sections of this chapter. Economic analysts historically only compared costs and benefits of ecosystem restoration – such as coastal habitat projects – by comparing the total value of restoration and total cost of restoration summed across all members of society together. In reality, differences between minority and general populations sometimes result in an uneven distribution of either benefits or costs among different socio-economic groups. The relative degree of equity across potentially-affected subsets of the population becomes an "environmental justice" (EJ) concern if the groups of people that either bear the costs of, or receive the benefits of, restoration *disproportionately* consist of low-income, minority, or other historically-marginalized individuals. EJ analyses provide a framework for examining the fairness of cost and benefit distributions across multiple racial, economic, or ethnic groups within society. Analyses can examine these distributions not only in terms of monetary value, but also in other dimensions such as access, protection, and involvement (US EPA, 2013[16]).

Activities like coastal restoration could be designed to purposefully ameliorate existing EJ concerns or actively seek to even out historically-disproportionate benefit/cost distributions. For example, the SBSPRP improves fish populations valued by subsistence fishers. Since subsistence fishers rely on self-caught fish for a larger share of their food intake than the general population, they may incur a larger share of benefits arising from coastal restoration that improves local fish populations. Additionally, if low-income and/or minority groups have historically had low access to coastal recreational resources, focusing restoration in areas in low-income or minority neighborhoods can reduce distance barriers to recreation access. Other restoration projects could provide EJ benefits in different dimensions, such as supporting small resource-dependent businesses such as owner-operated fishing boats. If appropriately designed, coastal restoration could potentially provide both monetary and qualitative dividends to disadvantaged population and small businesses over and above the benefits which we estimated for the general population.

This section summarizes Abt Associates' qualitative and quantitative assessment of the potential distributional impacts of the SBSPRP. We consider the overall matrix of projects rather than the ARRA-funded component alone. Our qualitative analysis follows statistical comparisons similar to those used in Environmental Justice screening analyses (U.S. EPA, 2013b).

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[16] http://www.epa.gov/environmentaljustice/

2.7.a Analysis

Qualitative Assessment

We first qualitatively assessed the extent to which habitat improvements from restoring South Bay salt ponds to tidal wetlands could benefit low-income, minority and other EJ communities. The focus here was to ask, "Of the ecosystem goods and services affected by restoration, are potentially 'more valued' by lower-income, minority, or underserved populations compared to the general population?" We identified several ways in which a variety of low-income and minority groups could disproportionately benefit from coastal restoration.

Table 2-15 provides some insight into factors that may affect how benefits are distributed between subgroups and whether benefits may be disproportionately distributed to subgroups within affected areas.

For example, providing additional access points to the South Bay salt pond/wetland complex, and improving recreational facilities at the complex, could potentially encourage outdoor recreation and could help cultivate an "appreciation of the natural and historical resources in the region" (EIS, 2007). A disproportionate benefit could arise if minority populations benefit from restoration over and above the general population. Table 2-15 lists several factors that could lead to disproportionate recreational benefits for low-income and minority groups. For example, research suggests that some minority groups are less likely to travel to parks that are far away from their homes. Because the South Bay restoration project is located in an area with relatively high proportions of minority groups, minority groups may be more likely to access the restored areas compared to sites that are more distant from their homes.

A survey of current trail users at salt ponds and marshes in the South Bay showed that among current visitors, African American, Hispanic, and Asian populations are under-represented when compared to local Census Tract demographics (Sokale & Trulio, 2013). Additionally, people most often visit the complex's trails when on their way to or from work, or as part of other local trips (Sokale & Trulio, 2013). Combined with prior research suggesting minority groups tend to travel shorter distances to participate in outdoor recreation relative to the general population (summarized in Table 2-15), the location of the SBSPRP in neighborhoods that contain disproportionately-large minority and low income populations may prove advantageous in increasing outdoor recreation access opportunity for EJ communities.

Table 2-15. Qualitative Screening for EJ Effects Following South San Francisco Bay Coastal Restoration.

Ecosystem Change/ Economic Benefit	Potential EJ Consideration
Increased habitat supporting commercially-valuable fisheries	Currently, there is a small-scale commercial bay shrimp fishery in the South Bay that could benefit from habitat improvements. • The SBSPRP EIS states, "two to four boats harvest shrimp in the South Bay each year and catch approximately 75,000 pounds of shrimp valued between $154,000 and $312,000 annually" (Hansen 2003). • The EIS found that restoration has the "potential to substantially enhance the shrimp populations, and as such it would provide economic benefits by revitalizing the bay shrimp harvesting industry." But, we have no evidence of a distributional impact broken down by EJ communities.
Increased habitat supporting non-commercial fisheries	• Some minority and low-income groups rely disproportionately on subsistence fishing as a source of food. These groups are particularly likely to benefit from increased numbers of fish (i.e., catch rates), and improved access to those fish.
Change in flood risk for homes within the coastal floodplain	• Zahran et al. (2008) found that, in Texas, there was a significant positive relationship between risk of casualties from flooding and social vulnerability (defined by socioeconomic disadvantage, including low-income and minority groups). • Low-income households are less likely to have residential flood insurance than higher-income households. Without insurance to recover flood-related losses, a low-income household would benefit from flood risk reduction more than higher-income household.
Increased recreational opportunity – acres of wetlands accessible; completion of new trail segments; improvements at the Don Edwards NWR visitor center	• If there is a disparity between EJ and non-EJ communities in the recreational value placed on coastal wetlands, benefits may be disproportionately distributed to the subgroup that values the resource more highly. • Literature generally suggests that minority and low-income populations engage in recreational opportunities less frequently, minorities are generally less likely to travel far to parks, and participate in different types of activities when doing so (Baas, Ewert, & Chavez, 1993; Gobster, 2002; Kakoyannis & Stankey, 2002; Payne, Mowen, & Orsega-Smith, 2002; Schneider, 2009).

Quantitative Assessment

Because our qualitative review suggested SBSPRP activities are likely to provide services that are valued differently by EJ communities and the general population, we quantitatively assessed whether affected communities actually include EJ groups. The purpose of this analysis was to determine whether low-income individuals or minority individuals are more or less present in the affected areas than in the general population.

We first conducted a screening analysis for EJ communities, examining the prevalence of low-income households, and of minority racial groups in surrounding counties that may constitute resource users who live relatively close to the Bay (Appendix C provides detailed methods).

The demographic profiles of the county populations tend to be different from that of the state-level population (Table 2-16). Results indicate communities in counties bordering the South San Francisco Bay are characterized by higher income, lower prevalence of households below the poverty line, and larger proportions of minority residents. Overall, the EJ index constructed from these components suggests EJ communities are less prevalent in the area surrounding the South Bay. Restoration activities would be unlikely to cause disparately-beneficial impacts to EJ communities based on the county-level analysis.

On the other hand, as part of the environmental impact assessment for the SBSPRP, analysts previously examined differences between the percentage of minority and low-income populations at a smaller, city-level scale (EIS, 2007). In general, non-white communities dominate the Census tracts contained in the Project Area, but households below the poverty line appear relatively less common than the state-wide average for California (Table 2-17). Results suggest that, at a highly local scale (Census tracts in the SBSP project area), minority and low-income populations tend to be more prevalent in the areas immediately adjacent to the SBSPRP than in surrounding cities. Although evidence is mixed across cities and indicators, benefits that are highly dependent on proximity (such as changes in flood risk) could disproportionately benefit EJ communities.

Table 2-16. Quantitative EJ Screening.

	California	Alameda County	Santa Clara County	San Mateo County
Total Population Estimates				
Population	36,637,290	1,477,980	1,739,396	704,327
Households	12,577,498	545,138	604,204	257,837
Population-weighted averages				
Median Household Income (2013$)	$67,197	$78,168*	$93,852*	$94,426*
Percent Poverty	13.8%	11.6%*	9.1%*	7.0%*
Percent Minority	59.8%	65.9%*	64.6%*	57.6%*
EJ Index (%Poverty * %Minority)	9.7%	8.7%	6.6%*	4.8%*

Notes: * denotes a statistically-significant difference between the county-level population-weighted average and the state –level average (two-tailed paired t-test, p <0.05). Source: U.S. Census, 2013.

Table 2-17. Prevalence of Non-white and Below-poverty Populations in Cities and Census Tracts Surrounding the SBSPRP.

City	% Non-White		% Below Poverty Level	
	City-wide	Range, in SBSP Tracts	City-wide	Range, in SBSP Tracts
Hayward	57	64-74	10	5-8
Fremont	52	48-79	5	1-9
San Jose	53	71-88	9	9-13
Sunnyvale	47	34-41	5	5-6
Mountain View	36	34-35	7	2-4
Menlo Park	28	75-79	7	15-20

Source: Census 2000 data as reported in South Bay Salt Pond Restoration Project Final Environmental Impact Statement/Report (2007). Section 3.11 Socioeconomics and Environmental Justice.

Poor, minority households are more susceptible to flood risk and the consequences of flooding than the average household (Fothergill, Maestas, & Darlington, 1999). With less income available, low-income households may not voluntarily purchase flood insurance (Kunreuther & Pauly, 2006) and thus may face greater than average difficulty in recovering assets after a flood. Low-income or minority households also may be less aware of flood risks or the implications of flooding (Fielding & Burningham, 2005; Troy & Romm, 2004), may occupy housing that is less resilient to flooding(Fothergill, et al., 1999), and because of lack of access to social capital or to baseline higher incidences of physical or mental health, may be less well-prepared to cope with flood damages (Walker & Burningham, 2011). Although "demographic and environmental changes [in the United States] have systematically exposed greater numbers [of people] to natural hazards," (Donner & Rodríguez, 2008, p. 1090), coastal restoration projects in low-income and minority communities may be able to counteract historical inequalities in flood risk and coastal resiliency.

In context of the South Bay salt pond project, which may marginally reduce coastal or fluvial flooding, coastal flood risk is quite geographically limited to communities near coasts and tidally-influenced rivers. Monetary benefits of reducing flooding in these areas are large. Coupled with the above-summarized literature suggesting the burden of flooding and flood risk falls heavier on low-income and minority populations than on the general population, spatial analyses suggesting Bay-adjacent neighborhoods have a higher-than-average proportion of low-income and minority residents indicates coastal restoration that reduces flood risk may provide EJ benefits.

2.8 Discussion

The South San Francisco Bay Salt Pond Restoration Project is designed to convert approximately 7,500 acres of commercially-productive salt ponds to tidal marsh. Ecosystem monitoring shows that within just three years of commencing restoration activity at sites funded by a NOAA-ARRA program to stimulate investment in coastal restoration, individual restored ponds (approximately 1,513 acres) are beginning to provide vegetated marsh habitat and are starting to support a different mix of bird, fish, and shellfish species, including T&E and iconic species. Based on review of the design and trajectory of ARRA-funded wetland restoration and activities at SBSPRP restoration sites and available data, we made the following conclusions regarding ecological resources:

- Restoring tidal flushing by breaching and following expected patterns of re-vegetation shown in adjacent areas, tidal wetland habitat have increased by 195 acres and will eventually increase to 1,513 acres.
- Vegetation species diversity and habitat quality will increase rapidly with re-vegetation with most ecosystem functions and services being largely restored within 15-20 years.
- Fish resources have shown a positive response in terms of numbers and diversity to the increased habitat availability and increased range of environmental conditions (primarily salinity). These increased numbers could provide additional forage base for larger game fish of recreational interest.
- South Bay is a critical habitat for avifauna and the restoration of the wetlands will provide additional habitats for many guilds of birds. Model predictions indicating a potential long-term decrease in water bird use have not been realized in the short-term. An adaptive management strategy using "lessons learned" to improve restoration design will also mitigate potential impacts.
- Federal- and state-listed T&E or sensitive species will benefit from the restoration. Creation of additional marsh habitat should benefit local populations of clapper rail and salt harvest mouse.

Restoring South Bay salt ponds to tidal wetlands will clearly enhance ecosystem goods and services available to local and regional communities. We estimated the total economic benefit of the ARRA-funded portion of, and overall SBSPRP. Over the current anticipated restoration trajectory, we estimate that regional households will experience an annual benefit between $3.04 to $9.58 million, or $2.86 million to $10.9 million, respectively (Table 2-18). Table 2-19 shows that these annualized values derive from estimated benefits with between $70.8 million to $222.1 million TPV (ARRA; through 2050) and $332.3 to $345.2 million TPV (overall SBSPRP; through 2110).

While it is unlikely that restoring coastal wetlands in the South Bay will divert the majority of new ecosystem service benefits away from EJ communities (and towards the general population), our analysis suggests that all but the most localized benefits of the restoration, would be unlikely to disproportionately enhance benefits to historically-underserved groups. On the other hand, when considered at a very local scale, we also found a degree of evidence that some South Bay neighborhoods have disproportionately-high proportions of residents that are minority and/or live below the poverty line. Restoring the South Bay salt ponds may thus provide some qualitative benefits by reducing vulnerable populations' exposure to environmental hazards, while also increasing their access to environmental "goods." The localized nature of some SBSPRP benefit categories and the presence of EJ populations in surrounding communities combine to suggest that restoration is likely to provide EJ benefits in two contexts:

- As Sokale & Truilio (2013) suggest in context of the South Bay trails, designing restoration to provide features that encourage minority access – such as trail segments that link minority neighborhoods with the existing trail system -- could be a worthy goal of restoration if it is designed to achieve double dividends to both coastal habitats and local community well-being.

- Compared to the general population, restoration may provide extra flood risk reduction benefits for EJ communities living within the coastal or river flood plains surrounding the South Bay wetland/salt pond complex. Because minority or low-income households may be less aware of flood risk or have less money available to protect assets by purchasing flood insurance, reducing flood risk in areas with larger-than-average EJ populations is a step in the direction of addressing historical inequalities.

Table 2-18. Summary of the Estimated Annualized Wetland Restoration Benefits (2013$).

Benefit Category	ARRA-funded Benefit	Overall South Bay Benefit[A]	Notes on Additivity
Total Value of Wetland Restoration (WTP)	$2,983,046- $9,528,353	$2,445,716- $10,487,609	Incorporates a mix of use and non-use values (flood control, biodiversity supply, size of wetland area restored; presence of boardwalks and/or viewing towers; endangered species; and preferences for preservation vs. restoration)
Commercial Fishing and Recreational Fishing	$23,332 – $29,987	$94,783 – $121,871	Overlaps with Total WTP value
Threatened & Endangered Species Protection	$2.08 million	$1.70 million	Included in Total WTP value
Flood Risk Reduction	Not monetized independently	$128,724 – $6.4 million	Overlaps with Total WTP value in the Overall South Bay benefit, but is not included in the ARRA-funded total benefit.
Carbon Sequestration	$54,303	$412,502	Additive to total WTP value
Biodiversity	Not monetized independently	Not monetized independently	Included in total WTP value
Bird Watching	Not monetized independently	Not monetized independently	Included in total WTP Value
Other Recreation	Not monetized independently	Not monetized independently	Included in total WTP value
Total Benefit Estimate	$3,037,349 - $9,582,656	$2,858,218- $10,900,111	

Notes (A): The same TPV annualized over a longer time period produces a smaller annualized present value, all else equal. Values obtained over different annualization periods are not directly comparable.

Source: Abt Associates analysis (2013).

Table 2-19. Summary of the Estimated TPV of Wetland Restoration Benefits (2013$).

Benefit Category	ARRA-funded Benefit	Overall South Bay Benefit[A]	Notes on Additivity
Total Value of Wetland Restoration (WTP)	$68,952,427 - $220,245,700	$77,281,946 - $331,396,958	Incorporates a mix of use and non-use values (flood control, biodiversity supply, size of wetland area restored; presence of boardwalks and/or viewing towers; endangered species; and preferences for preservation vs. restoration)
Commercial Fishing and Recreational Fishing	$539,078 - $693,139	$2,995,049 – $3,850,980	Overlaps with Total WTP value
Threatened & Endangered Species Protection	$2,844,300	$2,844,300	Included in Total WTP value
Flood Risk Reduction	Not monetized independently	$857,300 – $42,592,536	Overlaps with Total WTP value in the Overall South Bay benefit, but is not included in the ARRA-funded total benefit.
Carbon Sequestration	$1,810,111	$13,750,076	Additive to total WTP value
Biodiversity	Not monetized independently	Not monetized independently	Included in total WTP value
Bird Watching	Not monetized independently	Not monetized independently	Included in total WTP Value
Other Recreation	Not monetized independently	Not monetized independently	Included in total WTP value
Total Benefit Estimate	$70,762,538 - $222,055,811	$332,254,258 - $345,147,034	

Notes: (A): TPVs obtained over different annualization periods are not directly comparable. Source: Abt Associates analysis (2013).

3 Virginia Seaside Bays

3.1 Introduction

Virginia's Seaside Bays include a variety of shallow coastal ecosystems, including two key habitats that have critical roles in ecosystem habitat structure and function: oyster reefs (Figure 3-2) and submerged aquatic vegetation (SAV) in seagrass meadows (Figure 3-1). Like many temperate estuaries of the United States, these habitats were once ecologically- and economically- dominant, but in the last century have experienced sharp declines in quality and coverage.

Centuries of intensive exploitation, coastal zone development, and deteriorating water quality have damaged or eliminated many oyster reefs. It has been estimated that 85 percent of historic oyster reefs have been lost globally, making oyster reefs the most severely impacted marine habitat on the planet (Beck et al., 2009). Sharp declines in SAV habitats are similarly due to a multitude of factors, including: increased nutrient and sediment runoff, invasive species, hydrological alterations, and commercial fishing practices. Recent estimates suggest that globally, 14% of SAV species are at elevated risk of extinction (Short et al., 2011).

Virginia's Seaside Bays and surrounding regions have has experienced two major ecosystem declines: the loss of vast beds of one SAV species -- eelgrass (*Zostera marina*)-- due to the effects of disease and a hurricane in 1933, and the elimination of commercial oyster harvesting in the 1990s due to overharvesting and population declines (The Nature Conservancy, 2009). Loss of the eelgrass habitat also largely eliminated the bay scallop, formerly an important shellfish resource.

Figure 3-1. Eelgrass Meadow on the Virginia Coastline.

Source: Virginia Institute of Marine Science (2013).

Oyster reefs and eelgrass beds provide a variety of ecosystem functions (Table 3-1); restoring lost or degraded habitats is designed to restore these functions and improve the provision of associated ecosystem goods and services (Table 3-3). For example, in addition to shellfish production, oyster reefs create the physical structure and microhabitats for fish and invertebrate species. Eelgrass beds produce a variety of goods (finfish and shellfish) and provide ecological services (maintenance of marine biodiversity, regulation of the quality of coastal waters, protection of the coast line) which are directly used or beneficial to humans. In addition, they also stabilize sediments, have high productivity, and are excellent indicators of the status of environmental quality in the coastal zone (Orth et al., 2006).

Table 3-1. Ecosystem Structures and Functions of Oyster Reefs and Eelgrass.

Oyster Reefs	Eelgrass
• **Stabilization of benthic or intertidal habitat**: oyster reefs generally form the only hard substrate in predominately soft-sediment environments and act to stabilize and settle out suspended sediments. • **Oyster Production**: oysters are a highly valued commercial shellfish. • **Fish production**: juvenile pelagic fish and mobile crustaceans utilize oyster reefs as refuge and foraging grounds, such that oyster reefs augment the tertiary productivity of estuaries. • **Provision of habitat for invertebrates**: the reef structure formed by vertically upright oyster aggregations creates habitat for dense assemblage for other mollusks, polychaetes, crustaceans, and other resident invertebrates. • **Trophic structuring**: oysters promote pelagic fauna by preventing primary production from entering microbial loops and thus allowing it to pass up the food chain first to oyster predators like bottom-feeding fishes and crabs; and then to higher-order predators like red drum, tarpon, and dolphins. • **Water filtration and concentration of bio-deposits**: Removal of nutrients, sediments, and phytoplankton from the water column improves local water quality and routing of energy, carbon and nitrogen to benthic communities by biodeposition (i.e., feces). • **Carbon sequestration**: collection of carbon through filtration feeding on phytoplankton and organic material and deposition into shell material provides for semi-permanent carbon sequestration.	• **Stabilization of benthic or intertidal habitat**: the eelgrass leaf canopy, roots and rhizomes consolidate un-vegetated areas, stabilizing the sediments, and contributing to water clarity. • **Fish production**: the highly productive eelgrass habitat provides food, shelter, and essential nursery areas to commercial and recreational fishery species. Juvenile stages of many fish species spend their early days in the relative safety and protection of eelgrass. • **Provision of habitat for invertebrates**: the eelgrass habitat supports diverse invertebrate taxa such as crustaceans, bivalves (e.g., bay scallop), echinoderms, and other groups, that are produced within, or migrate to eelgrass. • **Provision of habitat for wildlife**: Eelgrass is an important food source for mega herbivores such as green sea turtles. • **Mitigation of shoreline erosion**: Eelgrass meadows dampen the effects of strong currents, providing protection to biota, while also preventing the scouring of bottom areas. • **Maintain biodiversity**: Eelgrass provide attachment sites to small macroalgae and epiphytic organisms such as sponges, bryozoans, foraminifera, and other taxa that use eelgrass as habitat. The abundance and diversity of the fauna and flora of eelgrass meadows are consistently higher than those of adjacent un-vegetated areas. • **Carbon sequestration**: Primary production among eelgrass and other species of SAV is only 1% of total primary production in the oceans but SAV are responsible for 12% of the total amount of carbon stored in ocean sediments.
Source: Grabowski & Peterson (2007)	Source: Terrados and Borum (2004), Orth et al. (2006)

To restore goods and services at degraded oyster reefs and eelgrass beds in the Virginia Seaside Bays, in 2009, NOAA-ARRA awarded $2,167,000 to The Nature Conservancy (TNC) and a project team including the Virginia Institute of Marine Science (VIMS), Virginia Marine Resources Commission (VMRC), and Virginia Coastal Zone Management Program (VCZM) (NOAA, 2012; The Nature Conservancy, 2009). Table 3-2 summarizes the restoration activities completed with available funds; we refer to the restoration activities at these sites collectively as the "Virginia Seaside Bays Restoration Project" (VSBRP). Funded and completed restoration activities at VSBRP included:

Figure 3-2. Oyster reef on the Virginia Coastline.

- **Constructing functional oyster reefs** at 14 sites by installing oyster reef substrate (shells or surrogate substrate) (22.1 acres);
- **Planting eelgrass seeds** in the non-vegetated bottom of four adjacent sub-basins along the lower Delmarva Peninsula (133 acres in South Bay, Cobb Bay, Spider Crab Bay and Hog Island Bay; Figure 3-5); and
- **Deploying adult bay scallops** as spawning stock in the restored eelgrass beds to support reintroduction of a self-sustaining bay scallop population (about 136,000 scallops).

Box 4. Virginia Seaside Bays Restoration Benefits Summary

- Added 22.1 ac of oyster habitat, and 133 ac of seeded eelgrass meadows expected to cover 1,703 ac within 24 years
- Provides an estimated $1.45 to $3.51 million annually in ecosystem service benefits
- Improves local fisheries and nature tourism opportunities, helping to improve overall community sustainability

Restoration partners completed these activities, along with associated water quality, vegetation, oyster, and scallop population monitoring during 2009-2011 (NOAA, 2012). Through restoring these species and habitats, this project will enhance the ecological health and resiliency of the Virginia Seaside Bays. Once restored, the oysters, eelgrass, and bay scallops will provide long term goods and services to people and nature by improving water quality, increasing production of fish, shellfish, and other species by providing essential habitat and nursery areas, increasing biodiversity and, as a result, enhancing commercial harvest and recreational opportunities near the restored sites and promoting local ecotourism (Box 4).

Table 3-2. Summary of Virginia Seaside Bays Restoration Project Activities Funded by ARRA.

Restoration Activity	Area (ac)[1,2]	Action	Approximate Date	Previous Habitat/Condition	Restoration Target Habitat
Oyster Reef Creation	22.1	Construction of new oyster reefs	October 2009 - September 2011	No oyster habitat present	Fully functional oyster reef
Eelgrass Restoration	133.0	Seeding of eelgrass in un-vegetated areas	October 2009 - September 2011	No eelgrass beds present	Fully restored eelgrass meadow
Bay Scallop	NA	Rearing and distribution of spawning stock	October 2009 - March 2012	Bay scallops absent from ecosystem	Introduction of reproducing bay scallop population

Notes:

(1): Completed restoration acreage or shellfish numbers as reported in ARRA Grant Award Summary 2012.

(2): 110 eelgrass acres were seeded in 2009-2010 (Orth, Moore, Marion, Wilcox, & Parrish, 2012); remaining acres assumed to be seeded in 2011.

Table 3-3. Ecosystem Goods and Services from Restored Oyster Reefs and Eelgrass Beds in Virginia's Sea-Side Bays.

Service Category	Ecosystem Services	Change as a Result of Restoration: Oyster Reefs	Change as a Result of Restoration: Eelgrass	Available Change Assessment Methods	Monetized?
Provisioning *of "products obtained from ecosystems" (MEA, 2005)*	Commercial seafood harvest	↑	↑	Quantitative/ Qualitative	Yes
	Subsistence seafood harvests	↑	↑	Qualitative	No, data not sufficient
Supporting *ecosystem services "that are necessary for the production of all other ecosystem services" (MEA, 2005)*	Primary production	n/a	↑	Quantitative	Yes
	Food web dynamics	↑	↑	Qualitative	No, data not sufficient
Regulating *ecosystem processes and associated benefits*	Carbon and nutrient cycling	↑	≈	Quantitative	Yes
	Coastal erosion protection/ Storm buffering	≈	↑	Qualitative	Yes
	Sediment stabilization	≈	↑	Qualitative	Yes, indirectly
	Water quality	↑	≈	Qualitative	No, data not sufficient to quantify
Cultural *benefits that are "nonmaterial…and gained through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (MEA, 2005)*	Recreational seafood harvest	↑	↑	Quantitative/ Qualitative	Yes
	Other recreation	↑	↑	Quantitative/ Qualitative	No, data not sufficient to quantify
	Aesthetic appreciation	≈	≈	Qualitative	No, data not sufficient to quantify
	Existence/ non-use values	≈	≈	Qualitative	Yes
	Information, science, education, and research	≈	≈	Qualitative	No, data not sufficient to monetize
	Biodiversity	↑	↑	Qualitative	Yes
	Other cultural and spiritual factors	≈	≈	Qualitative	No, data not sufficient to monetize

3.2 Oyster Reef

3.2.a Oyster Reef Establishment

The primary goal of oyster reef habitat restoration is the re-establishment of oyster populations at self-sustaining levels similar to historic or natural oyster communities and, where applicable, to help support commercial or recreational shellfisheries. Secondarily, by creating oyster reefs of sufficient scale and spatial distribution, restoration provides critical habitat structure and ecological functions for other biota (e.g., mussels, crabs, barnacles and other benthic invertebrates) (Meyer and Townsend 2000; Hadley et al. 2010). Further, oyster beds are efficient in filtering phytoplankton, pollutants, and suspended sediment from the water column and are important for nutrient cycling and maintenance of water quality (Kellogg, Cornwell, Owens, & Paynter, 2013; Nelson, Leonard, Posey, Alphin, & Mallin, 2004).

Oyster reef restoration typically consists of large-scale plantings of oyster shell (termed "cultch") and other natural or artificial substrates in shallow areas that receive active reliable settlement of oyster spat (i.e., larvae). These spat settle to the substrate and develop into harvestable oysters on the reef or can be transplanted elsewhere to act as seed populations at other locations. As the reef ages, the amount of surface substrate occupied by oyster increases, as does the diversity of shell sizes and number of harvestable oysters.

Placement of cultch or other artificial substrate materials (such as granite, limestone marl, and concrete structures) in the Southeastern United States has previously facilitated successful oyster colonization and growth. In as little as three years post-restoration, created oyster reefs in South Carolina and North Carolina have significant numbers of oysters in many size classes, including spat, small recruits, and mature harvestable oysters[17] (Hadley, Hodges, Wilber, & Coen, 2010; Meyer & Townsend, 2000; Powers, Peterson, Grabowski, & Lenihan, 2009). Sampling of oyster densities and recruitment levels in restored Neuse River (North Carolina) shallow reefs, 10 years after restoration, demonstrated both ecological success (high spat recruitment, reef community diversity) as well as sufficient market-sized oysters for fishery success (Powers, et al., 2009).

However, not all oyster reef restorations are successful for a variety of reasons including water quality, excessive sedimentation, toxic phytoplankton, and poor hydrodynamic flushing (Powers, et al., 2009). Assessment of the success of oyster reef restoration showed that success varies across locations, depending on substrate used, overall project goals, and ecological conditions(zu Ermgassen, Spalding, Grizzle, & Brumbaugh, 2013). To provide a uniform method for assessing restoration "success," the Oyster Metrics Workgroup ([OMW], 2011) developed a set of operational and functional performance metrics, measured at 6-12 months, 3 years, and 6 years post-restoration, and periodically thereafter (Appendix J).

[17] Oysters are functionally classified by maximum shell length. For VSB, the newly settled juveniles (less than 25 mm shell length) are called "spat"; small oysters are 25 up to 75 mm; while large ("harvest" or "market") oysters are greater than 75 mm.

Assessment of Oyster Reef Habitat Functionality

VSBRP applied ARRA funds to place 22.1 acres of oyster shell and artificial substrate were placed in 14 sites during 2009-2011 (NOAA 2013). Early post-restoration monitoring results estimated an average of 2,239 live spat per m^2 with a 20.2 mm average shell length (Lusk, Truitt, Wesson, & Lorber, 2011). These values compare favorably to 1-year-old reefs reported by Hadley et al. (2010) which had a mean recruitment of 1,039 spat per m^2 and an average shell size of 22.5mm (Appendix J). Based on these early monitoring results, it was judged that the oyster reef restoration was successful (Lusk, et al., 2011).

Total reef area, the age of the restoration site, oyster population size, and reef community richness are critical measures of the extent and relative success of oyster reef restoration that ultimately determine the quantity of ecosystem services provided. On a per-area basis, oyster population size and reef community richness generally increases with time. Abt Associates estimated the development of the oyster reef, assuming a 12 year period for reef development and using the OMW monitoring periods as convenient milestones. The planted cultch is assumed to be colonized with spat in year 1, provide oysters of harvestable size by year 3 and continue to grow increasing numbers of oysters and improve its ecological functions through approximately year 12. The oyster reefs in the Virginia Seaside Bays have been designated as a protected area, which means no commercial, recreational or subsistence harvesting of oysters is permitted.

Table 3-4 shows the effective area of restored oyster reefs. There is the initial time lag until harvestable oysters develop. Harvestable oysters, although the key to a fully functioning oyster reef, are not necessary to provide many of the ecosystem services that artificial reefs provide, such as structure and refugia for many benthic invertebrates and finfish (Luckenbach, Coen, Ross, & Stephen, 2005). Because oysters provide substrate stability and physical habitat to a variety of aquatic species, the reef area is always productive.

Table 3-4. Estimated Area of Functioning Restored Oyster Reef Area Over Time.

	Area Restored (ac)	Estimated Restored Area (ac)[1]				
		0-2 years (30%)	3-6 years (50%)	7-9 years (75%)	10-12 years (95%)	>12 Years (100%)
Oyster Reef	22.1	6.6	11.1	16.6	21.0	22.1

Note: (1) Functional oyster reef restoration area based on literature, OMW assessment classes and best professional judgment.

3.2.b Oyster Reef Restoration Benefits

Restoring oyster reefs enhances a variety of ecosystem goods and services, most of which are inputs to economic activity and offer real economic value to surrounding and distant communities. Section 2.2.b (above) summarizes potential benefits to society from improvements in coastal ecosystem conditions, and introduces a method for estimating the monetary value of these improvements. Table 4-2 inventories the ecosystem services associated with oyster reefs (discussed above, in Section 3.2) and eelgrass beds (discussed below, in Section 3.3.c).

Values for Restored Oyster Reefs

Oysters are valuable and iconic seafood in the mid-Atlantic: recently, the Virginia governor wrote, "The ripple effects through the economy from [2012's] unexpectedly large oyster harvest resulted in an estimated $42.6

million in economic value, using a multiplier of 2.63 on a dockside value of $16.2 million" (McDonnell, 2013). Virginia also recently invested $2 million for shell replenishment on oyster reefs, which is likely to net significant economic gains. As reported by the Chesapeake Bay Foundation (2013), "the Virginia Marine Resources Commission estimates that every $1 dollar the state spends to put oyster shells in the water yields $7 in economic benefits, including more oysters and more jobs."

Figure 3-3. Oysters.

Although these figures suggest a potentially large monetary value of restoring historically-degraded reefs in Virginia's Seaside Bays, restored reefs at VSBRP not currently intended for harvestable uses. But, these restored areas are still likely to provide long-term benefits by improving other market and non-market ecosystem goods and services. Researchers have only recently begun to investigate approaches that estimate total (WTP for the total value of healthy oyster reefs and thus available data are limited to a series of studies that each estimate oyster reefs' contributions to individual ecosystem goods and services such as carbon and nitrogen sequestration, fin fisheries productivity, and others. Notable examples of oyster reef valuation studies include several papers by Grabowski and colleagues (Grabowski et al., 2012; Grabowski & Peterson, 2007) and an application to oyster reefs in coastal Alabama by Kroeger (2012). These studies develop a monetary estimate of per-service benefits of oyster restoration and develop total monetary value of ecosystem services provided by oyster reef as the sum of changes in all component parts. We note that the current economic literature advocates estimating the total value of all ecosystem goods and services provided by the reef to reduce the potential for double-counting of overlapping benefits. Given the lack of total nonmarket values of oyster reef restoration, we apply an additive approach, but suggest that the total value estimates are interpreted with caution.

Benefit Estimation Assumptions

See Appendix A for general annualization and discounting assumptions used throughout this study. For all oyster reef benefit categories, we estimated partial benefits during the 12 year restoration trajectory using pro-rated unit benefits based on the percentage of established reef area to date. Once restored oyster reefs are fully established at the end of the 13-year restoration trajectory, the improved level of services will persist for the functional lifetime of the habitat. For modeling clarity, we examined benefits of oyster reefs for 28 years post-completion, or a 40 year period in total, ending in 2049. Oyster reefs and associated services may, however, persist for longer or shorter amounts of time depending on the occurrence of future events. For example:

- Restored reefs have potential to continue expanding over time through larvae propagation to new areas. This is a natural process, difficult to predict, and the further in the future that reef ecosystem evolution occurs, the more tenuous the link to initial restoration investments analyzed in this report.

- Storms, other natural events, or human pressures can damage reefs. Although these effects are variable across sites, they render many oyster reefs long-term, but not necessarily permanent, structures (Peterson, Grabowski, & Powers, 2003). Peterson et al. (2003) suggest that for protected reefs in the mid-Atlantic, a reasonable estimate of oyster reefs lifetime is 20-30 years.

- The half-life of a single oyster shell ranges from just 1-20 years (Powell, Klinck, Ashton-Alcox, Hofmann, & Morson, 2012; Waldbusser, Steenson, & Green, 2011). Services dependent on shell integrity (carbon sequestration) or reef assemblages (carbon and nitrogen sequestration, fisheries productivity) are affected by these timelines.

Depending on the above factors, actual total benefits may be higher or lower than our estimates through 2049. By valuing only the habitat area expansions clearly linked to ARRA funding, we attempt to avoid over-stating benefits of coastal restoration investment. The effect on TPV of limiting future benefits analysis to a 40-year period is uncertain but potentially generates an under-estimate: while also intended to improve the ecological "reasonableness" of our estimates, it may under-estimate benefits if the ecosystems persist beyond that date.

Economic Valuation of Carbon Sequestration Benefits

Climate change is widely viewed to be a significant long-term threat to the global environment. Although shellfish do not play a large role in the global carbon cycle, they can contribute to climate change mitigation by sequestering carbon in their shells and tissues (National Research Council, 2010). Calcifying organisms sequester carbon from a mix of sources. Carbon sequestration from biogenic sources in the ocean is carbon-neutral, whereas carbon storage from atmospheric sources is a true removal of carbon from the marine environment. Shells that are harvested and removed from the water and ultimately buried in landfills offer a relatively permanent form of atmospheric carbon storage, as they are unlikely to decompose rapidly and re-release the carbon (Fry, 2010; National Research Council, 2010). VSBRP oyster reefs will, for the foreseeable future, be managed as sanctuaries. Oyster shells that remain in the water may still offer some carbon storage sink capacity, as shells that are buried in sediment decompose slowly. Assuming carbon sequestered in oyster shells is largely atmospheric carbon[18], the shell building process reduces the quantity of carbon dioxide that is dissolved in sea water, thus helping to reduce ocean acidification and to prevent the harmful effects of climate change.

To approximate the carbon storage capacity of the preserved oyster reefs, Abt Associates modified carbon storage estimates from a life-cycle analysis of shellfish populations in Scotland. While carbon sequestration is likely to vary widely between Virginia and Scotland, at the time of our study this was the only identifiable estimate of carbon sequestration rates (Fry, 2010). Fry (2010) estimated that one ton of oysters permanently removed from the environment can sequester 441 kg of CO_2 per year (Fry, 2010). Fry (2010) also estimated that un-harvested mussels sequester 88% of the carbon that harvested mussels do. As a starting approximation of the carbon sequestration potential of protected restored oyster reefs, we applied this ratio to the carbon storage capacity of harvested oysters, suggesting one ton of un-harvested oysters could sequester approximately 388 kg CO_2/year. We

[18] In this analysis, we assume 100% of carbon sequestered in oyster shells is atmospherically-sourced. This assumption renders our carbon sequestration capacity estimates, and associated economic benefits, as extreme upper bounds.

then multiplied this approximated sequestration value by the change in the oyster population (in the dry weight of oyster shells, tons) at VSBRP following restoration.

Assuming that, due to the preserved status of the reef, all oysters die in the water and that their shells are subsequently buried, we estimate that the 22.1-acre reef is capable of removing a total of 320,459 tons of carbon. Valued over the 40-year period at 3% SCC values (Appendix B) the annualized present value of carbon storage is $132 (TPV $4,392).

There are a number of uncertainties associated with this value estimate. First, we have applied carbon sequestration rates for cultured oysters in Scotland to wild oysters in Virginia; this is likely to introduce some error in our sequestration estimates. Second, our estimates exclude the carbon storage by oyster growth that will occur as the reef continues to grow if the restored area continues to expand.

Economic Valuation of Nitrogen Sequestration Benefits

Oysters and the epifauna living in oyster reefs (collectively, the oyster reef assemblage) remove nitrogen (N) from the aquatic environment through a variety of pathways. Oysters are suspension-feeders, and remove N from the water column when consuming organisms and plankton. Some consumed N is sequestered in oyster shells and tissue. Oyster reef assemblages also alter localized ecosystem nutrient dynamics relative to areas of bare sediment (by enhancing denitrification). There is considerable variation in the timing and amount of nutrients removed by oysters and oyster reefs. Nonetheless, N removal measurements from existing studies in the same region could be used to approximate the potential N removal at given site (Grabowski, et al., 2012; Piehler & Smyth, 2011; U.S. Department of Agriculture Natural Resources Conservation Service, 2012). We reviewed two available estimates of N removal capacity of oysters and oyster reef habitats, one from the mid-Atlantic, and one from Cape Cod, to estimate total N sequestration enhancement at the VSBRP's restored reefs (Grabowski, et al., 2012; U.S. Department of Agriculture Natural Resources Conservation Service, 2012).

Of the two, we selected Grabowski (2012) because it provided clearer and sufficient documentation[19] and was based on a geographically closer reference site (Piehler & Smyth, 2011). Piehler & Smyth (2011) conducted a field study of denitrification rates (based on N flux rates) at oyster reefs and soft-bottom un-vegetated habitats in Bogue Sound, North Carolina. Any differences between Bogue Sound and Virginia's Seaside Bays – in either the amount of N removed per day, or in the monetary value of N removed – could each introduce transfer error across sites. However, Piehler (Personal Communication - 2014) confirmed to Abt Associates that the Bogue Sound, NC study site is quite similar to VSBRP sites in two key biological dimensions. First, like the Virginia Seaside Bays, "the [water quality] in Bogue Sound would be accurately described as 'nearly nitrogen deficient'," which affects both denitrification rates and the monetary value of N removal services. Second, oyster reefs in both locations are inter-tidal (rather than fully sub-tidal), implying that oysters in each location are submerged and filtering water for roughly similar amounts of time each day. While these similarities do not completely remove questions of uncertainty in transferred values, together they do suggest transfer of N-sequestration rates across sites is at least reasonable.

[19] USDA (2012) does not describe the nitrogen removal pathway on which their estimates are based.

Based on Piehler & Smyth (2011), Grabowski et al. (2012) assumed oyster reefs remove an additional 234 micromoles N/ m^2/ hour compared to bare sediment. After converting this removal rate to the total change in N removal per acre per year[20], Grabowski et al. value total annual removals per area per year using the average trading price of N removal in the North Carolina Nutrient Offset Credit Program [NCNOCP] ($28.23/year at the time of Grabowski's study). The authors estimate a range of benefits from $3,543/ac/year - $17,178/ac/year (2013$).

Applying Grabowski et al.'s dollar benefits to the constructed oyster reefs in VSBRP, we find that annualized present value of N removal benefits through 2049 may range from $11,449 to $55,519/year when annualized over the same period. The TPV associated with these values is $268,058 -$1.30 million (Table 3-6).

Grabowski et al.'s (2013) removal values are based only on total ecosystem denitrification in oyster reefs relative to bare sediment, and exclude removals by phytoplankton consumption and by incorporation into oyster shell and tissue. Thus, because they do not include N removal from all possible pathways, values based on Grabowski et al. (2012) may be a lower bound in terms of actual removals. On the other hand, N sequestration is a relatively transient phenomenon, and permanent removal is dependent on the continued existence of self-sustaining reefs.

Economic Valuation of Commercially Valuable Fisheries Productivity at Oyster Reefs

Fin Fish

Peterson et al. (2003) synthesized data from studies of fisheries productivity of oyster reef habitat in the Southeast Atlantic Ocean, from Virginia to Texas. They found that one acre of restored reef provides over 1,000 kg of fish and large mobile crustaceans per year (mobile crustaceans include crabs, but not oysters). Grabowski & Peterson (2007) blended Peterson et al.'s species-specific changes in fish productivity due to development of oyster reef habitat with commercial fisheries market price data to estimate the economic value of oyster reef habitat. They estimated that one acre of restored oyster reefs provides $1,730 (2013$) in annual commercial fisheries value.[21]

Applying this per-acre benefit to the 22.1 acres of oyster reefs provided by the VSBRP over the restoration trajectory (Table 3-4) and at full benefits through 2049, we estimate restoration provides $34,113 in annual benefit to commercial fisheries based on reefs' per-acre commercial fisheries value ($1,730 in 2013 dollar year). The estimated TPV of these commercial fisheries benefits is $798,675.

Oysters

While the VSBRP reefs are currently designated as no-harvest areas, oyster reef restoration could provide economic benefits to commercial fishermen if sustainable harvests are allowed in the future. Predicting the timing, nature and likelihood of such a policy change is beyond the scope of this work, but prior studies have estimated the harvestable value of oysters at specific mid-Atlantic locations: Lenihan & Peterson (2004) report that sanctuary reefs in Virginia and South Carolina contained harvestable oysters worth an average of $130,932/acre (2013$). Once accounting for approximate harvesting costs, Grabowski et al. (2012) adjust Lenihan & Peterson's estimates

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[20] The authors do not display the converted removal rate in terms of units used in the valuation function (N/ac/yr.).

[21] Unit value in the text has been adjusted from the originally-reported value to 2013$ currency using the Consumer Price Index (CPI), and scaled from 10 m^2 to acres. Source: ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt

downwards, to $43,667/ acre. As Grabowski et al. (2012) caution, harvests using mechanical methods could rapidly and significantly decrease the density of harvestable oysters within a year following reinstated harvesting, thus reducing the economic value of commercial harvests for the reef and other services that depend on oyster reef assemblages.

Given the relatively low annual value of harvests from degraded reefs, coupled with the difficulty in predicting future policy scenarios and the uncertainty about how ecosystem dynamics may change if commercial harvests are allowed, we do not estimate the potential harvestable value of oysters in the VSBRP. As Grabowski et al. (2012, p. 906) comment, "…enhancing habitat purely to support a traditional oyster fishery with harvesting practices that result in degradation of the habitat is a poor use of public funds."

On the other hand, the restored reefs will, over time, produce oyster larva that, during their planktonic life stage, are likely to travel to, settle on, and potentially colonize different reefs. Thus, by maintaining the restored areas as sanctuaries, restoration partners believe the "sanctuary reefs are often a source of new oyster recruitment for reefs outside of the sanctuaries, supporting commercial fishermen and restoration of non-sanctuary reefs" (email from Renick Mayer to Uhlenbrock, February 2014). Unfortunately, these "seed bank" benefits cannot be quantified using available biological data, and are probably contingent on the availability of suitable attachment areas. Although we can only qualitatively describe the value of sanctuary reefs as larval seed banks, the ecosystem service should be noted as a direct benefit of this restoration investment.

Economic Valuation of Recreationally Valuable Fisheries Productivity at Oyster Reefs

Reflecting statewide trends, eastern shore visitors cite nature-based tourism and rural character as main features of tourist trips to the region. Seven percent of people who visited Virginia for leisure travel came principally to participate in outdoor recreation, and 15% of all visitors participated in outdoor recreation even if it was not their primary purpose of the trip (Virginia Tourism Corporation, 2013b). While only three percent of visitors specifically noted participating in nature travel/eco-touring, 2% went fresh or salt water fishing; 10% went to state or national parks; 4% viewed wildlife; 2% did bird watching, and 15% did rural sightseeing (Virginia Tourism Corporation, 2013b).

Combining Virginia's statewide tourism statistics with approximate visitor numbers, we apply benefit transfer to estimate total WTP for recreational fishing improvements in the Seaside Bays. To do so, we approximate the number of anglers, following these steps and assumptions:

- Eastern Shore's Tourism Corporation has estimated that 1.6 million people visit the Eastern Shore per year.
- Assuming Eastern Shore visitors participate in recreational fishing at the same rate as all Virginia visitors (2%), roughly 32,000 visitors may participate in saltwater fishing each year.
- The Eastern Shore region is a peninsula that contains fishing grounds on both Chesapeake Bay and on the seaside Bays of the Atlantic Ocean. Forty-nine percent of public access fishing sites on Virginia's Eastern Shore are on the Bay coastline (NOAA National Marine Fisheries Service, 2013). Further assuming that anglers visit the Seaside Bays in proportion to the number of recreational fishing points on

the Seaside coast relative to all access points, we estimate WTP of the 15,628 (49% of 32,000) visiting anglers who may benefit from improved fish stocks in Seaside Bays.

Hicks et al. (2004) developed a model of anglers' willingness-to-pay (WTP) via increased trip cost for fish population improvements following a hypothetical Chesapeake Bay oyster reef restoration project creating between 1,000 and 10,000 acres of artificial reefs. Hicks (2004) finds that for oyster reefs that both provide suitable fishing habitat by attracting existing fish, and increase baseline fishery stocks in the restoration area, anglers are WTP between $0.25 - $1.63 (2013$) for shore-based and private charter-based recreational fishing trips, respectively.

Assuming that visitation does not change from the assumed current 15,628 visitors per year as a result of oyster reef restoration, we estimate – very approximately – that the annualized recreational fishing benefits of improved fishery resources through year 2049 could range from $3,439 to $22,696. The TPV of these benefits through 2050 would range from $80,510 to $531,366.

Chesapeake Bay and Virginia's Eastern Shores are relatively similar in terms of geographic location, species compositions, angler demographics and travel costs. Abt Associates consulted with Dr. Hicks (Personal Communication - 2014) about the use of his estimates to approximate benefits of fisheries improvements in Virginia. Several methodological, study site, and recreational fisherman demographic characteristics caveat the benefit transfer (Appendix K), including differences in restoration effectiveness, angler knowledge about fishing sites, baseline catch rates, the availability of substitute fishing sites, and the type of species encountered.

Some of the caveats imply the benefits transfer generates lower-bound estimates and others imply it generates an upper bound. We cannot precisely determine the overall effect of these caveats, but on net, we believe Hicks' (2004) estimates provide a good ballpark estimate of WTP for increased catch rates in VSBRP. If anything, slight differences in substitute site availability and restoration effectiveness imply the transferred benefits may slightly under-estimate recreational fishing benefits of the oyster reef restoration in Virginia.

3.3 Eelgrass

3.3.a Eelgrass Restoration Introduction

The time for establishment of eelgrass meadows in restored areas is variable—it depends on several factors including the light availability, nutrient regimes, sediment availability and rate of accumulation, energy environment (e.g., wave action), and distance to other eelgrass beds (Orth, Moore, Marion, et al., 2012). In the case of the Virginia Seaside Bays, the shallow water depth, low nutrients, high light availability, and substrate composition provide excellent eelgrass habitat which appears to be underutilized, largely due to past historical conditions.

Rapid seedling establishment and expansion of eelgrass meadows through artificial reseeding has been demonstrated (McGlathery et al., 2011). Studies by McGlathery et al. (2011) compared eelgrass growth on a series of replicate seeded plots located within the Virginia Coast Reserve Long Term Ecological Research (LTER) site on the Eastern Shore of Virginia. These plots were initially seeded in 2001, 2006, 2007, and 2008 with eelgrass growth measured annually mid-summer in 2007 to 2010. This provides a collective 9 year chronosequence from year 0 (un-vegetated) to 9 years after seeding. There appears to be an initial 4 year lag in newly seeded meadows, after which shoot density expands linearly, continuing through the 6 to 9 year period after seeding (Figure 3-4).

3.3.b Eelgrass Restoration in Virginia Seaside Bays

The ARRA-funded VSBRP, which broke ground in 2009, builds on nearly a decade of preliminary efforts to restore eelgrass throughout the Seaside Bays region. In 1999, VIMS and VCZM began the highly successful program to re-introduce eelgrass in Virginia through dispersal of developed seedlings. For this process, reproductive shoots of eelgrass are collected from healthy sites in the spring, protected in tanks of circulating seawater over the summer, and then seeds from the cultivated plants scattered overboard in the fall. The VIMS/VCZM program has tested various seed dispersal configurations, which overall have been remarkably successful in the establishment and rapid expansion of restored eelgrass beds. These beds quickly become densely vegetated, not only by initial vegetative growth, but also by new plants germinated from these plants' seeds and reproductive shoots. Such natural recruitment processes are important for eelgrass bed persistence, especially after diebacks due to stressors such as high summertime temperatures, high turbidity (e.g., phytoplankton blooms) or storms (Orth & McGlathery, 2012).

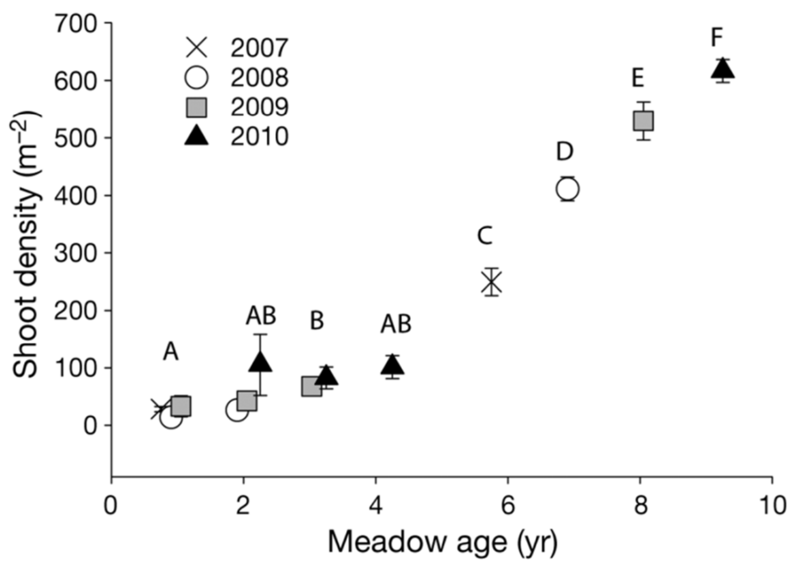

Figure 3-4. *Zostera marina* Shoot Density in Replicate 0.2 to 0.4 ha Plots of Eelgrass Meadows Restored by Seeding.

Note: Different letters indicate statistically significant differences between years.
Source: McGlathery et al. (2011).

The overall success of the reintroduction of eelgrass to Virginia's Seaside Bays has been notable. From 1999 through 2010, 37.8 million viable seeds were added to 369 individual plots totaling 309 acres (Orth et al., 2012). Vegetation monitoring and aerial photography indicated that seed dispersal from the restored plots to nearby un-vegetated areas resulted in an estimated 4,235 acres containing *Z. marina* by 2010 or approximately a 14-times increase in the original seeded area (Orth & McGlathery, 2012; Orth, Moore, Marion, et al., 2012). By 2013, the total eelgrass area has reportedly spread to almost 5,000 acres (Virginia Coastal Zone Management Program, 2013).

These improvements have potential to increase the ability of eelgrass to influence ecosystem goods and services from coastal ecosystems via eelgrass meadows' high primary productivity, alteration of hydrodynamics and consequently sediment characteristics, increasing habitat complexity for fauna, and influence on predator–prey dynamics (van der Heide, van Nes, van Katwijk, Olff, & Smolders, 2011). For example, McGlathery et al. (2011) showed that after 9 years, restored *Z. marina* meadows had 20-times greater rates of areal productivity than 1 to 3 year old meadows, double the organic matter and exchangeable ammonium concentrations, 3-times more carbon and 4-times more nitrogen, and had accumulated and retained finer particles than bare, un-vegetated sediments. Moreover, none of the parameters monitored appeared to be leveling off after 9 years, suggesting that maximal restoration of these ecosystem functions may require additional time.

For the VSBRP described below, we combine measures of vegetative coverage and areal extent to both quantify restoration progress at the site and to approximate the level of ecosystem services provided by restored eelgrass beds over time.

VSBRP Eelgrass Habitat Restoration Trajectories – Establishment, Expansion and Coverage

During fall of 2009-2011, eelgrass seedlings were hand broadcast from a boat into pre-determined un-vegetated plots in Cobb and Spider Crab bays, which are located in the central portion of Virginia's seaside bays (Figure 3-5). To estimate the area and quality of habitat restored as a result of this activity, Abt considered (a) the period of time necessary from seedling development to densely vegetated eelgrass beds with full ecological function and (b) the expansion/colonization of new areas due to seed production and rhizome elongation spreading out from original seeded plots.

For the vegetation density development period, Abt Associates assumed an initial lag period (years 0-4) with a low value of habitat area (10%), indicative of a period of seedling consolidation and low levels of vegetation growth (McGlathery, et al., 2011). We assumed increased vegetation density over 4 year increments with 50% density in years 5-8 and 75% density in years 9-12, and full vegetative density within the originally seeded area obtained at 12 years. We assume that density is maximized or in steady-state after year 12 and does not change over time, although there is always a finite possibility of disturbance by catastrophic storm events.

Independent of development in the original seeded area, Abt Associates assumed eelgrass will expand into new areas over a 24 year period. We assumed an expansion increase resulting in an 8-time expansion of area over 15 years. While this is less than the data of Orth et al. (2012), who showed a 14-fold expansion of area over 9 years it is more likely to reflect long-term rates of natural expansion (rhizome elongation and seed dispersal (Appendix J). The high rates of increase reported by Orth et al. (2012) during the early years of bed development are unlikely to be sustainable over the long-term. This can be seen in the declining rate of increase of eelgrass expansion at VSB between 2010 and 2013, suggesting decreased growth as eelgrass beds mature and/or spatially overlap and other environmental limitations (substrate, adjacent patch growth, nutrient availability) become more important. Appendix J provides further discussion on growth rates and comparison to other eelgrass restoration trajectories.

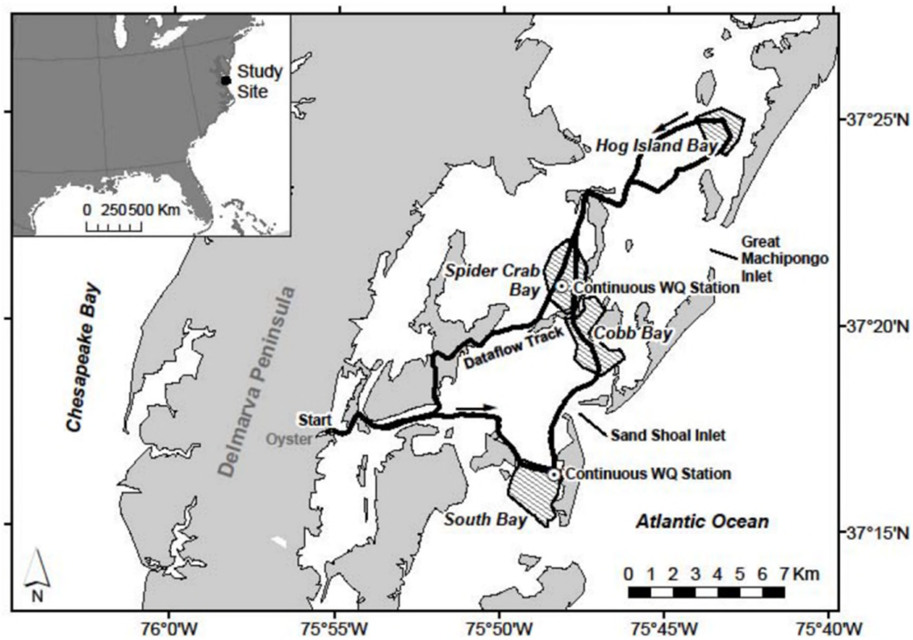

Figure 3-5. VSBRP Eelgrass Seeding and Scallop Reintroduction Sites in the Lower Virginia Seaside Bays.

Notes: The hatched polygons represent eelgrass seed distribution regions. Source: Orth et al. (2012)

We combined vegetation density increase and spatial expansion factors in Table 3-5, which shows the expected eelgrass habitat area in the VSB in subsequent years. The first row indicates the vegetative development of the initially-seeded 133 acres with full habitat development by year 12. The succeeding rows represent new eelgrass created by rhizome elongation and seed production ("colonization"). The rate of habitat expansion is assumed to be variable and site-specific. We used a simple approximate step-function model that assumes an initial 4-year lag period between initial colonization in a new area and significant vegetation density expansion using a long-term annual cover increase of 15% per year, based on VSB rates and patterns of natural restoration occurring in Chincoteague Bay and Tampa Bay (Greening & Janicki, 2006; Orth, Marion, Moore, & Wilcox, 2010). After 4 years, we assumed vegetative density in these newly-colonized areas increases following the same vegetative developmental model as described above. At year 8, another newly colonized patch starts to develop, and so forth. At the end of a 24 year period, eelgrass has migrated to an estimated 3,705 acres; however, fully vegetated areas are estimated at 1,703 acres.

Table 3-5. Estimated Expansion of Seeded Eelgrass Restoration Area Over Time.

Name	Total Area (ac)	Colonized Area (ac)	Year 0	Year 4	Year 8	Year 12	Year 16	Year 20	Year 24
Original plots	133.0	133.0	13.3	66.5	99.8	133.0	133.0	133.0	133.0
Years 0 - 4	231.6	98.6		9.9	49.3	73.9	98.6	98.6	98.6
Years 5 - 8	403.2	171.6			17.2	85.8	128.7	171.6	171.6
Years 9 - 12	702.0	298.8				29.9	149.4	224.1	298.8
Years 13 - 16	1,222.2	520.2					52.0	260.1	390.2
Years 16 - 20	2,128.0	905.8						90.6	452.9
Years 21 - 24	3,705.1	1,577.1							157.7
Total acres restored:			**13.3**	**76.4**	**166.2**	**322.6**	**561.7**	**978.0**	**1,702.8**

Note: Estimates based on assumed 15% annual yearly increase of acreage or until newly-colonized area is completely filled in.

3.3.c Economic Benefits of Eelgrass Restoration

Relative to bare sediment that had existed in the area since mid-1900, restored eelgrass beds at VSBRP will provide several ecosystem services (Table 4-2). Services include a richer habitat for native fish and shellfish species, including scallops and crabs; stabilization of coastal sediment; and overall enhancements to biodiversity and healthy coastal ecosystem functioning. Restored eelgrass bed benefits will accrue both on-site (e.g., shellfish harvests from the beds), while others are likely to accrue off-site (e.g., fish using eelgrass habitat may be landed in surrounding areas).

Benefit Estimation Assumptions

We followed the estimation assumptions outlined in Appendix A, with the following habitat-specific considerations:

- **Scaled Value Estimates.** We valued annual eelgrass services provided each year during the restoration process by scaling total value estimates (e.g., WTP) in proportion to the percentage of total habitat acreage restored to date (Table 3-5).

- **Functional Lifetime.** Eelgrass meadows function much like prairies or salt marshes, in that they persist over long periods of time, but punctuated by ecosystem patch dynamics. Thus, estimating bounds of a “functional lifetime” for a broad area of eelgrass habitat is a challenging and limiting way of describing the ecosystem and associated goods and services. As previously noted, we chose a 40-year benefit period for all projects because it is far enough in the future to serve as the basis for long-term benefits estimation yet is not so far in the future that uncertainty in benefits is likely to grow uncomfortably large relative to estimated annual benefits.

- **Natural Expansion.** Healthy eelgrass meadows have potential to continue expanding over time (to the natural limits of growth and habitat availability) through natural seed dispersal to new areas. We include in our benefits assessment some of this natural expansion from the ARRA-funded seeding of 133 acres, but have bounded ecosystem expansions in the valuation exercise such that, in our best professional judgment, we are valuing services from beds that are closely creditable to ARRA investment.

Economic Values for Restored Eelgrass Beds – Total Value per Acre

Household's Willingness to Pay for Eelgrass Restoration

While eelgrass provides a diversity of ecosystem goods and services, there have been few studies of household WTP for changes in eelgrass area and quality, or of changes in similar species of SAV (Barbier, et al., 2011). We use results from a study of eelgrass value in the Peconic Estuary (Johnston, et al., 2002; Mazzotta, 1996) to estimate a monetary value of improved eelgrass coverage in Virginia seaside bays. We selected Johnston et al.'s study because it estimates values for eelgrass (same type of SAV as is being restored in Virginia) and because aquatic species found in the eelgrass meadows in Virginia and New York are likely to be similar[22] as well.

Johnston et al. (2002)[23] present an original valuation function estimating New York residents' WTP for, and preferences about, different types of coastal habitat restoration in the Peconic Estuary system (PES). The valuation function is estimated based on results of a survey that provided background information on eelgrass in the PES, generally described eelgrass including its function as habitat for fish and shellfish species, and estimated WTP for the area of eelgrass restored or protected from further degradation. Thus, values from Johnston et al. (2002) provide a good match to the Virginia seaside Bay scenario and enable us to estimate the total value of restored eelgrass, including its existence value and its habitat value to human uses of fish and shellfish species. The authors estimated households are WTP an average of $0.12/acre/year for eelgrass restoration in the PES area; we did not adjust this value for fully-restored habitat Virginia Seaside Bays. However, in years before full restoration was achieved in VSBRP, we used a pro-rated measure of household WTP based on the percentage of established eelgrass habitat to date.

Benefitting Households

Households both nearby and distant from the seaside bays may have use and non-use values for ecosystem services provided by restored eelgrass meadows. Data on the number of households that use (i.e., view, recreate in, fish in, etc.) and do not use, but value these habitats (i.e., valuing the eelgrass purely because it exists) was unavailable. Johnston et al.'s original valuation function estimated WTP of year-round and seasonal residents in the five towns surrounding the Peconic Estuary. In keeping with this scope, we applied per-household benefits to the 20,793 households living in the two counties of Virginia's Eastern Shore (Accomack and Northampton Counties; US Census 2011 American Community Survey, 5-year estimates).

Total Estimated Values

We estimate that the total nonmarket value of 1,702 ac of ARRA-funded eelgrass restoration in Virginia's Seaside Bays is between $2.58 million and $3.51 million per year when annualized over the 40 years between restoration initiation (2009) and 2049 (Table 3-6). This period includes 24 years of restoration, in which eelgrass area is both

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[22] NOAA's Mid-Atlantic Regional Fishery Management Council includes coastal waters of both Long Island and Virginia. Source: http://www.nmfs.noaa.gov/sfa/management/councils/

[23] Based on Mazzotta's (1996) dissertation. Mazzotta (1996) provides full details on the survey.

expanding in extent and growing in vegetative cover within established areas (Table 3-5[24]). The TPV of these benefits is $60.34 million to $82.20 million.

Table 3-6. Total Economic Value of ARRA-Funded Eelgrass Restoration (2013$).

Estimate	Household WTP per Acre per Year	Annualized Benefit Value	TPV
Lower 95% CI	$0.11 ($180)	$2,577,182	$60,338,014
Average	$0.13 ($230)	$3,062,738	$71,706,046
Upper 95% CI	$0.14 ($245)	$3,510,943	$82,199,613

Notes: Values based on Johnston et al. (2002) and Mazzotta (1996). Pre-restoration values assumed to be zero, since eelgrass had not existed in the area for over 50 years prior to restoration activity. Future benefits are annualized over a 40-year period using a 3% discount rate.
Source: Abt Associates benefit transfer analysis (2013).

Habitat Productivity

Virginia's eelgrass beds were historically abundant, providing excellent habitat and food sources for a variety of marine and estuarine species, including birds, shellfish (bay scallops, crabs, shrimp, seahorses), and fish (e.g., pipefish, sticklebacks, anchovies, silversides) (Virginia Department of Environmental Quality, 2013). Restoration of healthy eelgrass habitats may once again restore these fishery and wildlife species, with potential for rather large economic returns. Anderson (1989) and Kahn & Kemp (1985) studied the economic value of statewide restoration of eelgrass beds to commercial landings of blue crab and striped bass, respectively. Anderson (1989) suggested fully restoring all of Virginia's eelgrass beds[25] could increase national blue crab consumer surplus by $2.4 million (1987 currency), and Kahn & Kemp (1985) estimated a 50% increase in Chesapeake Bay SAV area (including eelgrass) could produce a rough benefit of $5 million (1985 currency) to striped bass producers and consumers.

The VSBRP constitutes a much smaller restoration program than the aforementioned models, but is still expected to provide substantial fishery benefits to producers and consumers. We valued the potential total per-acre value of habitat restoration to a general assemblage of species which are likely to use the restored areas, following Johnston et al. (2002)'s habitat productivity model.

[24] Note that the referenced table suggests eelgrass coverage will continue to expand beyond 1,702 acres which we value in this report. However, as eelgrass expansion continues; direct ecological links to ARRA-funded investments become thin.

[25] Anderson (1989) reports that total acreage in the Virginia part of the bay was 5,750 ac in 1964.

Johnston et al. (2002):

- Estimated the average per-acre value of restoring Peconic Estuary (Long Island, NY) eelgrass habitat for species that preferentially use or depend on the habitat and are valued for human uses, including the abundance of wading birds and the expected yield bay scallops and blue crabs.
- Based the benefits from changes in these populations on the end value of each species or type/group of animal: bird values are based on recreational hunting and viewing, and specific fish and shellfish species values are based on commercial landings data.
- Summed all food web and habitat values for a single year and estimated a marginal annual value of healthy eelgrass habitat at $1,627/acre (2013$).

Abt Associates applied this per-acre point estimate to the total expected acreage of eelgrass habitat at VSBRP, assuming habitat productivity values persist through 2050 after reaching 100% ecosystem function at the end of the restoration trajectory. Annualized over the restoration time frame and through year 2050, we estimate the yearly habitat productivity value to fish, birds, scallops and crabs is $1.41 million, and the TPV is $32.95 million (Table 4-6). Given the high degree of overlap across services included in TPV estimates of eelgrass habitat productivity and TPV based on WTP, benefits estimates in this section are recommended as an *alternative* estimate, and not an additive estimate.

Coastal Protection

Eelgrass beds reduce flow velocities and it has been shown for a variety of eelgrass species that submerged eelgrass vegetation can significantly attenuate waves (Fonseca & Cahalan, 1992; Koch & Gust, 1999; Paul, Bouma, & Amos, 2011). This wave attenuation is due to a combination of the resistance of the benthic leaf canopy as well as the network of sediment-stabilizing root rhizomes, such that even sparsely vegetated (or heavily grazed) eelgrass beds can promote coastal protection. The presence of a sizeable eelgrass meadow maintains a shallower bed level, attenuating waves before they reach the beach and hence lowering beach erosion rates (Christianen et al., 2013). In the context of VSBRP, restored eelgrass beds in shallow embayments buffer coastal beach erosion and significantly reduce wave height and energy, potentially reducing storm damage to shoreline structures and conserving natural protective features. As the areal extent of the eelgrass meadows rapidly expand, the coastal protection service should also increase. Note, however, that eelgrass meadows are placed in between coastal homes and eastern barrier islands. In the context of barrier islands, eelgrass meadows may provide relatively marginal changes in coastal erosion.

While existing studies suggest restoring local eelgrass beds improves coastal protection (Christianen, et al., 2013), available data are not sufficient to quantitatively model the restoration's expected changes in wave height, coastal erosion, or other coastal processes that affect households living on Virginia's eastern shore and seaside bays. Boudreau (2012) reviews recent valuation literature for beach width protection on the Atlantic coastline, and finds positive WTP for measures that reduce beach erosion or preserve existing beaches and coastal areas (Table 3-7). Two studies are appropriate for estimating the value of improved coastal protection in the seaside bay restoration context:

- **Landry et al. (2003)** estimate coastal household WTP for coastal erosion endpoints at nearby beaches that may change as a result of VSBRP, including beach width, and
- **Huang et al. (2007)** examine regional residents' WTP for hypothetical erosion control programs that preserve beach attributes.

As a very approximate estimate of localized benefits from wave attenuation and buffered erosion, we applied per-household benefits from Landry et al. (2003) to the 6,873 households in Census block groups on the Seaside Bay coast of Northampton and Accomack Counties, VA (US Census ACS 2010 5-year estimates). We applied per-household benefits from Huang et al. (2007) to the 19,121 households in Northampton and Accomack Counties

Landry et al. (2003) estimated benefits to the sales price of a home. We converted the aggregate housing benefits to annual rental-equivalent housing benefits. These rental-equivalent values represent a typical homeowner's WTP for the flow of amenities (of all types) from living in that house for a single year. Because the price of a house represents the sum of the present discounted value of the flow of amenities from living in that house in all future periods (Abelson & Markandya, 1985; Diewert, Nakamura, & Nakamura, 2009; Dougherty & Van Order, 1982; Meese & Wallace, 1994), we calculated annual rental-equivalent housing values by multiplying the housing value benefits of reduced coastal erosion by the 3% discount rate.

Annual benefits based on each study (units of change in erosion metrics multiplied by reported marginal values) were pro-rated each year during the restoration trajectory in proportion to percentage of eelgrass habitat restoration completed. Estimating benefits accrued through 2049, we estimate annualized rental benefits of improved coastal protection from $36,216/year to $137,638/year, and TPV from $847,902 to $3.22 million.

Table 3-7. Coastal Protection Benefits of Eelgrass Enhancement (2013$).

Characteristic	Landry, Keeler, and Kriesel (2003)	Huang, Poor & Zhao (2007)[1]
Site	Tybee Island, a barrier island on the mouth of the Savannah River (GA)	Ocean sand beaches in Maine and New Hampshire
Households Considered	Residents on Tybee Island	Residents in Maine and New Hampshire; 37% of respondents lived in coastal counties
Original Model Type	Hedonic property value model of change in home price as a function of nearby erosion and sand beach characteristics.	Stated preference model of annual WTP for erosion control program to preserve a stretch of sand beach.
Coastal protection measures included in the original study	• Low tide beach width at nearest shore (b=0.0017) • Dummy variable for erosion high hazard zone • Dummy variable for erosion protection structures at nearest shore • Dummy variables for ocean-, marsh- and inlet-front location.	• Miles of sand beach preservation • Property value protection ($) • Presence of visible control structures on beaches • Recreational injury and restrictions at site • Wildlife disturbance • Deleterious effects of control structures
Endpoints potentially affected by eelgrass restoration at VSBRP	Low tide beach width at nearest shore	• Miles of sand beach preservation • Property value protection ($)
Marginal Value, as Originally Estimated	$346/property sale price per meter of beach width	$2.62/household/year per mile of beach preserved, in increased license plate fees
Annual Benefit	$10.38/property/year for preserving 1 m of beach width	$10.48/household/year for protecting 4 miles of beach
Benefitting Households	6,873 households in Seaside Bay-side Census Tracts of VA	19,121 households in Seaside Bay counties of VA
Total Annualized Value	$36,216	$137,638
TPV	$847,902	$3,222,432

Notes: (1) As cited in Barbier et al. (2011) and Boudreau (2012). Total annualized value is computed over the 40 years between 2009 and 2049. All values have been converted to 2013$.

3.4 Bay Scallops

3.4.a Ecological Assessment of Bay Scallop Fishery Reintroduction Program

A portion of the ARRA funds were allotted to research and development of methods to re-introduce the bay scallop back to the VSB. The ultimate goal of the bay scallop restoration is to establish a self-sustaining, wild meta-population distributed among numerous restored eelgrass beds in the VSB (Orth & McGlathery, 2012).

The proposed scallop restoration strategy is to maintain spawning stocks from hatchery-produced cohorts in cages within target eelgrass beds. The use of caged brood stock (plastic mesh bags) was selected to maximize survival, especially during the summer months when predation rates are high, and fertilization efficiency, by maintaining spawning animals in close proximity to one another.

During the period covered by the ARRA award, two generations of bay scallops were maintained within a field nursery system and used as brood stock for hatchery spawns to produce offspring for deploying in the eelgrass beds in South Bay and Cobb Bay (Orth, Moore, Lukenbach, et al., 2012). Approximately 15,000 scallops were released into the eelgrass beds in 2011. Scallops maintained in the project area become mature in 2 years. There are no plans for scallop harvesting because they are intended for use in cohort survivorship studies and in development of best practices for scallop reintroduction and reseeding.

Diver surveys were conducted in 2011 to provide preliminary estimates of the range of scallop abundance within the grass bed where brood stock scallops were placed. While this early survey suggested some increases in wild scallop populations, no definitive conclusions could be made regarding the success of this strategy and the investigation is continuing (Orth, Moore, Lukenbach, et al., 2012).

3.4.b Economic Value of Bay Scallop Fishery

Between 1920 and 1932, annual bay scallop harvests from eelgrass beds on Virginia's eastern shore ranged from 19,000 – 300,000 bushels per year, and may have supported 200-300 fishing boats during this time (MacKenzie, 2008). If restored to historical levels, bay scallops could provide commercial fishing revenues not seen since the 1930's. However, given the current ecological uncertainty about relative success of bay scallop reintroduction, we have not independently monetized benefits to commercial scallop fisheries. The value of scallop habitat is included in estimates of total values for eelgrass bed restoration. The structure of the benefit transfer function prevents us from estimating the fraction of the value of eelgrass habitat benefits due to scallops.

3.5 Recreational Investments

In 2011, tourism generated $20.4 billion in visitor spending in Virginia; supported 207,000 jobs; and provided $1.32 billion in state and local taxes for Virginia's communities (Virginia Tourism Corporation, 2013a). Much like the statewide case, tourism was an historically important economic sector on Virginia's seaside bay region (Virginia Coastal Zone Management Program, 2010). The Virginia Tourism Corporation estimates 2,635 people are employed in the tourism sector in Accomack and Northampton Counties, the two Seaside Bays counties. Further, they estimate that, in 2012, tourists to these two counties spent over $232 million in direct expenditures

(Virginia Tourism Corporation, 2013c). Further, it has been estimated that 1.6 million people visit the Eastern Shore each year (Eastern Shore of Virginia Tourism, n.d.).

Figure 3-6. Shorebird on the Virginia Seaside Bays Coastline.

Source: Virginia Tourism Corporation/C. Davidson.

Restoring oyster reefs, eelgrass beds, and scallop populations are likely to increase recreational use values for Virginia's Seaside Bay region. While NOAA-ARRA funds at this site were used exclusively for ecological restoration activities, improving the extent and quality of the two habitat types and many associated species may jointly enhance recreational opportunities throughout the region, including fishing, shell fishing, bird-watching opportunities, and aesthetics. Oyster reefs are closed to direct harvesting, but both reefs and eelgrass may indirectly support recreational fishing throughout the seaside bays area by providing spawning areas and nursery habitat for juvenile fish. Furthermore, increased abundances of fish and shellfish will attract water bird and wading populations (Figure 3-6), which can be viewed from shore or by watercraft.

While NOAA-ARRA funds were not applied to recreational infrastructure improvements, the broader restoration effort led by the Virginia CZM's "Seaside Heritage Program" has included some improvements and investments in user experience of the bays (Virginia Coastal Zone Management Program, 2010). These improvements may also attract new visitors or increase visitors' enjoyment of coastal ecosystems. The larger restoration efforts include:

- **Recreational Use Improvements.** Improving signage at access points, constructing floating docks, and providing other visitor resources on the 100-mile-long Virginia Seaside Water Trail, which is a series of day-use paddling routes. Portions of the trail pass through sites improved during VSBRP. While no quantitative visitor use data is collected systematically, anecdotal evidence from resource management officials and local tour guides indicates that water trail use has increased after installation of the recreational improvements (personal communication, Laura McKay).

- **Ecotourism Training Programs.** Investing in ecotourism and sustainable tourism education programs at local community colleges. The ecotourism certification course is designed to, "provide safe, responsible, and environmentally sound guidelines to encourage more responsible kayak and boating tours on the Eastern Shore and other Virginia coastlines (Virginia Coastal Zone Management Program, 2010, p. 8). Nineteen participants passed the course in its inaugural year (2003). Since then, VA CZM has supported additional programs each year, providing job training to local residents. Economic impacts to the overall community, or to individual participants, have not been documented; however, the program has potential to increase job opportunities in ecotourism, to improve visitor experiences, and to preserve the Seaside Bays tourism experience for future generations.

3.6 Environmental Justice Analysis

All populations living in the communities surrounding the VSBRP are expected to benefit from the ecological improvements enumerated in preceding sections of this chapter. Section 2.7 (above) outlines rationale for considering ways in which coastal restoration benefits are distributed across minority racial and economic groups. Environmental justice (EJ) considerations provide important context for benefits from the VSBRP. While the Eastern Shore historically supported rich coastal resources and rural character, the overall economic and social conditions of the region's many rural, poor residents were in decline by the early 2000's (Flint, McCarter, & Bonniwell, 2000).Traditional fishing, shell fishing and farming livelihoods have declined in profitability and prevalence as the region has urbanized (Flint & Danner, 2001)

Not surprisingly, eastern shore residents consider sustainable use of restored healthy ecological resources as a key for regional economic development (Potter, Provo, Atasoy, Howard, & Anders, 2007). Restoration and associated investments in nature- based tourism may open new economic opportunities for economically-disadvantaged groups (Flint & Danner, 2001). These benefits may become an "environmental justice" (EJ) benefit if the relative degree of equity across potentially-affected subsets of the population *disproportionately* consist of low-income, minority, or other historically-marginalized individuals. Activities like coastal restoration could be designed to purposefully ameliorate existing EJ concerns or actively seek to even out historically-disproportionate benefit/cost distributions. This section summarizes Abt Associates' qualitative and quantitative assessment of the potential distributional impacts of the VSBRP. Our qualitative analysis follows statistical comparisons similar to those used in Environmental Justice screening analyses (U.S. EPA, 2013b).

People of the Eastern Shore have long relied on agriculture, forestry, and fishing for their economic livelihoods (reviewed in Flint & Danner, 2001). While improving coastal habitats improves the basis for nature-based tourism industries, surveys in the 1990's suggested that local perceptions about benefits diverged across racial groups, such that "African Americans were less likely than Whites to view aquaculture and tourism as representing significant economic gains..." (Flint & Danner, 2001).

3.6.a Analysis

Qualitative Assessment

We first qualitatively assessed the extent to which habitat improvements from restoring oyster reefs and eelgrass beds could benefit low-income, minority and other EJ communities in the Seaside Bay region. Table 3-8 summarizes factors that may affect how benefits are distributed between subgroups and whether benefits may be disproportionately distributed to subgroups within affected areas.

Table 3-8. Qualitative Screening for EJ Effects of VSBRP.

Ecosystem Change/ Economic Benefit	Potential EJ Consideration
Increased habitat supporting commercially-valuable fisheries	• Oyster reefs are not designed for shellfish harvesting, but reefs and eelgrass beds support fin fisheries throughout the region. • 73% of Eastern Shore businesses are self-employed individuals, and over 99% are small businesses with less than100 employees. 18% of self-employed Eastern Shore residents work in the forestry, fishing, or hunting industries. Combined, these figures from Potter et al. (2007) suggest small fishing business could gain from even marginal improvements in local fish stocks.
Increased habitat supporting non-commercial fisheries	• Some minority and low-income groups rely disproportionately on subsistence fishing as a source of food. These groups are particularly likely to benefit from increased numbers of fish (i.e., catch rates), and improved access to those fish and shellfish.
Change in coastal erosion for waterfront homes	• Economic and housing conditions on the eastern shore range from historic and stately to "deplorable," with one out of every eight households lacking indoor plumbing (Bernard & Young, 1997). • Low-income households are less likely to have residential hazard insurance than higher-income households. Without insurance to recover erosion-related losses, a low-income household would benefit from coastal erosion reduction more than higher-income household.
Increased recreational opportunity	• If there is a disparity between EJ and non-EJ communities in the recreational value placed on oyster reefs and eelgrass beds, benefits may be disproportionately distributed to the subgroup that values the resource more highly.
Increased economic opportunity: tourism and other industries	• While not funded by ARRA, VSBRP project partner VA CZM helps support Virginia's first eco-tourism training program at local community colleges.

Quantitative Assessment

Because our qualitative review suggested VSBRP activities are likely to provide services that are valued differently by EJ communities and the general population, we quantitatively assessed whether affected communities actually include EJ groups. The purpose of this analysis was to determine whether low-income individuals or minority individuals are more or less present in the affected areas than in the general population.

We first conducted a screening analysis for EJ communities, examining the prevalence of low-income households, and of minority racial groups in surrounding counties that may constitute year-round resource users who live relatively close to the Bay. We limited the scope of our analysis to the two Virginia counties on the Delmarva peninsula – Accomack and Northampton Counties – to account for groups that, in the past, have borne a greater share of coastal erosion risk, economic dependence on the Seaside Bays as direct (e.g., commercial fishing) and indirect sources of income (e.g., tourism, which depends on quality environmental resources). Detailed EJ assessment methods are presented in Appendix C.

Table 4-5 summarizes results of the statistical analysis. Consistent with previous studies' qualitative discussions about communities on the Eastern Shore (Potter, et al., 2007), we find that average household income in Census block groups are lower than Virginia state-wide averages, more households live below the poverty line, and that a larger proportion of residents are non-white. Overall, the EJ index constructed from these components suggests EJ communities are more prevalent in the area surrounding the South Bay, although we detect significant differences only for Accomack County.

A higher EJ index implies that low-income and minority populations are relatively more-prevalent in the communities surrounding the restoration site. This implies restoration may distribute benefits *towards* EJ communities to some extent. Restoration in an area characterized by low socioeconomic status and relatively low connectivity to surrounding major metropolitan areas is an environmental justice benefit. For example, while the eastern shore is connected to mainland Virginia via the Chesapeake Bay tunnel, $10 tolls present a high cost for low-income residents who wish to travel off-peninsula for work or recreation. By providing restoration-related benefits (e.g., restoring ecosystems improves local fisheries and improves nature tourism opportunities) in an economically-depressed area, VSBRP helps improve overall community sustainability.

Table 3-9. Quantitative EJ Screening of VSBRP.

	Virginia	Accomack County	Northampton County
Total Population Estimates			
Population	7,841,754	34,066	12,572
Households	3,056,058	13,798	5,323
Population-Weighted Averages			
Median Household Income (2013$)	$71,498	$40,986*	$36,472*
Percent Poverty	10.5%	15.5%	18.8%
Percent Minority	35.0%	39.1%	45.7%
EJ Index (%Poverty * %Minority)	4.4%	6.3%*	9.1%

Notes: * denotes a statistically-significant difference between the county-level population-weighted average and the state –level average (two-tailed paired t-test, p <0.05). Source: U.S. Census, 2013.

3.7 Summary

3.7.a Ecological Summary

Our review of the design and trajectory of ARRA-funded oyster reef and eelgrass restoration and activities at VSBRP restoration sites and available data indicates that:

- 22.1 acres of oyster reef habitat were created, contributing to off-site oyster harvests, on-site reef habitat for many other invertebrates and finfish, and associated ecological services. On-site oyster harvests are not permitted.
- 133 acres of bare sediment were seeded with eelgrass seed, providing on-site habitats for fish and shellfish, coastal erosion mitigation, and other services. Available literature suggests seeded areas have the potential over the next 24 years to develop into over 1,703 acres of eelgrass meadows.
- 15,000 bay scallops were placed on spawning brood stock as a preliminary investigation of a new method to increase wild bay scallop stocks.

3.7.b Total Estimated Economic Value Summary

We estimated total economic values for the Virginia Seaside Bays project, including market values for commercial fin-fish production, and non-market values for a variety of other ecosystem goods and services (e.g., recreational fishing, flood risk reductions). We modeled the estimated oyster reef benefits from this project from 2009 through 2049, and estimate annualized values over the period span from $49,133 to $112,460 per year (Table 4-6). Estimated eelgrass benefits over the same time frame are expected to provide annualized benefits ranging from $1.46 million to $3.51 million per year (Table 4-6). The total annualized value of both oyster reef and eelgrass benefits ranges from $1.45 to $3.51 million. Our analyses suggest the TPV of the overall project may range from $34.92 to $84.80 million.

Table 3-10. Summary of Estimated Oyster Reef and Eelgrass Restoration Benefits at VSBRP (2013$).

Benefit Category	Annualized Value	TPV	Notes on Additivity
Oyster Reef Restoration			
Carbon Sequestration	$132	$4,392	One component of total value
Nitrogen Sequestration	$11,449 - $55,519	$268,058 - $1.30 million	One component of total value
Commercial Fin -Fisheries	$34,113	$798,675	One component of total value
Commercial Oyster Fishery	Unknown		
Recreational Fin-Fisheries	$3,439 -$22,696	$80,510 -$531,366	One component of total value
Total Oyster Benefit Estimate	$49,133 – $112,460	$1,121,635 – $2,634,433	
Eelgrass Restoration			
Total Value of Eelgrass Restoration (WTP)	$2,577,182 - $3,510,943	$60,338,014 - $82,199,613	Incorporates a mix of use and non-use values (existence value, crab, scallop and fin fish, waterfowl)
Habitat Provision	$1,407,432	$32,951,354	Overlaps with total WTP for eelgrass restoration
Coastal Erosion Mitigation	$36,216 -$137,638	$847,902 - $3,222,432	Overlaps with total WTP for eelgrass restoration.
Bird Watching	Not monetized independently		
Other Recreation	Not monetized independently		
Total Eelgrass Benefit Estimate	$1,446,216 - $3,510,000	$33,797,902 - $82,200,000	Range of total values based on *either* or the sum of habitat provision plus erosion mitigation or total WTP.
Bay Scallop Re-Introduction			
Bay Scallop Fishery	Not monetized independently		Outcomes of the reintroduction program are currently uncertain, but existing eelgrass beds may also provide habitat for sea scallops; these values are included in the eelgrass benefits.
Total Economic Value of Oyster Reef Restoration, Eelgrass Restoration, and Bay Scallop Reintroduction			
Total Economic Value	$1,495,349-$3,622,460	$34,949,537-$84,834,433	

4 Coastal Alabama

4.1 Introduction

Mobile Bay, part of Alabama's Gulf Coast shoreline, is an estuary of national significance. It supports a diversity of nationally-important bird, fish, and wildlife species, and provide Fish and Wildlife Service-designated critical habitat areas for the piping plover (Mobile Bay National Estuary Program, 2008). However, changes in sedimentation patterns and salinity and increased use of shoreline armoring have altered wildlife habitats, exacerbated shoreline erosion, and reduced the Bay's "… ability to withstand and recover from unusual wave stresses like those that occur during tropical storms and hurricanes" (Mobile Bay National Estuary Program, 2008).

4.1.a NOAA ARRA Funding

In July 2009, the Nature Conservancy (TNC) received a $2,931,446, two year grant from the ARRA through NOAA to restore oyster habitat and create protective breakwaters under the Coastal Alabama Economic Recovery and Ecological Restoration Project (i.e., "Alabama Coastal Restoration" project (ACR)). The goal of this project was to create a vertical oyster reef breakwater to provide shoreline stabilization/restoration along several stretches of shoreline within Mobile Bay, Alabama (Appendix L). The project lasted from July 2009 through March 2011, with team partners including the Dauphin Island Sea Lab (DISL) of the University of South Alabama, the Alabama Department of Conservation and Natural Resources, and the Alabama State Lands Division (ADCNR). Although not an official partner on the NOAA-ARRA award, The National Wildlife Federation also contributed to a volunteer project partially funded by ARRA (materials and partial labor costs).

Through the installation of oyster reef breakwaters, this project was intended to enhance the ecological health and resiliency of Mobile Bay marine habitats. The habitat protection and restoration were designed to support several long-term objectives including stabilization and restoration of eroding shorelines, the restoration of oysters and associated ecological benefits and the long-term creation of fishery related jobs for south Mobile County. The oyster reef breakwaters also provide long term goods and services by improving water quality, improving recreational fishing and increasing and sustaining benefits to local ecotourism (Box 5).

Box 5. Coastal Alabama (Mobile Bay) Restoration Benefits Summary

- Added 3.4 ac of living shoreline, providing oyster, fish, and mobile crustacean habitat, protecting 1.6 miles of coastline, and protecting 31 ac of potential SAV habitat
- Provides an estimated $9,000 to $15,000 annually in ecosystem service benefits
- Helps sustain traditional livelihoods of minority fishery workers, contributes to a growing restoration economy, adds new knowledge capital, and helps to improve overall community resilience
- Highlights the need for longer-term restoration monitoring funding

Table 4-1 briefly describes ecological resources of interest for the ACR sites and activities, along with the expected effects of restoration on these resources (i.e., conditions pre- vs. post-restoration). Restoration activities focused on two habitats – oyster reefs and protection of submerged aquatic vegetation (SAV) and adjacent coastal wetlands – that have critical roles in the Bay ecosystem's habitat structure and function.

The project used five different substrate or structures upon which oyster spat could settle and develop, including bagged oyster shells, ReefBLK® units, two types of pre-cast concrete Reef Balls® (Mini-Bay Ball, Lo-Pro Ball), and HESCO Barriers of oyster shell or gabion rock. The reef balls are pre-cast concrete pots with multiple openings to provide fish refuges along with a hard substrate for oyster attachment. ReefBLK units are constructed in zig-zag triangular units with rebar iron and contain bagged oysters in the interstices (Figure 4-2). The mesh covering the bagged oyster shell helped to maintain a desired 2.5-foot vertical relief for the breakwaters until adequate recruitment of sprat and oysters cemented the loose shell into place. The Reef Balls and ReefBLK units are each about 1.6 – 2 feet tall (DeQuattro, 2014; pers. comm.). An important research objective of the ACR was comparing the effectiveness of these different base materials in oyster reef restoration (Scyphers, Powers, Heck, & Byron, 2011).

Table 4-1. Summary of ACR field activities funded by ARRA.

Restoration Activity	Size[1]	Restoration Action	Previous Habitat Condition	Restoration Target Habitat
Oyster Reef Creation	3.4 acres	Construction of new oyster reefs	No oyster habitat present	Oyster reef with 100 live oysters/m^2
Reef Breakwater	1.6 miles	Installation of oyster reef breakwater	Existing shoreline	Coastal shoreline experiencing a reduced rate of erosion relative to baseline
Potential SAV Habitat Protection	31 acres	Protection of areas potentially suitable for SAV	Existing shoreline; no SAV	Enhancement of SAV habitat and coastal shoreline integrity

Notes: (1): Oyster reef size data are from a personal communication with Jeff DeQuattro, TNC.

Placement of the reefs had just begun in April 2010 when the Deepwater Horizon rig sank and oil began spilling into the northern Gulf of Mexico. When the oil spill threatened the reefs, construction workers involved in the project reorganized to lay oil-collecting booms and prevent oil from reaching the area. As a result, reef construction work at one site (Coffee Island) was delayed for more than three months.

Over all sites restored during this project, the completed project constructed 1.6 miles (rounded value) of vertical oyster reef/breakwaters along two stretches of shoreline at Coffee Island and Alabama Port, AL (Figure 4-1 shows site details; Figure A-1 shows a regional overview). ARRA funds also allowed deployment of demonstration of "living shoreline[26]" reefs at two more sites (Bon Secour Bay and Helen Wood Park) to complement other reef restoration projects in the region (Figure A-2; only Bon Secour site shown). In this study, we will refer to the restoration structures collectively as "oyster reef breakwaters" indicating the dual nature of their function.

Oyster reef breakwaters were installed at four locations around Mobile Bay, using the following materials:

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[26] NOAA defines living shorelines as "a suite of bank stabilization and habitat restoration techniques to reinforce the shoreline, minimize coastal erosion, and maintain coastal processes while protecting, restoring, enhancing, and creating natural habitat" (http://habitat.noaa.gov/restorationtechniques/public).

- **Coffee Island and Alabama Port sites:** 7,380 ft. of breakwater installed using bagged oysters, ReefBall units and ReefBlk units (DeQuattro, 2014 *pers. comm.*);

- **Helen Wood Park:** 863 ft. breakwater using bagged oysters and ReefBall units (DeQuattro, 2014 *pers. comm.*) (Heck, Powers, Scyphers, & Byron, 2010);

- **Bon Secour (Swift Tract):** 246 ft. of HESCO barriers installed with gabion stone and oyster shell (DeQuattro, 2014 *pers. comm.*) (The Nature Conservancy, 2012).

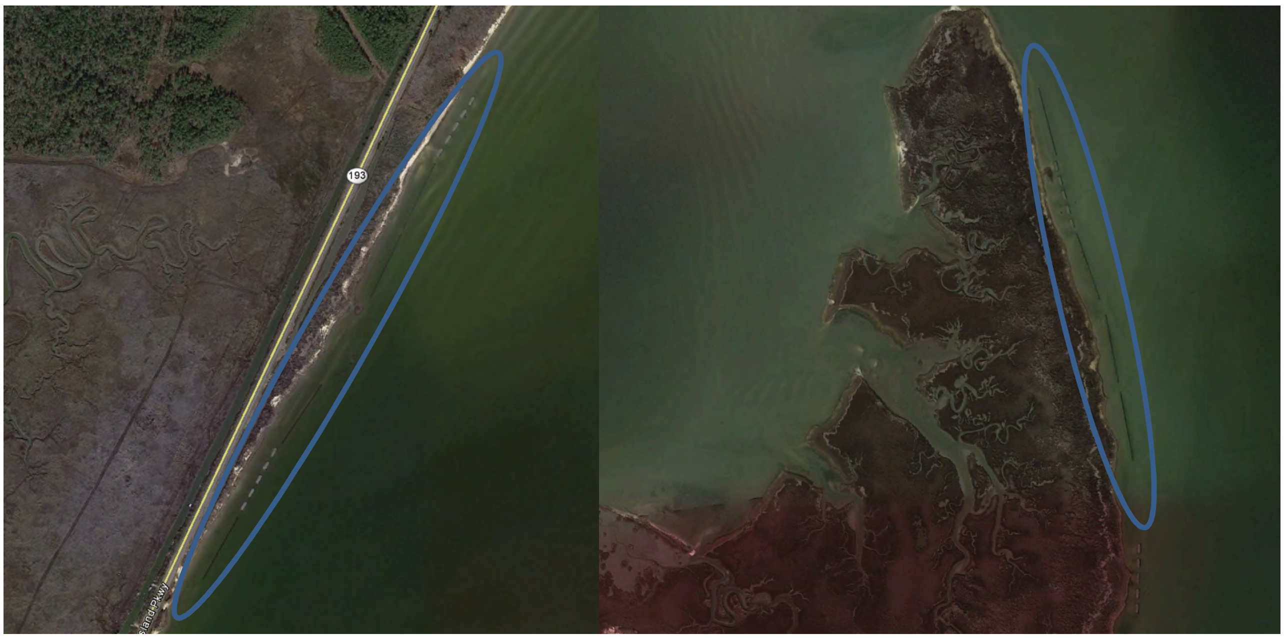

Figure 4-1. Aerial images of coastal breakwater installations at Alabama Port (left) and a portion of Coffee Island (right), Alabama.

Note: Coffee Island panel shows a portion of the constructed reefs; not all are shown for image clarity. Source: Google Earth, 2014

To monitor effectiveness relative to no-restoration baseline, project partners conducted pre- and post-construction physical and biological monitoring at two of the four restoration sites and several control sites. Restoration activities at Alabama Port and Coffee Island sites included seining for fish and mobile invertebrates; gillnetting; sediment grain size analysis; bathymetry; recording upper and lower marsh plant density; counting oysters (live, dead, spat, and adult); and documenting SAV presence or absence. Data were collected over different time frames and frequencies across the two sites and monitoring activities, but represent a maximum period of 12 months post-construction at Alabama Port, and 14 months post-construction at Coffee Island.

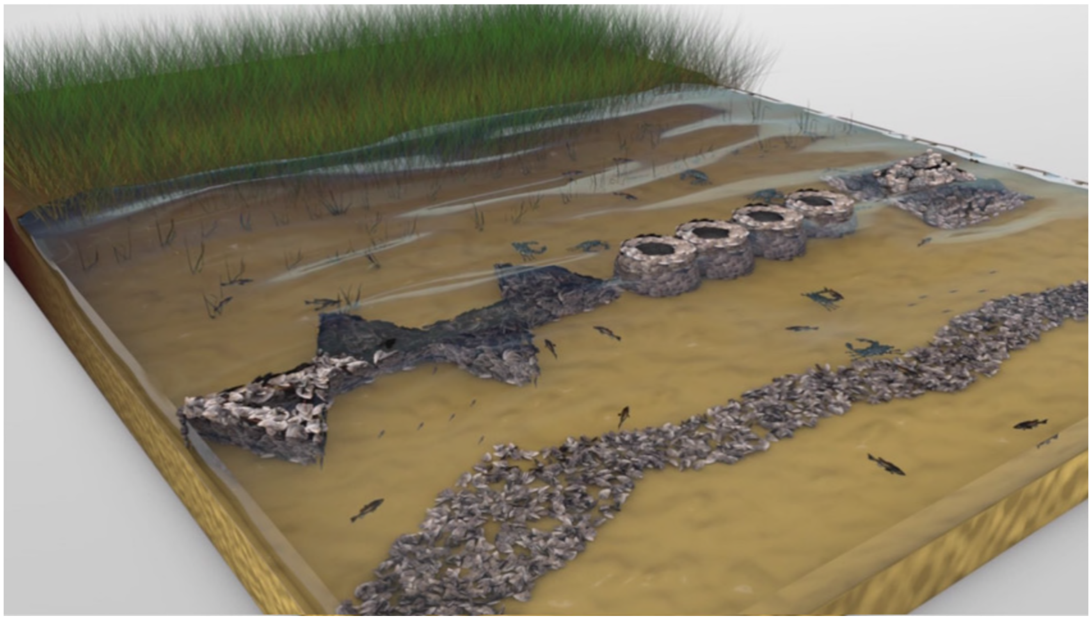

Figure 4-2. Schematic of natural and artificial oyster reef breakwater components used in ARRA-funded reef restoration in Mobile Bay.

Source: The Nature Conservancy (2014).

4.1.b Baseline Rate of Shoreline Loss

Coastal erosion (i.e., the inland migration of the tidal interface between open water and shoreline) is a historic and continuing problem for Mobile Bay. Coastal erosion and retreating shorelines also lead to displacement and/or loss of SAV and coastal wetland habitats. (At the ACR sites, no SAV was present in years prior to restoration). Coastal wetlands are already historically threatened in the Gulf Coast due to various natural occurrences, including flooding from storms in the Gulf, sea-level rise, flooding from rivers, natural land subsidence (Barbier, et al., 2011).

In recent years, the Alabama coastline has also undergone substantial modification due to beachfront development, installation of hard shoreline structures, beach nourishment, and tropical weather events (Douglass & Pickel, 1999; The Nature Conservancy, 2012). In Mobile Bay, it is estimated that structures have been installed on 30% of the shoreline to armor coastal areas against further shoreline retreat, including structures such as seawalls, rock jetties, and bulkheads (Douglass & Pickel, 1999). These hard shorelines reflect wave energy back into the Bay, subjecting adjacent shorelines to greater wave energy than natural conditions (Heck, et al., 2010). One consequence of this coastal development is additional physical stress is placed on remaining natural shoreline, resulting in high rates of beach erosion and coastal wetland loss.

The current rates of shoreline erosion in Mobile Bay are not known. The Mobile Bay National Estuary Program 2008 State of the Bay assessment noted that existing management actions have had an "uncertain" impact on reducing or managing the extent of shoreline change (Mobile Bay National Estuary Program, 2008). Due to the size and complexity of the Bay, there is little doubt that erosion and shoreline retreat vary greatly between locations due to difference in beach condition, wave and wind exposure, shoreline profile, adjacent land use, and other factors.

Some existing studies of shoreline erosion rates have estimated losses in recent history at two sites in Mobile Bay that are near or inclusive of ARRA-funded oyster reef restoration activity. Generally, the studies suggest shorelines are eroding or retreating between 3 to 10 feet per year. Specifically,

- Moody et al. (2013) measured rates of shoreline loss from three eroding areas at or near the Alabama Port breakwater site, extending monitoring of sites first reported on by Scyphers et al. (2011). Over a two-year period, control areas had annual median shoreline loss rate of 4.7 feet per year (range: 3.6 to 11.8 feet per year). It is not possible to judge how representative this rate is for other areas of Mobile Bay. However, the rates do indicate the importance of shoreline protection in the maintenance of existing SAV and wetland habitats.

- Existing data suggests shoreline erosion is proceeding at a faster rate on Coffee Island than on the mainland. Current aerial photographs of the outline of Coffee Island were compared to those taken in 1958 and 2001 aerial surveys and an overall erosional rate of 10 feet per year was estimated (Rainer, 2011; The Nature Conservancy, 2012). Due to its island setting, this rate would probably not be appropriate for application to shoreline environments in Alabama Port or other mainland Mobile Bay sites.

4.1.c Economic Assessment and Valuation of Shoreline Restoration Benefits

Oyster reefs and SAV provide a variety of ecosystem functions. By providing additional shoreline structure and providing new seagrass meadows, restoration will enhance ACR ecosystem functions and improve the provision of associated ecosystem goods and services. Table 4-2 characterizes the goods and services enhanced by installing "living shorelines" in Mobile Bay.

For example, artificial oyster reef structures create the physical structure and microhabitats for fish and invertebrate species, and provide coastal erosion protection by acting as breakwaters. By buffering wave action and providing sheltered embayment areas, breakwaters also provide more suitable conditions for seagrass growth and survival (e.g., reducing wave energy and increasing sedimentation), thereby facilitating the increased flow of ecosystem services from seagrass habitats. Seagrass beds produce a variety of goods (finfish and shellfish) and provide ecological services (maintenance of marine biodiversity, regulation of the quality of coastal waters, protection of the coast line) which are directly used or beneficial to humans.

Table 4-2. Ecosystem Goods and Services from Restored Oyster Reefs and Eelgrass Beds in Mobile Bay.

Service Category	Ecosystem Services	Change as a Result of Restoration		Available Change Assessment Methods	Monetized?
		Oyster Breakwaters	Seagrass and Coastal Marsh		
Provisioning *of "products obtained from ecosystems" (MEA, 2005)*	Commercial seafood harvest	↑	↑	Quantitative/ Qualitative	Yes
	Subsistence seafood harvests	↑	↑	Qualitative	No, data not sufficient
Supporting *ecosystem services "that are necessary for the production of all other ecosystem services" (MEA, 2005)*	Primary production	n/a	↑	Quantitative	Yes
	Food web dynamics	↑	↑	Qualitative	No, data not sufficient
Regulating *ecosystem processes and associated benefits*	Carbon and nutrient cycling	↑	≈	Quantitative	Yes
	Coastal erosion protection/ Storm buffering	↑	↑	Quantitative/ Qualitative	Yes
	Sediment stabilization	↑	↑	Qualitative	Yes, indirectly
	Water quality	↑	≈	Qualitative	No, data not sufficient to quantify
Cultural *benefits that are "nonmaterial…and gained through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (MEA, 2005)*	Recreational seafood harvest	↑	↑	Quantitative/ Qualitative	Yes
	Other recreation	↑	↑	Quantitative/ Qualitative	No, data not sufficient to quantify
	Aesthetic appreciation	≈	≈	Qualitative	No, data not sufficient to quantify
	Existence/ non-use values	≈	≈	Qualitative	Yes
	Information, science, education, and research	↑	≈	Qualitative	No, data not sufficient to monetize
	Biodiversity	↑	↑	Qualitative.	Yes
	Other cultural and spiritual factors	≈	≈	Qualitative	No, data not sufficient to monetize

Notes: "↑" indicates restoration of the indicated habitat enhance provision of the good or service. "≈" indicates restoration of the indicated habitat is unlikely to substantially enhance provision of the good or service. "n/a" indicates the indicated habitat does not provide the good or service.

4.2 Oyster Reefs and "Living Shorelines"

4.2.a Oyster Reef Breakwater Restoration and Outcomes

Oyster reef installation supports re-establishment of oyster populations, and under locally-relevant conditions can enhance population sizes that become self-sustaining and, where applicable, help support commercial or recreational shellfisheries. By creating oyster reefs of sufficient scale and spatial distribution, critical habitat structure and ecological functions for other biota (e.g., finfish, mussels, crabs, barnacles and other benthic invertebrates) is also provided (Hadley, et al., 2010; Meyer & Townsend, 2000; Scyphers, et al., 2011). Further, oyster beds are efficient in filtering phytoplankton, pollutants, and suspended sediment from the water column and are important for nutrient cycling and maintenance of water quality (Kellogg, et al., 2013; Nelson, et al., 2004). Lastly, oyster reefs can provide important wave attenuation, reducing the height and energy of wave action and reducing rates of coastal erosion (Swann, 2008). This not only reduces the rate of coastal erosion for open shorelines but may also be used to better protect developed shorelines and dock structures.

Oyster reef restoration typically involves placement of natural or artificial substrates in shallow estuarine areas that receive active reliable settlement of oyster spat (i.e., larvae). These spat settle to the substrate and develop into harvestable oysters on the reef; if designed for commercial fishery restoration, the developed oysters can be transplanted elsewhere to act as seed populations at other locations. As the reef ages, the amount of surface substrate occupied by oysters increases, as does the diversity of shell sizes and number of harvestable oysters. However, not all oyster reef restorations are successful for a variety of reasons including water quality, excessive sedimentation, toxic phytoplankton, lack of available larval recruits and poor hydrodynamic flushing (Powers, et al., 2009).

The total oyster reef area, as well as the age of the restoration site, is critical to estimating the amount of restored area, oyster population abundance, and ultimately the quantity of ecosystem services provided by oyster restoration. The total amount of potential oyster reef habitat created by ARRA-funded activities was estimated at 3.4 acres (De Quattro, 2014, personal communication). This acreage represents the potential contributions of all five oyster reef breakwater types (Section 4.1.a). The 3.4 acre value is an area-based estimate and does not fully take into account the potential extent of surface area for oyster settlement. The total area available for oyster colonization is greater than the surface area due to the complex three-dimensional shapes and vertical extent of the breakwater components (Figure 4-2).

Oyster Colony Establishment and Success

Previous reef breakwater restoration projects in Mobile Bay (non-ACR) have had mixed success regarding oyster settlement and development (Heck, et al., 2010; Scyphers, et al., 2011; Swann, 2008). However, in 2011, Alabama Port and Coffee Island's ACR breakwater reefs had an average of 36 (range 10.4 – 52.8) and 149 (range 0.49 – 325.3) live adult oysters/m^2, respectively (DeQuattro, 2014, personal communication). DeQuattro (2014, pers. comm.) reports, "commercial oyster reefs in Alabama are considered successful if they have 13-15 adult oysters per square meter." Although comprehensive monitoring has not been conducted at Helen Wood Park, informal reports suggest oysters have settled on approximately 50% of reef structures at that site (DeQuattro, 2014). The ACR sites thus appear successful when judged both in terms of restoration targets at ACR and in comparison to other recent oyster breakwater projects in Mobile Bay. ACR sites compare favorably to other recent oyster restoration activities in Mobile Bay (not funded by ARRA), including:

- **Scyphers et al. (2011)** studied oyster recruitment at earlier, separate restoration projects in Alabama Port and at a location near Coffee Island. In the first two years, they found excellent juvenile recruitment and development of adults at their sites' loose oyster shell reefs, but a sharp decline in oyster density in the third year prevented "cementing" of the reef and limited overall success. One potential cause of the decline was the predatory marine southern oyster drill (*Stamonita haemastoma*), whose advance into Mobile Bay was facilitated by increased salinity brought on more marine influence due to a breaching of the local barrier island by Hurricanes Katrina and Rita.[27]

- **Heck et al. (2010)** also studied early restoration projects nearby, but separate from the ARRA-funded project. These authors reported virtually no oyster recruitment and development over 12 months post-installation on breakwater structures placed off Helen Wood Park. Likely potential causes of the poor oyster colonization were water quality, low levels of available sprat for recruitment and bio-fouling of the substrates by barnacles and turf algae (Heck, et al., 2010). These studies indicate that oyster recruitment and development in Mobile Bay is likely to be highly variable and site-specific, with some sites developing faster than others and others not at all.

Oyster densities observed over six periods in the14 and 9 months post-restoration at Coffee Island and Alabama Port, respectively, appear generally variable across site, length of time post-restoration, type of breakwater, and spat versus adult oysters (Appendix M). TNC (DeQuattro, 2014, personal communication) recommends that more data would be needed to develop a restoration trajectory to estimate when reefs reach full habitat function (similar to trajectories developed for other case studies in this report). For example, in developing the Virginia Seaside Bays reef habitat restoration trajectory we used reef success metrics developed by Virginia's Oyster Metrics Working Group. These metrics include mean and minimum oyster coverage, the weight of the average oyster, age class distribution and shell budget maintenance over multiple points in time (Appendix J). Note, also, that although numeric and narrative oyster restoration targets may be different in Alabama and Virginia due to baseline conditions and substrate used, neither restored reef system is designed for commercial or recreational harvesting.

Where oyster reef restoration has been successful in the past, biologists identified key factors contributing to success, including suitable water quality and availability of spat. Several studies indicates that Alabama reefs could achieve long-term success First, DeQuattro's (2014) results on current oyster coverage and abundance suggest the Alabama reefs are reasonably successful. Second, TNC (2012) found there are ample oyster larvae in the water column for reef colonization, suggesting reef colonization may continue over time. Thus, under a scenario assuming adverse events seen in Scyphers et al. (2011) and Heck et al. (2010) are absent in the near future, we model ACR barrier reefs using the Virginia Seaside Bays case study trajectory, which was also developed for an area with early oyster recruitment success. Given that ACR oyster recruitment began within several[27] years of

[27] Note: The barrier breach eventually closed, salinity declined, and oyster densities have improved (Scyphers, pers. comm.). ACR/ARRA sites experienced successful oyster recruitment prior to the breach closure, but "significantly lower" recruitment and nearly complete predation after the cut was closed, and after the oil spill (DeQuattro, pers. comm.)

installation, we approximate potential restoration benefits by applying to the Alabama project acreage the restoration trajectory developed using the Virginia Seaside Bays case study data. In a sense, we are transferring the Virginia trajectory in in much the same manner that we transfer economic values for ecosystem services. Like economic benefits transfers, this restoration trajectory transfer introduces a degree of error based on site-to-site differences including ecosystem characteristics, restoration targets and goals, and locally-relevant success benchmarks. Table 4-3 shows the projected effective area of restored oyster reef that we used for benefits estimation.

Table 4-3. ACR Oyster Reef Habitat Estimates.

		Estimated Acres Functioning at Maximum Capacity[1]				
	Restored	0-2 years	3-6 years	7-9 years	10-12 years	>12 Years
Restoration Activity	Area (ac)	30%	50%	75%	95%	100%
Oyster Reef Development	3.4	1.0	1.7	2.6	3.2	3.4

Note: (1): Oyster reef restoration trajectory based on literature from Virginia reefs, see Section 3.2 for details.

Ecosystem Effects of Breakwater Structures

As discussed above, oysters are "ecosystem engineers" that provide physical habitat and substrate stability. Harvestable oysters, although the key to a fully functioning oyster reef, are not necessary to provide many of the ecosystem services (Luckenbach, et al., 2005). Further, the restoration trajectory of the diverse ecosystem functions offered by oyster reef breakwater reefs can operate at different times and scales (La Peyre, Humphries, Casas, & La Peyre, 2014).

For example, oyster reef breakwaters provide physical structure and refugia for many benthic invertebrates and finfish immediately upon installation. Since the prevailing benthic substrate in Mobile Bay is a soft mud, the introduction of a vertical structure and hard benthic substrate for attachment will likely lead to increases in local biodiversity. Swann's (2008) study of oyster reef breakwaters off Dauphin Island indicated that the structures provided habitat for locally important species such as: spotted sea trout (*Cynoscion nebulosus)*, blue crabs (*Callinectes sapidus*), Gulf stone crabs (*Menippe adina*), eastern oyster (*Crassostrea virginica*), red drum (*Sciaenops ocellatus*), southern flounder (*Paralichthys lethostigma*), and various species of commercially important shrimp including brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*F. duorarum*), and white shrimp (*Litopenaeus setiferus*).

Similarly, Scyphers et al. (2011) found that the waters adjacent to prior (non-ACR) oyster reef breakwaters near Coffee Island and at Alabama Port supported higher abundances and different communities of fishes and crabs than the control plots lacking structures. Economically-significant species exhibiting greater abundance near the breakwaters included: blue crab (+297% increase compared to control), red drum (*Sciaenops ocellatus*) (+108%), spotted sea trout (+88%), and flounder (+79%).

Also in a study of non-ACR (ARRA-funded) reefs, Heck et al. (2010) indicated limited enhancement of fish and mobile invertebrates with the effect more pronounced for smaller forage fish than larger fish. Juvenile drum, silver perch (*Bairdiella chrysoura*), silversides (*Menidia spp*.) and menhaden (*Brevoortia patronus*) were common.

Overall, the study found a more diverse assemblage of small fishes and invertebrates in association with the reef breakwaters. We note that increases in small fish provide an increased food base for larger fish, and as a result there are potentially-beneficial food web effects with monetizable endpoints for commercially- and recreationally-targeted sport and food fish (McCay & Rowe, 2003).

Overall, existing studies of artificial oyster reefs show reef structures are likely to support healthy fish communities even without live oysters.

4.2.b Oyster Reef Restoration Benefits

Public Support for Oyster Reef Restoration

As described above, coastal Alabama oyster harvests experienced a decades-long increase in annual landings, but declined following hurricanes Katrina and Rita in 2004 and 2005, and drought conditions in 2005. Various stakeholders in the Gulf Coast oyster industry, including residents, harvesters, and natural resource management professionals, generally support the use of restored or constructed oyster reefs to provide increased harvests and other ecosystem services (La Peyre, Nix, Laborde, & Piazza, 2012; Scyphers, Picou, Brumbaugh, & Powers, in press).

For example, a recent survey of oyster harvesters, shrimp harvesters, and natural resource management professionals found that while most oyster restoration stakeholder groups perceive oyster reefs as providing a rich set of ecosystem services, harvesters and managers tend to disagree about the primary motivation for oyster reef restoration (La Peyre, et al., 2012). Specifically, harvesters felt reefs should primarily be restored to enhance oyster harvests, but resource managers were more likely to be motivated by enhancing a suite of ecological services (La Peyre, et al., 2012). Perhaps unsurprisingly, harvesters were also unlikely to support restoration options that restricted use of restored reefs, such as those that involved harvest limits or un-harvestable sanctuary reefs. The authors suggest that, while ecosystem service provision and extractive uses are incompatible goals on individual reefs, viewing restoration as part of a regional landscape may enable stakeholders to develop plans that support production in some areas, reef conservation in others, and an "…end-goal of ensuring sustainable reefs across the region" (La Peyre, et al., 2012, p. 7).

Carbon and Nitrogen Sequestration

Mobile Bay is not nitrogen-limited, and although it receives "moderate to high nitrogen input and [has] … low ability for dilution and flushing of nutrients… Mobile Bay has a low [degree of] symptom expressions for dissolved oxygen, macroalgae, and nuisance/toxic blooms." Although very geographically distant from reefs examined by Piehler & Smyth (2011), the nutrient regime in Mobile Bay appears qualitatively similar to that in Bogue Sound, NC. Reefs at ACR are also similar to Piehler & Smyth's study site in that the artificial reefs are placed in the intertidal zone: sometimes, reefs re exposed to the air; sometimes, they are underwater and can remove nitrogen by filter-feeding. We use the same valuation approach as was documented in Section 3.2.b(Virginia Seaside Bays) because the new reefs at ACR may provide non-trivial N-sequestration benefits that affect the Mobile Bay ecosystem. However, the transfer of N-sequestration rates from mid-Atlantic reefs to Gulf Coast reefs likely introduces some transfer error. We suggest interpreting these estimates as ballpark values because of the geographic difference (and potential differences in other relevant ecological characteristics that may affect oyster functions, such as water temperature, salinity, oyster size, and tidal influence).

Additionally, given that oysters at these reefs will not be harvested, we were able to use carbon sequestration methods also first described in Section 4 (Virginia Seaside Bays) to estimate the monetary benefit carbon cycling support. Because constructed reefs where the underlying structure is placed shell may ultimately host higher oyster densities than those at concrete or constructed armoring structures (e.g., Appendix M), estimates here may be either an over- or under-estimate of benefits based on natural reefs or reefs based on placed shell.

Applying carbon and nitrogen sequestration methods to the restoration trajectory, we estimate that the new reefs could provide approximately $118 per year (TPV $3,930) in carbon sequestration services, and $1,717 to $8,325 per year ($39,685 to $192,438 TPV) in nitrogen sequestration services.

Economic Valuation of Fisheries Productivity at Constructed Oyster Reefs

Mobile Bay National Estuary Program (2008) reports that "in 2007, over 1.1 million trips were made by anglers to Alabama coastal waters, resulting in a recreational harvest of 4.4 million pounds of marine fish. Between 1995 and 2007, common saltwater species, including sheepshead, red drum, speckled trout, white trout, and ground mullet, accounted for 28.2 million pounds (64%) of the total 43.8 million pounds harvested in Alabama state waters (NOAA/NMFS)." As nursery ground and forage habitat for larger fish, changes in barrier reef habitat benefit recreational fishers and commercial fishermen by increasing the supply of harvestable fish. Indeed, at ACR sites, Kroeger (2012) and recreational fishers' anecdotal observations (Raines, 2012) suggest that reef installation has enhanced a variety of other commercially and recreationally-targeted species (flounder, redfish, and others) enough that local fishermen are now successfully targeting these fish near the constructed reefs and surrounding areas. Changes in barrier reef habitat may provide monetary benefits to recreational and commercial fisheries from improvements in recreational catch rates and an increase in commercial landings. Improved recreational fishing opportunities post-restoration, such as availability of additional fishing sites and an increase in catch rates, may also lead to an increase in the number of fishing trips.

Quantified Fishing Benefits

To estimate fisheries benefits, we first apply production enhancement values synthesized by Kroeger (2012) and then apportion the total change in harvest to recreational and commercial fisheries using historical data on the proportion of total documented landings caught by commercial and recreational fishers (Appendix M). The values presented in Appendix M account for increased production provided by habitat enhancements; net of natural mortality and the proportion of a wild population that is un-harvestable (e.g., due to size and fishing gear limitations). Assuming Kroeger's estimated catch rates are sustainable and can be maintained over the functional lifetime of the artificial reef structures, we estimated benefits to commercial fishermen and recreational fishers. This analysis included three key steps (projecting changes in harvestable weight; valuing commercial fishing benefits; and valuing recreational fishing benefits) which proceeded as follows:

- **To estimate changes in harvested weight,** we:
  - Compiled mean production enhancement rates per reef area (as reported in Kroeger, 2012: Table 4) and predicted annual enhancement at ARRA site acreage.
  - Estimated the fraction of the increased production that is feasibly harvestable, again generally employing Kroeger's compiled statistics on the fraction of harvestable biomass under the most commonly used types of fishing gear and regulations.
  - Allocated predicted increases in landings weight to commercial fishery using Kroeger's ratios of commercial landings to total landings in 2010, and for most species allocated remaining landings to the recreational fishery.
  - Projected the estimated annual landings increases through 2050, assuming fishery enhancements started in 2009 and are achieved in full each year because fish are attracted to artificial reefs for their structural features (independent of oyster populations).
  - An improvement in forage fish biomass can also contribute to commercial and recreational fishery yield. It can be measured as a biotic transfer of mass through the food web to fishery species that are subsequently harvested. Trophic transfer efficiency – the fraction of forage species biomass incorporated into predator (fishery) species biomass— is commonly assumed to be 0.10 (Pauly & Christensen, 1995). Given the lack of data on changes in forage fish population we did not include food web effects in this analysis.

- **To monetize commercial fishing benefits**, we:
  - Used producer surplus to provide an estimate of the economic benefits to commercial fishers from improved harvest.[28] Welfare changes can also be expected to accrue to final consumers of fish and to commercial consumers, including processors, wholesalers, retailers, and middlemen, if the projected increase in catch due to the rule is accompanied by a decrease in price. Given that expected change in commercial harvest of the analyzed species (642 kg/ year) is small in context of the overall Alabama Gulf Coast fisheries for these species (3,569 tons/ year in 2012) and the expected change in price ($1,918/ year) is negligible in the same context, we limited the analysis limited to producer surplus only.
  - Assumed the change in producer surplus, captured by "normal profits," is equivalent to a fixed proportion of the change in gross revenues. We first estimated changes in revenues from increased commercial fish landings using average 2012 Gulf Coast ex-vessel (dockside) commercial prices from NOAA National Marine Fisheries Statistics (NOAA Fisheries: Fisheries Statistics Division, 2014). The change in producer surplus is then calculated as the average fraction of a marginal change in gross revenue that is realized as producer surplus. For this fraction, we used Gulf Coast species- and group- specific average

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[28] In an unregulated fishery, the long-run change in producer surplus due to an increase in fish stocks will be zero percent of the change in gross revenues because in open access fisheries, excess profits are always driven to zero at the margin. Most fisheries are, however, regulated with quotas or restrictive permits to prevent overfishing. Thus, lasting economic benefits accrue to commercial fishers from an increase in harvest.

net benefit ratios reported in US EPA (2006)[29] and derived from species, gear, and region-specific data following NOAA's conventional methods (Appendix M).

- **To monetize recreational fishing benefits,** we:
  - Considered the three types of benefits to recreational fishers from installing new breakwater/barrier reef habitat:
    - Increased value per fishing trip due to higher catch rates.
    - Increased recreational opportunity, by providing new recreational sites. These sites may be valued by fishers because they are closer to home than existing sites or offer other amenities. However, fishers are likely to consider the new site as just one of a group of potential sites (an "opportunity set"), and may not change the total number of trips taken. In this case, the new recreational site simply reallocates fishing trips in a region (e.g., Alabama Gulf Coast): thus, although it may benefit local community, it does not generate new benefits at the state or county levels.
    - Increased number of fishing trips taken. Improved recreational fishing opportunities and an increase in catch rates may lead to an increase in the number of fishing trips taken by fishers. For example, Bergstrom (2004) suggests Louisiana recreational fishers are willing-to-pay (WTP) $42 (2013$) per fishing trip in Gulf Coast coastal waters. We did not estimate changes in the number of trips due to improvements in recreational catch because the total number of trips taken by Gulf Coast fishers' is influenced by many factors (e.g., availability of leisure time, presence of children in the household, income, and others) and thus relatively un-responsive to small, incremental changes in fish catch at a site (Bergstrom, et al., 2004)
  - Valued the change in recreational catch rates using fishers' WTP for catching additional fish. The estimated WTP per fish is based on a meta-analysis of recreational fishing studies (US EPA, 2013; see also, Johnston et al., 2005)[30]. This analysis included the following steps:
    - Converting increased recreational landings weights to numbers of fish using average weight of recreationally-landed fish – by species or species group – caught in 2010 (National Marine Fisheries Service, 2010).
    - Estimating the monetary value of recreational fishing benefits from increased catch of the species or groups of fish that are commonly targeted on the Gulf Coast, using WTP for fish types such as "saltwater fish" and "small game fish" (U.S. EPA, 2013a).

The productivity enhancements which we estimated for 20 commercially- and recreationally-targeted species (Kroeger, 2012) could provide a total of recreational and commercial fishery benefits of $6,841 per year in 2013

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[29] US EPA's 2006 Phase III 316(b) benefits analysis is available at: *http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/phase3/upload/2006_08_09_316b_phase3_ph3docs_p3-rba-final-part1.pdf*

[30] The independent variables included in the meta-analysis characterize the species being valued, study location, baseline catch rate, elicitation and survey methods, demographics of survey respondents, and other specific characteristics of each study. In the present analysis, we applied values for the Gulf of Mexico region and converted currency to 2011$.

dollar year. The TPV of these benefits through 2050 is $138,737. As stated elsewhere, the estimated fisheries benefits do not fully capture forage fish values.

Subsistence Fishing Benefits

Subsistence fisheries benefits include both direct and indirect nonmarket use values. Subsistence use of fishery resources can be important in areas where socioeconomic conditions (e.g., the number of low-income households) or the mix of ethnic backgrounds make such fishing economically or culturally significant to a component of the community. We did not approximate subsistence fishery benefits, but impacts on subsistence fishers may constitute an important environmental justice consideration. The relative degree of coastal community member support for "oyster gardening" efforts in Mobile Bay suggests that some restored reefs, although closed to commercial harvests, may be harvested for subsistence food (*pers. comm.*, S. Scyphers).

Coastal Protection Benefits

Much of the Alabama coastline experiences wave energies that exceed the natural tolerance of SAV and shoreline vegetation (Scyphers, et al., 2011). Natural shoreline retreat on the Gulf Coast has affected, and if not averted, will continue to negatively affect, the visual character of coastal resources and the integrity of coastal infrastructure (Morgan & Hamilton, 2009). Coastal Alabama homeowners value aquatic and marine environmental conditions in the region (Siegel, Caudill, & Mixon, 2013).Therefore, losses related to shoreline deterioration may negatively affect housing values. For example, Gulf Coast homeowners in Florida who live near retreating beaches have historically been willing to pay to restore shorelines using techniques such as importing off-site sand (Morgan & Hamilton, 2009). By reducing wave energy, breakwaters placed along shorelines mitigate coastal erosion both directly by buffering everyday wave action and influences from storm conditions, and indirectly by protecting healthy SAV and coastal marshes that also absorb storm surge. However, efficacy of breakwaters installed at ACR sites is small relative to the influence of flood events and thus are unlikely to alter the coastal floodplain boundaries. Further, although they have withstood some storm events, they are unlikely to materially reduce coastal flood risk during these times.

Figure 4-3. Installed oyster breakwaters at Bon Secour Bay, AL.

Source: Robert Costantini © The Nature Conservancy.

Thus, the shoreline protection benefits provided by oyster breakwaters are likely to be limited to mitigation of the shoreline erosion near coastal properties. Our review of aerial imagery and ARRA project documentation indicates only some of the installed oyster breakwaters were placed in the immediate vicinity of residential properties that could experience erosion reduction benefits: seven homes (a total of about 715 linear feet of residential shoreline) were protected in Bon Secour Bay[31].

Baseline coastal erosion rates vary quite widely across Mobile Bay, and research on relatively exposed sites suggests mean annual rates approach 3 to 10 feet per year (Section 4.1.b), but no data were available for the relatively more-protected residential area of Bon Secour Bay. Further, because breakwaters are not large enough to likely affect homes outside their "shadow" on the coastline, property value benefits from reduced coastal erosion are limited to these homes alone.

Using the low end of coastal erosion rates from Mobile Bay sites (Section 4.1.b) and the residential property benefits model based on Landry et al. (2003) [based on Tybee Island, GA data; described fully in Section 4 of this report], these seven households may be willing to pay approximately $10.38/year to preserve 1 m (3 feet) of shoreline width on their properties. Over the 40-year restoration timeline through 2050, this protection provides a total annualized value of $64 and a TPV of $1,473.

Near-shore communities in the Gulf of Mexico also value other shoreline protection benefits at publicly-accessible coastline (e.g., recreational values, ecosystem support services, and general coastal resilience) (Scyphers, et al., in press). We did not estimate the monetary value of living shorelines to non-residential areas due to a lack of available monetization studies suitable for the ACR context, but in this sections' discussion suggest the potential magnitude of benefits that could be gained by siting breakwaters on Gulf Coast barrier islands, such as Dauphin Island (AL) and the barrier islands of Mississippi.

Other Recreation and Tourism

Coastal wildlife tourism in the Gulf of Mexico generates $19 billion per year in spending on recreational fishing, wildlife watching and hunting activities, and on lodging and dining (Stokes, Lowe, Owen, & Mine, 2013). In addition, these expenditures garner roughly $5.3 billion in federal, state and local tax revenues (Stokes, et al., 2013). Alabama as a whole draws roughly 683,000 recreational fishers per year, and 1,114,000 wildlife viewers per year; their wildlife recreation expenditures amount to roughly $2 billion per year (Stokes, et al., 2013, based on US Fish and Wildlife Service 2012). These visitors represent a sizeable fraction of all visitors to the Alabama Gulf Coast. For example, in 2013, of all visitors to Alabama's Gulf Coast, 33% participated in wildlife or environmental-orient activities, 20% took a recreational fishing trip, and 6.6% participated in bird-watching activities (Evans-Klages Inc., 2013).

In addition to supporting tourists' recreational experiences, healthy coastal ecosystems support a sizeable number of tourism industry professionals. Alabama's coastal counties (Mobile and Baldwin Counties) alone host nearly 1,400 wildlife tourism-related businesses; further, these industries provide a healthy proportion of all jobs in the region. Compared to a national average of 12%, tourism-related businesses support 11% (11,237) to 20% (15,338) of county jobs in Baldwin and Mobile Counties, respectively (Stokes, et al., 2013, based on Bureau of Labor Statistics data).

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[31] http://www.futureofthegulfcoast.org/ob/032212-BRRCOrangeBeachStubljar.pdf

A recent survey of Gulf Coast nature-based tourism companies found that guide, outfitter, and hospitality business owners recognize the value for their business success of healthy coastal ecosystems in supporting tourist-valued aesthetic and recreational opportunities (Stokes, et al., 2013). Coffee Island's camping[32] and sport fishing[33] uses previously had been threatened by shoreline erosion totaling 90 feet of beach width over the last decade (Raines, 2010). But, following installation of ACR living shoreline segments on the eastern side of the island in 2010 (Figure 4-3), fishers have reported increased prevalence of redfish, speckled trout, and forage fish and crabs near the artificial reef (Raines, 2010). To the extent that coastal breakwaters installed throughout Mobile Bay also provide beneficial effects to non-fishing tourism and recreation-related services, restoration may help maintain current regional tourism values.

Unfortunately, data were unavailable to measure and monetize the value of breakwaters and shorelines as inputs to recreation values other than recreational fishing (e.g., studies of the value of wildlife viewing or estimates of how wildlife viewing opportunities might change at the ARRA-funded sites).

4.3 Submerged Aquatic Vegetation

4.3.a Restoration Outcomes

Submerged aquatic vegetation (SAV) forms an important ecological habitat and resource in Mobile Bay. Numerous studies have demonstrated the ability of SAV to influence ecosystems by altering hydrodynamics and consequently sediment characteristics; increasing habitat complexity for fauna; altering predator-prey dynamics; and enhancing primary production (van der Heide, et al., 2011).

The SAV community found in Mobile Bay and adjacent coastal Alabama waters is comprised of a diverse group of 21 species (Barry A. Vittor & Associates, 2009). The dominant species reported in 2009 included: Eurasian watermilfoil (*Microphyllum spicatum*), wild celery (*Vallisneria americana*), widgeon grass (*Ruppia maritima*), Southern naiad (*Najas guadelupensis*) and shoal grass (*Halodule wrightii*). The present SAV coverage in Mobile Bay is estimated at approximately 5,218 acres (Barry A. Vittor & Associates, 2009).

There has been a significant historical decline in the areal extent of SAV coverage in Mobile Bay. Comparisons of coverage identified by aerial photographic surveys from 1940 to 2002 indicate a potential 55% loss of SAV in the interim (Barry A. Vittor & Associates, 2005). This trend continued within the last decade as similar comparison between 2002 and 2009 surveys indicated 1,371 fewer acres or about a 21% loss in SAV. The magnitude of decline and persistent disappearance in acreage over this period indicate that human activity has significantly altered habitats formerly capable of supporting SAV (Barry A. Vittor & Associates, 2009; US Geological Survey, 2010).

Wave action and coastal erosion are two primary causes of SAV and coastal marsh vegetation loss, resulting in shoreward migration of the shoreline. Many stretches of Alabama's shoreline absorb wave energies well above critical limits where vegetation can naturally persist (Roland & Douglass, 2005). Where inland land use supports

[32] Anecdotal evidence from S. Scyphers (January 13, 2014) and from http://mountainstothesea.blogspot.com/2010/02/gulf-of-mexico.html (Accessed 1/13/2014)

[33] http://www.outdoorgulfcoast.com/fishing-report-coastal-alabama-waters/ (Accessed 1/13/2014)

it, marshes under this stress will retreat inland from the current water line and overtake previously “upland” habitats, shifting the wetland area inward without substantial loss of total marsh area. However, where inland land use is developed or does not allow marsh migration, wave action and coastal erosion simply erode marsh area at the water line. Accordingly, installing oyster reef breakwaters that promote protection and enhancement of SAV in the waters behind the breakwater ultimately helps retain adjacent coastal wetland vegetation through stabilizing the shoreline position.

This assertion is supported by several studies done in Mobile Bay and elsewhere. For example, Swann (2008) noted that installing “coastal havens” reduced the amount of erosion behind the breakwater and some sediment accumulated. In another study, installation of reef breakwaters mitigated vegetation retreat by more than 40% over two years at one site but was not significant at the other test location (Scyphers, et al., 2011). Moody et al. (2013) also found that wave attenuation afforded by oyster reef breakwaters reduced annual rates of local coastal erosion over a three year period. Comparing his results to prior work (Scyphers, et al., 2011), Moody suggested that longer post-construction monitoring may be important, as the effectiveness of breakwaters may increase as they become colonized and mature, depending on local wind and current regimes (Moody, et al., 2013).

Based on the coastal protection, wave attenuation, and erosion mitigation benefits provided by installing 1.5 miles of oyster reef breakwater, NOAA and restoration partners estimated that 31 acres of SAV habitat were enhanced between oyster breakwaters and the shoreline (DeQuattro, 2014; NOAA, 2012).

4.3.b Economic Valuation of SAV Restoration Benefits

In recent history, SAV was not present at the ACR project sites. By reducing wave action and erosion in subtidal and bare areas that are otherwise suitable for SAV meadows, restoration investments are increasing the potential for new SAV growth in Mobile Bay. If SAV does grow successfully in these areas, new SAV would provide a variety of ecosystem services post-restoration (Table 4-2), such as nursery habitat for fish, additional shoreline stabilization via root structures, and a contribution to overall biodiversity at the site. Although oyster reef installations protect 31 acres of potential SAV habitat, monitoring data has shown that, as of early 2014, new SAV beds have grown only at the Helen Wood Park site. Informal monitoring by TNC and partners indicates SAV growth at Helen Wood Park is present, and qualitatively significant compared to pre-restoration conditions in which no SAV was present (DeQuattro, 2014, personal communication). Unfortunately, data on the degree and detail of monitoring are not available to support quantitative estimation of benefits. The following discussion illustrates potential per-acre benefits of restoring healthy SAV in Mobile Bay.

Because SAV was previously absent at the restoration sites, any new SAV growth would improve aquatic habitat for fish and crustacean populations and potentially increase fish abundance. Developing monetary estimates of *total* ecosystem service improvements due to provision of new SAV is not feasible based on existing economic literature. Economic studies exist that quantify benefits of eelgrass and salt marshes (Bauer, et al., 2004; Johnston, et al., 2002; Mazzotta, 1996) but these habitats are substantially different from Mobile Bay’s SAV, which is comprised of a mix of plant species (rather than a mono-culture), is relatively more sparse than eelgrass and salt marsh vegetation, and provides habitat for different species than these ecosystems. Furthermore, new SAV beds are unlikely to provide noticeable changes in wave attenuation (and associated monetizable endpoints for property value effects) given relatively small scale of potential habitat protected. As a result, we did not estimate monetary benefits of restoring SAV in the Mobile Bay.

Available functions do exist to monetize fishery benefits following provision of SAV habitat for fish and crustaceans which utilize SAV as juvenile habitat Blue crab and white shrimp are important for commercial, recreational and subsistence harvests in Mobile Bay. For example, between 2008 and 2012, average landing prices for blue crabs were $0.73/lb., and $2.49/lb. for white shrimp; combined, the two species had an ex-vessel value of ~$471 million in 2008 (Jordan et al., 2012). In recent years, however, annual harvests have decreased from historic levels. Jordan et al. (2012) modeled habitat-fishery linkages for these species, finding that the Mobile Bay ecosystem generates 17% of the Gulf of Mexico's harvestable blue crab biomass, and 8.6% of white shrimp biomass. Jordan et al. (2012) found that a simulated restoration of 500 ha (1,254 ac.) of Mobile Bay SAV reduced (blue crab) or reversed (white shrimp) negative trends in recruitment; the 500-ha restoration was estimated to provide combined Gulf-wide ex-vessel fishery benefits of $682/ha ($276/ acre).

4.4 Environmental Justice

4.4.a Environmental Justice

All populations living in the communities surrounding the breakwater reefs are expected to benefit from the ecological improvements enumerated in preceding sections of this chapter. Both coastal residents and workers in environment-dependent industries stand to benefit greatly from coastal restoration work in Mobile Bay. For example, approximately 7% of Mobile Bay region's workforce is employed in the natural resources, mining and construction sector (Mobile Bay Area Chamber of Commerce, 2012); these workers stand to benefit greatly from large-scale coastal restoration surrounding Mobile Bay. In addition, coastal residents are likely to benefit from reduced shoreline erosion and storm related flooding.

Relative to nearby inland neighborhoods, the coastal neighborhoods immediately surrounding Coffee Island and Alabama Port tend to consist of relatively fewer minority individuals, but have moderately high poverty rates and lower educational attainment. Further, Mobile Bay hosts a rather sizeable Southeast Asian-American fishing community, with many workers employed in harvesting and seafood processing. If differences in resource use, dependence, or benefits vary systematically across racial and socioeconomic community groups, ACR may direct long-term ecosystem service benefits in a beneficial way, supporting groups that were historically marginalized but stand to benefit from ecosystem service improvements.

Environmental justice (EJ) considerations provide important context for the distribution of ecosystem service benefits across diverse Mobile Bay community members. These benefits may become an EJ or equity benefit if the most-affected subsets of the population *disproportionately* consist of low-income, minority, or other historically-marginalized individuals. Activities like coastal restoration could be designed to purposefully ameliorate existing EJ concerns or actively seek to even out historically-disproportionate benefit/cost distributions. While The Nature Conservancy hired approximately 9 unemployed workers of South-East Asian descent for six weeks to help construct barrier reefs – providing direct economic stimulus benefits to these workers – economic stimulus effects of NOAA-ARRA investments are not the subject of our report.

This section summarizes Abt Associates' qualitative and quantitative assessment of the potential distributional impacts of the Mobile Bay shoreline projects. Our quantitative analysis follows statistical comparisons similar to those used in EPA's Environmental Justice screening analyses (U.S. EPA, 2013b).

4.4.b Analysis

Qualitative Assessment

We first qualitatively assessed the extent to which habitat improvements from restoring oyster reefs and eelgrass beds could benefit low-income, minority and other EJ communities in the Seaside Bay region. Table 4-4 summarizes factors that may affect how benefits are distributed between subgroups and whether benefits may be disproportionately distributed to subgroups within affected areas.

Table 4-4. Qualitative Screening for EJ Effects Following ACR.

Ecosystem Change/ Economic Benefit	Potential EJ Consideration
Increased habitat supporting commercially-valuable fisheries (*Note: Oyster reefs are not designed for shellfish harvesting, but reefs and protected seagrass beds support fin fisheries.*)	• 65% of shrimp licenses in Alabama for vessels over 45' are held by Asians, and in 2005, nearly 8,500 Southeast Asian-Americans worked in Gulf Coast seafood processing plants (Burrage, 2009). • Kroeger (2012) estimates Southeast Asian-Americans own 11-12% of seafood processing businesses in Alabama.
Increased habitat supporting non-commercial fisheries	• Some minority and low-income groups rely disproportionately on subsistence fishing as a source of food. These groups are particularly likely to benefit from increased numbers of fish (i.e., catch rates), and improved access to those fish and shellfish.
Change in coastal erosion for waterfront homes (*Note: The scale of the ACR oyster reefs are not expected to provide widespread protection from coastal flooding, but may slow the pace of natural coastal erosion*)	• Low-income households are less likely to have residential hazard insurance than higher-income households. Without insurance to recover erosion-related losses, a low-income household with beachfront property would benefit from coastal erosion reduction more than higher-income household.
Increased recreational opportunity	• In part due to travel costs, lower-income households are more likely to select recreation sites in close proximity to their homes (compared to higher-income households). If recreation benefits, such as increased catch rates, occur at sites nearby lower-income neighborhoods, restoration may provide EJ benefits.
Increased economic opportunity and innovation	• 132 firms have assisted with reef restoration in the northern Gulf of Mexico; of these, 85 percent are small businesses, and 46% have fewer than 25 employees (Stokes, Wunderink, Lowe, & Gereffi, 2012).

Southeast Asian Fishing Community

Beginning in the 1970's, Vietnamese immigrants and Vietnamese-Americans have comprised a substantial portion of the traditional southern fishing communities in Alabama. Historically, new immigrant fishers reported choosing a fishing livelihood out of "desire for independence and freedom, being one's own boss, and good money. They also pointed out that fishing is one of the few professions one could enter without having to speak English" (Thomas, 1991).

Results of a series of focus groups and interviews conducted by Kroeger (2012) indicated that the Laotian-, Cambodian- and Vietnamese-American communities in coastal Alabama are highly dependent on the fishing and seafood processing industries. Although oyster industry workers have experienced unemployment or under-employment since the commercial fishery was closed following the 2010 Deepwater Horizon spill, many are still involved in other seafood sectors. Kroeger (2012) reports focus group findings that indicate three quarters of Southeast Asian-American community members derive income from seafood-related activities, and interviews suggested many also own their own fishing boats or work in shipyards and marine repair shops. Despite this high degree of involvement in seafood and shellfish related industries, focus group attendants generally had a low degree of awareness about oyster restoration activities in Mobile Bay, and many attendants reported being entirely unaware of coastal restoration activities in general (Kroeger, 2012).

Small Businesses in the Oyster Restoration Industry

Constructing and restoring oyster reefs entails a variety of planning, construction, and monitoring activities, and requires a variety of material inputs. While sometimes installed using volunteer labor, and sometimes installed by medium- to large businesses and non-profit organizations (DeQuattro, 2014 *pers. comm.*), a number of small firms are emerging that specialize in the design and manufacture of reef construction materials, such as the Reef Balls and oyster shell bags employed at ACR. Additionally, larger, existing construction and resource extraction firms have begun to diversify, potentially in efforts to, "be at the forefront of what they believe to be an emerging industry" (Stokes, et al., 2012, p. 26). In this report, we do not analyze potential job creation impacts of coastal restoration activity in the Gulf Coast, but summarize results of a recent study that analyzed the artificial reef industry.

> *"Those that live it know it-- citizens, fishermen, boaters, scientists, hunters and others have a unique insight into the environmental challenges we face, what works, and what doesn't.* ***Stakeholder input is vital to developing long-term solutions to local challenges."***
>
> *-- Stokes (2012, p. 4).*

Stokes et al. (2012) analyzed the number and type of companies that have provided materials and services to completed oyster reef restoration projects in the Gulf of Mexico. Although characterized as a "loosely organized" industry, the authors found 132 unique firms have assisted restoration activities, including both for-profit and non-profit entities. In total, the organizations operate 445 workplaces in the contiguous United States including headquarters, branch locations and manufacturing plants related to primary and secondary materials; planning and design; marine transport, deployment, and assembly; and land transport. Employee locations are predominantly in the five Gulf States of Texas, Louisiana, Alabama, Mississippi, and Florida (82 percent) but also include locations in 17 other states (18 percent). Furthermore, among all firms in their sample, Stokes et al. (2012) found that 85 percent qualified as small businesses under Small Business Administration guidelines based on industry-specific criteria, and 46% have fewer than 25 employees.

Quantitative Assessment

Because our qualitative review suggested oyster breakwater restoration activities are likely to provide services that are valued differently by EJ communities and the general population, we quantitatively assessed whether affected communities actually include EJ groups. The purpose of this analysis was to determine whether low-income individuals or minority individuals are more or less present in the affected areas than in the general population.

We first conducted a screening analysis for EJ communities, examining the prevalence of low-income households, and of minority racial groups in surrounding counties that may constitute resource users who live relatively close to Mobile Bay (Appendix C outlines our methods). Table 4-5 briefly summarizes findings from the EJ analysis. As shown in Table 4-5, Census data suggest Baldwin may have a relatively lower EJ concern, and Mobile County may be at relatively higher risk of EJ concern. In Baldwin County, average household income per Census block is higher than state-wide averages, and minority populations are smaller; on average, Baldwin County neighborhoods have a lower EJ index than the average Alabama neighborhood. In Mobile County, average household income per Census block is lower than state-wide averages, minority populations are larger, and on average, Mobile County neighborhoods have a higher EJ index than the average Alabama neighborhood.

Table 4-5. Quantitative EJ Screening at ACR.

	Alabama	Baldwin County	Mobile County
Population Totals			
Population	4,712,651	175,791	408,620
Households	1,883,791	73,180	158,435
Population-Weighted Averages			
Median Household Income (2013$)	$46,747	$52,099*	$44,320*
Percent Poverty	17.4%	12.3%*	19.2%*
Percent Minority	33.2%	16.1%*	41.4%*
EJ Index (%Poverty * %Minority)	7.9%	2.6%*	10.8%*

Notes: * denotes a statistically-significant difference between the county-level population-weighted average and the state –level average (two-tailed paired t-test, p <0.05). Source: U.S. Census, 2013.

A higher EJ index implies that low-income and minority populations are relatively more-prevalent in the communities surrounding the restoration site. This implies restoration may distribute benefits *towards* EJ communities to some extent. Restoration in an area characterized by low socioeconomic status, and with minority populations heavily involved in coastal fisheries, indicates that this oyster restoration project -- if part of a broader coast-wide initiative-- could provide substantial changes in ecological conditions that benefit environmental justice communities. For example, while the fisheries benefits of the ARRA-funded portion of the project are small in context of total fisheries landings in the northern Gulf of Mexico, more widespread restoration could elicit fishery restoration on a scale that is noticeable across Gulf communities. Further, in light of language and other historical barriers between Southeast Asian immigrant communities and restoration professionals, our EJ analysis suggests that restoration projects that allocate funds to increase cross-cultural awareness, education, and participation could provide community benefits beyond those ordinarily gained in ecosystem services alone.

4.5 Summary

4.5.a Ecological Summary

Based on review of the design and installation of ARRA-funded oyster reef breakwaters at ACR restoration sites and the available data, the following conclusion regarding ecological resources were made:

- 3.4 acres of oyster reef habitat were created, providing structural habitat for invertebrates and finfish, and other ecological services associated with the oyster communities structural features.
- Approximately 1.6 miles of coastline were better protected by the installation of breakwaters and local rates of coastal erosion reduced.
- 31 acres of SAV habitat were protected, enhancing the ability of near-shore areas to support new, SAV beds, such as those anecdotally observed at Helen Wood Park.

4.5.b Total Estimated Economic Value

Ecological outcomes gained from installing oyster reef breakwaters in Mobile Bay will enhance ecosystem goods and services available to local and regional communities. We estimated the total economic benefit of the ARRA-funded activities to Gulf Coast households and commercial fishers. If oyster populations continue to be successful, the project has potential to produce annualized benefits from $8,740 to $15,348 per year (2013$). Over an assumed project lifetime through 2050, the TPV of all benefits from reef structures and oyster populations may produce $183,824 to $336,577 in TPV (Table 4-6).

The scale of the particular oyster reef restoration case studies examined in this chapter results is relatively small in acreage compared to other ARRA-funded oyster reef investments in the NOAA portfolio[34]. Because the total value of oyster reefs and shoreline protection is a function of per-unit values as well as the restoration area (for example, Grabowski et al, 2010), total values of a small-area project are lower than those of a large-area project, all else equal. The high success of this case study's reef structures for fisheries suggests that, other oyster reef restoration projects in the Gulf may also provide fin fishery benefits. Benefits from oyster populations may persist in the future if circumstances continue to be favorable for oyster survival – for example, if environmental factors hypothesized to have caused poor initial success at other recent oyster restoration projects are not present at (or continue to have minor effect on) ACR sites. If conducted efficiently and in areas conducive to oyster survival, one project that has potential to achieve both a large geographic scale and relatively good per-unit benefits (based on baseline environmental characteristics) is the public/private Gulf Coast restoration partnership called the

[34] In addition to ACR, NOAA-ARRA also funded oyster reef restoration projects in Virginia (22 ac. of cultch planted, but not designed primarily to provide breakwater services), North Carolina (78 acres) and in Louisiana (approximately 3 miles of breakwater structures).

"100-1000 Project" (*http://100-1000.org*), so called for its intent to install 100 miles of oyster reefs and protect 1,000 acres of existing or potential coastal marsh and SAV habitat. There is no single size threshold that determines optimal project scope; in addition to size, project success is also determined by site-specific characteristics, nearby ecological resources that can lead to synergistic effects. Location may be as important for cost-effectiveness as size.

Future oyster breakwater projects can also be sited and developed to increase benefits not achieved on a per-acre basis, such as locating oyster reefs in areas that have the most to gain from breakwater-related benefits. For example, site choice affects oyster recruitment (and thus services stemming from oysters' role as ecosystem engineers), so breakwater structures must be placed in waters that have large numbers of available oyster larvae. Without these larval populations, no oysters will settle onto the reef structure. Future projects can provide oyster benefits if they consider larval abundance, such as are reported on maps by The Dauphin Island Sea Lab. On the other hand, breakwater-related benefits to coastal protection and risk reduction are a potentially large benefit category not achieved at this case study due to location in areas relatively distant from residential development (Barbier, 2013; Landry & Hindsley). To enhance the coastal protection benefits (and value) at future breakwater projects, structures could be placed in areas that are closer to populated areas or to federally and state protected land such as wildlife refuges or parks. On the other hand, water quality near developed coastlines tends to be lower than water quality on the undeveloped coasts of ACR. If this is the case, poor water quality would harm oyster success and create a trade-off in the source of oyster breakwater benefits.

Projects that combine both location near economically-valuable human uses and the spatial scale needed to produce significant coastal erosion mitigation may provide the largest "bang for the restoration buck." A prior study of coastal residents' WTP to prevent future losses of barrier island beaches in the Mississippi Gulf coast (Petrolia & Kim, 2009) found that state residents were willing to make a one-time payment of $23.76 (95% Confidence Interval: $22.68 – $25.92) (2013$) to maintain status quo barrier island conditions for 30 years, avoiding a no-action base case of continued land loss. While Petrolia & Kim (2009) did not examine variations in WTP based on services provided by the barrier islands, authors believe most respondents considered hurricane protection and other environmental services when reporting WTP. To the extent that oyster reefs present a viable option for mitigating shoreline loss on Gulf Coast barrier islands (and thus avoiding loss of barrier islands' functions as hurricane breakwaters), regional residents may be willing to support future oyster breakwater investments at barrier islands. But, if future projects are limited in size and scope, barrier island protection services may not be realized.

In addition to extending the quantifiable and monetized benefits enumerated in this report to future and perhaps more successful projects, the ACR oyster reef restoration activities provide several non-monetary benefits to society that should not be omitted, including infrastructure protection, "knowledge capital," and employment benefits:

- Breakwaters in Alabama Port protect a stretch of coastline that has the only access road to and from Dauphin Island. We did not quantitatively value the protective benefits of avoiding shoreline loss near this stretch of road, but people who live, work, and recreate on Dauphin Island are likely to qualitatively value avoiding road damage or wash-outs in the face of shoreline retreat.

- Much research and development has been invested in developing best practices and artificial reef structure manufacturing technology. Investing in developing this "knowledge capital" improves the efficiency and perhaps effectiveness of future coastal restoration projects. Further, the small but growing oyster reef restoration industry is national in scope but also consists primarily of small businesses. To the extent that supporting small businesses and local livelihoods benefits community character and economic diversity, oyster reef restoration and innovation generate community vitality in ways that other types of coastal restoration do not.

- Artificial reef construction activity is labor-intensive, and temporarily employs workers displaced from traditional livelihoods in seafood processing during periods of under- or un-employment.

- A socioeconomic survey conducted as part of the ACR measured the infusion of stimulus funds and job creation in coastal communities. While the final version of this study was in press at the time of our report (Scyphers, et al., in press), a similar analysis of two oyster breakwater installations located near the ACR in southern Mobile Bay (5.6 acre footprint) found that planning and construction expenditures of the project produced a total of $11.15 million in increased output and household earnings, and supported 88 full- and part-time jobs over the restoration duration (Kroeger, 2012).

Table 4-6. Summary of Estimated Oyster Reef and Seagrass Restoration Benefits (2013$).

Benefit Category	Annualized Value	TPV	Notes on Additivity
Oyster Reef Restoration			
Carbon Sequestration	$118	$3,930	One Component of total (hypothetical) value.
Nitrogen Sequestration	$1,717- $8,325	$39,685 - $192,438	One component of total (hypothetical) value.
Commercial Oyster Fishery	Not Monetized		Reefs are managed as sanctuaries and will not be commercially harvested for oysters.
Commercial Fin Fishery	$1,918	$38,902	One component of total value
Recreational Fin Fishery	$4,923	$99,834	One component of total value
Coastal Erosion Mitigation	$64	$1,473	One component of total value
Total Economic Value of Oyster Reef Restoration and SAV Protection			
Total Economic Value	$8,740 - $15,348	$183,824 - $336,577	Includes fishery, erosion mitigation, and carbon and nitrogen sequestration benefits.

5 Uncertainty Analysis

Uncertainty and limitations inherent in the ecological estimation and economic valuation methodologies are described below in Table 5-1. Examples from individual case studies are provided in the table.

Table 5-1. Uncertainties and Limitations of Estimated Ecological and Economic Benefits.

Methodological Component

Ecological Success of the Restoration Project

Uncertain Effect on Benefits Estimate

Throughout this report, we project future ecological success of restoration projects based on a combination of short-term (e.g., two to three years) post-restoration monitoring data and on scientific reports from different, but comparable and more established restoration projects. It is possible that ecosystem functions at a site could recover faster and/or with greater success (or more slowly and/or with lower success) than available short-term reports and prior research suggest. If so, the ecological and economic assessments in this report will under-represent (over-represent) restoration benefits. Examples include:

- SBSPRP: Project documentation indicates levees surrounding restored wetland ponds will be actively managed to prevent flood risk from *increasing* post-restoration. Such a degree of planned active management implies ecological resources may also be maintained and managed, rather than subject to natural forces. If this is the case, the ecological benefits of the restoration project would persist beyond the 40-year benefit period used in this report, rendering the economic values under-estimates.
- ACR: We estimated benefits related directly to oyster populations using an approximate restoration trajectory based loosely on initial monitoring results. This introduces a substantial degree of uncertainty around benefits tied to oyster production (carbon and nitrogen cycling), but less so to benefits related only to the presence of structural breakwaters (such as fisheries benefits), which are immediately available. As a result we recommend the overall ACR results are discussed as an "order of magnitude" bounding exercise for the project.

Changes in Nutrient Sequestration

Uncertain Effect on Benefits Estimate

There is both scientific uncertainty in, and geographic variability among, available generalized estimates of oysters' and oyster reefs' nitrogen and carbon sequestration abilities. Examples include:

- VSBRP: Geographic proximity and biological similarity in our N-sequestration source study (Piehler & Smyth's study of North Carolina oyster reefs) and the VSBRP suggest N sequestration benefits for the VSBRP case study are relatively reasonable.
- ACR: Transferring Piehler & Smyth's N-sequestration benefits to Mobile Bay introduces substantial uncertainty due to varying features of these two sites and the great geographic distance between them. Although the magnitude and direction of this uncertainty on benefits estimates is uncertain, a conservative approach would treat nutrient sequestration benefits reported in this study as upper bound estimates.

Table 5-1 (continued). Uncertainties and Limitations of Estimated Ecological and Economic Benefits.

Methodological Component
Scaling Up and Scaling Down
Increases or Decreases Benefit Estimate Ecological benefits calculated using marginal production rates per area of habitat may over-estimate benefits from smaller habitat protection projects, due to scale-based differences in habitat quality of small and large habitat patches. To the degree possible we have attempted to tailor per-area benefit estimates, and to transfer benefits from studies that provide a close match to each ARRA project's size and geography. Nonetheless, in many cases the only available benefit estimates are point-estimates based on sites that were larger or smaller than the restoration case study.
Benefit Transfer Across Sites
Uncertain Effect on Benefits Estimate To the extent possible, we selected transfer studies that closely matched the ecological characteristics, size, and geographic region of each restoration case study site. However, transferring values for ecological changes due to restoration (and associated WTP for the changes) across sites introduces an unknown amount of transfer error. The amount of error increases with geographic distance, and site characteristic differences. Increasing geographic distance may imply differences in household characteristics and preferences, different ecological baselines and responsiveness to restoration, etc. Examples include: • SBSPRP: In transferring total WTP for east coast salt marsh restoration to California, we were able to calibrate transfer functions using demographic, site, and policy characteristics. However, there remains statistical uncertainty in the underlying estimated WTP functions, as well as in our choice of calibrations. • VSBRP: Transferring carbon sequestration of oysters in Scotland to oysters in Virginia, without adjusting for site-specific variation in biological conditions, introduces uncertainty of unknown magnitude and direction. • ACR: Transferring WTP for coastal beach protection on the Atlantic coast to homes on the Gulf Coast has limited precision due to differences in baseline rates of shoreline exposure, and differences in household characteristics.

Table 5-1 (continued). Uncertainties and Limitations of Estimated Ecological and Economic Benefits.

Methodological Component

Restoration Timeline Length

Net Neutral or Negative Effect on Benefit Estimate

The length of time over which restored or protected ecosystems persist into the future affects the monetary benefit of each project. Storms, climate change, and other factors may prevent case study restoration projects from persisting in perpetuity at full capacity. In addition, our estimates do not account for changes in societal time preference (or other preferences) over this period. Truncating the future stream of benefits 40 years after restoration began (ending in either 2049 or 2050 depending on project start year) acknowledges our assumptions that conditions today are unlikely to hold in the distant future. However, restored sites may persist beyond this period or fall short of it, and social preferences (such as the rate of time preference, or values for specific ecological services) may change before or after this date. In particular:

- SBSPRP: The 40-year timeline may under-estimate benefits if the ponds are maintained for the foreseeable future.
- VSBRP: The 40-year timeline may generally approximate benefits derived directly from the seeded reefs, since we used the 40-year period to approximate reef lifetime. However, eelgrass beds may persist for much longer; hence, eelgrass benefits truncated at 2049 may under-estimate TPV of eelgrass restoration investments.
- ACR: The 40-year timeline may generally approximate benefits derived directly from the seeded reefs, since we used the 40-year period to approximate reef lifetime. However, benefits tied to the structural components of the reef (regardless of oyster viability) may be under-estimated if structures persist beyond 2050 and are not eroded, washed away, or otherwise degraded.

Choice of Discount Rate

Increases or Decreases Benefit Estimate

Because people generally feel that receiving benefits now is preferable to receiving benefits in the future, society discounts the value of future benefits relative to current benefits. Throughout this analysis we discounted future values using the constant 3% discount rate recommended in best practices in the United States (U.S. EPA, 2010; U.S. Office of Management and Budget, 2003). However, as Conrad (2010, p. 15) writes, “A society where time is of the essence or where a large fraction of the populace is on the brink of starvation would have a higher rate of discount.” Use of a higher discount rate would mean ecosystem service benefits in the future are worth less today, and would make, “investments to improve or protect environmental quality unattractive when compared with alternative investments in the private sector” (Conrad, 2010, p. 15).

6 References

Abelson, P. W., & Markandya, A. (1985). The interpretation of capitalized hedonic prices in a dynamic environment. *Journal of Environmental Economics and Management 12*(3), 195-206.

Anderson, E. E. (1989). Economic benefits of habitat restoration: seagrass and the Virginia hard-shell blue crab fishery. *North American Journal of Fisheries Management, 9*(2), 140-149.

Aronson, J., Blignaut, J. N., Milton, S. J., Le Maitre, D., Esler, K. J., Limouzin, A., . . . Lederer, N. (2010). Are socioeconomic benefits of restoration adequately quantified? A meta-analysis of recent papers (2000–2008) in Restoration Ecology and 12 other scientific journals. *Restoration Ecology, 18*(2), 143-154. doi: 10.1111/j.1526-100X.2009.00638.x

Association of Bay Area Governments. (2005). The San Francisco Bay Trail Project Gap Analysis Study: A Report on Closing the Gaps in the 500-mile Regional Trail System Encircling San Francisco Bay. In I. Alta Planning + Design, I. Questa Engineering & GreenInfo Network (Eds.). San Francisco.

Avian Knowledge Network. (2013). Data from the AKN Retrieved September, 2013, from http://www.avianknowledge.net/

Baas, J. M., Ewert, A., & Chavez, D. J. (1993). Influence of ethnicity on recreation and natural environment use patterns: Managing recreation sites for ethnic and racial diversity. *Environmental Management, 17*(4), 523-529.

Bagstad, K. J., Stapleton, K., & D'Agostino, J. R. (2007). Taxes, subsidies, and insurance as drivers of United States coastal development. *Ecological Economics, 63*(2–3), 285-298. doi: http://dx.doi.org/10.1016/j.ecolecon.2006.09.019

Barbier, E. B. (2013). Valuing Ecosystem Services for Coastal Wetland Protection and Restoration: Progress and Challenges. *Resources, 2*(213-230).

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs, 81*(2), 169-193.

Barry A. Vittor & Associates. (2005). Historical SAV distribution in the Mobile Bay National Estuary Program area and ranking analysis of potential SAV restoration sites (pp. 1-13). Mobile, AL: Prepared for the Mobile Bay National Estuary Program,.

Barry A. Vittor & Associates. (2009). Submerged aquatic vegetation mapping in Mobile Bay and adjacent waters of coastal Alabama in 2008 and 2009. Mobile, AL: Report prepared for Mobile Bay National Estuary Program.

Battelle Memorial Institute. (2008). San Francisco Bay Subtidal Habitat Goals Report, Appendix 1-2: Economic Valuation of San Francisco Bay Natural Resources Services (pp. 1-76). Portland.

Bauer, D., Cyr, N. E., & Swallow, S. K. (2004). Public preferences for compensatory mitigation of salt marsh losses: a contingent choice of alternatives. *Conservation biology, 18*(2), 401-411.

Beck, M. W., Brumbaugh, R. D., Airoldi, L., Carranza, A., Coen, L. D., Crawford, C., . . . Zhang, G. (2009). Shellfish Reefs at Risk: A Global Analysis of Problems and Solutions (pp. 1-52). Arlington, VA: The Nature Conservancy.

Bergstrom, J. C., Dorfman, J. H., & Loomis, J. B. (2004). Estuary Management and Recreational Fishing Benefits. *Coastal Management, 32*(4), 417-432. doi: 10.1080/08920750490487430

Bernard, T., & Young, J. M. (1997). Fishing, farming and ecotourism: the Eastern Shore of Virginia *The ecology of hope: Communities collaborate for sustainability*. East Haven, CT: New Society Publishers.

Binard, K., Chiang, K., Rafferty, M., Greer, P., & Semion, J. (2008). *Vegetation Coverage in Cooley Landing Salt Pond Restoration Area, Menlo Park, CA*. Paper presented at the South Bay Science Symposium, San Jose State University.

Boudreau, D. (2012). *Coastal Climate Adaptation: Ecological and Socioeconomic effects of Climate Change in Dare, Hyde, and Tyrrell Counties.* Master of Environmental Management, Duke University.

Boyer, T., & Polasky, S. (2004). Valuing urban wetlands: a review of non-market valuation studies. *Wetlands, 24*(4), 744-755.

Braden, J. B., & Johnston, D. M. (2004). Downstream economic benefits from storm-water management. *Journal of Water Resources Planning and Management, 130*(6), 498-505.

Brander, L. M., Florax, R. J., & Vermaat, J. E. (2006). The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature. *Environmental and Resource Economics, 33*(2), 223-250.

Brian Fulfrost and Associates. (2012). Habitat Evolution Monitoring ProjectL Final Report (2009 - 2011).

Brouwer, R., Langford, I. H., Bateman, I. J., & Turner, R. K. (1999). A meta-analysis of wetland contingent valuation studies. *Regional Environmental Change, 1*(1), 47-57.

Brusati, E. D., & Grosholz, E. D. (2006). Native and introduced ecosystem engineers produce contrasting effects on estuarine infaunal communities. *Biological Invasions, 8*(4), 683-695.

Burrage. (2009). Addressing Ethnic Change in the Northern Gulf of Mexico Seafood Industry. *Journal of Extension, 47*(5), 1-4.

California Coastal Conservancy. (2011). Staff Recommendation: Middle Bair Island Wetland Restoration (pp. 1-11).

Callaway, J. C., Borgnis, E. L., Turner, R. E., & Milan, C. S. (2012). Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands. *Estuaries and coasts, 35*(5), 1163-1181.

Carver, E. (2009). Birding in the United States: a Demographic and Economic Analysis (pp. 20): U.S. Fish and Wildlife Service.

Carver, E., & Caudill, J. (2009). Banking on Nature 2006: The economic benefits to local communities of National Wildlife Refuge visitation. Washington, D.C.: U.S. Fish and Wildlife Service.

Champ, P. A., Boyle, K. J., & Brown, T. C. (Eds.). (2003). *A Primer on Nonmarket Valuation*. Boston: Kluwer Academic Publishers.

Chesapeake Bay Foundation. (2013). Oysters Making a Splash in Virginia Retrieved December 3, 2013, from http://cbf.typepad.com/bay_daily/2013/11/oysters-making-a-splash-in-virginia.html

Christianen, M. J. A., van Belzen, J., Herman, P. M. J., van Katwijk, M. M., Lamers, L. P. M., van Leent, P. J. M., & Bouma, T. J. (2013). Low-Canopy Seagrass Beds Still Provide Important Coastal Protection Services. *PloS one, 8*(5), e62413.

Conrad, J. M. (2010). *Resource Economics* (2nd ed.). New York: Cambridge University Press.

Dahl, T. E. (2011). Status and Trends of Wetlands in the Conterminous United States 2004 to 2009 (pp. 108). Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service.

Dame, R. F., & Kenny, P. D. (1986). Variability of Spartina alterniflora primary production in the euhaline North Inlet estuary. *Marine Ecology Progress Series, 32*, 71-80.

Daniel, V. E., Florax, R. J., & Rietveld, P. (2009). Flooding risk and housing values: an economic assessment of environmental hazard. *Ecological Economics, 69*(2), 355-365.

DeQuattro, J. (2014). [E-mailed Notes: Oxfam Report Assessment].

Diewert, W. E., Nakamura, A., & Nakamura, L. (2009). The housing bubble and a new approach to accounting for housing in a CPI. *Journal of Housing Economics, 18*(3), 156-171.

Donehower, C., Tokatlian, K., Robinson-Nilsen, C., & Strong, C. (2013). Western Snowy Plover Monitoring in the San Francisco Bay (pp. 1-53). Milpitas, CA: San Francisco Bay Bird Observatory and Don Edwards San Francisco Bay National Wildlife Refuge.

Donner, W., & Rodríguez, H. (2008). Population composition, migration and inequality: The influence of demographic changes on disaster risk and vulnerability. *Social Forces, 87*(2), 1089-1114.

Dougherty, A., & Van Order, R. (1982). Inflation, housing costs, and the Consumer Price Index. *American Economic Review, 72*(1), 154-164.

Douglass, S. L., & Pickel, B. H. (1999). "The Tide Doesn't Go Out Anymore"- The Effect of Bulkheads on Urban Bay Shorelines Retrieved January, 2014, from http://www.southalabama.edu/cesrp/Tide.htm

EDAW. (2007). South Bay Salt Pond Restoration Project: Final Environmental Impact Statement/Report: Submitted to U.S. Fish and Wildlife Service and California Department of Fish and Game.

Edwards, P. E. T., Sutton-Grier, A. E., & Coyle, G. E. (2013). Investing in nature: Restoring coastal habitat blue infrastructure and green job creation. *Marine Policy, 38*(0), 65-71. doi: http://dx.doi.org/10.1016/j.marpol.2012.05.020

Evans-Klages Inc. (2013). Spring 2013 Visitor Profile. Tampa, FL: Prepared for the Alabama Gulf Coast Convention and Visitors Bureau.

Fielding, J., & Burningham, K. (2005). Environmental inequality and flood hazard. *Local Environment, 10*(4), 379-395.

Flint, R. W., & Danner, M. J. E. (2001). The nexus of sustainability & social equity: Virginia's eastern shore (USA) as local examples of global issues. *International Journal of Economic Development, 3*(2).

Flint, R. W., McCarter, W., & Bonniwell, T. (2000). Interdisciplinary education in sustainability: links in secondary and higher education. *International Journal of Sustainability in Higher Education, 1*(2), 191-302.

Fonseca, M. S., & Cahalan, J. A. (1992). A preliminary evaluation of wave attenuation by four species of seagrass. *Estuarine, Coastal and Shelf Science, 35*(6), 565-576. doi: http://dx.doi.org/10.1016/S0272-7714(05)80039-3

Fothergill, A., Maestas, E. G., & Darlington, J. D. (1999). Race, ethnicity and disasters in the United States: A review of the literature. *Disasters, 23*(2), 156-173.

Freeman, A. M. I. (2003). *The measurement of environmental and resource values: theory and methods* (2nd ed.). Washington, D.C.: RFF Press.

Fry, J. M. (2010). Carbon Footprint Of Scottish Suspended Mussels And Intertidal Oysters: Scottish Aquaculture Research Forum.

Goals Project. (1999). Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project (pp. 1-209 (plus appendices)). San Francisco, CA: U.S. Environmental Protection Agency /S.F. Bay Regional Water Quality Control Board.

Gobster, P. H. (2002). Managing urban parks for a racially and ethnically diverse clientele. *Leisure Sciences, 24*(2), 143-159.

Grabowski, J. H., Brumbaugh, R. D., Conrad, R. F., Keeler, A. G., Opaluch, J. J., Peterson, C. H., . . . Smyth, A. R. (2012). Economic valuation of ecosystem services provided by oyster reefs. *BioScience, 62*(10), 900 - 909.

Grabowski, J. H., & Peterson, C. H. (2007). Restoring oyster reefs to recover ecosystem services. *Theoretical ecology series, 4*, 281-298.

Greening, H., & Janicki, A. (2006). Toward reversal of eutrophic conditions in a subtropical estuary: Water quality and seagrass response to nitrogen loading reductions in Tampa Bay, Florida, USA. *Environmental Management, 38*(2), 163-178.

Grijalva, E., & Kerr, D. (2012). San Francisco Estuary Invasive Spartina Project: 2011 Treatment Report (pp. 1-28 (Plus Appendices)). Berkeley, CA: Prepared For California Coastal Conservancy.

H.T. Harvey Associates. (2005). South Bay Salt Ponds Restoration Project - Biology and Habitat Existing Conditions: Prepared for U.S. Fish and Wildlife Service and CA Department of Fish and Game.

Hadley, N. H., Hodges, M., Wilber, D. H., & Coen, L. D. (2010). Evaluating intertidal oyster reef development in South Carolina using associated faunal indicators. *Restoration Ecology, 18*(5), 691-701.

Heck, K. L., Jr., Powers, S. P., Scyphers, S. B., & Byron, D. (2010). Shoreline stabilization and habitat restoration at Helen Wood Park, AL: Final Report to the Mobile Bay National Estuary Program.

Hicks, R. L. (2004). Recreational Fishing and the Benefits of Oyster Reef Restoration in the Chesapeake Bay. Williamsburg, VA: College of William and Mary.

Hicks, R. L. (2014, February 12, 2014). [Conference Call Re: Benefit Transfer from Hicks (2004) to VSBRP.].

Hobbs, J. A., Moyle, P., & Buckmaster, N. (2012). Monitoring the Response of Fish Communities to Salt Pond Restoration: Final Report (pp. 1-115). Davis, CA: University of California-Davis, prepared for South Bay Salt Pond Restoration Program & Resource Legacy Fund.

Hogle, I. (2012). San Francisco Estuary Invasive Spartina Project: 2011 Monitoring Report: Prepared for California Coastal Conservancy.

Holl, K. D., & Howarth, R. B. (2000). Paying for Restoration. [Article]. *Restoration Ecology, 8*(3), 260-267. doi: 10.1046/j.1526-100X.2000.80037.x

Huang, J.-C., Poor, P. J., & Zhao, M. Q. (2007). Economic valuation of beach erosion control. *Marine Resource Economics, 22*(3), 221.

Interagency Working Group on the Social Cost of Carbon. (2013). Techincal Support Document- Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.

Johnston, R. J., Grigalunas, T. A., Opaluch, J. J., Mazzotta, M., & Diamantedes, J. (2002). Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. *Coastal Management, 30*(1), 47-65.

Jordan, S. J., O'Higgins, T., & Dittmar, J. A. (2012). Ecosystem Services of Coastal Habitats and Fisheries: Multiscale Ecological and Economic Models in Support of Ecosystem-Based Management. *Marine and Coastal Fisheries, 4*(1), 573-586. doi: 10.1080/19425120.2012.703162

Kahn, J. R., & Kemp, W. M. (1985). Economic losses associated with the degradation of an ecosystem: The case of submerged aquatic vegetation in Chesapeake Bay. *Journal of Environmental Economics and Management, 12*(3), 246-263.

Kakoyannis, C., & Stankey, G. H. (2002). Assessing and Evaluating Recreational Uses of Water Resources: Implications for an Integrated Management Framework: U.S. Forest Service, U.S. Department of Agriculture. .

Kellogg, M. L., Cornwell, J. C., Owens, M. S., & Paynter, K. T. (2013). Denitrification and nutrient assimilation on a restored oyster reef. *Mar Ecol Prog Ser, 480*, 1-19.

Kneib, R. (2003). Bioenergetic and landscape considerations for scaling expectations of nekton production from intertidal marshes. *Marine Ecology Progress Series, 264*, 279-296.

Koch, E. W., & Gust, G. (1999). Water flow in tide-and wave-dominated beds of the seagrass Thalassia testudinum. *Marine Ecology Progress Series, 184*(1), 63-72.

Kroeger, T. (2012). Dollars and Sense: Economic Benefits and Impacts from two Oyster Reef Restoration Projects in the Northern Gulf of Mexico: The Nature Conservancy.

Kunreuther, H., & Pauly, M. (2006). Rules rather than discretion: Lessons from Hurricane Katrina. *Journal of Risk and Uncertainty, 33*(1-2), 101-116.

La Peyre, M. K., Humphries, A. T., Casas, S. M., & La Peyre, J. F. (2014). Temporal variation in development of ecosystem services from oyster reef restoration. *Ecological Engineering, 63*, 34-44.

La Peyre, M. K., Nix, A., Laborde, L., & Piazza, B. P. (2012). Gauging state-level and user group views of oyster reef restoration activities in the northern Gulf of Mexico. *Ocean & Coastal Management, 67*, 1-8.

Landry, C. E., & Hindsley, P. *Willingness to pay for risk reduction and amenities: applications of the hedonic price method in the coastal zone.*

Landry, C. E., Keeler, A. G., & Kriesel, W. (2003). An economic evaluation of beach erosion management alternatives. *Marine Resource Economics, 18*(2), 105-128.

Lenihan, H., & Peterson, C. H. (2004). Conserving oyster reef habitat by switching from dredging and tonging to diver hand-harvesting. *Fishery Bulletin, 102*, 298-305.

LifeSciences! Inc. (2003). Section 6, "Biological Resources" *South Bay Salt Pond Initial Stewardship Project. Draft Environmental Impact Statement/Environmental Impact Report*: Submitted to U.S. Fish and Wildlife Service and CA Department of Fish and Game.

Lonzarich, D. G. (1989). *Temporal and spatial variations in salt pond environments and implications for fish and invertebrates.* M.S. , San Jose State University. (SJSU Scholarworks Paper 3087)

Loomis, J. (2000). Vertically summing public good demand curves: an empirical comparison of economic versus political jurisdictions. *Land Economics, 76*(2), 312-321.

Loomis, J., Hanemann, M., Kanninen, B., & Wegge, T. (1991). Willingness to pay to protect wetlands and reduce wildlife contamination from agricultural drainage *The economics and management of water and drainage in agriculture* (pp. 411-429): Springer.

Luckenbach, M. W., Coen, L. D., Ross, P. G., Jr., & Stephen, J. A. (2005). Oyster Reef Habitat Restoration: Relationships Between Oyster Abundance and Community Development based on Two Studies in Virginia and South Carolina. *Journal of Coastal Research*(40), 64-78. doi: 10.2307/25736616

Lusk, B., Truitt, B. R., Wesson, J. A., & Lorber, G. (2011). Restoring Functional Oyster Reef Habitat in the Coastal Bays of Virginia, from http://conference.ifas.ufl.edu/ncer2011/Presentations/Monday/Kent/pm/1540_BLusk.pdf

MacKenzie, C. L. (2008). The Bay Scallop, Argopecten irradians, Massachusetts Through North Carolina: Its Biology and the History of Its Habitats and Fisheries. *Marine Fisheries Review, 70*(3-4), 6-79.

Mather Economics, & The Walton Family Foundation. (2012). Job creation from Gulf Coast wetlands restoration.

Mazzotta, M. J. (1996). *Measuring public values and priorities for natural resources: an application to the Peconic Estuary Program.* Doctor of Philosophy, University of Rhode Island.

McCay, D. F., & Rowe, J. J. (2003). Habitat restoration as mitigation for lost production at multiple trophic levels. *Marine Ecology Progress Series, 264*, 233-247.

McDonnell, B. (2013, November 18, 2013). Virginia Posts Largest Oyster Harvest Since 1987 Retrieved December 3, 2013, from http://www.governor.virginia.gov/News/viewRelease.cfm?id=2081

McGlathery, K. J., Reynolds, L. K., Cole, L. W., Orth, R. J., Marion, S. R., & Schwarzschild, A. (2011). Recovery trajectories during state change from bare sediment to eelgrass dominance. *Marine Ecology Progress Series, 448*, 209-221.

Meese, R., & Wallace, N. (1994). Testing the present value relation for housing: should I leave my house in San Francisco. *Journal of Urban Economics, 35*(3), 245 - 266.

Mejia, F., Saiki, M. K., & Takekawa, J. Y. (2008). Relation between species assemblages of fish and water quality in salt ponds and sloughs in South Sand Francisco Bay. *The Southwestern Naturalist, 53*(3), 335-345.

Meyer, D. L., & Townsend, E. C. (2000). Faunal utilization of created intertidal eastern oyster (Crassostrea virginica) reefs in the southeastern United States. *Estuaries, 23*(1), 34-45.

Millenium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Washington, D.C.: Island Press.

Mobile Bay National Estuary Program. (2008). State of Mobile Bay: A Status Report on Alabama's Coastline from the Delta to Our Coastal Waters (pp. 1-46). Mobile, AL.

Moody, R. M., Cebrian, J., Kerner, S. M., Heck Jr, K. L., Powers, S. P., & Ferraro, C. (2013). Effects of shoreline erosion on salt-marsh floral zonation. *Marine Ecology Progress Series, 488*, 145-155.

Morgan, O. A., & Hamilton, S. E. (2009). Estimating a Payment Vehicle for Financing Nourishment of Residential Beaches using a Spatial-Lag Hedonic Property Price Model. *Coastal Management, 38*(1), 65-75. doi: 10.1080/08920750903398287

Moskal, S. M., Takekawa, J. Y., Smith, L. M., & Shaffer, S. A. (2013). *If You Build It, Will They Come? Response of Waterbirds to Salt Pond Enhancements and Island Creation in the San Francisco Bay*. Paper presented at the South Bay Science Symposium 2013.

National Marine Fisheries Service. (2010). U.S. Marine Recreational Fisheries. In A. Lowther (Ed.), Fisheries of the United States 2010 (pp. 20-38). Silver Spring, MD. Retrieved from http://www.st.nmfs.noaa.gov/st1/fus/fus10/index.html.

National Research Council. (2010). *Ecosystem Concepts for Sustainable Bivalve Mariculture*: The National Academies Press.

Nelson, K. A., Leonard, L. A., Posey, M. H., Alphin, T. D., & Mallin, M. A. (2004). Using transplanted oyster (Crassostrea virginica) beds to improve water quality in small tidal creeks: a pilot study. *Journal of Experimental Marine Biology and Ecology, 298*(2), 347-368.

NOAA. (2012, V 2.6.1 - Updated 4/16/2012). Restoration Atlas: Marine and Coastal Habitat Restoration Projects Funded Under the American Recovery and Reinvestment Act, from http://www.nmfs.noaa.gov/habitat/restoration/restorationatlas/recovery_map.html

NOAA Fisheries: Fisheries Statistics Division (Producer). (2014, January 9, 2014). Commercial Fisheries Statistics. [Database] Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index

NOAA National Marine Fisheries Service. (2013). Marine Recreational Information Program Site Register (Map and Database). Retrieved 12/11/2013 https://www.st.nmfs.noaa.gov/siteregister/html/siteRegister.jsp

Opaluch, J. J., T. Grigalunas, M.J. Mazzotta, J. Diamantides, & Johnston, R. (1998). Resource and Recreational Economic Values for the Peconic Estuary: Report prepared for Peconic Estuary Program, Suffolk County Department of Health Services by Economic Analysis, Inc.

Orth, R. J., Carruthers, T. J. B., Dennison, W. C., Duarte, C. M., Fourqurean, J. W., Heck Jr, K. L., . . . Olyarnik, S. (2006). A global crisis for seagrass ecosystems. *BioScience, 56*(12), 987-996.

Orth, R. J., Marion, S. R., Moore, K. A., & Wilcox, D. J. (2010). Eelgrass (Zostera marina L.) in the Chesapeake Bay region of mid-Atlantic coast of the USA: challenges in conservation and restoration. *Estuaries and Coasts, 33*(1), 139-150.

Orth, R. J., & McGlathery, K. J. (2012). Eelgrass recovery in the coastal bays of the Virginia Coast Reserve, USA. *Marine Ecology Progress Series, 448*, 173-176. doi: 10.3354/meps09596

Orth, R. J., Moore, K. A., Lukenbach, M. W., Bonniwell, S., Curry, A. J., Fate, S., . . . Wilcox, D. J. (2012). Eelgrass and Bay Scallop Restoration in the Seaside Bays of Virginia (pp. 1-17): The Virginia Institute of Marine Science, College of William and Mary.

Orth, R. J., Moore, K. A., Marion, S. R., Wilcox, D. J., & Parrish, D. B. (2012). Seed addition facilitates eelgrass recovery in a coastal bay system. *Marine Ecology Progress Series, 448*, 177-195.

Oyster Metrics Workgroup. (2011). Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries: Report submitted to the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program.

Paul, M., Bouma, T. J., & Amos, C. L. (2011). Wave attenuation by submerged vegetation: combining the effect of organism traits and tidal current. *Marine Ecology Progress Series, 444*, 31-41.

Payne, L. L., Mowen, A. J., & Orsega-Smith, E. (2002). An examination of park preferences and behaviors among urban residents: the role of residential location, race, and age. *Leisure Sciences, 24*(2), 181-198.

Pendleton, L. H. (2006). Understanding the potential economic impact of marine wildlife viewing and whale watching in California: Executive summary (pp. 1-15). Los Angeles: University of California.

Peterson, C. H., Grabowski, J. H., & Powers, S. P. (2003). Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. *Marine Ecology Progress Series, 264*, 249-264.

Petrolia, D. R., & Kim, T.-G. (2009). What are Barrier Islands Worth? Estimates of Willingness to Pay for Restoration. *Marine Resource Economics, 24*(2), 131-146.

Phillip Williams and Associates. (2004). Design guidelines for tidal wetland restoration in San Francisco Bay. San Francisco: Prepared for The Bay Institute and California Coastal Conservancy.

Piehler, M. F. (2014, March 4, 2014). [E-mail Discussion: Study site characteristics of Piehler & Smyth (2011)].

Piehler, M. F., & Smyth, A. (2011). Habitat-specific distinctions in estuarine denitrification affect both ecosystem function and services. *Ecosphere, 2*(1), art12.

Pitkin, M., & Wood, J. (Eds.). (2011). *The State of the Birds, San Francisco Bay*: PRBO Conservation Science and the San Francisco Bay Joint Venture.

Potter, M., Provo, J., Atasoy, S., Howard, E., & Anders, C. (2007). Community Economic Development for the Eastern Shore: Summit Report. Blacksburg, VA: Virginia Tech Office of Economic Development.

Powell, E. N., Klinck, J. M., Ashton-Alcox, K., Hofmann, E. E., & Morson, J. (2012). The rise and fall of Crassostrea virginica oyster reefs: the role of disease and fishing in their demise and a vignette on their management. *Journal of Marine Research, 70*(2-3), 2-3.

Powers, S. P., Peterson, C. H., Grabowski, J. H., & Lenihan, H. S. (2009). Success of constructed oyster reefs in no-harvest sanctuaries: implications for restoration. *Marine Ecology Progress Series, 389*, 159-170.

Rainer, D. (2011). Restoring Little Bay: Outdoor Alabama.

Raines, B. (2010, April 13, 2010). Crews try to save Coffee Island from washing into the sea, Blog Article, *AL.com*. Retrieved from http://blog.al.com/live//print.html?entry=/2010/04/crews_try_to_save_coffee_islan.html

Raines, B. (2012, August 13, 2012). Coffee Island oyster restoration project more successful than designers imagined, Blog, *AL.com*. Retrieved from http://blog.al.com/live//print.html?entry=/2012/08/coffee_island_oyster_restorati.html

Richardson, L., & Loomis, J. (2009). The total economic value of threatened, endangered and rare species: an updated meta-analysis. *Ecological Economics, 68*(5), 1535-1548.

Roland, R. M., & Douglass, S. L. (2005). Estimating Wave Tolerance of Spartina alterniflora in Coastal Alabama. *Journal of Coastal Research, 21*(3), 453-463. doi: 10.2307/4299432

Rowan, A. (2010). Effects of the South Bay Salt Pond Restoration Project on Mud Flats and their Carrying Capacity for Shorebirds (pp. 1-11): San Francisco State University.

San Francisco Bay Restoration Authority. (n.d.). San Francisco Bay Restoration Authority: Introduction Retrieved October 2013, from http://sfbayrestore.org/

Save the Bay. (2011). Greening the Bay: Financing Wetland Restoration in San Francisco Bay. Oakland.

Schneider, I. E. (2009). Urban water recreation: Experiences, place meanings, and future issues *The water environment of cities* (pp. 125-140): Springer.

Scyphers, S. B., Picou, J. S., Brumbaugh, R. D., & Powers, S. P. (in press). Integrating societal perspectives and values for improved stewardship of a coastal ecosystem engineer. *Ecology & Society*.

Scyphers, S. B., Powers, S. P., Heck, K. L., Jr., & Byron, D. (2011). Oyster Reefs as Natural Breakwaters Mitigate Shoreline Loss and Facilitate Fisheries. *PloS one, 6*(8), e22396. doi: 10.1371/journal.pone.0022396

Short, F. T., Polidoro, B., Livingstone, S. R., Carpenter, K. E., Bandeira, S., Bujang, J. S., . . . Zieman, J. C. (2011). Extinction risk assessment of the world's seagrass species. *Biological Conservation, 144*(7), 1961-1971. doi: http://dx.doi.org/10.1016/j.biocon.2011.04.010

Siegel, C., Caudill, S. B., & Mixon, F. G. (2013). Clar skies, dark waters: the Gulf oil spoll and the price of coastal condominiums in Alabama. *Economics and Business Letters, 2*(2), 42-53.

Smith, V. K., Van Houtven, G., & Pattanayak, S. K. (2002). Benefit transfer via preference calibration:"Prudential algebra" for policy. *Land Economics, 78*(1), 132-152.

Sokale, J., & Trulio, L. (2013). South Bay Salt Pond Restoration Project: Trail User Satisfaction Study [DRAFT REPORT] (pp. 1-22).

South Bay Salt Pond Restoration Project. (2012). Annual Report 2012. Retrieved from http://www.southbayrestoration.org/documents/technical/2012sbspannualreport.FINAL.pdf

Southwick Associates. (2011). The Economics Associated with Outdoor Recreation, Natural Resources Conservation and Historic Preservation in the United States (pp. 1 - 33). Fernandina Beach.

Stanley, D. L. (2005). Local Perception of Public Goods: Recent Assessments of Willingness-to-pay for Endangered Species. *Contemporary Economic Policy, 23*(2), 165-179.

Stokes, S., Lowe, M., Owen, R., & Mine, S. (2013). Wildlife tourism and the Gulf Coast economy (pp. 1-55): Datu.

Stokes, S., Wunderink, S., Lowe, M., & Gereffi, G. (2012). Restoring Gulf Oyster Reefs: Opportunities for Innovation (pp. 1-60): Center on Globalization, Governance & Competitiveness, Duke University.

Streiner, C., & Loomis, J. (1995). Estimating the Benefits of the Urban Stream Restoration Program. *Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, Col. Photocopy*.

Swann, L. (2008). *The use of living shorelines to mitigate the effects of storm events on Dauphin Island, Alabama, USA.* Paper presented at the American Fisheries Society Symposium.

Takekawa, J. Y., Athearn, N. D., Hattenbach, B. J., & Schultz, A. K. (2006). Bird Monitoring for the South Bay Salt Pond Restoration Project: Data Summary Report (pp. 1-74). Vallejo, CA: U.S. Geological Survey Western Ecological Research Center, San Francisco Bay Estuary Field Station.

Takekawa, J. Y., Woo, I., Gardiner, R., Casazza, M., Ackerman, J. T., Nur, N., . . . Spautz, H. (2011). Avian Communities in Tidal Salt Marshes of San Francisco Bay: A Review of Functional Groups by Foraging Guild and Habitat Association. *San Francisco Estuary and Watershed Science, 9*(3).

Terrados, J., & Borum, J. (2004). Why are seagrasses important?-Goods and services provided by seagrass meadows. In J. Borum, C. M. Duarte, D. Krause-Jensen & T. M. Greve (Eds.), European seagrasses: an introduction to monitoring and management (pp. 8-10).

The Bay Institute. (2003). San Francisco Bay Fish Index: Indicator Analysis and Evaluation (pp. 1-23). San Francisco, CA.

The Nature Conservancy. (2009, June 30, 2009). Virginia's Eastern Shore Receives Economic Stimulus Funding for Oyster, Seagrass, and Scallop Restoration, 2013, from http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/virginia/newsroom/virginias-eastern-shore-receives-economic-stimulus-funding.xml

The Nature Conservancy. (2012). Restoration for Resiliency, from http://www.futureofthegulfcoast.org/ob/032212-BRRCOrangeBeachStubljar.pdf

The Nature Conservancy. (2014). Oyster Reef Conservation Retrieved January, 2014, from http://www.nature.org/science-in-action/science-features/oyster-reef-interactive-graphic.xml

Thomas, S. J. (1991). Indochinese adjustment and assimilation in an Alabama coastal fishing community. *Comparative Civilizations Review, 24*, 1-12.

Troy, A., & Romm, J. (2004). Assessing the price effects of flood hazard disclosure under the California natural hazard disclosure law (AB 1195). *Journal of Environmental Planning and Management, 47*(1), 137-162.

U.S. Department of Agriculture Natural Resources Conservation Service. (2012). Oyster Reef Restoration Project 2012/USDA Report. Retrieved from http://www.wellfleetma.org/public_documents/WellfleetMA_Wastewater/Wellfleet%20Oyster%20Project%20and%20Water%20Quality%202012%20Results.pdf

U.S. EPA. (2010). *Guidelines for Preparing Economic Analyses*. (EPA 240-R-10-001).

U.S. EPA. (2011). *Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule*. (EPA 821-R-11-002).

U.S. EPA. (2013a). Benefits Analysis for the Final Section 316(b) Existing Facilities Rule.

U.S. EPA. (2013b). Draft technical guidance for assessing environmental justice in regulatory analysis (April 3, 2013 - Post-Internal Agency Review Draft ed., pp. 1-56).

U.S. Fish and Wildlife Service. (2013). Don Edwards San Francisco Bay National Wildlife Refuge Comprehensive Conservation Plan.

U.S. Fish and Wildlife Service. (2014). Restoration Returns: The contribution of partners for Fish and Wildlife Program and Coastal Program restoration projects to local U.S. economies (pp. 1-21).

U.S. Office of Management and Budget. (2003). Circular A-4, September 17, from http://www.whitehouse.gov/OMB/circulars/a004/a-4.pdf

US Geological Survey. (2010). Seagrass Habitat in the Northern Gulf of Mexico: Degradation, Conservation, and Restoration of a Valuable Resource: USGS Gulf of Mexico Program

Valoppi, L. (2013, September 17, 2013). [Conference Call: South San Francisco Bay Salt Pond Discussion].

van der Heide, T., van Nes, E. H., van Katwijk, M. M., Olff, H., & Smolders, A. J. P. (2011). Positive feedbacks in seagrass ecosystems–Evidence from large-scale empirical data. *PloS one, 6*(1), e16504.

Virginia Coastal Zone Management Program. (2010). Virginia Seaside Heritage Program: Accomplishments 2002-2009.

Virginia Coastal Zone Management Program. (2013). Virginia Seaside Heritage Program: Hope Revived for a Seaside Treasure.

Virginia Department of Environmental Quality. (2013). Virginia CZM Program Eelgrass Restoration Efforts from http://www.deq.state.va.us/Programs/CoastalZoneManagement/CZMIssuesInitiatives/SeaGrass.aspx

Virginia Tourism Corporation. (2013a). Tourism $$ in Virginia, from http://www.virginia.org/pressroom/tourism.asp

Virginia Tourism Corporation. (2013b). Travel Data and Profiles. http://www.vatc.org/research/travel-data/

Virginia Tourism Corporation. (2013c). Virginia Locality Economic Impact Data (Database). Retrieved 11/25/2013, from Virginia.gov http://virginiascan.yesvirginia.org/localspending/localspending.aspx

Waldbusser, G. G., Steenson, R. A., & Green, M. A. (2011). Oyster shell dissolution rates in estuarine waters: effects of pH and shell legacy. *Journal of Shellfish Research, 30*(3), 659-669.

Walker, G., & Burningham, K. (2011). Flood risk, vulnerability and environmental justice: Evidence and evaluation of inequality in a UK context. *Critical Social Policy, 31*(2), 216-240.

Williams, P. B., & Orr, M. K. (2002). Physical Evolution of Restored Breached Levee Salt Marshes in the San Francisco Bay Estuary. *Restoration Ecology, 10*(3), 527-542. doi: 10.1046/j.1526-100X.2002.02031.x

Woodward, R. T., & Wui, Y.-S. (2001). The economic value of wetland services: a meta-analysis. *Ecological Economics, 37*(2), 257-270.

Zahran, S., Brody, S. D., Peacock, W. G., Vedlitz, A., & Grover, H. (2008). Social vulnerability and the natural and built environment: a model of flood casualties in Texas. *Disasters, 32*(4), 537-560. doi: 10.1111/j.1467-7717.2008.01054.x

Zedler, J. B., & Callaway, J. C. (1999). Tracking wetland restoration: do mitigation sites follow desired trajectories? *Restoration Ecology, 7*(1), 69-73.

zu Ermgassen, P. S. E., Spalding, M. D., Grizzle, R. E., & Brumbaugh, R. D. (2013). Quantifying the Loss of a Marine Ecosystem Service: Filtration by the Eastern Oyster in US Estuaries. *Estuaries and coasts, 36*(1), 36-43. doi: 10.1007/s12237-012-9559-y