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An analysis of coastal restoration projects in Alabama and Mississippi

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This study aims to review thirteen coastal restoration projects considering the various ecosystem services provided by restoration and estimates the economic value of one of the ecosystem services of restoration. These ecosystem services include water quality improvement, fish and benthic species productivity, shoreline stabilization, oyster abundance, and marsh growth. The projects represent a set of large-scale projects within Alabama and Mississippi, with construction and monitoring costs ranging from $2.3 million to $50 million per project. To determine the economic value of one of the ecosystem services of coastal restoration projects, I used the meta-analysis method to estimate the willingness to pay (WTP) for coastal water quality improvements. The estimated function from the meta-analysis is applied to parameters specific to the study area. The WTP for improved coastal water quality, from a baseline of fishable but likely to degrade, to an improved fishing catch rate, is $203 per household annually among residents of Alabama and Mississippi.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

GENEARAL INTRODUCTION

Coastal restoration is the use of marsh, reefs, sand, and natural barriers to reduce erosion and flooding, maintain shoreline processes, and improve human health and property (EPA, 2023). This can involve activities like creating or restoring oyster and marsh habitats, and breakwaters to enhance ecosystem performances in coastal areas. The purpose of this study is to ascertain the ecosystem services that result from thirteen coastal restoration projects implemented in Alabama and Mississippi. The economic value of improved coastal water quality resulting from restoration for residents in Alabama and Mississippi is also estimated, where economic value is synonymous with willingness to pay (WTP). These restoration projects are being carried out to reduce the effects of chronic flooding, shoreline erosion, declining oysters and to compensate for the consequences of the Deepwater Horizon (DWH) oil spill disaster.

1.1 Historic Loss of Coastal Species

Coastal regions are susceptible to the impacts of climate change: rising sea levels and intense storms which cause erosion and flooding in these areas, leading to the loss of habitat (EPA, 2023). Overfishing of wild oysters and environmental mismanagement have led to the collapse of oyster reefs. (Grabowski and Peterson, 2007, Beck et al. 2011)). Habitat degradation, poor water quality and detrimental species interactions have also contributed to the loss of oysters (Ruesink et al.,2005). In the Chesapeake Bay, oyster harvest declined by 90% between 1890 and 1991 (Grabowski and Peterson, 2007). Beck et al. (2011) predict an 85% historic decline in oyster reefs, and Lotze et al. (2006) predict a greater than 65% decline in wetland habitat.

In the case of Alabama and Mississippi, data from the National Oceanic and Atmospheric Administration (NOAA) fisheries and the Gulf States Marine Fishery Commission (GSMFC) on oyster landings from 1950 to 2021 indicates a downward trend in oyster landings. Figures 1.1 and 1.2 show the annual average oyster landings with a trend line showing the decline in oyster landings over time. Figure 1.1 representing Alabama and Figure 1.2 representing Mississippi show a downward trend of oyster landings from 1950 to 2021. It is observed that oyster landings are very low in 1950 for Mississippi but relatively high for Alabama followed by gradual declines over that period for both Alabama and Mississippi with both states reaching very low levels from 2010 to 2021.

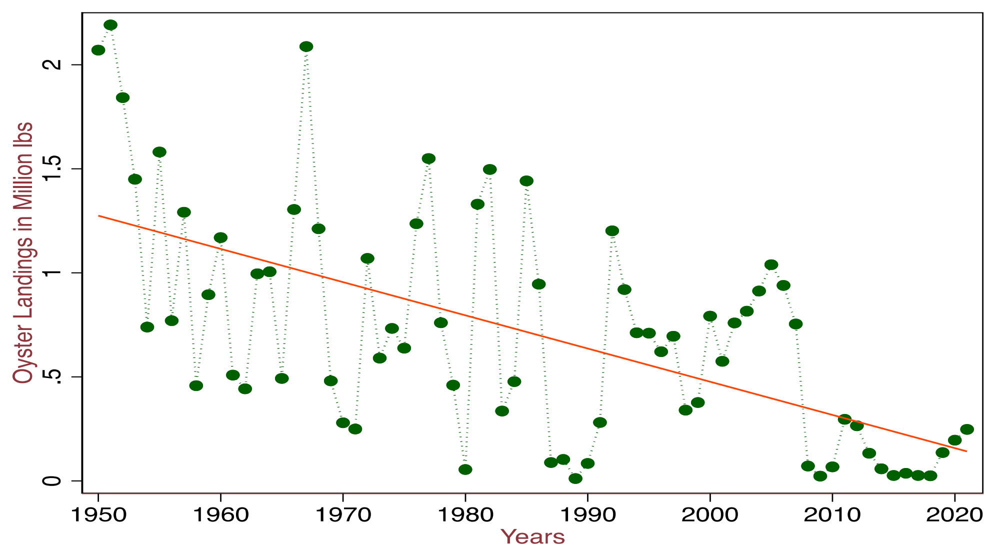

Figure 1.1 Trends in Alabama Oyster Landing in Million (lbs): 1950-2021

Source: Data sourced from NOAA Fisheries (2021) and Gulf States Marine Fishery Commission (2021)

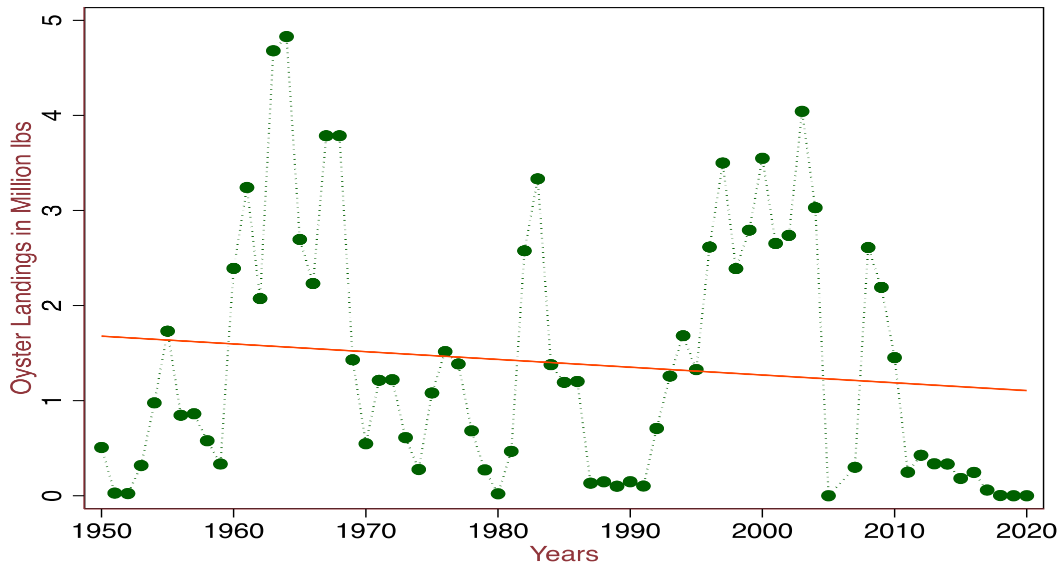

Figure 1.2 Trends in Mississippi Oyster Landings in Million (lbs): 1950-2021

Source: Data sourced from NOAA Fisheries (2021) and Gulf States Marine Fishery Commission (2021)

Marsh shorelines change rates in Alabama and Mississippi are shown in Figure 1.3, which demonstrates the historic shoreline position from 1848 to 2017. The shoreline position changes are measured by the Linear Regression Rate in meters per year(m/yr). In Figure 1.3, the historical shoreline position change rate ranges from a loss of 6.55 m/yr to a gain of 0.38 m/yr. Additionally, it is evident from Figure 1.3 that marsh shoreline loss is far greater than marsh shoreline gain since there are more line strips for red and yellow lines (representing loss) than the green lines (representing gain). These decline in coastal habitat is what has necessitated coastal restoration project construction in the study area.

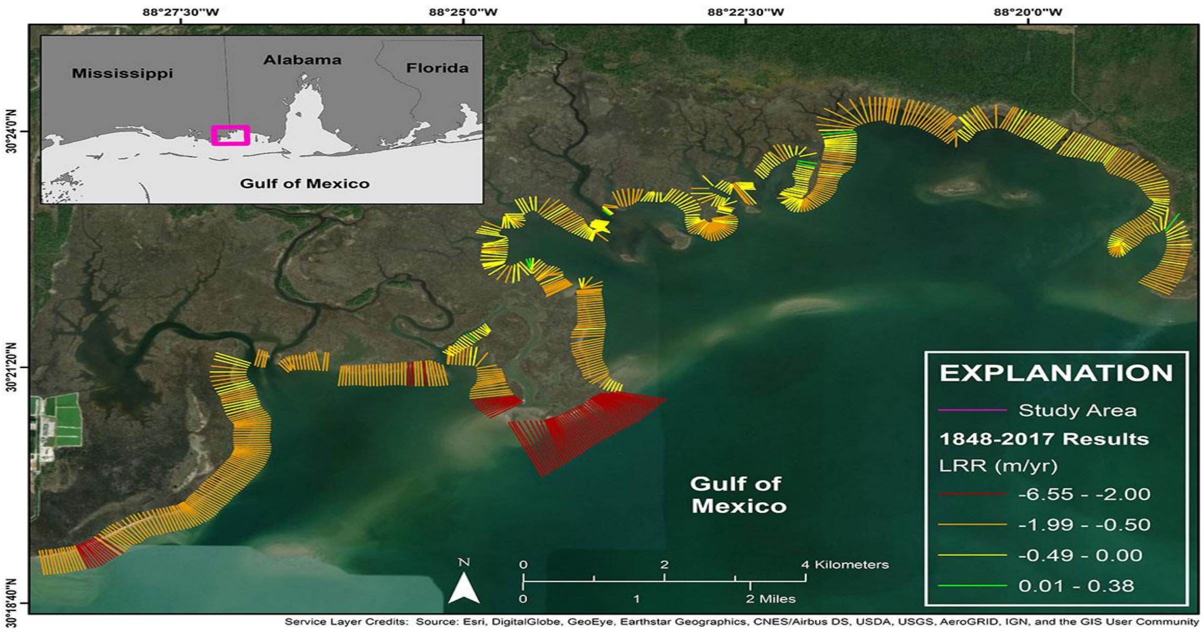

Figure 1.3 Shoreline Change Analysis in Alabama and Mississippi: 1848 – 2017

Source: Terrano et al. (2019)

1.2 Coastal Restoration Efforts

According to Beck et al. (2011), there are several areas with habitats that are critical for conservation, such as bays with reefs that are in fair to good condition which serves as critical areas for habitat management and conservation. Restoration of oyster species has been widely advocated in the literature as a solution to the reduction of excessive nutrients in water bodies (Pomeroy, D'Elia, and Schaffner, 2006). Most research on coastal species has been focused on a limited number of well-known estuaries with oysters such as Chesapeake Bay, which has a substantial oyster population. In the Gulf of Mexico where coastal species have been declining overall, there is a notable opportunity for sustainable oyster fisheries (Beck et al, 2011).

NOAA fisheries (2022) has thus, identified coastal restoration projects as a conservation priority because of the many benefits it provides. Previous studies on restoration have shown that large-scale restoration is technically feasible and that restored coastal species function just as well as their natural habitats (Kroeger, 2012). Coastal restoration projects typically involve: the distribution of large quantities of shells that serve as a suitable base for oysters to join and grow; or the construction of a linear reef of shell and rock to protect marsh, stabilize the shoreline, and function as a habitat for other sea animals; or the collecting and bagging of oyster shells; or the creation of hatcheries to provide seed oysters in a location with nonexistent oysters (NOAA Fisheries, 2022). Overall restoration projects can achieve large social gains by focusing on restoration projects that mimic their natural state (Nguyen et al., 2022).

A way to ascertain the social gains from restoration is by examining the ecosystem services of restoration. The ecosystem services of coastal restoration include fish and benthic species productivity, water quality improvements, shoreline stabilization, oyster abundance and marsh protection (NOAA Gulf Spill Restoration, 2022). Ecosystem services are the conditions and processes that allow the ecosystem, and its species, to sustain and fulfil human life (Daily, 1997). These ecosystem services of restoration represent the list of all intended outcomes (or objectives) for the thirteen restoration projects. From this list, I create charts that compares project-specific intended outcomes across projects and project years to determine the extent of variability or similarity of intended outcomes against actual monitored outcomes.

Furthermore, I select water quality improvements as a representative ecosystem service of restoration and employ the benefit transfer method to estimate the monetary value of coastal water quality improvement. Water quality is chosen as a representative ecosystem service for coastal restoration because it is directly related to all the other ecosystem service of coastal restoration and provides an all-inclusive outlook on the interconnectedness of the other ecosystem services of restoration. I summarize economics valuation literature on water quality and conduct a meta-analytic benefit transfer on water quality improvements. The estimated function from the meta-analysis is then applied to parameters specific to Alabama and Mississippi to obtain the WTP value for water quality.

The rest of the study will consist of three additional chapters and will follow this outline. In the second chapter, I will introduce the section on project analysis, discuss the literature on restoration projects, the methodological aspects, and present the project analysis results and their implications. In Chapter III, I will provide an overview of the meta-analysis, discuss related literature, present the meta-regression model, and share the results, and implications of the meta-analysis. Finally, in Chapter IV, I will present a general conclusion that highlights the main findings and some limitations of both the project analysis and meta-analysis sections of this study.

CHAPTER II

PROJECT ANALYSIS

2.1 Introduction

Restoration project analysis involves the systematic review of onsite monitoring data from monitoring reports for these purposes: 1) to determine whether a project has been completed per the restoration plan 2) to assess the extent of restoration projects meeting its intended objectives and 3) to learn from restoration efforts in such a manner that may enhance the efficacy of both current and future restoration efforts (The National Academy of Sciences, 2017). According to Clewell, Aronson, and Winterhalder (2004), a well-planned restoration project will often attempt to achieve its intended objectives by tracking these objectives. In this project analysis chapter, I compare the objectives of thirteen coastal restoration projects while probing into these questions: 1) How do the intended outcomes of coastal restoration projects vary from actual monitored outcomes? 2)What are the metrics used to measure intended outcomes? 3)Are metrics used measured consistently across projects and project year?

To answer these questions, I analyze the outcomes of seven living shorelines and six subtidal reef restoration projects in coastal Alabama and Mississippi that have been implemented since 2014. I create a catalog of the ecosystem services that arise from coastal restoration, where coastal restoration refers to the process of creating subtidal reefs or living shorelines, or breakwaters. A living shoreline refers to a type of estuarine protection that incorporates marsh and habitat preservation to build shoreline resilience against floods or storms (Davis et al., 2015).

Living shorelines can either be made up of marsh alone or its design may involve grading and sandfill, an offshore structure made of rock, or the inclusion of oyster reef to reduce wave energy (Davis et al. 2015). A subtidal reef is a preserved on-bottom reef that provides important structural habitats for aquatic species (NOAA Fisheries, 2022). Breakwaters are rocks or hardened structures placed off the coast for protection from storms. Living shorelines or subtidal reefs built together with breakwaters maintains the shoreline of waterbodies much more than solely using breakwaters (Currin, 2018).

The data employed for this project's analysis includes data on restoration costs, projects intended outcomes, and projects actual monitored outcomes. The cost of restoration for these thirteen projects ranges from $2.3 million to $50 million. With this cost involved, analyzing the outcomes of coastal restoration can provide a guide for when the restoration is a worthwhile investment of scarce resources (Grabowski et al., 2012).

A common characteristic of restoration projects is their shared project development life cycle, which includes planning, design, implementation, and maintenance. Since there may be regional factors (such as rising sea level, extreme weather, and species invasions) driving restoration outcomes, documenting, and understanding the long-term dynamics of restoration projects will be important (The National Academy of Sciences, 2017). Furthermore, given that the aggregate effects of individual projects can be understood through coordinated observations of all projects within a given region (Steyer et al., 2003), I enlist thirteen large-scale coastal restoration projects in Alabama and Mississippi to ascertain the extent of similarity (or variability) between planned restoration projects and implemented restoration projects.

2.2 Literature Review on Project Analysis

The analysis of restoration projects is widespread (Chichilnisky, 1997), as evidenced by the substantial literature surrounding the evaluation of restoration projects (Hynes et al., 2022; De Groot et al. 2013; DePiper, Lipton, and Lipcius 2017; Cameron, 1992; Holl and Howarth, 2000; Cooper et al. 2016; Caffey, Wang, and Petrolia, 2014; Logar, Brouwer, and Paillex, 2019; Bayraktarov et al., 2016). Since the cost of restoration projects depends on the ecosystem restored, and the economy where the restoration projects are carried out (Bayraktarov et al., 2016), the outcome of the thirteen coastal restorations in Alabama and Mississippi is being analyzed as a yardstick for comparing projected restoration objectives to monitored outcomes post-restoration.

Generally, a project's restoration analysis can either be conducted before a policy change (ex-ante), during a policy change (in-media res) or after a policy change has occurred (ex-post). A project's analysis must often be conducted either explicitly or implicitly whenever an event or change in policy affects the quality or availability of nonmarket goods (Cameron, 1992). Given that the median and average cost of restoring an acre of a marine habitat can be approximately $45,000 and $900,000 in 2022 dollars respectively (Bayraktarov et al., 2016) it is prudent to know if the ecosystem services that result from restoration generate environmental benefits of equal or greater magnitude (Holl and Howarth, 2000). Moreover, the ecosystem services of coastal restoration, vary across locations and habitats (Grabowski et al., 2012; Interis & Petrolia, 2016) making it prudent to ascertain specific project outcomes for different locations.

The cost of restoration involves the recurring cost which is the maintenance cost of restoration, and non-recurring costs which is the one-time investment cost or construction cost of the restoration (Logar, Brouwer, and Paillex, 2019). These costs can be obtained by borrowing the estimated cost of prior studies, market data on costs, estimated cost from restoration construction experts, and actual expended investment and management cost of the project if this is known. De Groot et al. (2013) obtains cost estimates of restoration by synthesizing ninety-four restoration studies. Logar, Brouwer, and Paillex (2019) use both benefit transfer and expert opinion to estimate both the investment and management cost of river restoration. Cooper et al., (2016) obtain the total cost of implementing climate adaptation projects for hazard mitigation through an expert's judgement. Bellas and Kosnik (2019) use the actual investment cost expended in restoring the Elwha River in Washington. In my analysis on coastal restoration projects, cost data is obtained from expended investment cost for each of the thirteen projects.

2.2.1 Ecosystem Services of Coastal Restoration

There are a variety of metrics used in the literature for assessing the ecosystem services that result from coastal restoration projects. For living shoreline restoration: metrics such as marsh density, vegetation cover, and benthic species have been used by studies like Baumann et al. (2018), Franco et al. (2020), and Rozas et al. (2005); sediment accretion and salinity are also used as a metric by Boerema et al., (2016). To assess the ecosystem services resulting in oyster reef restoration, metrics such as nitrogen removal, submerged aquatic vegetation (SAV), and benthic species have been used by Grabowski et al. (2012), Fish count and nitrogen removal have been used by Kroeger (2012). Boerema et al., (2016) assert that static measurements of restoration projects can produce misleading estimates if dynamic changes, which includes a variety of metrics, is not considered. This may explain why several literature analyzing restoration projects uses a variety of metrics.

The quantification of ecosystem services of restoration can be obtained through the benefit transfer method or by monitoring on-site conditions or nutrient trading credit (which is a purchase of a certified a unit of improvement to the environment by reducing excessive nutrients in waterbodies). Studies like Grabowski et al. (2012), and Kroeger (2012) quantify the ecosystem service of restoration for the Chesapeake Bay and the Gulf of Mexico respectively using the benefits transfer method. Studies like DePiper, Lipton, and Lipcius (2017) use nutrient credit to estimate the ecosystem services derived from restoring oysters at Harris Creek, Maryland, and Hynes et al. (2022) use on-site data of the number of trips to estimate the recreational value or the ecosystem services resulting from Renville coastal walk trail restoration. Several of the recent literature that quantifies the ecosystem services of coastal restoration seem to quantify these services either by nutrient credit trading (DePiper et al. 2017, Hall & DeAngelis 2022), benefits transfer (Grabowski et al. 2012; Blancher and Blancher 2016; Kroeger and Guannel, 2014; Kroeger, 2012) or using aggregated benefits (Hynes et al. 2022; Logar, Brouwer, and Paillex, 2019).

Kroeger (2012) estimates the quantitative benefits of oyster reefs in Mobile Bay and finds that coastal (or oyster reef) restoration can reduce coastal erosion by 51-90%, reduce wave energy at shores by 76-99%, remove 280 - 4167 pounds of nitrogen annually to improve water quality and can yield fish weights of about 6914 pounds. Liu, Fagherazzi, and Cui, (2021) also finds that restoration that incorporates natural habitats such as marsh significantly increased marsh accretion by 20 millimeters per year. The findings of Kroeger (2012) and Liu, Fagherazzi, and Cui (2021) seems to show that restoring coastal species (such as marshes or oyster reefs) reduces erosion, improves water quality, increases marsh growth, and enhances fish productivity.

Regarding the monetary value of the ecosystem services of coastal restoration, Grabowski et al. (2012) estimate that ecosystem services of the oyster reefs in the Chesapeake Bay, excluding oyster harvesting, have a value that is between $5,500 and $99,000 annually in

2011 dollars. Weber et al. (2018) predict a nutrient trading price range of $10 - $190 per pound of nitrogen removed by oyster reefs. Beseres Pollack et al. (2013) estimate that oyster reefs can reduce the nitrogen removal management cost in the Mission-Aransas Estuary by $1190 per acre annually. Piehler and Smith (2011) find that oyster reefs generate a nutrient removal value of $3000 per acre annually in Bogue Sound. Lai et al (2020) estimate the annual economic benefit of increased fish productivity that oysters provide in Mobile Bay, Alabama is $509,000 in direct commercial fishing and $19.59 million in recreational fishing.

In my analysis, data limitations on specific quantities of the ecosystem services of restoration hinder the ability to monetize the ecosystem service of the restoration projects in Alabama and Mississippi. Moreover, the success criteria of restoration have historically been based on the individual project or the site being restored (Kentula, 2000). Consequently, I fill the gap in the literature by comparing project outcomes for multiple projects whose construction and monitoring are either completed or underway since there are no studies that I am aware of that conduct a cross-comparison of multiple project outcomes for the restoration projects in Alabama and Mississippi.

2.3 Methods and Data

I identified thirteen large-scale coastal restoration projects that are either completed or ongoing in Alabama and Mississippi and reviewed their corresponding monitoring reports. Seven of the projects are in Alabama and six of them are in Mississippi. Table 2.1 summarizes common characteristics from the projects such as project names, construction year and monitoring status, funding sources, and investment costs. Project investment costs obtained from project reports are assumed to capture both construction and monitoring costs since project reports include the total budget and an approximated monitoring end date. For each project, construction is either completed (and assigned construction completion year) or in-progress (for projects that are currently under construction). Monitoring status is classified as ongoing (for projects that are currently being monitored), closed (for projects that have completed monitoring) and none (for projects with no monitoring reports). Seven of the projects in Alabama and two of the projects in Mississippi's construction have been completed, and monitoring records are available for these nine projects.

The projects are being restored to compensate for the DWH oil spill that occurred in 2010, to improve coastal ecosystem performance, or to mitigate recurring storm damages. The source of funding dictates the motivations for these restoration projects. For example, from Table 2.1, projects funded by phases I – IV of Natural Resource Damage Assessment (NRDA) framework are projects that restore or replace resources injured from the release of hazardous substances to the environment (US Department of Interior, 2021). Projects funded by the National Fish and Wildlife Foundation-Gulf Environmental Benefit Fund (NFWF-GEBF), restore endangered species, habitats and improves ecosystem health.

Table 2.1 Restoration Projects implemented in Alabama and Mississippi

Type	State	Name	Construction Year	Monitoring Status	Investment Cost	Funding Source*	Foot-print (acres)	Foot-print (miles)
Living Shorelines	AL	Mon Louis Island	2017	Ongoing	$2,969,000	NFWF-GEBF	4.8	0.27
		Marsh Island	2017	Ongoing	$11,280,000	NRDA I	50	—
		Alabama Swift Tract	2017	Ongoing	$5,000,080	NRDA	—	1.75
		Lightning Point	2020	Ongoing	$15,000,000	NFWF-GEBF	40	1.5
		Point aux Pins	2020	Ongoing	$2,300,000	NRDA	—	0.57
	MS	Hancock County Marsh	2017	Ongoing	$50,000,000	NRDA III	92	5.9
		Living Shorelines and Reefs in St. Louis Bay	In-progress	None	pending	NRDA IV	30	2.3
Subtidal Reefs	AL	Alabama Oyster Cultch	2015	Ongoing	$3,200,000	NRDA III	519	—
		Oyster Reef in Alabama	2020	Ongoing	$3,750,000	NFWF-GEBF	600	—
	MS	Oyster Cultch Deployment	2014	closed	$11,000,000	NRDA I	1430	—
		Living Shorelines and Reefs in Back Bay Biloxi	In-progress	None	pending	NRDA IV	—	—
		Living Shorelines and Reefs in Graveline Bay	In-progress	None	pending	NRDA	72	—
		Living Shorelines and Reefs in Grand Bay	In-progress	None	pending	NRDA IV	80	—

NFWF - National Fish and Wildlife Foundation, NRDA - Natural Resource Damage Assessment (I-IV represents funding phases) GEBF - Gulf Environment Benefit Fund, NOAA - National Oceanic and Atmospheric Administration, MBNEP – Mobile Bay National Estuary Program, AL-DCNR - Alabama Department of Conservation of Natural Resources, TNC- The Nature Conservancy, MS-DEQ - Mississippi Department of Environmental Quality

Aside from the motivation for carrying out restoration projects, each of the thirteen projects have specific intended objectives which are outlined in Table 2.1. This section thus, aims to ascertain when monitoring records were compiled, what metrics are being recorded and reported relative to the stated objectives of each project, and the extent to which stated objectives matches reported metrics over the course of the monitoring period. Monitoring data (or records) are sourced from NOAA Gulf Spill Restoration (2022) website, Mobile Bay Natural Estuary Program (2022) website, and The Nature Conservancy (TNC, 2022 & 2023) websites and personnel (Judy Haner, email, September 14th, 2022). Monitoring data can be defined as the collection and analysis of information on living organisms within a specific environment or system (Brebbia and Zannetti.2004). To understand the health, status and changes occurring in ecosystem services, various biological indicators such as plants, and animals, are studied, assessed, and collected over a time frame and compiled into monitoring reports for each project. Monitoring reports are compiled by a contracted company or agent to inspect and document restoration outcomes based on project-specific pre-determined objectives. These predetermined objectives for each project are presented in Table 2.2

Table 2.2 Restoration Objectives for Each Project

	Objectives	Water quality protection	Habitat creation for benthic and fish species	Shoreline protection	Enhancement of oysters and oyster habitat	Marsh creation and protection
Living Shorelines	Mon Louis Island		✓	✓		✓
	Marsh Island	✓		✓		✓
	Alabama Swift Tract	✓	✓	✓	✓	✓
	Lightning Point		✓	✓	✓	✓
	Point Aux Pins		✓	✓		✓
	Hancock County Marsh	✓	✓	✓	✓	✓
	Living Shorelines and Reefs in St. Louis Bay	✓	✓	✓	✓	
Subtidal Reefs	Alabama Oyster Cultch	✓			✓	
	Oyster Reef in Alabama	✓	✓	✓	✓	
	Oyster Cultch Deployment		✓		✓	
	Living Shorelines and Reefs in Back Bay Biloxi	✓	✓	✓	✓	
	Living Shorelines and Reefs in Graveline Bay	✓	✓	✓	✓	
	Living Shorelines and Reefs in Grand Bay	✓	✓	✓	✓	

2.4 Results and Discussion

A review of monitoring data reveals that each project's monitoring report presents different ways of assigning a calendar year to a project year. To ensure consistency and easy cross-comparison of project performances, I present a project's life to involve the pre-construction years (P), the construction year (0), and the post-construction years (1 to 7) as seen in Table 2.3. Additionally, monitoring reports for the projects contain a wide range of metrics and different units of measurement for some metrics. Tables 2.4-2.7 illustrate the metrics covered by five ecosystem service categories (water quality, fish productivity, shoreline stabilization, oyster abundance, marsh species), the years (P, and 0, through to 7) that each metric was reported, and the different units of measurement used by each metric for the 9 projects that have monitoring status as on-going or closed. The five ecosystem service categories correspond to the five objectives listed in Table 2.2.

In Tables 2.4-2.7, a checked cell under a metric implies monitoring data have been reported for that metric in a particular project year and an unchecked box with no text implies monitoring data have not been reported for that metric in a particular project year. Boxes with text are either within a future year (TBD) for the corresponding project or that metric is not an objective for that project. For all Tables presented in the section, a shaded cell implies "no longer monitoring or monitoring has ceased".

Table 2.4 reports water quality coverage for metrics like temperature, depth, conductivity, salinity, dissolved oxygen, and turbidity. Table 2.5 reporting on fish productivity metric includes fish count, submerged aquatic vegetation patches (which are plants in water that provide habitat and food for aquatic organisms), and benthic species (which are organisms that live near the bottom of a waterbody). Table 2.6 for shoreline stabilization includes shoreline change rates, and elevation. Table 2.7 for both oyster abundance and marsh growth include oyster count and oyster density, plant density, and vegetation cover. The different units of measurement for each metric in Tables 2.4-2.7 show that, there is no common unit of measurement across all projects for metrics like salinity, and dissolved oxygen. The rest of the discussion in this chapter briefly describes each of the restoration projects including project-specific intended outcomes and monitored outcomes.

Table 2.3 Project Construction and Monitoring Timeline

Project Year	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mon Louis Island	2016*	2017	2018	2019	2020	2021	2022					
Marsh Island	2015	2017	2018	2019	2020	2021	2022	2023				
Alabama Swift Tract	2015	2017	2018	2019	2020	2021	2022	2023	2024			
Lightning Point	2019	2020	2021	2022	2023	2024	2025					
Point aux Pins	1992 -2010	2020*	2021	2022	2023	2024	2025					
Hancock County Marsh	2016	2017	2018	2019	2020	2021	2022	2023	2024			
Alabama Oyster Cultch		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Oyster Reef in Alabama		2020*	2021*	2022	2023	2024	2025					
Oyster Cultch Deployment	2013	2014	2015	2016	2017	2018	2019	2020	2021			

*Represents project years that have no quantifiable data collected

Table 2.4 Coverage of Water Quality Metrics Included in Monitoring Reports (Units of Measurement)

	Temperature (°)									**Conductivity (mS)**									**Salinity (ppt, %)**								
Project Year	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mon Louis Island	Water quality is not an objective																										
Marsh Island		✓	✓					TBD			✓	✓					TBD			✓	✓					TBD	
Alabama Swift Tract		✓	✓	✓	✓	✓	✓	TBD			✓	✓	✓	✓	✓	✓	TBD			✓	✓	✓	✓	✓	✓	TBD	
Lightning Point	Water quality is not an objective																										
Point aux Pins	Water quality is not an objective																										
Hancock County Marsh			✓	✓				TBD									TBD				✓	✓				TBD	
Alabama Oyster Cultch																						✓	✓				
Oyster Reef in Alabama				TBD									TBD									TBD					
Oyster Cultch Deployment								✓																		✓	

Table 2.4 Coverage of Water Quality Metrics Included in Monitoring Reports (Units of Measurement) Continued

	Turbidity (NTU)									**Dissolved Oxygen (%, mg/l)**									**Depth (feet)**								
Project Year	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mon Louis Island	Water quality is not an objective																										
Marsh Island		✓	✓					TBD			✓	✓					TBD			✓	✓					TBD	
Alabama Swift Tract		✓	✓	✓	✓	✓	✓	TBD			✓	✓	✓	✓	✓	✓	TBD			✓						TBD	
Lightning Point	Water quality is not an objective																										
Point aux Pins	Water quality is not an objective																										
Hancock County Marsh			✓	✓				TBD				✓	✓				TBD				✓	✓				TBD	
Alabama Oyster Cultch													✓	✓													
Oyster Reef in Alabama						TBD									TBD									TBD			
Oyster Cultch Deployment																	✓									✓	

Table 2.5 Coverage of Fish Productivity Metrics Included in Monitoring (Units of Measurement)

	Fish (count, weight in grams)									**Submerged Aquatic Vegetation Patches (counts)**									**Benthic Species (counts, m²)**								
Project Year	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mon Louis Island							TBD									TBD					✓	✓	✓				
Marsh Island	Fish Productivity is not an objective																										
Alabama Swift Tract		✓	✓	✓	✓	✓	✓	TBD					✓				TBD			✓	✓	✓	✓	✓	✓	TBD	
Lightning Point				TBD						✓	✓	✓	TBD									TBD					
Point aux Pins				TBD									TBD								✓	TBD					
Hancock County Marsh								TBD									TBD		✓	✓	✓	✓	✓	✓	✓	TBD	
Alabama Oyster Cultch	Fish Productivity is not an objective																										
Oyster Reef in Alabama					TBD									TBD									TBD				
Oyster Cultch Deployment		✓	✓	✓	✓	✓														✓	✓	✓	✓	✓			

Table 2.6 Coverage of Shoreline Stabilization Included in Monitoring (Units of Measurement)

	Elevation (meter)									Shoreline Change (feet/year, feet)								
Project Year	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mon Louis Island							TBD									TBD		
Marsh Island			✓	✓				TBD		✓	✓	✓	✓	✓	✓	✓	TBD	
Alabama Swift Tract		✓		✓		✓		TBD		✓	✓		✓	✓	✓	✓	TBD	
Lightning Point			✓	TBD						✓		✓	TBD					
Point aux Pins			✓	TBD						✓			TBD					
Hancock County Marsh			✓	✓	✓	✓	✓	TBD		✓	✓	✓	✓				TBD	
Alabama Oyster Cultch	Shoreline Stabilization is not an objective																	
Oyster Reef in Alabama				TBD									TBD					
Oyster Cultch Deployment	Shoreline Stabilization is not an objective																	

All shoreline changes data for Mon Louis Island will be collated and published in project year 5 monitoring report (Annual Monitoring Report Mon Louis Island, 2018

Table 2.7 Coverage of Oyster Abundance and Marsh Species Metrics Included in Monitoring (Units of Measurement)

	Oyster Abundance (count, per m², per acre)									Marsh Growth (% cover, per m²)								
Project Year	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**P**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mon Louis Island	Oyster enhancement is not an objective											✓	✓	✓	✓			
Marsh Island	Oyster enhancement is not an objective											✓	✓	✓	✓	TBD		
Alabama Swift Tract		✓	✓	✓	✓	✓	✓	TBD									TBD	
Lightning Point		✓	✓	✓	TBD						✓	✓	✓	TBD				
Point aux Pins			✓	TBD									TBD					
Hancock County Marsh				✓			✓	TBD									TBD	
Alabama Oyster Cultch		✓	✓	✓	✓	✓	✓	✓	✓		Marsh Growth is not an objective							
Oyster Reef in Alabama					TBD						Marsh Growth is not an objective							
Oyster Cultch Deployment		✓		✓	✓	✓	✓	✓			Marsh Growth is not an objective							

2.4.1 Mon Louis Island

The Mon Louis Island Restoration project (shortened as Mon Louis Island) aimed to protect shoreline, restore marsh, and create a habitat for fish and benthic species (Mobile Bay National Estuary Program, 2016). The project is located at the mouth of the East Fowl River, on the western shore of Mobile Bay, in Mobile County, Alabama. This project constructed 0.27 miles of rock breakwaters and 4.8 acres of tidal marsh along eight acres of pre-existing tidal marsh previously restored in 2005. This project was funded by the NFWF-GEBF and implemented by the Mobile Bay National Estuary Program (MBNEP) at an investment cost of $3 million (Table 2.1). The project also included maintenance dredging of the Fowl River navigation channel with funding from the State of Alabama through the DWH grant program (Thompson Engineering 2018).

The monitoring data were compiled by Thompson Engineering, Inc., who also designed, and completed the construction of this project in 2017. From Table 2.5 benthic species metric is recorded for years 1 to 3 and monitoring of this objective is stopped as per correspondence from United States Army Corps Engineers. For this project, all shoreline changes data will be collated and published in project year 5 monitoring report (Construction Annual Monitoring Report Mon Louis Island, 2018). Marsh growth for years 1-4 is also monitored but no pre-construction marsh growth is reported since no marsh existed prior to the construction of the project. Performance monitoring for this project began in 2017 (year 0) and is supposed to end in 2022 (year 5). The monitoring reports provides year 0 post-storm water peak levels, but this does not fall in any of the five ecosystem service categories.

2.4.2 Marsh Island

The Marsh Island Living Shoreline project (abbreviated as Marsh Island) is targeted at shoreline protection, marsh habitat protection, and water quality protection (Marsh Island Living Shoreline project annual report, 2018). This project is in Portersville Bay, Mobile County (Alabama), south of Bayou La Batre (figure 2.1) and planted a total, 50 acres of native salt marsh along with segmented breakwaters. Thompson Engineering, Inc. designed and constructed this project in 2017, at a total cost of $11.2 million. This project was funded under the first phase of the NRDA process and led by of the Alabama Department of Conservation of Natural Resources (AL-DCNR).

The monitoring reports for this project were provided by Barry A. Vittor & Associates Inc and Thompson Engineering Inc. The reports document shoreline erosion rates for pre-construction and post-construction (years 0-5). For the marsh habitat objective of this project, marsh elevation, vegetation growth and vegetation cover are recorded for years 1, 2, 3 and 4 (see Table 2.7) but marsh metric for years 0, is not included in monitoring reports. For water quality, it can be observed from Table 2.4 that salinity, temperature, depths, turbidity, conductivity, and dissolved oxygen are reported for years 0 and 1, but not for subsequent years. Monitoring of project intended outcomes is planned to go on from 2017 to 2023 (see Table 2.3). Monitoring of project intended outcomes is planned to go on from 2017 to 2023. From Tables 2.4-2.7 monitoring data for year 5 is available for only shoreline change but there are no monitoring reports for year 6 and beyond.

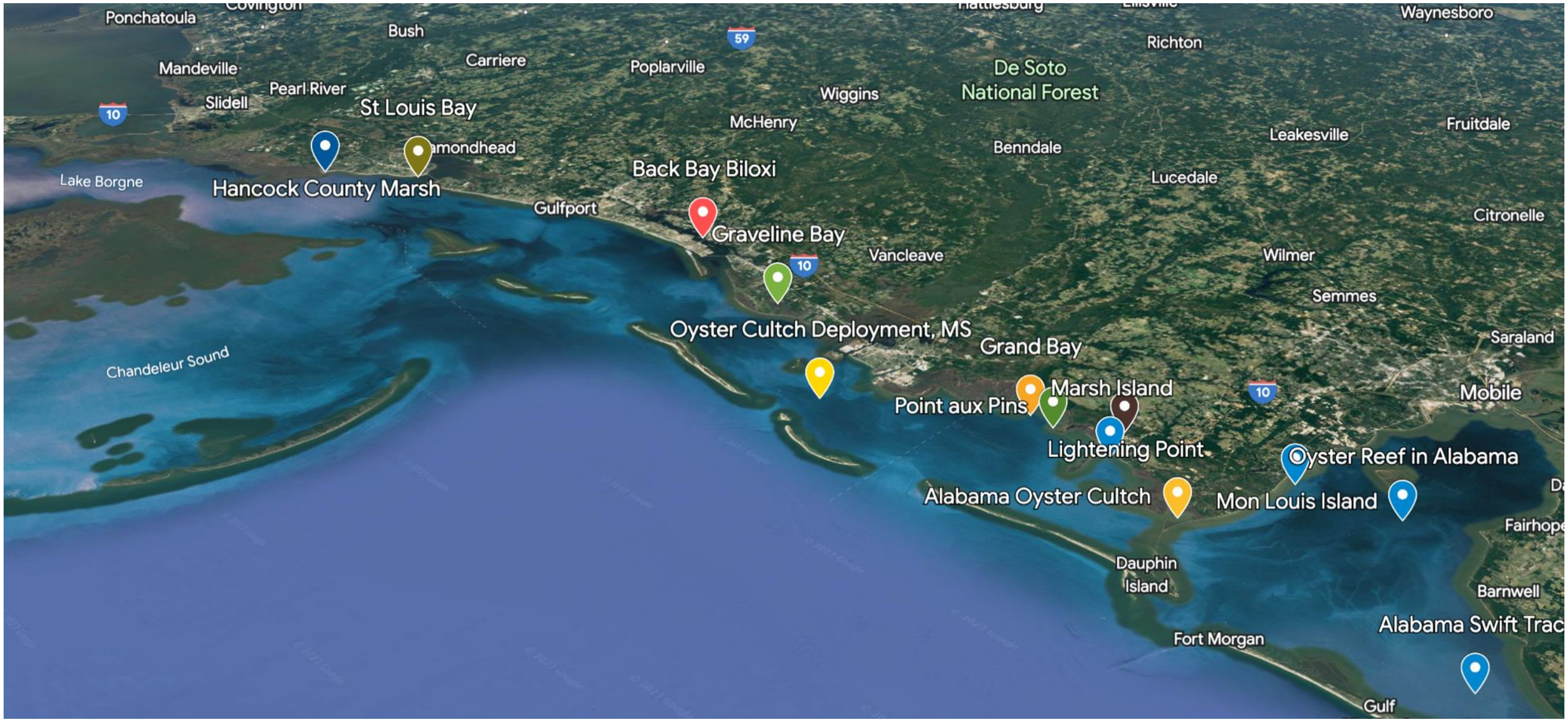

Figure 2.1 Map of Restoration Area

2.4.3 Alabama Swift Tract

The Alabama Swift Tract Living Shoreline project (abbreviated as Alabama Swift Tract) in eastern Bon Secour Bay (figure 2.1), Baldwin County (Alabama) provides oyster habitats for fish and benthic species, improve water quality, support marsh growth, and protect shoreline along an actively eroding shoreline (Alabama Swift Tract Living Shoreline annual report, 2017). It involved the construction 1.75 miles of 21 low-crested breakwaters completed in 2017 at an investment cost of $5 million provided by NRDA framework and implemented by the NOAA.

Monitoring reports for the Swift Tract project were compiled by HDR Engineering Inc., TNC, Dauphin Island Sea Lab (DISL), and Thompson Engineering, Inc. Table 2.4 indicates that the monitoring reports for this project provides data on water quality parameters such as salinity, temperature, depths, turbidity, conductivity, and dissolved oxygen for year 0 to year 4. Fish and other benthic species counts are also included in monitoring reports for year 0 to year 4 (see Table 2.5). The report also includes shoreline change data for years P, 0, 2, and 4 (refer to Table 2.6). Since monitoring of project's intended outcomes is planned to go on from 2017 to 2024, the performance monitoring of project outcomes is ongoing and as such there are no monitoring data for years 6 and 7.

2.4.4 Lightning Point

The Lightning Point Restoration project (shortened as Lightning Point) in Mobile County restores the coastal shoreline at the mouth of Bayou La Batre. The intended objectives of this project are shoreline protection, marsh protection, oyster enhancement, and providing support for benthic species and fish (The Nature Conservancy in Alabama, 2019). The lightning point project involved the construction of 1.5 linear miles of segmented breakwaters, the construction of two jetties that is 0.15 miles long, creation of 40 acres of marsh, 4 tidal creeks and 5 upland habitats. The construction of this project was completed in 2020 and NFWF-GEBF funds this project at a total investment cost of $ 15 million and the project is led by TNC.

The monitoring reports which are collated by the DISL, and Moffat and Nichol it was observed that the shoreline protection objective is measured in the form of pre-construction year shoreline changes (see Table 2.6). Performance monitoring reports also provide information on submerged aquatic vegetation patches and marsh species for years 0 through to year 2. Table 2.7 indicates records of marsh species for year 0 – 2. As monitoring of project's intended outcomes is planned to go on from 2019 to 2025, the performance monitoring of project outcomes is ongoing and as such monitoring data for years 2, 3, 4, and 5 is TBD. Oyster enhancement was not initially an objective for this project, but TNC includes this as a goal and records oyster count data for years 0, 1 and 2. In Table 2.3 monitoring of this project's outcomes ends in year 5.

2.4.5 Point aux Pins

This Point aux Pins Living Shorelines project (shortened as Point aux Pins) in Portersville Bay Mobile County is located along the northeastern part of Point aux Pins (southwest of Bayou La Batre in figure 2.1) creates breakwaters to restore and protect an eroding estuarine shoreline. The intended outcomes for this project include shoreline protection, enhanced marsh habitats and productivity of benthic species (Point aux Pins Living Shorelines annual report, 2020). This project involved the construction of 0.57 miles of 15 breakwaters containing 39 wave attenuation units each with a dimension of 10 ft by 10 ft, 6 inches thickness, weighing 12,500 pounds. The NRDA framework funds the $2.3 million total investment cost of this project and this project is led by the AL-DCNR.

Stantec consulting service completed construction in 2020 and compiles the monitoring reports for this project. The project's monitoring reports provide data on pre-construction erosion rates, shoreline elevation, and benthic species for post-construction year 1 (Table 2.5). Since the monitoring of project's intended outcomes is planned to go on from 2020 to 2025, the performance monitoring of project outcomes is ongoing and monitoring data for years 2, 3, 4, and 5 is TBD.

2.4.6 Alabama Oyster Cultch

The Alabama Oyster Cultch Restoration project (abbreviated as Alabama Oyster Cultch) is centered in Heron Bay and Cedar Point, Mobile County- north of Dauphin Island in figure 2.1. This project is designed to restores historic oyster reefs, and support oyster settlement and growth (Alabama Oyster Cultch Restoration project annual report, 2016). The project placed a total of 65,540 cubic yards of suitable oyster shell cultch of which 13,194 cubic yards were oyster shells and 52,344 cubic yards were limestone over an approximately 519 acres of subtidal reef habitat. This project is implemented by the AL-DCNR and funded by the third phase of NRDA process at an investment cost of $ 3.2 million.

The construction of this project was completed in 2015 and the monitoring data are collated by AL-DCNR. The oyster growth objective of this project is recorded by oyster count for post-construction year 0 through to year 7. For the water protection objective, salinity and dissolved oxygen are monitored from year 1 to year 2. Monitoring of this project's intended outcomes is planned to go on from 2015 to 2025. Thus, monitoring data for years 8 to 10 is TBD as seen in Table 2.3.

2.4.7 Oyster Reef in Alabama

This Restoration and Enhancement of Oyster Reefs in Alabama project (shortened as Oyster Reefs in Alabama) restores 600 acres of oyster reefs in Mobile Bay, Mississippi Sound and Bon Secour Bay, Baldwin County (see figure 2.1) by enhancing the quantity and quality of cultch material available at existing oyster reefs and establishing new reef sites. This project involved the planting of 50,000 cubic yards of new cultch material, dissemination of seed oysters and cultivation of existing reef beds. The intended outcomes are water filtration, habitat creation for benthic species, improvements to commercial and recreationally fish species, shoreline protection and an anticipation of 30% increase in Alabama's oyster reefs (National Fish and Wildlife Foundation, 2020). This project which was completed in 2020 is funded by NFWF-GEBF at an investment cost of $3.7 million and project construction and monitoring is led by the AL-DCNR. There are no monitoring data for years 0 to 2 for any of the ecosystem service categories. Years 3 and beyond monitoring data for all ecosystem service categories are yet to be collected.

2.4.8 Hancock County Marsh

The Mississippi Hancock County Marsh Living Shoreline project (shortened as Hancock County Marsh) is centered in Bayou Caddy and the mouth of the east of Pearl River (figure 2.1) in the western part of Hancock County, Mississippi. The project was designed to protect the shoreline from wave energy and reduce the rate of shoreline erosion while providing a habitat for benthic species and protecting water quality (Mississippi Project Factsheet, 2020a). The project involved the construction of 46 acres of Marsh, 46 acres of subtidal reefs, and 5.9 miles of the breakwater. This Project was constructed over multiple phases (1, 2 and 3). The Phase 1 (2017) extends from the Pearl River to Heron Bay. Phases 2 (2018) and phase 3 (2021) extend from the eastern limit of Heron Bay to the northeast, ending at Bayou Bolan. From Table 2.1 this project which was first completed in 2017 is funded under the third phase of the NRDA framework at a total cost of $50 million and is led by the Mississippi Department of Environmental Quality (MS-DEQ).

The project construction design and monitoring reports were collated by the Anchor QEA team. The protection of water quality objective of this project is being monitored by parameters like salinity, temperature, depths, turbidity, and dissolved oxygen. The shoreline protection objective of this project is measured as shoreline change for years P, 0, 1 and 2. The provision of habitat objective is measured as the number of benthic species for year P, through to year 5. This project has been monitored since 2017 and is expected to end in 2024. Thus, years 6 and 7 are TBD for all categories.

2.4.9 Oyster Cultch Deployment

The Mississippi Oyster Cultch Deployment project (shortened as Oyster Cultch Deployment) in the western Mississippi Sound area (figure 2.1) aimed to enhance oyster harvest and growth and provide a habitat for fish and other benthic species (Mississippi Oyster Cultch Restoration Project, 2017). This project restored a total of 1,430 acres of cultch material which is primarily oyster shell and limestone. Oyster reefs within this footprint are made harvestable by providing a hard substrate to which oyster larvae can attach and grow. The third phase of the NRDA framework invests $11 million in this project under the leadership of MS-DEQ. The construction for this project was completed in 2014 and the monitoring of the intended outcomes for this project has ceased. The monitoring data were compiled by the Mississippi Department of Marine Resources (MDMR) and the Gulf Coast Research Laboratory. Enhanced oyster harvest objective is measured in the form of oyster densities for years 0, 2, 3, 4, 5, and 6 (see Table 2.7). Fish count and other benthic species' counts are reported for years 0 through year 4.

2.4.10 Living Shoreline and Reefs: Back Bay Biloxi, Graveline Bay, Grand Bay, St Louis Bay

The last four projects still under construction with the project name "Restoring Living Shorelines and Reefs Projects in Mississippi Estuaries: Back Bay Biloxi, Graveline Bay, Grand Bay and St. Louis Bay" (abbreviated as Living Shoreline and Reefs) are centered within the Harrison and Jackson counties. From Table 2.1, these projects are funded under the first and fourth phases NRDA at a total cost of $30 million with the MS-DEQ being the project lead (Restoring Living Shorelines and Reefs in Mississippi Estuaries project, 2020). These projects which are joint initiatives carried out by TNC, NOAA, and the MDMR aimed at protecting shorelines, providing support for oyster growth, and creating a habitat for fish, and benthic species (Mississippi Project Factsheet, 2020b).

The Living Shoreline and Reefs project in Back Bay Biloxi is within Jackson and Harrison Counties. This project is located along four Islands: Channel Islands, Big Island, Little Island and Deer Island which are currently experiencing shoreline erosion. This project aims to construct 1.6 acres of breakwaters, 70 acres of subtidal reef and 7.9 acres of temporary floating channels for the Channel Island project. For the Big Island 3.5 acres of breakwaters and 9.3 acres of temporary floating channels will be constructed. For Little Island, 1.6 miles breakwaters and 4.5 acres of temporary floating channels will be constructed. Finally, for Deer Island, 20 acres of subtidal reefs will be constructed. The objectives of these four projects are to protect shorelines, enhance water quality, and create habitat for benthic and fish species.

The Living Shoreline and Reefs project in Graveline Bay project, Jackson County will involve the construction of 70 acres of subtidal reef habitat and 2 acres of intertidal reef habitat. This project anticipates that intertidal and subtidal restoration areas will develop into reefs that support fish and benthic species productivity, water quality protection, shoreline protection, and marsh protection.

The Living Shoreline and Reefs project in Grand Bay, Jackson County will restore 77 acres of subtidal reef and 3 acres of intertidal reef habitat. The intended outcomes for this project include shoreline protection, water quality enhancement and the creation of a habitat for benthic and fish species. Also, the Living Shoreline and Reefs project in St Louis Bay, Hancock County will restore 2.3 miles of breakwaters, and approximately 30 acres of subtidal reef habitat. The intended outcomes for this project include shoreline protection, water quality enhancement and the creation of habitat to support benthic and fish productivity.

2.5 Implications

From the discussion above, projects' intended outcomes match actual monitored outcomes for projects like Alabama Oyster Cultch, and Lightning Point. For projects like Alabama Swift Tract, Mon Louis Island, Marsh Island, Hancock County, and Oyster Cultch Deployment, Oyster Reef in Alabama, and Point Aux Pin intended outcomes do not match actual monitored outcomes. Furthermore, for the water quality objective, the recorded metrics which include temperature, salinity, dissolved oxygen, depth, and conductivity are only important for a particular sampling event but do not indicate any relevant trend in relation to the quality of water as being improved before or after restoration. For fish and benthic species productivity, only the Oyster Cultch Deployment and Alabama Swift Tract project provide relevant metrics. For shoreline stabilization, the shoreline change metric provides relevant indicators about the impact of restoration projects on the restoration area. For the oyster enhancement objective, the Alabama Swift Tract, Alabama Oyster Cultch, and the Oyster Cultch Deployment projects provide relevant metrics.

Although the determination of the success of restoration projects is somewhat challenging and contentious since this is predominately dependent on a project's objective (Kentula, 2000), a policy recommendation from this analysis will be the strengthening of project performance monitoring and reporting. Developing clear and standardized monitoring indicators, methodologies, and data collection protocols that align with project objectives and outcomes will also help create quality data that may be used for evaluation restoration projects. Additionally, periodic evaluations of the monitoring and reporting framework to identify areas for improvement and address emerging challenges or gaps can enhance the quality of monitoring data.

CHAPTER III

META-ANALYSIS

3.1 Introduction

This chapter estimates the WTP for coastal water quality improvements resulting from coastal restoration using the non-market valuation method, benefit transfer. Non-market valuation methods are the means of assigning a dollar value to an environmental resource and can be classified into primary valuation methods and secondary valuation methods. Primary valuation methods can be separated into revealed preference and stated preference, and the secondary valuation method relies on the primary valuation estimates.

The revealed preference method is based on observable market choices. Revealed preference methods include the Hedonic price method which is the measurement of observed property values in particular locations to estimate the quality of life, the avoided cost approach which analyzes the cost that is required to avoid damages resulting from depletion of ecosystem service (Holland et al., 2010) and the travel cost method which is a price proxy measuring the impacts of recreational activities (NOAA, 2016). The avoided cost method has been used by Beseres Pollack et al., (2013); DePiper, Lipton, and Lipcius, (2017); Grabowski et al (2012); and Kroeger (2012) to measure the nitrogen removal benefit of oyster reefs. The travel cost method was used by Hynes et al. (2022) to estimate the value of resilient coastal walking trails, and Joshi et al. (2021) to estimate the value of fish. Poor et al. (2000) estimate the value of water quality using the Hedonic method for residents living close by a watershed.

The stated preference method used for unobservable markets, relies on data from structured surveys, and can be classified into different variations of contingent valuations and choice experiments. Contingent valuations involve survey questions that solicit for WTP values (Holland et al., 2010). Logar, Brouwer, and Paillex, (2019) use the contingent valuation method to estimate the WTP of people in Switzerland to cover the cost of river restoration. Choice experiments have been used by Interis and Petrolia (2016) on how to value ecosystem services and Petrolia et al. (2014) for coastal wetland valuation. According to Adamowicz et al. (1998), choice experiments could provide a suitable stated preference method when used to measure an unobservable economic monetary value resulting from a change in the environmental resource.

Benefit transfer is a secondary method of valuation that uses the benefit estimates from existing studies combined with economic theory to predict incremental benefits from a change in a resource's characteristics (Smith, 2018). The benefit transfer method can be further separated into three categories: the value transfer approach which involves the use of point estimates from the stated preference or revealed preference methods, the function transfer approach which uses an estimated function from either stated preference or revealed preference methods and the meta-analysis approach which combines and synthesizes the results from multiple valuation studies to estimate the WTP from a change in resources characteristics (Casey et al, 2014).

Wilson and Carpenter (1999) use the value benefit transfer to estimate context-dependent values of ecological assets and the goods and services they provide. In comparing the validity of benefit transfer, Barton (2002) uses the function transfer method by transferring an estimated function from a contingent valuation study to derive WTP estimates for coastal water quality improvements for the Pacific coast of Costa Rica. In this study, the meta-analysis method is used because this method can be an improvement of both the value and function benefit transfer, and it can potentially deal with generalization errors that result from assumptions made when estimates from study sites are transferred directly to policy sites (Johnston and Bauer 2020).

According to Bennet and Morrison (2004), there is a tradeoff between the advantage of using benefit transfer and the errors that may result from the use of benefit transfer instead of generating benefit estimates from primary valuation studies. I use the meta-analysis method to assess the willingness-to-pay (WTP) for coastal water quality improvements, relying on extensive valuation literature for water quality enhancements in the US since the method has the advantage of estimating WTP estimates more cost-effectively than other primary valuation methods (Holland et al., 2010). By using this method, I aim to achieves these objectives: 1) Estimating the WTP of changes in water quality resulting from coastal restoration using the benefit transfer method. 2) Comparing the WTP of coastal water quality with that of both freshwater quality and coastal water quality 3) Determining the causes of variation of WTP estimates within a study and across studies.

3.2 Literature Review on Meta-Analysis

The meta-analysis method takes one or multiple estimates from each valuation study while attempting to draw a relationship between the WTP estimates of the studies as a dependent variable, and the different study-specific and study-site characteristics as independent variables (Brouwer, 2000). This method involves a statistical analysis of the findings from empirical studies that deal with the same or equivalent resource improvements (Eshet, Baron, and Shechter, 2007) which according to Johnston and Bauer (2020) ensures commodity consistency for the different observations employed in the meta-analysis. Commodity consistency refers to the attribute of the commodity (water quality improvements) being valued similar across studies and within studies (Bergstrom and Taylor, 2006).

Moeltner et al. (2019) use meta-analysis to estimate the social benefits of wetlands in the US. Moeltner compiles meta-data of 17 wetland valuation studies from 1991 to 2016 and predicts benefit values to represent incremental changes in wetland acreage using non-linear meta-regression models. EPA (2006) uses meta-analysis to generate WTP values for catching additional fish. This EPA report uses 48 studies published between 1982 and 2004 to estimate and predict the incremental benefit values of fish. Brouwer et al. (1999) estimate the economic benefits of wetlands across North America and Europe using meta-analysis from only contingent valuation studies and synthesizes 30 different valuation studies of wetlands. Alvarez, Asci, and Vorotnikova (2016) compiled 18 valuation studies to estimate the value of water quality improvements for watersheds affected by non-point source pollution. Johnston et al. (2005), Johnston, Besedin, and Stapler, (2017), and Johnston and Bauer (2020) estimate the WTP of water quality improvements via meta-analysis using only stated preference studies within the US. The common variables used by most meta-analytic studies include: the WTP estimate which is the dependent variable, and the explanatory variables includes: resource quality characteristics (baseline and change), the study's demographic characteristics, and methodologies.

Meta-analysis has been conducted with studies centered in the same country (Alvarez Asci, and Vorotnikova, 2016, Johnston and Bauer, 2020, Ge, Kling, and Herriges, 2013 Moeltner et al., 2019, Van Houtven, Powers, and Pattanayak, 2007), a region in a country (White, 2020) and over multiple countries (Brouwer, 1999, EPA, 2006, Johnston and Thomassin, 2010). The advantage of choosing studies in proximity to the policy site is that it generates more representative data and reduces transfer errors (Kaul et al. 2013) but there is the risk of having relatively fewer observations than expanding the database of studies across a country or internationally. In contrast, Barton (2002) found no support for the claim that the reliability of benefit transfer increases with proximity between the study site and the policy site. Kaul et al. (2013) find that using contingent valuation studies for meta-analysis reduces transfer errors and combining data from multiple studies also reduces transfer errors. To reduce benefit transfer errors, I used a meta-data set that comprise of 61% contingent valuation studies, 14% other stated preference studies, and 25% revealed preference studies. Including a total of 24 valuation studies, with more stated preference studies, also helps reduce benefit transfer errors.

3.3 Methods and Data

I conduct a systematic review of valuation studies on water quality improvements for studies centered in the US. To build the database for this analysis, I use key phrase searches on Econlit and Google Scholar to find valuation studies pertaining to water quality. This analysis employs key phrase searches of 'water-quality' and 'economic value/benefit of water' in both Econlit and Google Scholar while including 'United States,' allowing the incorporation of only studies centered on the US. Using the single keyword search (like water) yields relatively broader results than including economic value/value/benefits or a synonym for ‘economic value’ which generates narrower and more relevant results in the search for valuation studies.

The second approach that is used to obtain these estimates involved reviewing the reference list of both primary and secondary valuation literature on water quality. Recognizing that the initial key phrase search yielded a limited number of relevant studies, I conduct an additional key phrase search for 'meta-analysis of water quality. The results from this search generated studies like Johnston and Bauer (2020) and Alvarez, Asci, and Vorotnikova (2016) whose reference list and the data summary are reviewed to obtain more valuation studies.

After searching through the reference lists of valuation studies and conducting key phrase searches, a total of 34 different valuation studies on water is acquired. Of the 34 studies obtained, 24 revealed preference or stated preference studies on water quality are included. The 10 studies excluded which were either on water quantity or other valuation methods (such as avoided cost or benefit transfer) are eliminated from the final meta-data used in the meta-regression model.

3.3.1 Quantifying Water Quality Using RFF Ladder

While compiling the databases used in this analysis, I face the challenge of reconciling all the variety of water quality improvement scenarios across studies into one metric. These scenarios include the reduction in pollutants, increased fish catch rates, and achieving swimmable water quality levels. Several of the water quality studies used some variation of the Resources for the Future (RFF) Water Quality Ladder and other studies used pollution indicators or fishing catch rates or recreation activities engaged in the waterbody. Researchers often encounter this problem in meta-analysis studies on water quality and have resolved it by utilizing the Water Quality Index (WQI) or the RFF water quality ladder. The WQI is a standard 100-point scale used to quantify changes in water quality by combining multiple water quality parameters into a single value within the 100-point scale (Walsh and Wheeler, 2013). The RFF ladder developed by Vaughan William (1986), is a ten 10-point scale that links water quality to specific pollutant levels which, in turn, are linked to the presence of aquatic species and suitability for recreational uses like boating, fishing, and swimming (Johnston et al. 2005). All water quality scenarios are mapped to the RFF ladder to reconcile the different measurements of water quality change. The modified version of the RFF ladder designed by Alvarez Asci, and Vorotnikova (2016) seen in Figure 3.1 is used to map the different water quality scenarios. The RFF ladder scales severely polluted water as 1, different ranges of water that are fishable from 4 – 6, and 10 for unpolluted water.

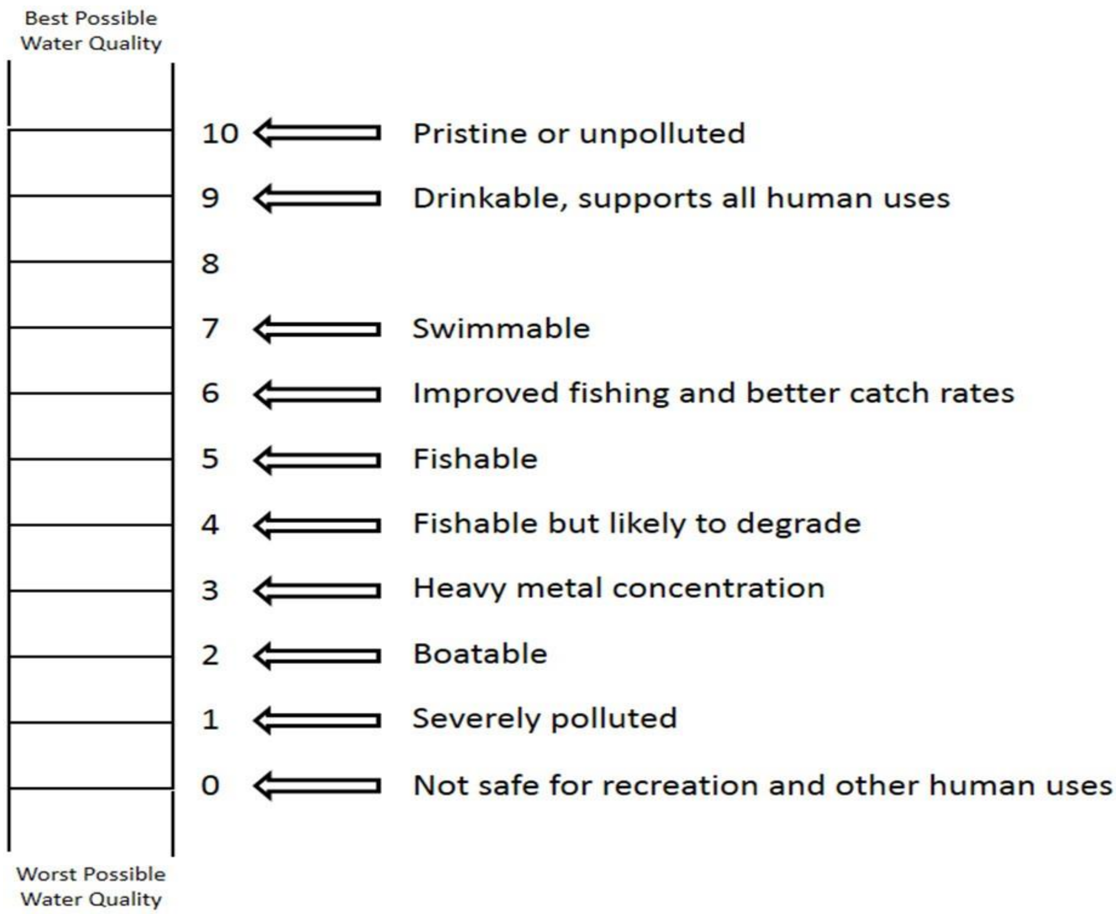

Figure 3.1 Water Quality Ladder

Source: Alvarez, Asci, and Vorotnikova (2016)

In mapping, each study's water quality baseline and new water quality, studies that used the RFF ladder as a measure of water quality in their surveys, were relatively simple to map the baseline and new water quality. For other studies that did not use the RFF ladder the survey and background description of the study area is applied in defining the baseline and the new water quality scale. For instance, to determine the baseline, any indication of highly degrading or polluted water level is scaled at 1, any indication of the high presence of heavy metals pollution is rendered a baseline value of 3, and any indication of unsustainable fishing is rendered a baseline value of four. The new water quality measure is mapped based on the recreational activities engaged in by survey respondents, or future recreational activities that can be engaged in (if the study is estimating for a proposal of new policy change) or based on the specific recreationists (which can be anglers, snorkelers, boaters) that the study focuses on. For example, if a study asserts that recreational activities that can be attributed to an improved water quality change include fishing, and swimming then a swimming index of 7 which represents the highest extent of that water quality change is used to represent the new water quality for that study.

The new water quality variable is obtained to find the magnitude of the change in water quality which is used as a variable along with the baseline water quality variable for this analysis. Other variables' data collected for our analysis include WTP estimates, WTP measurements (mean, median, marginal, per person/per household, per trip/annual), WTP dimension(annual, one-time, per trip), the publication (or survey) year, type of study (journal or not), US state, type of waterbody, non-market valuation method, survey method, response rate, sample size, type of waterbody, income, population density, and the average age of survey respondents.

The WTP estimates (which is the outcome variable) are converted to lumpsum equivalent using an annual discount rate of 6% as used by Moeltner and Woodward (2009) and converted to 2022 dollars to account for inflation. The US state variable represents the states in which a valuation study's survey was conducted or the state in which the water body is located, and type of water body is an indicator for saltwater, brackish water, and freshwater classifications. Variables like income, and population density not provided by some studies are extracted and approximated from the US census data. The meta-analysis is conducted with 24 studies which yielded 105 observations since some studies provide multiple WTP estimates as seen in Table 3.1.

Table 3.1 Valuation Studies on Water Quality Improvements Used in Meta-Analysis

Authors	Publication Year	Survey Year	States	Waterbody	Estimates	Valuation Method	WTP range in 2022 dollars
Azevedo, Herriges, & Kling	2001	2000	IA	Saltwater	5	Travel Cost	$1253 - $8375
Berrens, Ganderton, & Silva	1996	1995	NM	Freshwater	7	Contingent Valuation	$55 - $ 172
Bhat	2003	1996	FL	Saltwater	2	Contingent Behavior - Travel Cost	$842 - $1364
Bockstael, Mcconnell, & Strand	1989	1984	MD	Brackish	4	Contingent Valuation	$61 - $1273
Borisova et al.	2008	2006	WV	Brackish	5	Contingent Valuation	$16 - $90
Carson and Mitchell	1993	1990	N/A	Saltwater	5	Contingent Valuation	$134 - $208
Cordell & Bergstorm	1993	1989	NC	Freshwater	4	Contingent Valuation	$98 - $177
Duffield, Neher, & Brown	1992	1988	MT	Freshwater	8	Contingent Valuation	$437 - $7412
Eiswerth, Kashian, & Skidmore	2008	2004	WI	Saltwater	1	Contingent Behavior	$838
Farber & Griner	2000	1996	PA	Brackish	12	Choice Experiment	$43 - $194
Hayes, Tyrell, & Anderson	1992	1985	RI	Freshwater	16	Contingent Valuation	$91 - $203
Hurley, Otto, & Holtkamp	1999	1998	IA	Brackish	3	Contingent Valuation	$91 - $147
Lipton	2004	2000	MD	Brackish	4	Contingent Valuation	$51 - $159
Loomis	2002	1998	IH	Saltwater	1	Contingent Behavior - Travel Cost	$1,469
Loomis & Santiago	2013	2011	PR	Saltwater	4	Contingent Valuation & Choice Experiment	$349 - $704
Mathews, Homans, & Easter	2002	1997	MN	Saltwater	1	Contingent Behavior- Travel Cost	$225
McKean, Johnson, & Taylor	2003	1997	ID	Freshwater	2	Travel Cost	$536 - $ 593
Murray & Sohngen	2001	1998	OH	Freshwater	5	Travel Cost	$43 - $204
Park, Bowker, & Leeworthy	2002	1996	FL	Brackish	2	Contingent Valuation & Travel Cost	$897 - $1377
Shrestha, Stein, & Clark	2007	2000	FL	Brackish	1	Travel Cost	$7,043
Stumborg, Baerenklau, & Bishop	2001	2000	WI	Brackish	2	Contingent Valuation	$97 - $148
Thomas & Stratis	2002	1998	FL	Saltwater	2	Travel Cost	$634 - $761
Welle & Hodgson	2011	2008	MN	Brackish	5	Contingent Valuation	$15 - $402
Whitehead, Haab, & Huang	2000	1995	NC	Freshwater	4	Contingent Valuation- Travel Cost	$379 - $914

3.3.2 Value Judgements in Data Collection

Some challenges encountered in gathering the meta-data for include having a unified unit of measurement for WTP estimates across studies and deciding which observation to include in the data for studies that provide multiple WTP estimates. Many studies had the WTP estimates as a mean value, other studies estimated median or marginal WTP. Another challenge had to do with the dimension of the WTP, which included annual WTP (per person or per household), and WTP per trip (per person or per household). Johnston et al. (2005) deal with these issues by restricting their analysis to only WTP per household data. I deal with these issues by creating indicator variables for the various WTP estimates measurements and dimensions. Furthermore, for some studies that used multiple models in estimating WTP, this analysis chooses to include the estimates of the preferred models or estimates that were statistically significant.

3.3.3 Meta-Regression Model

The semi-log and log-log models with clustered standard errors which account for heteroscedasticity and heterogeneity are estimated using the meta-data. In the semi-log model, the natural log of WTP is used as the outcome variable while none of the explanatory variables is logged. The log-log model however has the natural log of WTP as the outcome variable, the natural log of change in water quality and income, along with other explanatory variables that are not logged. In the log-log model, the baseline water quality variable is not logged because there of a minimum baseline value of 0 in the meta-data. The clustered standard error is used due to the panel nature of meta-data to adjust for the standard errors since the data used provides different observations in one unique study (Van Houtven, Powers, and Pattanayak, 2007) which can create within-study cluster correlation. Thus, the clustered standard error accounts for heteroscedasticity within the study cluster. Heterogeneity in WTP estimation across studies is accounted for by controlling for study-specific attributes in the estimated models. The estimated function below is a combination of elements from the meta-regression models on water quality from Alvarez, Asci, and Vorotnikova (2016), Johnston, Besedin, and Stapler (2017) and Van Houtven, Powers, and Pattanayak (2007).

$$ln\,WTPWQ_i = \beta_0 + \boldsymbol{X_i\beta_1} + \boldsymbol{M_i\beta_3} + \boldsymbol{D_i\beta_2} + \boldsymbol{O_i\beta_4} + \varepsilon_i \tag{3.1}$$

The estimated model has a dependent variable which is a natural log of WTP for water quality improvements $ln\,WTPWQ_i$. This dependent variable is a function of the vector of the water quality ladder scale X_i, the vector of study's method M_i, the vector of the study's demographic characteristics D_i, the vector of other study-specific characteristics O_i, and ε_i error term, where i represent the number of observations. The vector X_i includes baseline and change in water quality scales. The vector M_i includes the type of valuation method (revealed preference or stated preference), payment vehicle (tax or non-tax), payment method (one-time or annual or per trip), type of manuscript (journal or report) and survey year index. The vector D_i includes income and nonresidents (or residents). The vector O_i, includes the type of waterbody, WTP measurement (mean, median, marginal, per person or per household) and sample size. Refer to Table 3.2 for an explanation of the variables used in the meta-regression model.

Table 3.2 Variable Descriptions

Variable	Description
WTP	Lumpsum WTP for water quality improvements in 2022 dollars
Baseline water quality	Baseline water quality using RFF ladder (0-10, 0 worst, 10 best)
Change in water quality	Change in water quality using RFF ladder (0-10, 0 worst, 10 best)
Survey year index	An index of survey year (survey year – oldest survey year +1)
Revealed preference	=1 if study uses only Revealed Preference, 0 if include Stated preference
Report	=1 if study is a report and 0 if study is a journal
Tax	=1 if payment vehicle is tax and 0 for not a tax payment vehicle
One-time	=1 if WTP is onetime payment and 0 for otherwise
Marginal	=1 if WTP is marginal and 0 for mean or median
Per person	=1 if WTP is per person and 0 for per household
Income	Annual income (2022 dollars) of study's population obtained from studies or U.S. Census Bureau scaled by 1000
Non-resident	=1 if survey respondents include nonresidents, 0 for only residents
Saltwater	=1 if waterbody is saltwater and 0 for freshwater
Brackish	=1 if waterbody is brackish and 0 for freshwater
Sample size	Sample of observations used in study's regression scaled by 100

Table 3.3 Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
WTP	$759.605	1642.255	14.954	8375.436
ln wtp	7.813	1.529	2.771	11.783
Baseline water quality	2.562	1.531	0	5
Change in water quality	3.657	1.720	1	7
ln change in water quality	1.173	.523	0	1.946
Survey Year Index	15.571	7.741	1	32
Revealed Preference	.171	.379	0	1
Report (Azevedo et al. 2001)	.048	.214	0	1
Tax (payment method)	.495	.502	0	1
One-time (Borisova et al. 2008)	.019	.137	0	1
Per person	.438	.499	0	1
Marginal	.219	.416	0	1
Income (1000)	$70.286	17.678	24.281	119.895
ln income	11.125	.284	10.097	11.694
Nonresident	.352	.480	0	1
Saltwater	.171	.379	0	1
Brackish	.390	.490	0	1
Sample Size (100)	6.030	4.616	.890	24.870

3.4 Results and Discussion

Table 3.3 reports the summary statistics for variables used in the meta-regression with the average of the income variable for all 24 studies being $70,000 (2022 dollars) and an average study sample size of 603. Four meta-regressions models are estimated i.e., two log models with data on both freshwater and coastal water (where coastal water represents saltwater and brackish water) and two log models for only coastal water. The model with both freshwater and coastal water uses 105 observations (Combined) whereas the model with only coastal water studies uses 59 observations (Coastal). Since collinearity and multicollinearity is a problem in meta-analysis (Alvarez, Asci, and Vorotnikova, 2016), I check for correlation among variables to address this issue and only include variables that exhibit correlation lower than 0.6 in the regression models. The 0.7 R-square value for the combined model and 0.8 R-square value for the coastal model is consistent with meta-analysis studies like Alvarez, Asci, and Vorotnikova, (2016) 0.7, Johnston et al. (2005) 0.8 and 0.6 for Van Houtven, Powers, and Pattanayak (2007)

From Table 3.4, the water quality baseline variable is insignificant for all four models presented. For some studies on meta-analysis, the baseline water quality variable has been found to be statistically insignificant Johnston et al., (2017), and others found it to be statistically significant depending on the model applied to the meta-data (Van Houtven, Powers, and Pattanayak 2007; Ge, Kling, and Herriges, 2013, Johnston et al. 2005). The change in the water quality variable is however significant for all four models and has a positive association with the WTP for water quality improvements. For the combined the semi-log model, a 1-point-scaleimprovement in water quality leads to an 18% increase in WTP for water quality ceteris paribus. In the combined log-log model, a 1% improvement in water quality is likely to lead to a

0.7% increase in WTP for water quality improvement. Similarly, for the coastal semi-log and log-log models the magnitude of change in WTP associated with a 1-point-scale improvement in water quality is 24% and a 1% improvement in water quality and 0.8% respectively.

Table 3.4 Meta-regression Log Models, Clustered Standard Errors for freshwater and coastal water (N= 105) and only Coastal water (N= 59)

Variables	**Combined Semi-log**	**Combined Log -log**	**Coastal Semi-log**	**Coastal Log-log**
Baseline water quality	-0.0680	-0.0654	0.0850	0.0428
	(0.0739)	(0.0819)	(0.114)	(0.107)
Change in water quality	0.1800**	—	0.2490**	—
	(0.0719)	—	(0.108)	—
ln change in water quality	—	0.7010**	—	0.8480**
	—	(0.289)	—	(0.332)
Survey year index	-0.0908***	-0.0863***	-0.0538**	-0.0521***
	(0.0276)	(0.0248)	(0.0183)	(0.0112)
Revealed Preference	-0.1650	-0.330	0.6010*	0.3470
	(0.573)	(0.583)	(0.343)	(0.371)
Report	2.371***	2.442***	—	—
	(0.534)	(0.528)	—	—
Tax	-1.474***	-1.477***	-0.9120**	-0.9630***
	(0.462)	(0.426)	(0.358)	(0.256)
One-time	-4.4470***	-4.5370***	-3.7820***	-3.9150***
	(0.316)	(0.282)	(0.359)	(0.233)
Per person	0.0099	0.0654	-0.1450	-0.0007
	(0.304)	(0.290)	(0.239)	(0.191)
marginal	-0.7710***	-0.7130**	-0.3210	-0.2960
	(0.273)	(0.278)	(0.265)	(0.244)
Income	0.0119	—	0.0169**	—
	(0.00821)	—	(0.00702)	—
ln Income	—	0.9950*	—	1.258**
	—	(0.497)	—	(0.450)
Non-resident	-0.2390	-0.2410	0.7480	0.7920*
	(0.431)	(0.418)	(0.488)	(0.433)
Saltwater	0.8640*	0.9540**	0.4230	0.5530
	(0.478)	(0.450)	(0.410)	(0.419)
Brackish	0.0068	-0.1020	—	—
	(0.386)	(0.367)	—	—
Sample size	-0.0125	-0.0119	0.1160***	0.1150***
	(0.0313)	(0.0309)	(0.0390)	(0.0284)
Constant	8.8120***	-1.6420	5.7700***	-7.0830
	(0.788)	(5.585)	(1.572)	(5.461)
Observations	105	105	59	59
R-squared	0.7190	0.7330	0.8030	0.8120
AIC	281.1298	273.5472	142.5879	134.7160

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, *

The four regression models presented in Table 3.4 control for methodological traits such as type of valuation study (revealed preference or otherwise), type of manuscript (report or journal), survey year index, and payment method. From the data used in this analysis, the revealed preference variable is statistically not different from stated preference for both the combined and coastal models. The report variable provides no information on variation within or across studies due to its inclusion of only estimates from Azevedo, Herriges, & Kling (2001). This suggests that, on average, Azevedo's study had higher WTP estimates compared to other studies. Survey year index is significant for all four models and has a negative relationship with WTP implying that studies conducted in recent years tend to have a relatively lower WTP than older valuation studies.

The payment method used in a valuation study for the combined model have a negative relationship with the WTP for water quality improvements. Using taxes or one-time payment (as opposed to annual or per-trip payment) as a payment method is likely to lead to lower WTP for water quality improvements. The negative relationship between the tax payment vehicle and WTP can be attributed to respondents' bias to exaggerate their WTP when non-tax payment is used in stated preference studies (Ivehammar, 2009). Carson and Groves (2007) also states that binding payment vehicles (such as taxes) tend to have relatively lower WTP response amounts which explains the negative relationship between WTP and tax indicator variable. The relationship between the payment period (one-time) variable is only comparable to the five-year annual payment period within the Borisova et al. (2008) study since that study estimates WTP for water quality improvements using two different payment vehicles. Within that study, WTP estimates using the one-time payment period were lower than those using the five-year annual payment period.

Demographic variables included in the models include income and nonresidents. The income variable is significant for the combined log-log model and coastal log model but insignificant for the semi-log models. The positive relationship of the income variable means that percentage improvements in income is likely to increase the WTP. There are mixed findings about the relationship of between income and WTP for meta-analysis studies. Van Houtven, Powers, and Pattanayak. (2007), Johnston and Bauer (2020), Alvarez Asci, and Vorotnikova (2016), Johnston and Thomassin (2010) find a positive relationship and White (2020), Johnston and Thomassin (2010). Johnston et al. (2017) find the income variable to be insignificant whereas Alvarez Asci, and Vorotnikova (2016) find it significant. The nonresident variable which represents the inclusion of nonresidents respondents in a survey is controlled for in this analysis because it created a better fit for the data. The nonresident variable is statistically significant for the coastal log-log model and has a positive relationship with WTP for both coastal models. The coefficient signs for the nonresident variable are however negative for the combined models. The difference in signs can be attributed to WTP outliers or the number of observations used in the models. Alvarez, Asci, and Vorotnikova (2016) meta-analysis used population density to capture the spatial extent or population of the study area. However, it was not controlled for due to its high correlation with other explanatory variables, and its coefficients were not statistically significant.

Other control variables that are likely to influence WTP estimates used in the log models are the marginal (instead of mean or median) WTP variable and the study's sample size. The marginal indicator variable is statistically different from the median and mean WTP in the combined model. Since the marginal indicator variable has a negative coefficient, marginal WTP estimates are likely to have lower WTP than the median or mean WTP estimates. For the combine semi-log model, marginal WTP is 54% lower than the mean or median WTP and for the combined log-log model, marginal WTP is 51% lower than the median and mean WTP. The sample size variable which is insignificant for all models is used as an alternative for the response rate variable which is commonly used to capture the precision of WTP estimates. In the coastal models, the sample size is positively related with WTP for water quality but in the combined models, the sample size is negatively related with WTP for water quality improvements. The type of waterbody also influences WTP since saltwater variable is significant and positively related with WTP for the combined models.

The dependent variable WTP is transformed to ln WTP because log transformation makes the WTP variable normally distributed. The Shapiro-Wilk W test in Table 3.5 is used to check for the normality of ln WTP and WTP variables. Additionally, the log-log model is the preferred model since it has comparatively higher R-squared and lower Akaike Information Criterion than the semi-log models for both the coastal and combined models (see Table 3.4).

Table 3.5 Shapiro-Wilk W Normality Test

	WTP	ln WTP
Null Hypothesis	Normally Distributed Data	Normally Distributed Data
Shapiro-Wilk W Statistics	0.4312	0.9798
P-value	0.0000	0.1094
Conclusion	Reject the Null Hypothesis	Fail to reject the Null Hypothesis

Using the estimated coefficients from the log-log function and applying means related to the study area (Alabama and Mississippi) gives an annual WTP (mean or median) per household for water quality in 2022 dollars for the combined model to be $250 and $203 for the coastal model. Based on the meta-data used, there is a difference of $47 in WTP for coastal water compared to both coastal water and freshwater. Annual household marginal WTP for water quality improvements is $151 for both freshwater and coastal water and $122 for only coastal water. These WTP estimates are within the range of WTP estimates in the literature on the meta-analysis of water quality improvements which ranges from $18.69 to $1,035 in 2022 dollars. (Ge, Kling, and Herriges 2013, Van Houtven, Powers, and Pattanayak, 2007, Johnston and Bauer, 2020, Alvarez Asci, and Vorotnikova, 2016). The WTP estimate of $203 represents the amounts that a household in Alabama and Mississippi will be WTP annually to improve water quality from a state of fishable but likely to degrade (4) to improved fishing catch rates (6) given a median household income of $56,189 in 2022 dollars.

3.5 Implications

I find that there are relatively fewer studies on the valuation of saltwater quality improvements since 17% of the sample of observations were saltwater compared to 39% for brackish water and 44% for freshwater. By using data on brackish water, freshwater, and saltwater quality improvements studies, I estimate the two combined models. The coastal model is also estimated using only brackish and saltwater quality improvements. The preferred regression model in this analysis is the log-log model for both the combined and coastal water model estimation because it has a lower AIC value and a higher R-squared value compared to the semi-log model. In the coastal model, the annual WTP (mean or median) per household is $203, whereas the annual WTP (mean or median) per household is $250 for the combined model.

The variations in WTP are caused by the change in water quality improvements (measured by the RFF ladder scale), income, payment method survey year, sample size, the WTP dimension (marginal or mean or median), and whether the survey respondents includes non-resident or only residents of the surveyed area. A research implication from this analysis will be for researchers to use multiple payment methods in the valuation of an environmental resource. Researchers can improve accuracy in WTP estimation, by incorporating any prior knowledge of the income levels within the study area into the survey design of a study.

CHAPTER IV

GENERAL CONCLUSION

Coastal Restoration programs provide several benefits to the communities or residents located in coastal areas. These benefits include the provision of habitat for benthic and fish species, building coastal shoreline resilience, enhancing oyster settlements and growth, and marsh protection. Monitoring reports that synthesize onsite data on the health and changes in the ecosystem services that occur from coastal restoration seems to support the literature on the variety of benefits associated with coastal restoration although monitoring reports are difficult to understand and inconsistent in recording ecosystem services changes. A summary of the ecosystem services changes across project years and projects for the restoration projects in Alabama and Mississippi is presented in Tables 2.4-2.7.

Additionally, From the Tables presented in this chapter, it can be inferred that monitoring data are not consistent across project years. While some projects still have monitoring status as ongoing or construction status as ongoing, reports from previous years indicate that it will be challenging to quantify the intended outcomes for these restoration projects. The project analysis can inform the nature of monitoring data collection for subsequent years, especially for projects that are still under construction.

Furthermore, the annual household WTP for Alabama and Mississippi coastal water quality improvement is $203. This estimated WTP for coastal water quality is approximately 19% less than WTP for both freshwater and coastal water quality improvements. The variations in WTP estimates among studies are influenced by the magnitude of the change in WTP, survey year, income of study area, the payment method used and the type of WTP measurements (marginal, mean, median). This estimated WTP for water quality improvements can be used as a gauge or a benchmark for household WTP for water quality improvements in Alabama or Mississippi since, to the best of my knowledge, there is no water quality valuation study centered on Alabama or Mississippi

4.1 Limitations

A limitation of this study is the number of observations used in the meta-data. The challenge of accurately reconciling the water quality baseline and change to the water quality ladder restricted the number of studies that could be included in the final data. This restriction on the number of observations coupled outliers (high WTP estimates) from some valuation studies may have influenced the WTP value. The different WTP measurement dimensions also restricted the number of observations used in the meta-analysis. Consequently, the few observations used in the meta-regression models also influenced the variables that could be retained in the final regression models. This allowed, some important variables (such as response rate, population density, and type of survey method) which were highly correlated with other explanatory variables to be replaced with proxies or discarded from the regression models.

On the part of the project restoration report review, reports for 2022 which should have ideally been available were unpublished. Moreover, some published reports were imprecise and reports data on multiple metrics since multiple companies collect and compile these reports and sometimes reports. For some projects, monitoring of outcomes for a metric will start and cease reporting for subsequent years without explanation for ceasing monitoring. For instance, in the

Marsh Island project, the water quality metric was measured for years 1 and 2 and no more monitoring data were published for subsequent years.

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