8-8-2023

Valuation of oyster reef restoration along the Gulf Coast

Freedom Enyetornye
Mississippi State University, freedomfraser83@gmail.com

Valuation of oyster reef restoration along the Gulf Coast

By

Freedom Enyetornye

Approved by:

Daniel R. Petrolia (Major Professor/Graduate Coordinator)
Seong Yun
Zhenshan Chen
Scott T. Willard (Dean, College of Agriculture and Life Sciences)

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Agricultural Economics
in the Department of Agricultural Economics

Mississippi State, Mississippi

August 2023

Name: Freedom Enyetornye

Date of Degree: August 8, 2023

Institution: Mississippi State University

Major Field: Agricultural Economics

Major Professor: Daniel R. Petrolia

Title of Study: Valuation of oyster reef restoration along the Gulf Coast

Pages in Study 48

Candidate for Degree of Master of Science

The objective of this study is to estimate the willingness to pay of U.S. Gulf Coast residents to support oyster reef restoration. The Gulf Coast is the leading commercial oyster-producing region in the United States, accounting for approximately 46% of the total commercial oyster harvest in 2021. My benefit estimates were based on data obtained from a contingent valuation survey of 6,475 Gulf Coast respondents. I estimated the willingness to pay (WTP) for oyster reef restoration using interval regression and Turnbull lower-bound methods. The estimated mean WTP value is in the range of $142 and $436 per household. The results show respondents who eat oysters and those that hold saltwater fishing licenses have significantly higher WTP.

DEDICATION

I dedicate this thesis to my lovely family, whose unwavering love, support, and belief in me have been my constant motivation throughout this journey. Justice, my dear brother, your unfailing faith in me has been a source of inspiration. My intellectual growth has been fueled by your constant encouragement and shared passion for knowledge. I appreciate you all for your love.

ACKNOWLEDGEMENTS

I thank God for life and the strength to finish this thesis. Special thanks also go to the funding source for this project, NOAA RESTORE Science, for their generous support and funding, which made this research possible. I am also grateful for my assistantship support from the USDA Agricultural Marketing Service.

I would like to thank my advisor, Dr. Daniel R. Petrolia, for his amazing support and guidance. His expertise, insightful feedback, and dedication to my academic growth have played a vital role in shaping this thesis. I am truly grateful for his patience, encouragement, and mentorship. He has been a great mentor.

I am also grateful to the members of my thesis committee, Dr. Seong Yun and Dr. Zhenshan Chen, for their valuable input and suggestions. Their critical evaluation has helped refine this thesis and improve its quality. I would also like to express my sincere gratitude to Jessica Browne for her invaluable assistance with the cameo voice recording for our survey videos.

Finally, I appreciate my friends, who have provided me with their support and friendship throughout this process. Their encouragement, discussions, and exchange of ideas have been a constant source of inspiration. Thank you all for your support and contributions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Oysters provide vital economic and ecological benefits (NOAA 2022). They provide a range of nonmarket environmental benefits, such as better water quality by removing nitrogen from the water (Grabowski and Peterson 2007, DePiper et al. 2017, and Kroger 2012), protection of shorelines from erosion (Barrett et al. 2022), and habitat for other fish species (Fodrie et al. 2017, La Peyre 2015, and Grabowski et al. 2012). Petrolia et al. (2022) found that the nonmarket benefits of restored oyster reefs are estimated to be $92,104 per acre. In addition to the nonmarket benefits, oysters provide a significant opportunity for commercial harvest. The commercial harvest of oysters began in the mid-1800s in Louisiana (Banks et al. 2016) and in Mississippi in the 1880s. The Gulf Coast is the leading commercial oyster-producing region in the U.S., accounting for 46% of the total commercial oyster harvest in 2021. The historically large population of oysters along the Gulf Coast plays an important role in the health of the region's ecosystem (TNC 2018).

Around 85% of oyster reefs worldwide have been lost, with over 90% of bays and estuaries experiencing functional extinctions of their reefs. Most of the remaining wild oysters are captured in North America, specifically the Gulf of Mexico, accounting for 75% of the total according to Beck et al. (2011). Eastern oysters have significant societal and ecosystem benefits, but a decline in oyster harvest over recent decades threatens those benefits (Beckensteiner et al. 2020). The significant reductions in oyster populations are due to hurricanes, increased numbers

of tropical storms, overharvesting, disease, oil spills, pollution, and habitat loss (Martinez et al. 2022, Beck et al. 2011, Soniat et al. 2019, Grabowski and Peterson 2007, Kroger 2012, Halpern et al. 2008, Costanza et al. 2014, and National Research Council 2004). However, the decline of oyster reefs varies considerably across Gulf regions. The Mississippi Sound and Pensacola Bay both experienced a staggering 90–99% decline (Beck et al. 2011), and Mobile Bay lost approximately 80% (zu Ermgassen et al. 2011).

According to La Peyre et al. (2014), restoration of shellfish reefs has grown increasingly widespread in recent decades due to increased awareness of the functional deterioration of shellfish systems. For example, in Alabama, "Restoration and Enhancement of Oyster Reefs in Alabama" and in Mississippi, "Restoring Living Shorelines and Reefs in MS Estuaries: St. Louis Bay" are some of the ongoing restoration projects in the Gulf region.

An understanding of how the public values oyster reef restoration can aid policymakers in prioritizing restoration efforts. An important component of this understanding is a dollar estimate of the benefits associated with restoration, which can then be compared to the cost of restoration. This study presents some dollar values associated with a hypothetical oyster reef restoration that can be used by policymakers in their decision-making.

The primary objective is to estimate the willingness to pay of U.S. Gulf Coast residents to support oyster reef restoration. Data were collected via a contingent valuation survey administered to a sample of residents throughout the five U.S. Gulf Coast states. A secondary objective was to perform a scope test in this study. Other secondary objectives were to control for respondent confidence in voting (ex-post confidence adjustment), control for respondent attention and understanding, and use videos to make it easier for respondents to understand and take the surveys.

CHAPTER II

LITERATURE REVIEW

There is limited research on oyster reef valuation. The closest study conducted on this topic is by Interis and Petrolia (2016). They examine how ecosystem service values associated with coastal restoration vary across locations (Alabama and Louisiana) and habitats (oyster reef, salt marsh, and black mangrove). Based on their results, providing details about the habitat to the respondent is more essential for estimating willingness to pay. This study also supports the reasons why we provided respondents with information about the reef's condition and the benefits associated with the restoration in our survey. Understanding the specific characteristics and ecological significance of the reefs allows respondents to make informed decisions regarding their willingness to pay for the restoration project.

Other related studies include Grabowski et al. (2011) and Parker and Bricker (2020), who conducted ecosystem valuations where they estimated the nitrogen removal benefits of oyster reefs. They both employed different methods. Grabowski et al. (2011) used cost-benefit analysis, while Parker and Bricker (2020) used the avoided or replacement cost approach. Grabowski et al. (2012) used benefit transfer method to estimate the economic value of oysters, but they excluded commercial oyster harvesting benefits. Petrolia et al. (2022) also used Monte Carlo simulation to evaluate the nonmarket ecosystem benefits associated with oyster reefs. Furthermore, my study differs in a number of ways from these studies; they used different methods to value ecosystem services, whereas I used contingent valuation surveys to monetize

the benefits of oyster reef restoration. However, my study does not value oyster reefs per ecosystem service; it values oyster reefs as a whole and the benefits they provide.

Given the limited research on oyster reef valuation, my study has broadened to include studies on related ecosystems, such as wetlands, to explore how their economic values were estimated and how much people are willing to pay for their restoration. Petrolia et al. (2014) estimated the welfare associated with large-scale wetland restoration using contingent valuation and choice experiment survey instruments in coastal Louisiana. Kim & Petrolia (2013) also analyzed the WTP for a large-scale coastal restoration wetland in Louisiana using a contingent valuation survey (referendum-style). Singh (1997) used the contingent valuation method to estimate the WTP of wetlands for New Jersey households. He, Dupra, and Poder (2016) examined the non-market values of ecosystem services provided by wetlands in southern Quebec. In order to assess these values, they conducted contingent valuation experiments and choice experiments. They also found that the WTP values are affected by households' socioeconomic characteristics. WTP is positively affected by income.

Studies with uncertainty

Several studies have examined the role of uncertainty in valuation surveys, though the source of uncertainty has varied. Most studies focus on preference uncertainty, which is being uncertain about whether you will be willing to pay for something in the future. In other words, it refers to the difficulty people have in determining their true preferences or how much they value a particular product or service. Some studies, such as Chang et al. (2007), Brouwer (2011), and Hakanssan (2008), investigate households' preference uncertainty by presenting them with multiple willingness to pay question choices. Another source of uncertainty is "posterior uncertainty," which refers to the degree of uncertainty or lack of confidence in the estimated

values of parameters. It simply means the dispersion of the distribution. Cameron (2006) used posterior uncertainty, where the respondents provided a range value within which they believe the true values about future temperatures lie with a 95% confidence level. In addition to that, Cameron (2006) used those values to establish an individual baseline for each respondent.

Interval uncertainty is another source of uncertainty, which is uncertainty regarding the potential outcomes or values of a parameter or variable within a given range or interval. Isik (2006) used interval uncertainty to investigate how it affects willingness to pay for a project that could preserve several crocodiles in a manner that is comparable to mine. He informed the respondents that the number of American crocodiles that could be saved by the project is uncertain and asked whether they would be willing to pay $X if the crocodiles saved could be Y1 or Y2. Isik (2006) found that uncertainty about the value of environmental quality improvements can alter the WTP measure, and the level of uncertainty affects the difference in mean WTP between certainty and uncertainty. In my study, I used the interval uncertainty to help determine how uncertainty in the future expected outcome of oyster harvest affects WTP values.

CHAPTER III

SURVEY DESIGN AND IMPLEMENTATION

Based on suggestions made by Dillman (2007) we created the survey using a comprehensive approach that included focus group meetings and pre-testing the survey using snowballs. Snowball is a sampling method that involves selecting respondents through referrals from other respondents. In our case, a small group of respondents who met our criteria for the study were initially identified and recruited, and then asked to refer others who may also be interested in participating. The process continues, with each new respondent referring more potential participants, creating a "snowball" effect.

We engaged focus groups from Alabama and Mississippi to get their candid opinions, and these opinions were taken into consideration before the final survey questions were administered. We tested and treated the first draft of the survey with the focus groups to gather some information, which helped us identify some details about the survey that people think are important. The main motive was to use the focus groups to assess the public's general knowledge of oyster reef restoration, test some photographs of oysters for use in the survey, test our survey videos, and get their opinions on the wording of the survey. We went to Mobile, Alabama, on March 21st, 2022, and Gulfport, Mississippi, on April 21st, 2022. We met 15 people from each state as our focus group. We administered a sample of the questionnaire for the survey to them to see how they react to it and to determine how much they are willing to pay for oyster reef restoration and the benefits they derive from oyster harvesting. We also

conducted a snowball survey test to give us an overview of the final survey. Before permitting Qualtrics to distribute our survey to the respondents, the final survey was one more revised in light of the constructive comments and suggestions from the snowball. The summary of survey design and implementation field periods is as follows:

Table 1 Survey design and implementation field periods.

Stage	Duration
Survey Design	Nov. 2021 to May 2022
(Focus groups): Mobile, AL	March 21, 2022
Gulfport, MS	April 21, 2022
Internal testing/editing	May to September, 2022
Pre-test (snowball)	September to October, 2022
Qualtrics launch	October 2022

We used videos in our survey. The videos were used to introduce the survey, the benefits of oyster reefs, background of commercial oyster harvest, scenarios, and the project outcomes. The survey questionnaire was divided into three parts: (1) an introduction on the benefits of oysters, the household's understanding of restoration, and their experiences; knowledge about the benefits of oysters and the population of oysters; (2) their WTP under a certainty scenario and an uncertainty scenario; and (3) demographic and household information. The valuation question asked households about their one-time WTP for each of the two scenarios: (1) a scenario where the respondents were presented with a future outcome which is certain (a specific number); and (2) uncertainty about future outcomes (the future outcome was in the form of a range). The survey instrument provided information on oyster harvest from 1950 to 2021; the expected outcome of oyster harvest in the next ten years when the restoration project occurs; and when the restoration project does not occur. Subsequently, a WTP question asked respondents to

vote on a proposed oyster restoration project to promote the expected growth of the oyster population. We also developed a second scenario format question and gave some respondents from Florida and Texas an uncertain expected outcome value of oyster harvest. If the project goes ahead, the oyster harvest is expected to range between XX and XX. Most willingness to pay studies present proposed outcomes as certain, thus a fixed change from X to Y, but in reality, many project outcomes are uncertain, and the actual change may lie within some range (Isik 2006). Appendix B contains examples of these scenarios.

Data and Study Area

The study focused on respondents (18 years old and older) in the five U.S. Gulf Coast states of Alabama, Florida, Louisiana, Mississippi, and Texas, and the data came from an online contingent valuation (CV) survey. We used Qualtrics to distribute the survey. Below, Figure 1 details our study area, where the blue dots represent the coastal respondents, while the red dots represent the non-coastal respondents. This is based on data description from NOAA (2017) coastal county definition, which states that the Federal Emergency Management Agency (FEMA) defines coastal counties as those that have coastlines adjacent to the open ocean or Great Lakes or contain velocity zones (V-zones) or coastal high-risk areas.

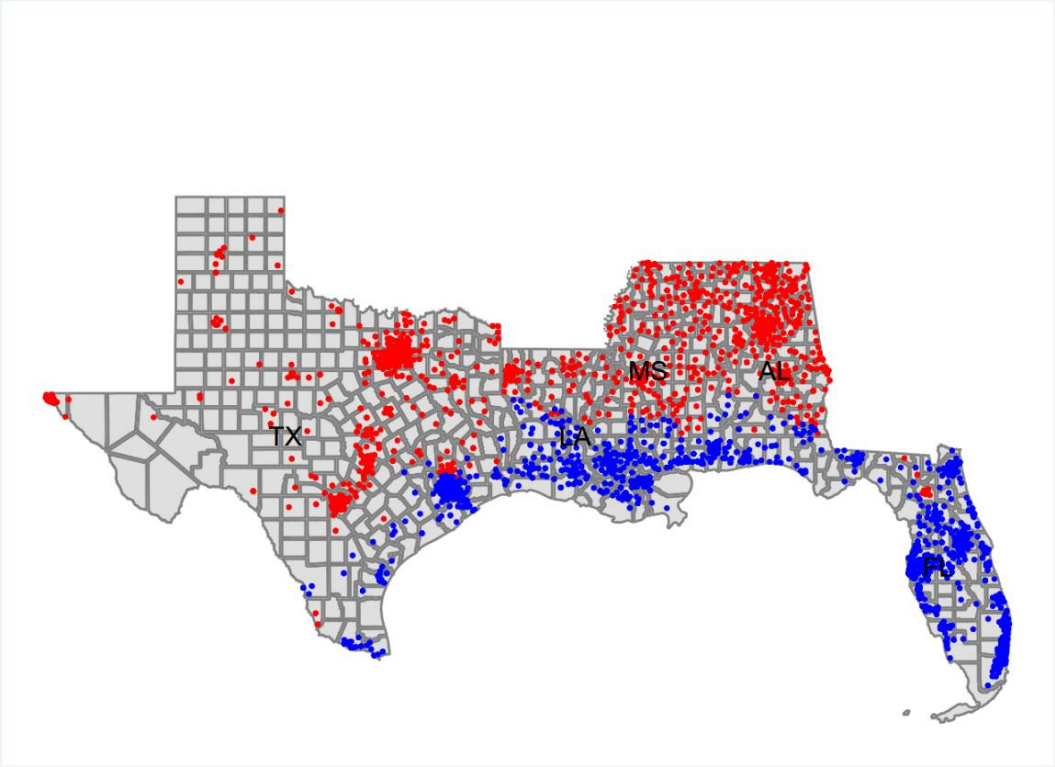


Figure 1 The five U.S. Gulf Coast states where the blue dots represent the coastal respondents and the red dots represent the non-coastal respondents.

Approximately 6,893 survey responses were collected between mid-October and late October of 2022. In order to ensure that our sample size was representative, we considered Dillman (2007)'s approaches to determining sample size. This also helps reduce the chances of having a higher sampling error. Out of the 6,893 recorded responses, only a total of 6,475 passed our flagging criteria. We based our flagging rule on the following: (1) screening criteria [(age 18+, specific state (the five Gulf Coast states), oath (respondents were asked to provide their best answer to each question in the survey)]; (2) survey duration (drop responses completed in less than 3.5 minutes) and (3) other (bad text, incomplete survey). Bad text contains irrelevant text from the open-ended questions and incomplete surveys were based on if the progress is less

than 90. For the purpose of this study, I dropped all the observations on the uncertainty treatment and only focused on the certainty treatment. This resulted in a total of 4,858 certainty treatment observations out of 6,475 observations. All the results used in this study are based on these certainty observations. The mean duration was 9 minutes, 49 seconds. In Figure 2, I show the sample distribution across the Gulf states.

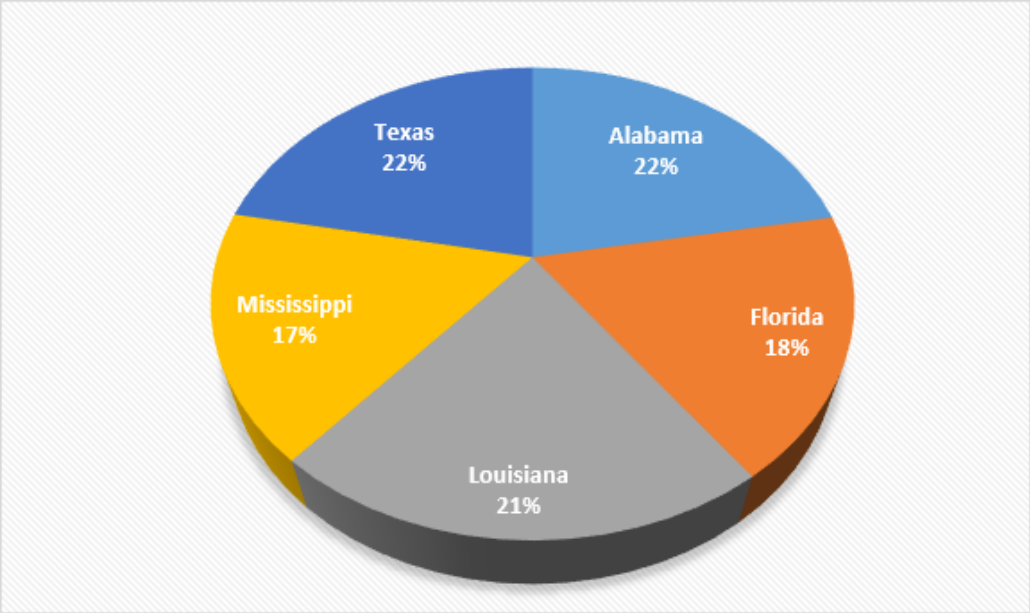
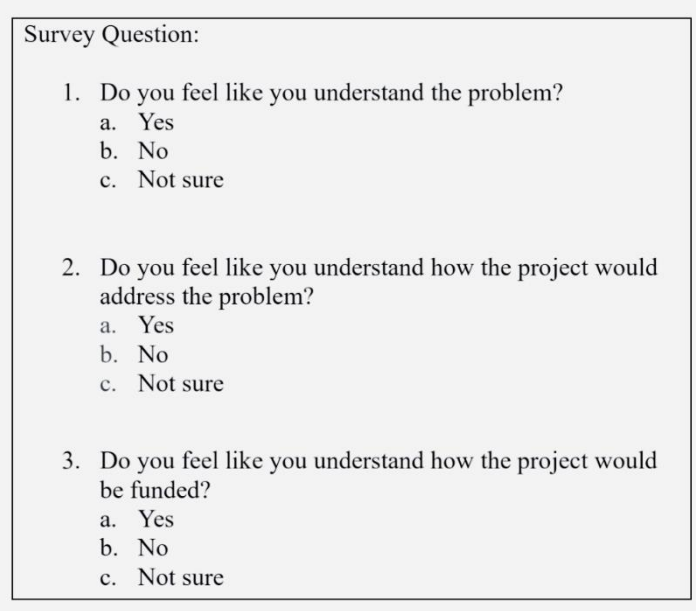


Figure 2 The population sample from the various states.

Data Collection

The survey gathered information on how the respondents reacted to the general bid (the amount respondents were offered to vote on), do you eat oysters, do you hold a saltwater fishing license, their understanding of the problem of oyster reefs, their understanding of the project, and how the project would be funded, as well as some personal information such as annual income, age, and gender. Our survey had multiple sections. The various sections are the introduction,

background, scenario section, vote, follow-up questions, demographics, and closing statement. The introduction comprised an introduction to the survey, a question on the respondent's state of residence, a video explaining the benefits of oyster reefs, and questions on whether they eat oysters or hold saltwater license. The background section explained the trends in commercial oyster harvest and also asked questions on how the respondents understood the problem and how much they cared about the issues with oysters. The scenario section comprises the scenario videos and the scenario questions. We used the scenario videos to explain the various scenarios to the respondents. The scenario questions asked about whether they understood how the project would address the problem, how it would be funded, and whether they were willing to pay to restore oyster reefs as shown in figure 3.


Survey Question:

1. Do you feel like you understand the problem?
   a. Yes
   b. No
   c. Not sure

2. Do you feel like you understand how the project would address the problem?
   a. Yes
   b. No
   c. Not sure

3. Do you feel like you understand how the project would be funded?
   a. Yes
   b. No
   c. Not sure

Figure 3 Control questions for respondents' understanding of the survey.

The vote section informed the respondents that “Suppose that each taxpaying household in “state YY” would need to make a one-time payment of $XX to fund the project.” The payment would be fixed at the same amount for every taxpaying respondent and would be collected on their 2023 state income tax return. “Given the expected benefits and costs, would you vote for or against the project?” As detailed in figure 4.

Survey Question:
Suppose that each taxpaying household in **{e://Field/state} would** need to make a one-time payment of **$${e://Field/Bid}** to fund the project.

The payment would be fixed at the same amount for every taxpaying household and would be collected on your 2023 state income tax return.

Given the expected benefits and costs, would you vote FOR or AGAINST the project?

a. I would vote FOR the project.
b. I would vote AGAINST the project.

Figure 4 Willingness to pay question.

The follow-up section consists of three questions. The first question asks the respondents, on a scale of 1 to 10, how sure they are about being willing to pay $XX. This follow-up question was specifically for those who voted for the project. The second question was, “On a scale from 1 to 10, how confident are you that this survey will influence what is actually done?” This question was for all the respondents. The last question asks, “You said you would vote AGAINST the project if the cost was $XX.” “What is the highest one-time payment at which you would vote for the project?” Figure 5 shows the follow-up questions.

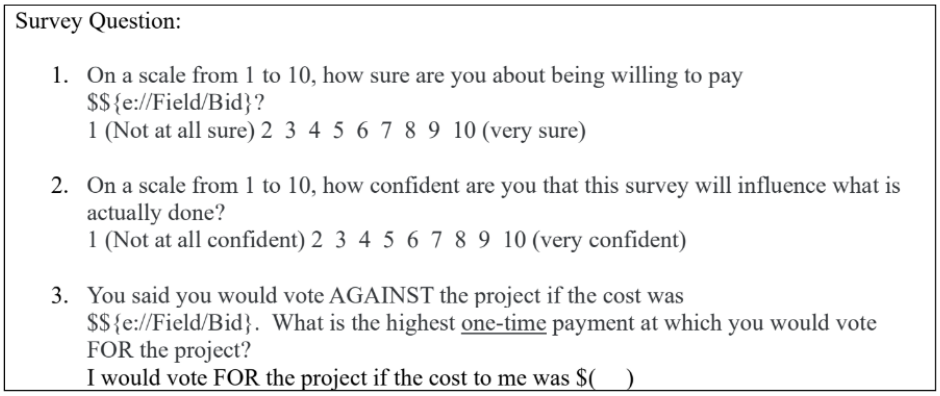


Figure 5 Follow-up questions.

The demographic section asks questions about their 5-digit zip code, their gender, the year they were born, their highest level of education, their annual household income before taxes, their race, the number of children under 18 living with them, and their affiliated political party. The closing statement thanked the respondents for their participation and also asked them to share their comments about the survey.

We began the questionnaire by asking the respondents the state in which they reside. This question served as a screening question to identify which state each respondent lives in. Our focus was on respondents from the five Gulf Coast states. Any respondent who fails the screening question is removed from the survey. Secondly, we asked an oath question to ensure they were willing to give their best responses. The survey introduced the benefits of oysters to the respondents. The respondents were then asked about their knowledge of oysters, their experience with fishing, and how much they cared about the issue of oysters in their states. We then informed the respondents about the proposed project and how much they would pay in tax. We assigned them bids of $25, $50, $100, $250, and $500.

Contingent Valuation Vote Questions

We informed the respondents about the project outcomes using our built-in videos. With the project outcome in mind, we framed a hypothetical scenario as follows: “Without the project, oyster harvest is expected to be around [X] million pounds per year during the next 10 years, as shown below, but with the project, the oyster harvest is expected to increase by [X] million pounds, for a total of [X] million pounds per year. These expected outcomes varied in magnitude. This project would require additional state funding. Funds would likely come from multiple sources, but at least part of the funds would come from households like yours. Suppose a special fund was set up for this purpose and a one-time fee of [X] was collected from each household, including yours. Each county would arrange to collect the fees from their households and deposit them into the special fund in 2023. Some people were administered with a high scale, and others also had low scales.

We then asked the respondents whether the details of the proposed project and how it would be funded were understandable and informative to them. The response categories for this question were "yes," "no," and "not sure." The survey continued, as “suppose a vote was held today on whether the state should carry out this project.” "We would like to know how you would vote. Would you vote FOR or AGAINST the project based on the expected benefits and costs? We asked a follow-up question: “On a scale from 1 to 10, how sure are you about being willing to pay [X]?” (1--not certain... 10--certain)."

Another key thing we considered in our survey was consequentiality. Carson and Groves (2007) argued that consequentiality is a crucial attribute of any CV survey. According to Petrolia et al. (2019), consequentiality is the extent to which a respondent thinks the survey will have a lucrative probability of influencing the provision of the proposed good. We considered

the consequentiality principles suggested by Carson and Groves (2007). In doing so, we asked a final question that asked, "On a scale from 1 to 10, how confident are you that this survey will influence what is actually done?" (1=not at all confident; 10=extremely confident). Bulte et al. (2005) believe that in some cases, consequentiality can help to mitigate hypothetical bias. Table 2 details the key valuation questions in the survey.

Table 2 Key valuation questions asked in the survey.

	Questions
Quality control questions	1. *Do you feel like you understand the problem?*
	2. *Do you feel like you understand how the project would address the problem?*
	3. *Do you feel like you understand how the project would be funded?*
Care about oyster	*How much do you care about the issue of XXX's oysters?*
Vote	*Given the expected benefits and costs, would you vote FOR or AGAINST the project?* *I would vote FOR the project.* *I would vote AGAINST the project.*
Follow-up questions	1. *On a scale from 1 to 10, how sure are you about being willing to pay $XX?*
	2. *On a scale from 1 to 10, how confident are you that this survey will influence what is actually done?*
	3. *You said you would vote AGAINST the project if the cost was $XX. What is the highest <u>one-time</u> payment at which you would vote FOR the project?*

Test of Consistency

From economics theory, it has been argued that when the bid increases, the proportion of yes votes should decrease (Hwang 2013). Based on the summary results from the survey, it can be inferred that our survey responses meet this criterion. As detailed in figure 6, as the bid increases, the % yes votes decrease for both unadjusted and adjusted confidence levels.

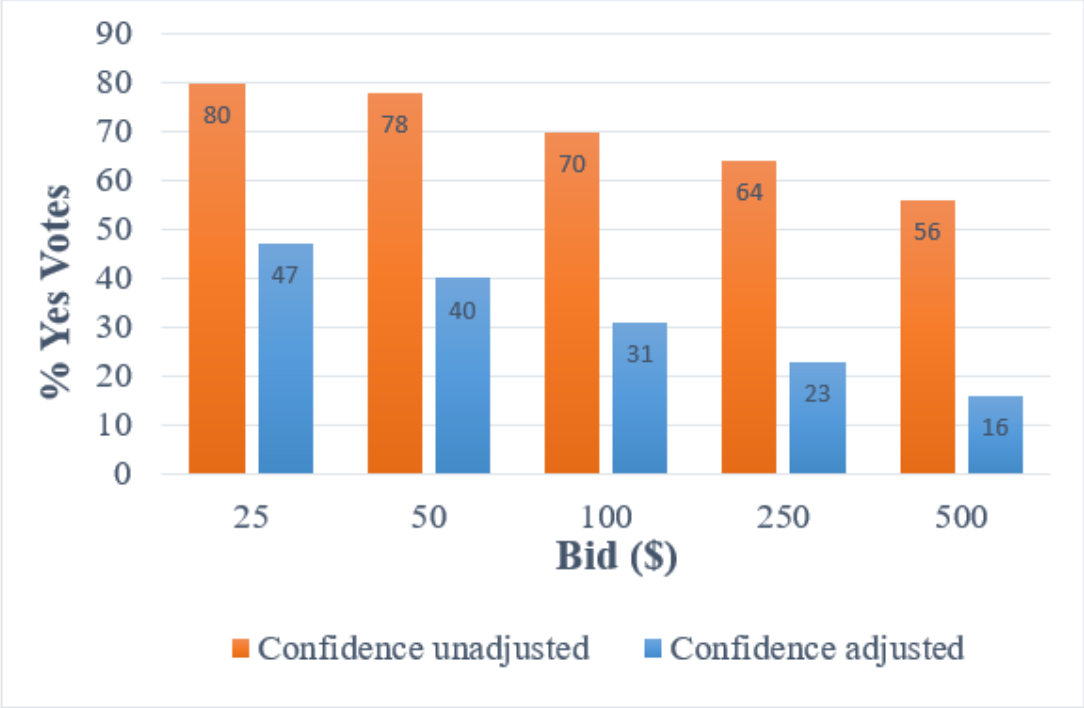


Figure 6 Percentage of "YES" votes by bid distribution.

CHAPTER IV

RESULTS

Summary of household responses

Table 3 details the definitions for all survey variables, and Table 4 reports the summary statistics of the variables going into the regression with my expected signs. Out of the survey responses, 60% said they eat oysters at least once a year, and 16% said they hold a saltwater license. 33% ranked better water quality as the most important benefit of oyster reefs, as detailed in figure 7. And about 70% of the households voted for the project. Twenty-two percent of the respondents are Alabama residents; 18% are from Florida; 21% are from Louisiana; 17% are from Mississippi; and 22% are from Texas. The mean age of my sample is approximately 45 years.

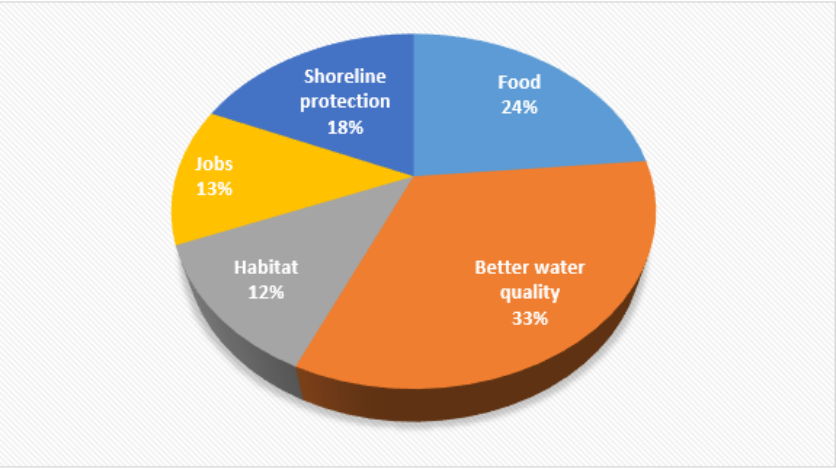


Figure 7 Percentage ranking of the most important benefits of oyster reefs.

Table 3 Definition of variables

Variable	Definitions
Vote	= 1 if voted for the project, = 0 otherwise
Vote8	= 1 if at least on a scale of 8 voted for the project, = 0 otherwise
Confidence adjusted	Ranking [1(not at all sure)-10(very sure)]; asked as a confidence follow-up question to adjust the "YES" votes
Bid	= $25, $50, $100, $250, or $500; the amount offered respondents to vote on
Eats oysters	=1 if the person eats oysters at least once a year, = 0 otherwise
Saltwater fishing	=1 if the person fishes, = 0 otherwise
Improvement	Improvement in the amount of commercial oyster harvest after the project based on each state
Baseline	The current status of commercial oyster harvests in each state
Scope of improvement	= improvement / baseline
Coastal	=1 if the respondents stay in a coastal area, = 0 otherwise
Age	The age of the respondent, from 18 years and above
Education	The level of education of the respondent (Associate degree, Bachelor's degree, graduate degree, High school, Some college, and some school)
White	= 1 if the respondent's reported race is white, = 0 otherwise
Female	= 1 if respondent is female, = 0 otherwise
Households	= number of individuals living in household
Children	= 1 if there are children present in the household, = 0 otherwise

Table 4 Summary statistics of variables used in regression analysis (N=4,855)

	Mean	Std. Dev	Minimum	Maximum
Vote	0.70	0.46	0	1
Vote8	0.31	0.46	0	1
Bid (−)	185.70	175.91	25	500
Eats oysters (+)	0.60	0.49	0	1
Saltwater fishing (+)	0.17	0.37	0	1
Scope of improvement (+)	5.40	10.78	0.26	40
Coastal (+)	0.47	0.50	0	1
Children (?)	0.75	1.25	0	20
Level of education (?)	3.53	1.42	1	6
Female (?)	0.71	0.45	0	1
White (?)	0.67	0.47	0	1
Age (?)	44.6	16.21	18	102

Model Specification

The conceptual framework was based on the Random WTP model, $y_j = \boldsymbol{\beta}'\mathbf{X}_j + \varepsilon_j$ (Cameron and James 1987). Where y_j is the WTP of respondent *j* for the project, $\mathbf{X_j}$ is an m-dimensional vector of respondent characteristics, $\boldsymbol{\beta}$ is the corresponding coefficients, and ε_j error term. Typical model of WTP assumes negative infinity to positive infinity and uses probit model which does not allow for reasonable bounds. To implement these practical and reasonable bounds on unobserved WTP, I used an interval regression model which allows for lower bound of zero, and an upper bound of income (Haab and McConnell 1998). I employed the interval regression model ($y_j = \boldsymbol{\beta}'\mathbf{X_j} + \varepsilon_j$) to estimate the willingness to pay of respondents towards oyster reef restoration along the Gulf Coast. The dependent variable involves a multistep. My

dependent variable (y_j) takes into account the vote based on offered bid (the bid is used to set part of the bounds), ex-post confidence adjustment for "yes" votes (at least 8), and reasonable bounds (lower and upper). I only know that the unobserved y_j is in the interval (y_{1j} , y_{2j}), which is (0, income) for my study. Looking at just "no" responses, it has an interval of (0, bid), while "yes" responses are in the interval of (bid, income). The likelihood contribution is $\Pr(y_{1j} \leq Y_j \leq y_{2j})$, where Y_j is the random variable denoting the dependent variable (WTP) in the model (Stata helpfile).

The log likelihood of the interval regression model is:

$$LL = \sum_{j\epsilon\tau} w_j \log\left\{\Phi\left(\frac{y_{2j}-x\beta}{\sigma}\right) - \Phi\left(\frac{y_{1j}-x\beta}{\sigma}\right)\right\} \quad (1)$$

Where Φ is the cumulative distribution function of the standard normal distribution, w_j are weights, y_j is the outcome of the jth observation; either observed or unobserved, σ is the asymptotic standard errors.

I had a clear expectation of the directional effect of some of my variables, as detailed in Table 4. I expected income, 'eats oysters', 'saltwater fishing', 'coastal' and 'scope of improvement' to have positive effects. I did not have any expected effects for race, age, the household's state of residence, and the political party the household supports. Table 5 reports the estimates of the interval regression model. This table includes the results of the confidence adjusted level of 8 (1—not at all sure to 10—very sure) and differs according to whether sampling weights were used or not. Using a confidence adjustment of 8, a "YES" response with a follow-up scale of 7 or lower is recoded as a "NO" response. This is based on findings from Champ and Bishop (2001). Other studies, like Blomquist et al. (2009) and Penn and Hu (2023)

also found a similar confidence adjusted cutoff. Respondents who eat oysters were significantly more likely to pay $36 more for the restoration of oyster reefs than those who do not eat oysters under the unweighted model. With the weighted model, they were willing to pay $35 more, which is significant at 1%. With this, there is an insignificant difference in the effect of "eats oysters" under both models. For respondents who go saltwater fishing, they were willing to pay $38 more under the unweighted sample and $47 more under the weighted sample. Under both levels, respondents with higher educational attainment were more willing to pay for the restoration, and this is statistically highly significant. The same is true for elderly respondents, who intend to pay ¢40 more than the mean WTP. The results on age and the level of educational attainment are consistent with the findings of Tan et al. (2018), who found that older respondents were less willing to pay for coastal wetland restoration, while the younger and more educated respondents were more likely to pay for the wetland restoration. Female respondents were significantly less likely to pay $18 less for the restoration of oysters relative to male respondents in the unweighted sample and $12 less in the weighted sample. For every given proportional increase in oysters, respondents were willing to pay ¢49 more to restore oysters. It turns out that coastal respondents were less likely to pay for the restoration of oysters relative to non-coastal respondents, and this is not statistically significant.

Table 5 Interval Regression Results for Confidence-adjusted, with and without sampling weights, N = 4,855.

	Confidence-adjusted (Unweighted)	Confidence-adjusted (Weighted)
Eat oyster	36.19***	35.68***
	(4.50)	(5.85)
Saltwater fishing	38.24***	46.815***
	(6.44)	(11.07)
Children	7.53	6.69
	(4.71)	(6.55)
Level of education	4.86***	6.00**
	(1.72)	(2.37)
Scope of improvement	0.19	0.49*
	(0.21)	(0.29)
Coastal	-5.29	-4.68
	(4.48)	(6.12)
Female	-18.30***	-12.48*
	(5.04)	(6.46)
White	10.96**	11.02
	(5.06)	(7.08)
Age	0.48***	0.41**
	(0.15)	(0.18)
Republican	-2.38	-6.47
	(4.71)	(6.72)
Income	0.00***	0.00***
	(0.00)	(0.00)
Constant	67.20***	56.30***
	(28.12)	(13.30)
N	4,855	4,855
Loglikelihood	-5751.99	-59796313

*p<0.10, **p< 0.05, ***p<0.01. With standard errors in parentheses.

Table 6 reports the results of our restricted sample. The restricted sample comprises only respondents who met our quality control criteria. We based this on respondents who answered that they understood the problem, how the project would address the problem, and how the project would be funded. The total number of observations for this sample was 3,524. The effect of whether a respondent eats oysters at least once a year or saltwater fish remains the same. People who eat oysters or saltwater fish were still more likely to pay for the restoration

project, as it was under the unrestricted sample. Compared to the unrestricted sample, the effects of "eats oysters" or "saltwater fishes" have a higher positive magnitude.

Table 6 Interval Regression Results for Confidence-adjusted, with and without sampling weights, N= 3,524 (Restricted sample)

	Confidence-adjusted (Unweighted)	Confidence-adjusted (Weighted)
Eat oyster	41.62***	38.74***
	(6.12)	(7.72)
Saltwater fishing	42.13***	52.99***
	(8.18)	(13.42)
Children	10.39*	7.71
	(6.26)	(8.61)
Level of education	3.25	1.57
	(2.34)	(3.06)
Scope of improvement	0.13	0.38
	(0.28)	(0.39)
Coastal	-12.28**	-7.43
	(6.01)	(8.27)
Female	-31.75***	-27.75***
	(6.74)	(8.44)
White	10.34	11.26
	(6.90)	(8.89)
Age	0.78***	0.67***
	(0.21)	(0.23)
Republican	-1.41	-0.29
	(6.33)	(8.94)
Income	0.00***	0.00***
	(0.00)	(0.00)
Constant	88.48***	86.75***
	(28.12)	(16.67)
N	3,524	3,524
Loglikelihood	-4145.27	-59796313

*p<0.10, **p< 0.05, ***p<0.01. With standard errors in parentheses.

My findings indicate that the only big difference between these two samples is the magnitude of the effects on willingness to pay. And also, the significance level of some variables. For example, with the restricted sample, coastal respondents were statistically significant but not significant in the unrestricted sample.

WTP Value

I estimated the WTP value using the Turnbull Lower-bound estimator (Haab and McConnell 2002) and the Interval Regression-based approach. I used these approaches because WTP is assumed to be non-negative, and the Turnbull Lower-bound estimator and the Interval Regression-based approach do satisfy this non-negative condition. According to Haab and McConnell (1997), estimating negative willingness to pay under the contingent valuation method is simply wrong for most of the problems since the public good can be disregarded if it does not benefit the respondent.

Turnbull Lower-bound estimator and Interval Regression-based approach satisfy this condition. With large samples and having an increasing bid, the percentage of no responses to each bid is expected to increase (Haab and McConnell 2002). In calculating for the estimated WTP using the Turnbull model, I estimated the model as: $E(WTP) = \sum(f_j \times t_j)$, where t_j is the offered bid, and f_j is the probability density function of the No votes at a specific point. The expected lower-bound is estimated as $E_{LB}WTP = E(WTP) - 1.96[std(WTP)]$, where $std(WTP)$ is the standard deviation associated with WTP. A detailed description of this model can be found in Appendix B. This is labelled as a detailed description of the Turnbull Estimator.

For the interval-regression-based approach, I used the Delta method to estimate the confidence intervals for WTP. Simulation approaches offer only approximations of confidence

intervals, whereas Delta offers exact standard intervals for WTP estimates (Daly et al. 2012a). The Delta method is not only accurate in many cases but also avoids extensive simulation (Bliemer & Rose 2013).

Table 7 reports the WTP at the certainty adjusted level and the certainty unadjusted level and also includes the WTP of the unrestricted sample and the restricted sample. Under the unrestricted sample with no certainty adjusted level, the mean WTP is estimated to be $311 per respondent, with a 95% confidence interval of ($309, $312). Certainty adjusted responses resulted in a lower WTP value of $112 per respondent, while the use of the restricted sample increases the WTP slightly ($338 for no certainty adjusted and $139 for certainty adjusted).

Table 7 WTP Estimates using Turnbull Lower-bound.

Not Certainty Adjusted	Certainty Adjusted
Turnbull Lower-bound WTP	
Unrestricted sample (N=6,475)	
$311 ($309, $312)	$112 ($110, $114)
Restricted sample (N=4,746)	
$338 ($336, $340)	$139 ($137, $141)

Table 8 WTP Estimates using Interval Regression.

Certainty Unadjusted (Weighted)	Certainty Adjusted (Weighted)
Interval Regression-based WTP	
Unrestricted sample (N=6,475)	
$387 ($368, $407)	$142 ($132, $151)
Restricted sample (N=4,746)	
$436 ($410, $460)	$167 ($156, $179)

Interval regression-based estimates are greater than the Turnbull Lower-bound estimates. This is true because the Turnbull Lower-bound provides the lowest possible estimates. Under the unrestricted sample, the one-time mean WTP value is $387 per respondent, which is greater than the Turnbull Lower-bound estimate of $311 per respondent, and even greater under the certainty-adjusted responses ($142). With the restricted sample, the mean WTP is estimated to be $436 under no certainty adjustment and $167 under certainty adjusted. As stated earlier, the closest study to mine is by Interis and Petrolia (2016). They estimated the mean willingness to pay for oysters across locations (Alabama to Louisiana) to be $702 and (Louisiana to Alabama) to be $393, whereas my estimated willingness to pay for oysters along the Gulf Coast is around $112 to $412. Grabowski et al. (2012) also estimated the economic value of oysters, where they excluded oyster harvesting, to be $5,500 per hectare per year, which is way greater than my estimated WTP value. Kim & Petrolia (2013) also estimated the WTP for the restoration of wetland in Louisiana to be $580 per household. As wetlands are closely related to oyster reefs, this estimate is a close approximation of oyster reefs' WTP.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

The decline in oyster harvest is a result of overharvesting, oyster disease, oil spills, pollution, and habitat loss, which are detrimental to aquatic life. It is an annual issue along the Gulf Coast. Though the Gulf Coast is the leading commercial oyster-producing region in the United States, accounting for approximately 46% of the total commercial oyster harvest in 2020, this rapid decline in oyster reefs will leave the Gulf Coast with no oysters if proper care is not taken. This serves as a reason why I estimated how much respondents are willing to pay to restore the oyster reefs. My goal for this study was to carry out a contingent valuation survey of respondents along the Gulf Coast, analyze how much they are willing to pay for the restoration project, and also gather their knowledge about the benefits of oysters and the population of oysters.

My study significantly adds to the existing literature in many ways. This study analyzes the benefits of oyster reefs that people consider to be the most important. The respondents ranked better water quality as the most important benefit of oyster reefs. In addition, 97% of the respondents cared at least somewhat about the issue of oysters, but just 38% were willing to pay for the project.

Secondly, this study extends geographically to all five states along the Gulf Coast and also controls for respondent attention and understanding. A study by Interis and Petrolia (2016), which is the closest study to my study, focused their valuation research on Louisiana and

Alabama, where my study extends geographically to include Florida, Mississippi, and Texas. After controlling for respondent attention and understanding, I found that the mean WTP value for oyster reefs is $436 which is comparable to the mean WTP value of $393 estimated by Interis and Petrolia (2016).

My study also methodologically contributes to the literature by using the contingent valuation approach. Most of the existing studies, to the best of my knowledge, did something different known as an ecosystem service valuation, where they valued the benefits associated with oyster reefs. My study, on the other hand, is not a valuation per ecosystem service valuation; I am valuing the entirety of oyster reefs and the benefits they provide.

Overall, the findings of my study provide compelling evidence that respondents within my sample are willing to pay for the restoration of oyster reefs. Extrapolating from my results, assuming my sample is representative of the Gulf region, I estimate that each respondent's willingness to pay to restore oysters would amount to approximately $436. Though they are willing to pay this amount of money, they do not naturally notice the change in the size of the expected outcome of the project before making their decisions. This is because during the survey, some respondents received high scales and others received a low scale, but I did not identify any significant differences between the two scales.

REFERENCES

Andradi-Brown, D. A., Howe, C., Mace, G. M., & Knight, A. T. (2013). Do mangrove forest restoration or rehabilitation activities return biodiversity to pre-impact levels? *Environmental Evidence*, *2*(1), 20. https://doi.org/10.1186/2047-2382-2-20

Barrett, L. T., Theuerkauf, S. J., Rose, J. M., Alleway, H. K., Bricker, S. B., Parker, M., Petrolia, D. R., & Jones, R. C. (2022). Sustainable growth of non-fed aquaculture can generate valuable ecosystem benefits. *Ecosystem Services*, *53*, 101396. https://doi.org/10.1016/j.ecoser.2021.101396

Bauer, D. M., 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. https://doi.org/10.1111/j.1523-1739.2004.00367.x

Beck, M. W., Brumbaugh, R. D., Airoldi, L., Carranza, A., Coen, L. D., Crawford, C., Defeo, O., Edgar, G. J., Hancock, B., Kay, M. C., Lenihan, H. S., Luckenbach, M. W., Toropova, C. L., Zhang, G., & Guo, X. (2011). Oyster reefs at risk and recommendations for conservation, restoration, and management. *BioScience*, *61*(2), 107–116. https://doi.org/10.1525/bio.2011.61.2.5

Beckensteiner, J., Kaplan, D. M., & Scheld, A. M. (2020). Barriers to eastern oyster aquaculture expansion in Virginia. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00053

Bliemer, M. C. J., & Rose, J. M. (2013). Confidence intervals of willingness-to-pay for random coefficient logit models. *Transportation Research Part B: Methodological*, *58*, 199–214. https://doi.org/10.1016/j.trb.2013.09.010

Brouwer, R. (2011b). A mixed approach to payment certainty calibration in Discrete Choice Welfare Estimation. *Applied Economics*, *43*(17), 2129–2142. https://doi.org/10.1080/00036840903035977

Bulte, E., Gerking, S., List, J. A., & de Zeeuw, A. (2005). The effect of varying the causes of environmental problems on stated WTP values: Evidence from a field study. *Journal of Environmental Economics and Management*, *49*(2), 330–342. https://doi.org/10.1016/j.jeem.2004.06.001

Dillman, D.A. (2007) Mail and Internet Surveys: The Tailored Design Method. John Wiley and Sons, Inc., Hoboken, NJ.

Cameron, T. A., & James, M. D. (1987). Estimating willingness to pay from survey data: An alternative pre-test-market evaluation procedure. *Journal of Marketing Research*, *24*(4), 389. https://doi.org/10.2307/3151386

Carson, R. (2011). Contingent valuation. https://doi.org/10.4337/9780857936288

Carson, R. T. (1999). *Contingent valuation: A user's guide*. University of California, San Diego, Dept. of Economics.

Carson, R. T. (2012). Contingent valuation: A practical alternative when prices aren't available. *Journal of Economic Perspectives*, *26*(4), 27–42. https://doi.org/10.1257/jep.26.4.27

Carson, R. T., & Louviere, J. J. (2011). A common nomenclature for stated preference elicitation approaches. *Environmental and Resource Economics*, *49*(4), 539–559. https://doi.org/10.1007/s10640-010-9450-x

Carson, R. T., Flores, N. E., & Meade, N. F. (2000). *Contingent valuation: Controversies and evidence*. University of California, San Diego, Dept. of Economics.

Carson, R. T., & Groves, T. (2007). Incentive and informational properties of preference questions. *Environmental and Resource Economics*, *37*(1), 181–210. https://doi.org/10.1007/s10640-007-9124-5

Chang, J.-I., Yoo, S.-H., & Kwak, S.-J. (2007). An investigation of preference uncertainty in the contingent valuation study. *Applied Economics Letters*, *14*(9), 691–695. https://doi.org/10.1080/13504850600592713

DePiper, G. S., Lipton, D. W., & Lipcius, R. N. (2017). Valuing ecosystem services: Oysters, denitrification, and nutrient trading programs. *Marine Resource Economics*, *32*(1), 1–20. https://doi.org/10.1086/688976

Fodrie, F. J., Rodriguez, A. B., Gittman, R. K., Grabowski, J. H., Lindquist, N. L., Peterson, C. H., Piehler, M. F., & Ridge, J. T. (2017). Oyster reefs as carbon sources and sinks. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1859), 20170891. https://doi.org/10.1098/rspb.2017.0891

Grabowski, J. H., & Peterson, C. H. (2007). Restoring oyster reefs to recover ecosystem services. *Theoretical Ecology Series*, 281–298. https://doi.org/10.1016/s1875-306x(07)80017-7

Grabowski, J., Piehler, M. F., & Peterson, C. H. (2011). Assessing the Long-Term Economic

Value and Costs of the Crab Hole and Clam Shoal Oyster Reef Sanctuaries in North Carolina. *Morehead City, NC: University of North Carolina at Chapel Hill, Institute of Marine Sciences, Morehead City, NC*.

Grabowski, J. H., Brumbaugh, R. D., Conrad, R. F., Keeler, A. G., Opaluch, J. J., Peterson, C. H., Piehler, M. F., Powers, S. P., & Smyth, A. R. (2012). Economic valuation of ecosystem services provided by Oyster Reefs. *BioScience*, *62*(10), 900–909. https://doi.org/10.1525/bio.2012.62.10.10

Gulf States Marine Fishery Commission. (n.d.). *Alabama Florida Mississippi Louisiana and Texas Oyster landings 2021*. Public databases. Retrieved April 12, 2022, from https://data.gsmfc.org/apex/public/f?p=1495%3A300%3A11538671572933%3A%3ANO%3A%3AP300_GO_FLAG%3A-1

Haab, T. C., & MacConnell, K. E. (2002). *Valuing environmental and natural resources: The econometrics of non-market valutation*. E. Elgar.

Håkansson, C. (2007). A new valuation question: Analysis of and insights from interval open-ended data in contingent valuation. *Environmental and Resource Economics*, *39*(2), 175–188. https://doi.org/10.1007/s10640-007-9102-y

Haab, T. C., & McConnell, K. E. (1998). Referendum models and economic values: Theoretical, intuitive, and practical bounds on willingness to pay. *Land Economics*, *74*(2), 216. https://doi.org/10.2307/3147052

Hwang, Joonghyun, "What to do with "Prefer Not To Vote" Responses from Stated Preference Surveys?" (2013). Theses and Dissertations. 5008.

He, J., Dupras, J., & G. Poder, T. (2016). The value of wetlands in Quebec: A comparison between Contingent Valuation and choice experiment. *Journal of Environmental Economics and Policy*, *6*(1), 51–78. https://doi.org/10.1080/21606544.2016.1199976

Interis, M. G., & Petrolia, D. R. (2016). Location, location, Habitat: How the value of ecosystem services varies across location and by habitat. *Land Economics*, *92*(2), 292–307. https://doi.org/10.3368/le.92.2.292

Isik, M. (2006). An experimental analysis of impacts of uncertainty and irreversibility on willingness-to-pay. *Applied Economics Letters*, *13*(2), 67–72. https://doi.org/10.1080/13504850500119203

Kim, T.-G., & Petrolia, D. R. (2013). Public perceptions of wetland restoration benefits in Louisiana. *ICES Journal of Marine Science*, *70*(5), 1045–1054. https://doi.org/10.1093/icesjms/fst026

Kroeger, T., & Guannel, G. (n.d.). Fishery enhancement and coastal protection services provided by two restored Gulf of Mexico oyster reefs. *Valuing Ecosystem Services*, 334–358. https://doi.org/10.4337/9781781955161.00028

Kroeger, T., & Guannel, G. (n.d.). Fishery enhancement and coastal protection services provided by two restored Gulf of Mexico oyster reefs. *Valuing Ecosystem Services*, 334–358. https://doi.org/10.4337/9781781955161.00028

La Peyre, M., Furlong, J., Brown, L. A., Piazza, B. P., & Brown, K. (2014). Oyster reef restoration in the northern Gulf of Mexico: Extent, methods and outcomes. *Ocean & Coastal Management*, *89*, 20–28. https://doi.org/10.1016/j.ocecoaman.2013.12.002

Link, J. S., & Marshak, A. R. (2021). The northern Gulf of Mexico. *Ecosystem-Based Fisheries Management*, 283–342. https://doi.org/10.1093/oso/9780192843463.003.0007

MacKenzie, C. L. (1996). History of oystering in the United States and Canada, featuring the eight greatest oyster estuaries. *Marine Fisheries Review*, *58*. https://doi.org/link.gale.com/apps/doc/A19847493/AONE?u=googlescholar&sid=bookmark-AONE&xid=2e7b9ed7

Martinez, M. J., Palmer, T. A., Breaux, N. J., & Beseres Pollack, J. (2022). Dynamics of restored and natural oyster reefs after a hurricane. *Frontiers in Ecology and Evolution*, *10*. https://doi.org/10.3389/fevo.2022.791739

National Oceanic and Atmospheric Administration. *Defining coastal counties*. NOAA Office for Coastal Management. (n.d.). https://www.coast.noaa.gov/digitalcoast/training/defining-coastal-counties.html

National Oceanic and Atmospheric Administration (2022, February 4). *Oyster Reef Habitat*. NOAA. https://www.fisheries.noaa.gov/national/habitat-conservation/oyster-reef-habitat

Petrolia, D. R., Interis, M. G., & Hwang, J. (2014). America's wetland? A national survey of willingness to pay for restoration of Louisiana's coastal wetlands. *Marine Resource Economics*, *29*(1), 17–37. https://doi.org/10.1086/676289

Petrolia, D. R., Walton, W. C., & Cebrian, J. (2022). Oyster Economics: Simulated costs, market returns, and nonmarket ecosystem benefits of harvested and nonharvested reefs, off-bottom aquaculture, and Living Shorelines. *Marine Resource Economics*, *37*(3), 325–347. https://doi.org/10.1086/719969

Singh, H. (1997). Contingent Value Measurement of Coastal wetlands: A case study of New Jersey. *Middle State Geographer*. https://doi.org/https://msaag.aag.org/wp-content/uploads/2013/05/7_Singh.pdf

Tan, Y., Lv, D., Cheng, J., Wang, D., Mo, W., & Xiang, Y. (2018). Valuation of environmental improvements in Coastal Wetland Restoration: A choice experiment approach. *Global Ecology and Conservation, 15*. https://doi.org/10.1016/j.gecco.2018.e00440

The Nature Conservancy. (2018). *Oyster Restoration in the Gulf of Mexico*. https://www.nature.org/content/dam/tnc/nature/en/documents/OysterRestorationintheGulf.pdf

APPENDIX A

EXTENDED LITERATURE REVIEW

Background of valuation

Valuation is defined as assigning monetary value to a good or service. This is mostly done by acquiring the willingness to pay value of a household. Carson (2000) explained willingness to pay (WTP) as an appropriate measure of economic value in a situation where an agent wants to acquire a good and a way to estimate the value of nonmarket goods. WTP is measured by using revealed preference or stated preference. Revealed preference is a means of valuing products that consider market choices. Stated preference is an approach for establishing valuations where individuals are asked how much they value a product. Choice experiments (CE) and contingent valuation (CV) are the two types of stated preference methods (Hensher, Rose et al., 2005). Choice experiment helps explore consumer preferences based on hypothetical markets where individuals choose between several goods. Contingent valuation, on the other hand, is a method used for valuing environmental goods and services that are not purchased on the market (Carson 2012). In this study, I used the contingent valuation approach.

Valuation studies on oyster reefs

Oyster valuation with stated preference

Interis and Petrolia (2016) used a choice experiment to examine how ecosystem service values vary across locations, and across habitats. Oyster reef, black mangrove, and salt marsh were the three habitats that were the focus of their research in Louisiana and Alabama. According to their findings, it is more important to give the respondent information about the habitat when determining the respondent's readiness to pay for attribute modifications than for compensating surplus. They added to the literature by analyzing the suitability of choice

experiment data to estimate value transfers between various ecosystem services provided at the same location.

Valuation studies on oyster reefs without using stated preference (other methods)

According to Grabowski et al. (2011), the annual commercial fish value of the two oyster sanctuaries at Clam Shoal and Crab Hole was assessed to be $32,448 and $44,134, respectively. The value of the nitrogen removal service provided by oysters was also evaluated by the authors, and they found that it varied between $491 and $4,908 and $711 and $7,114 annually in each sanctuary, respectively. Grabowski et al. (2012) also estimated the economic value of oysters where they excluded oyster harvesting, to range between $5,500 and $99,000 per hectare per year. The value of an oyster benefit for removing nitrogen from the atmosphere was estimated by Parker and Bricker (2020) to be between $57.68 and $1.28 million per year.

Valuation studies on other related ecosystems (Wetland, fish, & salt marsh)

Valuation studies on related ecosystems with contingent valuation

Petrolia et al. (2014) estimate welfare associated with large-scale wetland restoration using contingent valuation and choice experiments survey instruments in coastal Louisiana. Their objective was to use a model that will help estimate WTP for increments in three ecosystem services: wildlife habitat provision, storm surge protection, and fisheries productivity. Their findings show that all the three ecosystem services significantly influenced the restoration project, with increased fisheries productivity having the largest effect, followed by improved storm surge protection and the increment of wildlife habitat having the least influence. In addition to that, they found that individuals were willing to pay more of a one-time tax, with a

mean household WTP estimated to be $909 (confidence interval $732-$1185). Kim & Petrolia (2013) also analyzed the WTP for a large-scale coastal restoration wetland in Louisiana using a contingent valuation survey (referendum-style). The authors investigated the public perceptions of wetland restoration benefits. Their results indicate that the annual mean WTP was $580 per household.

Singh (1997) used the contingent valuation method to estimate the WTP of wetlands for New Jersey households. They conducted their survey over three consecutive years: 1994, 1995, and 1996. The authors found the median WTP value to remain constant at $25.00. They then calculated the total WTP value of New Jersey by multiplying the $25 by the total population of 2.8 million. This resulted in a total WTP of $71 million. Huppert (1989) measured the economic values associated with recreational fishing of chinook salmon and striped bass in California using the contingent valuation method and the travel cost method. Using the CVM technique, they found the average WTP value for doubling the catch rate to be $49.4. They evaluated the estimates from both models to determine if they were consistent. They found most of the estimates were inconsistent.

He, Dupra & Poder (2016) evaluate the non-market values of ecosystem services generated by wetlands in southern Quebec by using contingent valuation and choice experiments. They used bids of $5, 10, 15, 25, 40, 60, 80, 150, 250, 400, and 600. According to their findings, the WTP per year per household varies from $447 (CE) to $465 (CV). They also found that the WTP values are affected by households' socioeconomic characteristics. WTP is positively affected by income.

Valuation studies on related ecosystems with other methods

Bauer et al. (2004) used a choice experiment survey to identify the willingness to pay of households in Rhode Island. They calculated an estimated willingness to pay value of $0.48 per acre-per household, where their estimates are in line with some published studies. For instance, Kline and Swallow (1998) discovered that people would be ready to pay $3 to $4 per person to access a tiny island. According to their study of the literature, the average cost per visitor for 11 out of 13 studies of WTP for access to US beaches ranges from $1 to $25. Tan et al. (2018) used a choice experiment to estimate the value of environmental improvements in coastal wetland restoration and found that people valued the positive benefits of wetland restoration. Their findings suggest that older respondents were less willing to pay for coastal wetland restoration, while younger and more educated respondents were more likely to accept the wetland restoration scenarios. The authors also used the conditional logit model and the random parameter logit model to estimate the respondent's utility associated with wetland characteristics.

Studies with uncertainty

From the literature, a few research studies used uncertainty in their survey. There are different kinds of uncertainty, namely preference uncertainty, posterior uncertainty and interval or range uncertainty. Preference uncertainty refers to the uncertainty that individuals may face when asked to express their willingness to pay for a specific good or service. On the other hand, interval or range uncertainty refers to uncertainty regarding the potential outcomes or values of a parameter or variable within a given range or interval. Chang et al. (2007), Brouwer (2011), Hakanssan (2008), and Isik (2006) are a few of these studies. Chang et al. (2007), Brouwer (2011), and Hakanssan (2008) investigate households' preference uncertainty by presenting them with multiple willingness to pay (WTP) question choices ranging from "definitely yes,"

"probably yes," "maybe yes," "probably no," and "definitely no" to a given single bid amount. Isik (2006), on the other hand, used interval uncertainty or range uncertainty in a manner that is comparable to ours. He calculated the effect of uncertainty over the result of a project that could preserve several crocodiles. He informed the respondents that the number of American crocodiles that could be saved by the project is uncertain. He then went on to ask them whether they would be willing to pay $X if the crocodiles saved could be Y1 or Y2? He varied Y1 from 40 to 100, while Y2 is varied from 100 to 160. He investigated the difference in mean WTP between certainty and uncertainty. He found that when the uncertainty is rather great, the difference is statistically significant, and when the level of uncertainty is minimal, the difference is not statistically significant. Finally, he said that uncertainty about the value of environmental quality improvements can alter the WTP measure. The study area is a fundamental distinction between his approach and mine. While I did field research on Gulf Coast households, Isik (2006) conducted a laboratory experiment on seventy students from a natural resource economics program at the University of Idaho. My study used a contingent valuation method, which also makes my methodology different from his.

APPENDIX B

METHODS

Summary Statistics

Table B1. Descriptive statistics of the sample demographics as proportions.

	Unweighted Sample	Weighted Sample	Population
Age 65+	11%	11%	17%
White	70%	67%	76%
Black or African American	20%	19%	14%
Other	4%	3%	8%
Hispanic or Latino	10%	8%	19%
High school graduate or higher, age 25 years+	98%	97%	90%
Bachelor's degree or higher, age 25 years+	42%	35%	34%
Median household income	$57,715	63,072	$69,021
N	4,855	4,855	49,770,639

Table B2. The total distribution of YES votes for various certainty-adjusted levels

Bid	No certainty adjustment	Certainty adjustment (=5)	Certainty adjustment (=7)	Certainty adjustment (=9)	Certainty adjustment (=10)
25	758	630	534	336	268
50	779	591	472	271	204
100	690	507	380	209	159
250	619	415	302	143	105
500	545	345	225	102	72
Total	3,391	2,488	1,913	1,061	808

Table B3. The sample split according to various bids and level of scale.

Certainty		**Bids**				
	Scale	**$25**	**$50**	**$100**	**$250**	**$500**
AL	Low	84	104	115	95	96
AL	High	99	104	93	109	107
FL	Low	90	91	77	95	84
FL	High	87	80	89	68	92
LA	Low	94	100	108	111	98
LA	High	105	95	93	86	98
MS	Low	73	75	71	86	68
MS	High	74	71	80	57	76
TX	Low	94	96	100	100	92
TX	High	89	102	100	102	105
Uncertainty						
FL	Low	107	91	100	91	90
FL	High	74	94	86	109	96
TX	Low	94	103	110	90	86
TX	High	116	90	74	103	113

Probit Results

Table B4 reports the estimates of the probit model. This table also includes the certainty adjust level of 8 (1—not certain to 10—very certain) and differs according to whether sampling weights were used or not. Using a certainty adjustment of 8, a "YES" response with a certainty scale of 7 or lower is recoded as a "NO" response. The bid is negative and significant (at the 1% level) under both the weighted and unweighted samples. “Eats oysters”, and “saltwater fishing” are also positive and significant (1% level) at both levels. Considering the unweighted sample, the effects of “Eats oysters”, and “saltwater fishing” turn out to be reduce a little. Respondents with children under 18 living in their household are more likely to respond affirmatively than those without children under 18. This is only significant at the 10% level with the unweighted sample. Higher educational attainment turns out to positively influence votes. Also, female respondents were less likely to vote for the project relative to male respondents. This is significant at the 1% level. Relative to other races, white respondents have a positive effect on vote outcome. The effect of age is positive and consistent with the findings of Tan et al. (2018), who found that older respondents were less willing to pay for coastal wetland restoration, while the younger and more educated respondents were more likely to vote for the wetland restoration.

Table B4. Probit Regression Results for Confidence-adjusted, with and without sampling weights, N=4,855

	Confidence-adjusted (Unweighted)	Confidence-adjusted (Weighted)
Bid	-0.002***	-0.002***
	(0.00)	(0.000)
Eats oysters	0.416***	0.397***
	(0.042)	(0.059)
Saltwater fishing	0.261***	0.285***
	(0.054)	(0.076)
Scope of improvement	0.003	0.006**
	(0.002)	(0.002)
Coastal	-0.009	-0.033
	(0.05)	(0.056)
Children	0.080*	0.087
	(0.061)	(0.061)
Level of education	0.053***	0.066***
	(0.015)	(0.022)
Female	-0.159***	-0.144**
	(0.044)	(0.04)
White	0.128***	0.078
	(0.047)	(0.067)
Age	0.006***	0.006***
	(0.001)	(0.002)
Republican	-0.048	-0.094
	(0.043)	(0.060)
Constant	-1.066***	-1.158***
	(0.096)	(0.125)
Loglikelihood	-2729.983	-35661394

*p<0.10, **p< 0.05, ***p<0.01. With standard errors in parentheses.

Detailed description of the Turnbull Estimator

In calculating for the estimated WTP, we estimated the model as:

$$E(WTP) = \sum (f_j \times t_j) \quad (2)$$

Where:

- t_j is the offered bid.
- f_j is the probability density function of the No votes at a specific point.

a. Lower-bound WTP ($E_{LB}WTP$):

$$E_{LB}WTP = E(WTP) - 1.96[std(WTP)] \quad (3)$$

b. Upper-bound WTP ($E_{UB}WTP$):

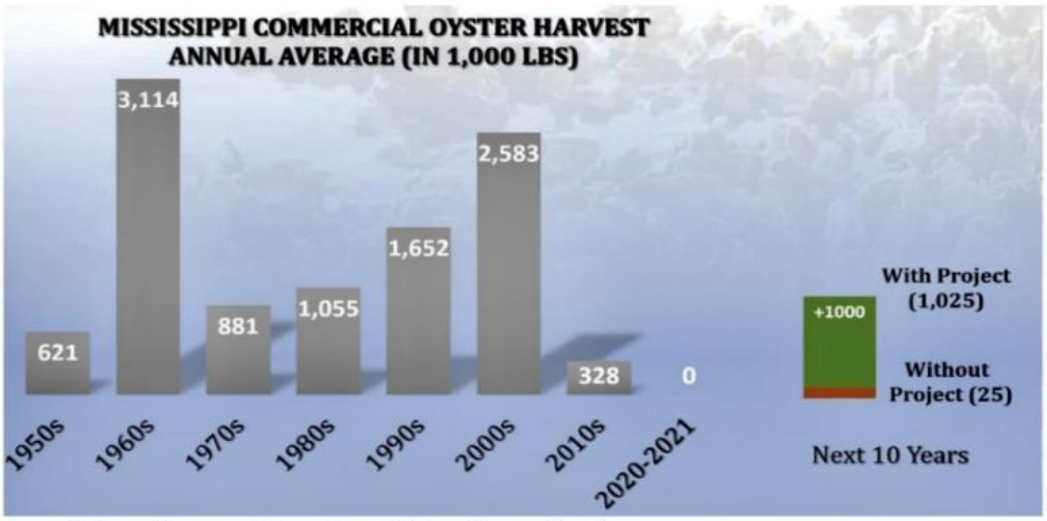
$$E_{UB}WTP = E(WTP) + 1.96[std(WTP)] \quad (4)$$

Where:

- $E(WTP)$ is the expected willingness to pay.
- $std(WTP)$ is the standard deviation.

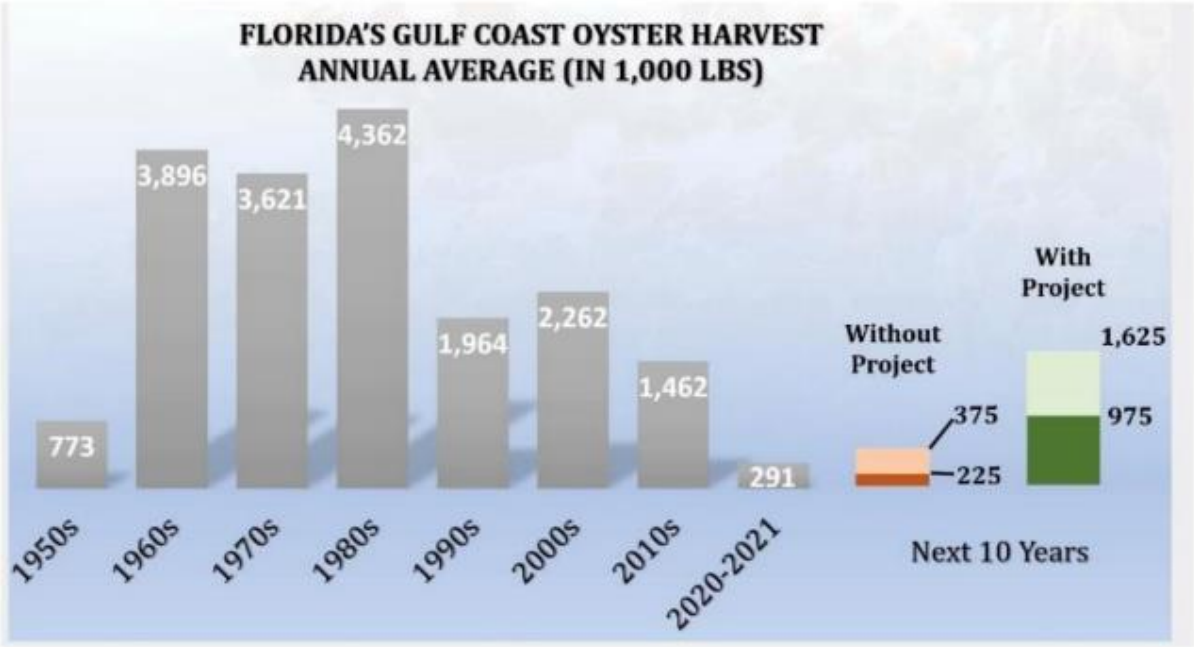
Table B5. WTP Estimates using Probit Regression.

Certainty Unadjusted	Certainty Adjusted
Unrestricted sample (N=6,475)	
\$184 ($31, $338)	\$125 ($ − 9, $259)
Restricted sample (N=4,746)	
\$165 ($ − 41, $371)	\$124 ($ − 9, $258)



- This project would require additional state funding.
- Suppose that each taxpaying household in Mississippi would need to make a one-time payment of $250 to fund the project.
- The payment would be fixed at the same amount for every taxpaying household.
- The payment would be collected on your 2023 state income tax return.
- Given the expected benefits and costs, would you vote YES or NO?
  - ☐ I would vote YES
  - ☐ I would vote NO

Figure 8 An example of a certainty scenario



- **This project would require additional state funding.**
- **Suppose that each taxpaying household in Florida would need to make a one-time payment of $50 to fund the project.**
- **The payment would be fixed at the same amount for every taxpaying household.**
- **The payment would be collected on your 2023 state income tax return.**
- **Given the expected benefits and costs, would you vote YES or NO?**
  - ☐ **I would vote YES**
  - ☐ **I would vote NO**

Figure 9 An example of an uncertainty scenario